ELECTROMAGNETIC PERTURBATION OF PERCEPTION

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Introduction

An earlier study by the author (Stevens, 7/96) appeared to show that humans exposed to a weak electromagnetic field (EMF) exhibited marked changes in their physiological arousal in the absence of any external cues other than the presence of the field itself - a finding similar to that of other researchers (Bell et al, 1994). However, although the physiological change was relatively large - showing a 2% decrease in level and a 64% decrease in variability - there did not appear to be any conscious awareness of the fields. This was puzzling to say the least, as such a change in physiological activity would normally relate to a the perception, or expectation, of a significant event in an organism's environment (Cacioppo and Tassinary, 1985) and would probably be apparent to the person experiencing it. In the original study (Stevens, 7/96), several different techniques were used to try and translate the physiological response into conscious perception - introspection, random 'guessing' and an ideomotor response - but none of these was successful. It was concluded that the EMF induced effect was such that it might in fact be removed by direct attempts to detect it. That is, the EMF affected systems within the human body were the same systems as would be used to detect such an effect; observation of the effect destroyed that effect (cf. self-observation of meditative states). This would imply that the EMF was having a direct effect on the body rather than one which was conveyed through a sensory channel.

If this were the case, then we might still expect to see the EMF induced effect affecting other systems, especially other perceptions. This study was therefore constructed to look at whether perceptions of stimuli would be different when the percipient was concurrently experiencing an applied EMF.

Method

Apparatus

The basic set-up consisted of a pair of parallel coils 0.65 metres in radius and separated by the same distance (the Helmholtz condition). This ensured a reasonably homogeneous (to within a few percent) field in the centre region between the coils. The coils were constructed of wood, and wrapped with enamelled copper wire. For a detailed discussion of this type of apparatus, the reader is referred to (Bell et al, 1994). The field was controlled by amplified output from a PC sound card which enabled easy generation of waveforms. The field had a magnetic flux densities similar in magnitude to that of the natural geomagnetic field (500 mG), and was applied in an East-West direction. The field was sinusoidally modulated at 20 Hz (these characteristics having previously given the largest effects), and was of 5 seconds duration. The study was conducted in a sound-attenuated room. No attempt was made to eliminate geomagnetic field fluctuations as it was reasoned that these would be part of any real-life sensing.

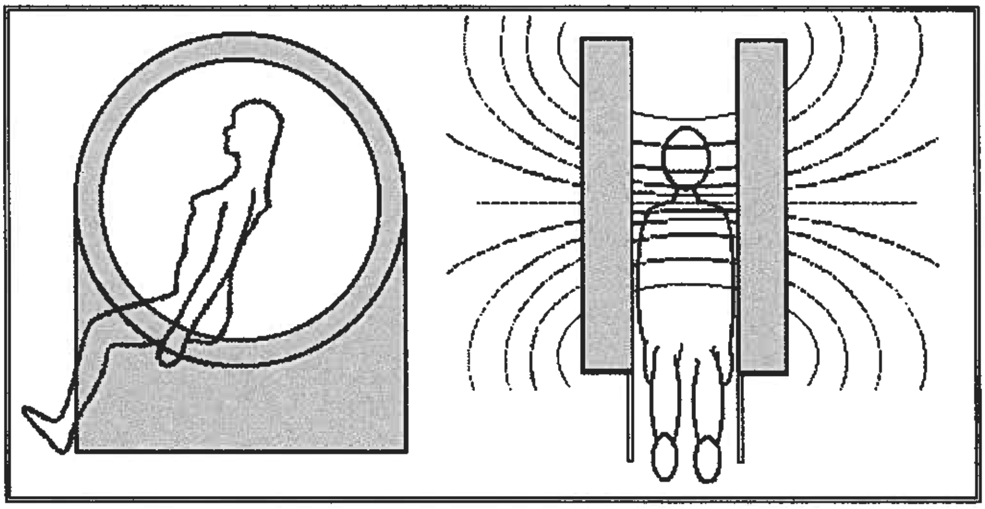

Figure 1: Schematic diagram of Helmholtz coils and participant

Physiological measurements were taken with the Physiodata monitoring system model I410, with sensors for bipolar electrodermal (EDA) activity, peripheral blood flow and hand temperature. The unit was interfaced to a high speed serial port on a 100 Hz Pentium PC. Data was sequentially sampled at 1024 Hz, and time-averaged samples saved to disk at 16 Hz. Electrodes were silver chloride, used in conjunction with a water-based electrode cream.

The perceptual stimuli used consisted of 20 GIF images, presented full-screen at a resolution of 300x200 pixels on a 17" colour monitor. These images were selected to approximately correspond to those contained within the International Affective Picture System (IAPS), as these had been categorised as to valence and arousal of content (Davis et al, 1995). As such, a selection of image topics could be chosen to evenly cover a range of valence and arousal ratings. Of the 20 images chosen, 5 were classed as being arousing and pleasant (AP), 5 were calming and pleasant (CP), 5 were arousing and unpleasant (AU) and 5 were calming and unpleasant (CU). An example of an image from each category would be a happy, laughing baby (AP), a field of flowers (CP), an aimed gun (AU), and a polluted, industrial landscape (CP).

Procedure

Participants were seated in the coils and electrodermal recording electrodes placed on the first and second fingers of their non-dominant hand. They were instructed to keep this hand as still as possible for the duration of the experiment.

The images were presented in a pseudo-random order, this being determined by the computer program. For the first part, participants were told that this was a calibration session and that they would be presented with 10 images while their physiology was recorded. After each image, they were asked by the computer to give a rating for the level of arousal and valence for that image. They responded by using a joystick to move an on-screen sliding scale, labelled 'calming - neutral - arousing' and 'unpleasant - neutral -pleasant' for the arousal and valence scales respectively. Unknown to them, there might have been an electromagnetic field present during their viewing of each image, this also being determined by a pseudo-random decision with a 50% probability.

For the second part, they were told that they would be shown another 10 images, again rating each one, but that this time they might experience an electromagnetic field concurrently with the presentation of the image. Again, field presentation was controlled by a 50% probability pseudo-random decision.

Hypotheses

With respect to baseline levels, the presence of an applied weak electromagnetic field will:

H1: be accompanied by a lowered EDA response
H2: be accompanied by lowered EDA variability.
H3: result in the current perception being rated as less arousing.
H4: result in a different affect rating being given to the current perception.

H1 and H2 were based on the findings of the previous study (Stevens, 7/96). H3 was based on the idea that a participant's arousal rating would be based in part on their self-perception of their physiological arousal. If the EMF did suppress physiological activity, this would then result in a lower arousal rating. H4 suggests that the EMF effect would also alter related perceptions such as valence. However, as it was not known whether the alteration would be an enhancing or decreasing one, this prediction was non-directional.

It was further predicted that any effects found would be stronger if the participant was unaware of the potential presence of an electromagnetic field, the reasoning being that any self-perceived physiological changes would be less likely to be causally attributed to the current perception if an alternative explanation were offered (that it was caused by the EMF). Thus:

H5: Any EMF-related effects will be stronger when the participant is unaware that a field might be present.

Analysis of Results

Analysis of participant PHYSIOLOGICAL response

Table 1 presents summary data of the levels and variances of electrodermal activity (EDA) for the control (no field present) and EMF conditions. As predicted, there is a slight decrease in mean levels and variances when a field is present.

Table 1: Summary of levels and variance of Electrodermal activity

	Control		EMF	
	EDA	Variance	EDA	Variance
N of cases	30	30	30	30
Minimum	2.0	0.0	2.0	0.0
Maximum	41.4	1.2	41.5	0.6
Mean	15.8	0.2	15.7	0.1
Std deviation	7.7	0.1	7.7	0.2

A non-parametric Wilcoxon Signed Ranks test was performed to compare the control and EMF conditions.

For the EMF condition showing lower EDA levels than the control condition, this resulted in z = 2.022 (p = 0.02, 1-tailed). Further inspection showed that this was a result consistent with 20 out of the 30 cases (66%). The mean change in EDA level was -1%. H1was therefore supported.

For the EMF condition showing lower EDA variance than the control condition, this resulted in z = 0.915 (p = 0.16, 1-tailed). Although non-significant, the result was in the predicted direction, consistent with 16 out of the 30 cases (53%). The mean change in EDA variance was -22%. H2 was therefore not supported, though suggestive.

Analysis of participant AROUSAL response

Table 2 summarises the overall arousal ratings for all images. Had the images been properly balanced for arousal, the mean response should have been 50.0 in the control condition. The actual figure of 49.7 is a good match. The EMF mean value indicates a lowering of mean arousal ratings in the presence of a field.

Table 2: Summary of participant arousal responses for presented images

	Control	EMF
N of cases	300	300
Minimum	1.0	0.0
Maximum	100.0	100.0
Mean	49.7	47.5
std dev	22.1	21.8

Table 3 shows how the images were ranked overall by their arousal rating (calculated by combing all individual ratings - see the appendix for actual values). Rankings 1-10 in the control condition contain 70% of the images originally classed as being arousing, offering some indication that the pictures were correctly classified. In the EMF condition, this is reduced to 50%, again showing that there did appear to be an alteration in participants' perceptions of the images.

Table 3: Ranking of participant arousal responses (*Arousing* or *Calming*)

Arousal Ranking	Control condition		EMF condition	
	Image #	Arousal Category	Image #	Arousal Category
1st	14	C	13	A
2nd	13	A	20	C
3rd	5	A	16	C
4th	6	C	3	A
5th	3	A	1	A
6th	7	A	17	A
7th	1	A	8	C
8th	9	A	5	A
9th	15	A	14	C
10th	4	C	18	C
11th	12	C	9	A
12th	8	C	4	C
13th	18	C	19	A
14th	16	C	2	C
15th	20	C	15	A
16th	11	A	7	A
17th	10	C	6	C
18th	17	A	11	A
19th	19	A	12	C
20th	2	C	10	C

A Wilcoxon Signed Ranks test was again performed to compare the arousal rating in the control and EMF conditions. This resulted in a marginally significant z = -1.700 (p = 0.045, 1-tailed). H3, that the arousal rating would be less in the presence of an EMF, was therefore supported.

Figure 2 shows the distribution of arousal ratings for the control and EMF conditions, showing the slight shift towards less arousing ratings when an EMF was present, although there may also be a tendency for more midrange arousal ratings.

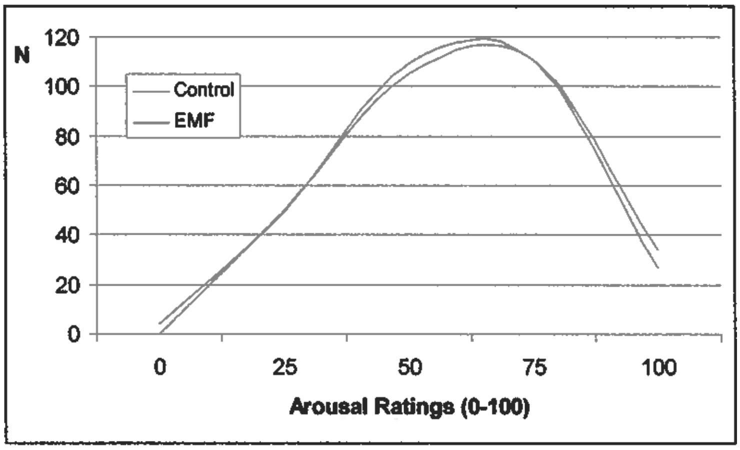

Figure 2: Distribution of arousal ratings

Analysis of participant VALENCE response

Table 4 summarises the overall valence ratings for all images. Once again, had the images been properly balanced for valence, the mean response should have been 50.0 in the control condition. The actual figure of 48.9 is a fairly good match. The EMF mean value indicates an change of perceived valence in the presence of a field, corresponding to a more positive rating.

Table 4: Summary of participant valence ratings for presented images

	Control	EMF
N	300	300
Minimum	0	2
Maximum	100	100
Mean	48.9	52.7
std dev	22.3	21.1

Table 5 shows how the images were ranked overall by their valence rating (calculated by combing all individual ratings). Rankings 1-10 in the control condition contain 80% of the images originally classed as being arousing, again offering some indication that the pictures were correctly classified. In the EMF condition, this was increased to 90%, indicating that there was no qualitative change in the way the images were affectively perceived.

Table 5: Ranking of participant valence responses (**P***leasant* or **U***npleasant*)

Valence Ranking	Control condition		EMF condition	
	Image #	Valence Category	Image #	Valence Category
1st	18	P	5	P
2nd	14	P	18	P
3rd	2	P	14	P
4th	13	P	9	P
5th	10	P	10	P
6th	6	P	2	P
7th	11	U	13	P
8th	15	U	1	P
9th	17	P	11	U
10th	9	P	6	P
11th	12	U	15	U
12th	8	U	12	U
13th	19	U	4	U
14th	1	P	3	U
15th	7	U	17	P
16th	16	U	20	U
17th	4	U	7	U
18th	5	P	19	U
19th	20	U	8	U
20th	3	U	16	U

As before, a Wilcoxon Signed Ranks test was performed to compare the valence rating in the control and EMF conditions. This resulted in a significant z = 2.318 (p = 0.02, 2-tailed). H4, that the valence rating would be different in the presence of an EMF, was therefore supported. In fact, all images were perceived to be either more positive or less negative when a field was present.

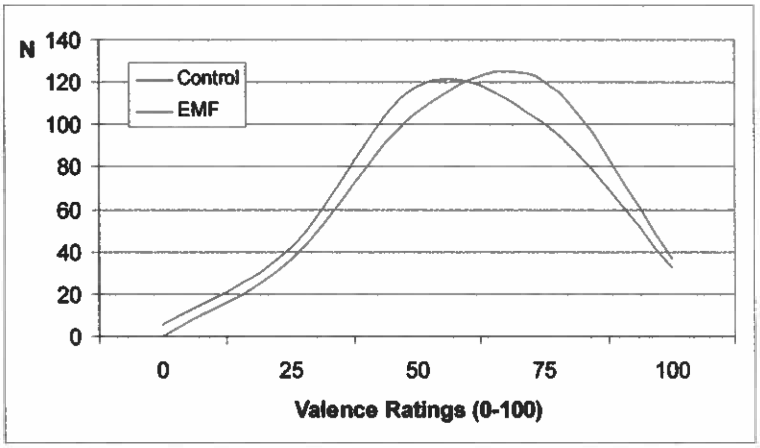

Figure 3: Distribution of valence ratings

As can be seen from the distribution of results in figure 3, the distribution of ratings when an EMF is present show an overall shift, confirming the earlier conclusions that the presence of a field is associated with a more positive (or less negative) perception of image affect.

Analysis of Known vs. Not Known EMFs

It was predicted that any EMF associated effect seen would be stronger when participants were unaware that there was the possibility of a field being present. The rationale for this was that, should participants experience any EMF-induced physiological effects, they would be more likely to attribute these to the presumed presence of a field rather than to their perception of the image.

Table 6: Comparison of mean arousal and valence ratings under EMF-known and EMF-unknown conditions.

	Mean Valence Rating	Mean Arousal Rating
EMF Not Known	50.7	48.2
EMF Known	51.0	49.0

For the valence ratings, a t-test (1-tailed, df=598) gave t= -0.15, p=0.44. Thus H5 is not supported for the valence ratings. The small difference found was actually in the opposite direction to that predicted.

For the arousal ratings, a t-test (1-tailed, df=598) gave t= -0.41, p= 0.34. H5 is thus also not supported with respect to arousal, although the small effect found was in the predicted direction.

Discussion

This study investigated the possibility that an applied weak electromagnetic field might be associated with a change in physiological functioning in humans. Results showed that, in 66% of cases, a mean change in EDA level of -1% was found when an EMF was present - a statistically significant effect. A mean change in EDA variance of -22% was also observed in 53% of cases when an EMF was applied, although this was not statistically significant. It was further hypothesised that this change in physiology would act to alter the time-matched perception, as self-perception of physiological arousal plays a part in the classification of external perceptions. It was found that the presence of an EMF was indeed associated with lower arousal ratings for the images, and that the valence ratings were more positive. Combining the results, it may be suggested that an applied EMF acts in some way to suppress physiological activity, and that this perturbs ongoing perceptions in a manner consistent with a sense of being relaxed. That is, suppressed physiological activity leads the participant to believe they are less aroused. Such a state is seen as being associated with more positive feelings, so perceptions will be seen either as more positive or as less negative than they might be otherwise.

The results found in this study compare favourably to those found in the original study (Stevens, 7/96) which also showed decreased EDA in the presence of an EMF. In that study, a greater magnitude difference was found for the variance measure (Wilcoxon z = 3.10, p = 0.002, 2-tailed), and a lower magnitude difference for the level measure (Wilcoxon z = 0.83, p=0.41, 1-tailed). This difference may have been due to the different protocols (that study utilised a training procedure, so results represented a large number of collapsed trials) or individual differences (it was found that field-independent people contributed the most significant results). As such, the effect of an applied EMF on human physiology was replicated.

Conclusions

It is concluded that electromagnetic fields with characteristics such as those used in this study would probably be associated with a physiological response in a general population; this response is characterised by a decrease, with respect to resting levels, in both the magnitude and the variability of electrodermal activity. Furthermore, this response appears to be interpreted as being caused by the current sensory perception, resulting in a less arousing and more positive affect being attributed to that perception. There do appear to be individual differences for sensitivity to electromagnetic perceptual perturbation, possibly related to baseline physiological activity, but the details of these are not yet known.

References

Bell, G. B., Marino, A. A., and Chesson, A. L., (1994). Frequency-specific responses in the human brain caused by electromagnetic-fields, *Journal of the Neurological Sciences*, 123 (1-2), 26-32.

Cacioppo , J. T. and Tassinary, L. G.(Eds.) (1995). *Principles of Psychophysiology*, Cambridge University Press.

Dalton, K. and Stevens, P. (1996). Geomagnetism and the Edinburgh Automated Ganzfeld, European Journal of Parapsychology, 12, 23-34.

Davis, W.J., Rahman, M.A., Smith, L.J., Burns, A., Senecal, L., McArthur, D., Halpern, J.A., Perlmutter, A., Sickels, W. and Wagner, W. (1985). Properties of human affect induced by static color slides (IAPS): dimensional, categorical and electromyographic analysis. *Biological Psychology*, 41, 229-253.

Appendix: Mean participant ratings for each image, split by electromagnetic field condition

Valence Ratings

Image		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	2
Valence		P	P	U	U	P	P	U	U	P	P	U	U	P	P	U	U	P	P	U	U
EMF	$\bar{x}$	58.2	59.2	50.4	52.2	62.7	56.1	47.9	38.1	61.8	59.9	57.6	53.9	59.1	61.9	53.7	36.1	50.4	62.6	46.1	4
	SD	16.1	14.3	26.1	21.4	19.6	17.3	17.3	23.7	14.5	12.8	19.8	16.7	24.1	25.9	20.7	21.2	23.1	16.5	16.3	2
Control	$\bar{x}$	44	57.9	39.5	42.6	42.6	52.8	43.7	44.9	49.9	54.2	52.2	45.5	54.4	61.0	50.7	43.5	50.5	62.8	44.3	42
	SD	21.4	15.5	26.3	22.3	23.4	25.0	19.3	24.8	26.3	16.0	21.0	19.9	29.1	28.5	17.5	19.6	13.4	19.4	22.1	21
$\bar{x}_{emf} - \bar{x}_{control}$		14.2	1.3	10.9	9.6	20.1	3.3	4.2	-6.7	11.9	5.7	5.4	8.4	4.8	0.9	3.0	-7.4	-0.1	-0.2	1.8	

Mean ($\bar{x}_{emf} - \bar{x}_{control}$) = 4.8 (i.e EMF > Control. True in 16/20 cases) Images rated as more positive or less negative in presence of applied field.
Exceptions: 8: Pollution (U), 16: Prison Arm (U), 17: Eagle (P), 18: Happy Adult (P)
→ Split by Valence: P Mean ($\bar{x}_{emf} - \bar{x}_{control}$) = 6.14 , U Mean ($\bar{x}_{emf} - \bar{x}_{control}$) = 2.96

Arousal Ratings

Image		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Arousal		A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
EMF	$\bar{x}$	52.7	43.5	53.8	46.2	50.8	38.9	39.3	51.8	47.7	30.8	37.6	33.9	59.8	50.5	43.3	54.8	52.0	48.1	44.0	55.1
	SD	14.4	20.7	21.0	21.5	17.8	25.9	21.8	26.8	16.7	28.1	26.2	25.0	18.7	24.3	15.7	16.6	21.0	22.7	18.9	21.9
Contro l	$\bar{x}$	54.1	38.4	54.5	52.8	56.1	54.5	54.1	50.2	53.7	40.9	44.1	52.3	59.7	61.6	53.0	47.8	40.5	50.2	39.9	44.2
	SD	19.8	23.8	28.7	22.3	14.1	24.4	23.1	23.7	17.5	23.1	24.6	21.8	25.1	16.9	10.4	19.0	16.2	22.6	20.3	21.7
$\bar{x}_{emf} - \bar{x}_{control}$		-1.4	5.1	-0.7	-6.5	-5.4	-15.6	-14.8	1.6	-6.0	-10.2	-6.5	-18.4	0.0	-11.1	-9.7	7.0	11.5	-2.0	4.1	10.9

Mean ($\bar{x}_{emf} - \bar{x}_{control}$) = **-3.4** (i.e EMF < Control. True in 13/20 cases) Images rated as less arousing in presence of applied field.
→ Split by Arousal: A Mean ($\bar{x}_{emf} - \bar{x}_{control}$) = -2.89, C Mean ($\bar{x}_{emf} - \bar{x}_{control}$) = -3.92
Exceptions: 2: Finch (C) ,8: Pollution (C), 13: Female Nude (A),16: Prison Arm (C), 17: Eagle (A), 19: Snake (A),20: Concentration Camp (C)

ELECTROMAGNETIC PSYCHOKINESIS?

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As with many other branches of science, it is unlikely that a good understanding of psi phenomena will be reached before there exists a better conception of how the underlying mechanism of psi might work. This assumes that psi is not radically different from other physical phenomena - an assumption which is not accepted by all in the field - so can this be justified ?

The first question must be: does psi need to be due to any sort of physical signal ? There appear to be a number of advantages to taking this as a working hypothesis. First of all, we know that living organisms radiate different forms of energy, all of which contain a lot of information about that organism. The extent to which other organisms might be able to detect and make use of such information is only just beginning to be explored. Assuming that psi in at least some of its forms might be related to such energetic emissions does not seem implausible. Such an approach also establishes a continuum between living organisms and inanimate objects as the latter also emit energy, often covering frequency ranges which overlap those utilised by biological organisms.

Secondly, if psi were *not* physical then there are problems in having a non-physical phenomenon interact with a physical system. Such an interaction would require the invocation of some acausal principle. Moreover, if psi is related to the concept of a non-physical mind, as some of the dualist perspective would argue (Beloff, 1994), then the problem is just relegated to how such a mind might interact with the physical brain. While this could turn out to be the case, the lack of any viable theories that could model such an interaction mean that taking this approach is unlikely to further our understanding of psi phenomena.

Finally, and perhaps most simply, there is no convincing reason to assume psi is not energetic. At our current level of scientific knowledge, we know of no non-energetic phenomena that can directly affect physical systems. It would seem premature to suppose psi is fundamentally different from other phenomena without having good reason to do so. So the question becomes, do we have reason to conclude this is the case? Other researchers have proposed that some characteristics of psi phenomena differ from our concept of everyday reality in that psi can apparently exhibit some degree of independence from both spatial and temporal parameters. That is, the distance in both space and time between the target system and the presumed psi agent is, to some extent, not an important factor in the success of a psi task. While this may be the case, the work done has not ruled out other interpretations (e.g. real-time extrapolation of ESP information, or precognitive viewing of remote targets), and certainly is not comprehensive enough to warrant the conclusion that psi is beyond physics as we currently understand it.

So what could be the nature of this signal? Based on the knowledge of the functioning of biological systems, and of the typical target systems used in psi research, I favour a psi signal consisting of an electromagnetic wave. There has long been the suggestion of a possible link between electromagnetic phenomena and psi effects (Becker, 1992), either in that specific electromagnetic fields may be conducive to psi (Persinger, 1989), or that psi itself could be an electromagnetic phenomenon. Although the consensus has been that not all of the properties of psi can be fully explained by conventional electromagnetic effects, there do still seem to be sufficient parallels to suppose an interrelationship between the two. I am proposing therefore that there exists a psi signal which consists of an electromagnetic wave generated by *electrodynamic* (involving the movement of electrical charge) events. In a biological system, these events take place on a cellular level. In non-biological systems, the events will involve whatever electrodynamic processes are of relevance to the psi phenomena under study. The generation of a psi signal is thought to be the result of normal activity rather than any novel, psi-specific process. Specifically, the change in the motion of charged particles (electrons or ions) within the generating system produces electromagnetic radiation - for example, as electrical pulses start to travel along the axon of a neuron, or when they terminate at the synapses. Interference effects between interacting electromagnetic waves (as any activity within the system will involve large numbers of particles) will encode information about system activity that will propagate outwards, eventually interacting with the target system. This would mean that, as opposed to the conventional idea of a carrier wave (i.e. a base electromagnetic wave which is modulated in some way to carry additional information), the characteristics of the 'carrier' wave itself make up the necessary information. That is, the base frequency and duration of the wave are all the information that is conveyed by the psi signal. The detection process is then either by associative feedback (the receiving system learning to associate a particular pattern of psi signals with explicit feedback) or a driving effect between emissive and receptive systems (as when brain activity synchronises to match the frequency of a flashing light).

However, while some psi phenomena - such as local, real-time ESP (i.e. not including cases of true precognition) and dowsing - may be explainable purely in terms of an electromagnetic wave, there are effects commonly seen in psi research which can not be explained purely by classical electromagnetic theory. Examples of target systems which have shown apparent perturbations related to human intention include background radiation levels and quantum noise systems (Edge et al, 1987), neither of which would conventionally be expected to be affected by a weak electromagnetic wave. For this reason, electromagnetic explanations of psi have not been widely accepted. However, based on some theoretical ideas of the author (Stevens, 1997), it was decided to look at the possibility that weak electromagnetic fields might indeed be responsible for some instances of micro-PK. These ideas essentially propose that the semiconductor properties of certain materials are the site of interaction for psi. That is, an electromagnetic psi signal would act to modify the spontaneous fluctuations within the semiconductor material. Such materials include the chips used in many random event generators (REG), and the cell membranes of biological cells (which undergo a stochastic gating process akin to electronic noise - Ho, 1993).

The study looked at the effects of electromagnetic fields on a typical Zener-diode based REG (a serial port device, supplied by Professor Dick Bierman, University of Amsterdam), postulating that a psychokinesis-like effect would be found. Earlier work by the author into human sensitivity to electromagnetic fields (Stevens, 1997) found that the mean level and variance of human autonomic activity was decreased in the presence of weak electromagnetic fields. Based on the proposed shared site of interaction of an electromagnetic field (and so possibly a psi signal) between the biological system and the nonbiological semiconductor-based systems, it was predicted that there would also be a decrease both in the mean number and the variance of events produced by the REG when comparing different applied fields to the baseline condition of no applied field.

METHOD

Apparatus

A computer controlled system was set up such that there was a random presentation of different types of electromagnetic fields applied via Helmholtz coils - a pair of parallel coils 0.65 metres in radius and separated by the same distance. This set-up ensured a reasonably homogeneous (to within a few percent) field in the centre region between the coils. The coils were constructed of wood, and wrapped with enamelled copper wire. For a detailed discussion of this type of apparatus, the reader is referred to Bell and Marino (1989).The electromagnetic field had its own separate power supply, but was controlled via the amplified output from a PC sound card. This enabled easy generation of different types of wave-forms. The main restriction with this method was that signals could not be generated below 20 Hz as the sound card was intended primarily for audio-range frequencies and rapidly degraded the signal below this limit. For the system used in this study, a field was produced by supplying a direct current, modulated at specific frequencies, to the coils. This field, applied in an East-West direction, was directly measured using a flux-gate magnetometer. The field frequencies were chosen to lie within the range of biological system activity. The computer used a pseudo-random algorithm to determine the type of field, all random selections having equal probabilities of being selected each time.

Within the coils was placed a serial port (Bierman) REG based on two Zener diodes, this being a typical REG used in many different psi studies. Possible electromagnetic fields types were fields of 40 Hz, 20 Hz, or 10 Hz pure tone sinusoidal wave forms, white noise (a random mix of frequencies), or a period equivalent in terms of duration and computer activity but with no field generated (a 'silent' field). All wave forms were of 30 seconds duration, with a flux density of either 500 mG, 250 mG or 10 mG (N.B. 1mG is one-thousandth of a Gauss, the c.g.s. units of magnetic flux density. It corresponds to 10^{-7} Tesla in S.I. units.). No attempt was made to shield against additional effects of the natural geomagnetic field as this would have been extremely difficult and expensive. Instead, these values were later retrieved from the internet site (telnet://vaxa.nerc-murchison.ac.uk, username: GIFS, password: GMINFO) of the British Geological Survey geomagnetic monitoring station to be taken in to account in the statistical analysis. The K_p index was used, this being a three-hourly measure of the largest geomagnetic field fluctuation in the North-South, East-West or vertical axes recorded at any one of 13 geomagnetic recording stations around the world. The average K_p for the 12 hour period covering each experimental session was calculated and used in the statistical analyses.

PROCEDURE

Once initiated, a complete experimental session lasted for 12 hours, this being 1440 trials each of thirty seconds duration at approximately 4 Hz (equivalent to 119 REG samples in each trial). Each sample was 175 bits (so the expected number of mean events was 87.5). Sessions were started in the evening, and allowed to run unsupervised in a locked room overnight, or over the weekend, this arrangement minimising any possible effects due to the presence of people in the immediate environment.

PREDICTIONS

The main predictions were:
H1: In an applied field, the REG output would show a decreased:
(a) number of events.
(b) variance.
The effect of the geomagnetic field on the system (essentially a confounding variable that could not be shielded against), and an interaction between the GMF and the applied field was also looked for. As there has long been thought to be a relationship between success in psi and GMF activity, it was further predicted that there would be a difference in mean events and variance depending on the geomagnetic field activity, but no direction was specified. ESP protocol research has often found that lower GMF activity is associated with success, whereas the few PK protocol looking at a possible relationship have been less consistent. Secondary predictions were thus:
H2: Irrespective of the experimentally applied electromagnetic field, geomagnetic field activity would show a relationship with the REG output based on:
(a) mean number of events
(b) variance

RESULTS

The following tables 1-6 give summaries of the results obtained over 10 sessions (299,880,000 binary events) spaced over a period of 1 month.

Table 1: Mean of REG events and variance for 500 mG field, split by field type

	Mean Events	Mean Variance	N
No field	87.49	43.63	6487
Field	87.49	43.21	4848
20 Hz	87.50	43.38	1631
40 Hz	87.49	43.27	1629
White Noise	87.49	42.98	1588

Table 1 shows results for the highest field flux density used. The mean number of events observed was not noticeably altered, but the variance of those events did show an overall decrease when an electromagnetic field was applied. A further breakdown shows that the white noise (a random mix of frequencies) showed the greatest decrease in variance.

Table 2 shows an analysis of variance (ANOVA) for the 500mG applied field. This showed no significant change in the number of mean events due to the presence of the applied fields but did show that the variance was significantly altered. The geomagnetic field alone did not appear to have an overall effect on either the mean number of events or on the variance of those events, but there was a significant interaction between the applied field and the GMF in for the variance of the REG events.

Table 2: Analysis of variance for 500 mG applied field and GMF effects

	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p (F)
By Applied Field (df = 3, 11307)						
Mean Events	0.029	4159.629	0.010	0.368	0.026	0.994
Mean Variance	440.863	365699.95	146.954	32.343	4.544	**0.004**
By GMF (df = 6, 11307)						
Mean Events	0.927	4159.629	0.155	0.368	0.420	0.866
Mean Variance	168.140	365699.95	28.023	32.343	0.866	0.518
Interaction (df = 18, 11307)						
Mean Events	6.891	4159.629	0.383	0.368	1.041	0.409
Mean Variance	985.653	368699.95	54.758	32.343	1.693	**0.033**

Table 3: Mean events and mean variance for 250 mG field, split by field type

	Mean Events	Mean Variance	N
No field	87.49	43.63	6487
Field	87.49	43.45	4921
20 Hz	87.47	43.34	1659
40 Hz	87.52	43.32	1590
White Noise	87.48	43.68	1672

For the 250 mG applied field, results are shown in table 3. Again, the mean number of events was not noticeably altered for the field versus no field comparison, although there was a difference when the breakdown into different types of fields was considered. The variance of those events again showed an overall decrease when an electromagnetic field was applied, although this turned out to be true only for the two pure frequencies. The white noise this time showing an increase in variance.

Table 4: Analysis of variance for 250 mG applied field and GMF effects

	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p (F)
By Applied Field (df = 3, 11307)						
Mean Events	1.826	4229.763	0.609	0.372	1.638	0.179
Mean Variance	186.386	371547.137	62.129	32.649	1.903	0.127
By GMF (df = 6, 11380)						
Mean Events	1.256	4229.763	0.209	0.372	0.563	0.760
Mean Variance	39.033	371547.137	6.506	32.649	0.199	0.977
Interaction (df = 18, 11307)						
Mean Events	4.760	4229.763	0.264	0.372	0.711	0.803
Mean Variance	764.701	371547.137	42.483	32.649	1.301	0.175

The ANOVA for the 250 mG applied field is shown in table 4. The change in the mean number of events due to the applied fields was not significant, nor were the changes in the mean variance due to the presence of the applied field significant.

Table 5: Mean events and mean variance for 10 mG field, split by field type

	Mean Events	Mean Variance	N
No field	87.49	43.63	6487

Field	87.49	43.41	4839
20 Hz	87.47	43.76	1622
40 Hz	87.49	43.15	1647
White Noise	87.50	43.33	1570

Table 5 shows the results for the 10 mG applied field. Yet again, the mean number of events was not noticeably altered for the field versus no field comparison, and there was a slight difference for the breakdown into different types of fields. The mean variance showed the expected overall decrease when there was an applied field, but the breakdown by field type was not consistent, showing an increase for the lowest frequency, and a decrease for the mid-frequency and the white noise.

The ANOVA for the 10 mG applied field (table 6) showed no significant change in the number of mean events but the mean variance was just significantly altered in the case of the applied field and for the GMF alone. No significant interaction effects were found, implying that the noted effects might be cancelling each other out?

Table 6: Analysis of variance for 10 mG applied field and GMF effects

	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p (F)
By Applied Field (df = 3, 11298)						
Mean Events	2.202	4142.612	0.734	0.367	2.002	0.112
Mean Variance	259.592	367712.83	86.531	32.547	2.659	**0.047**
By GMF (df = 6, 11298)						
Mean Events	2.573	4142.612	0.429	0.367	1.170	0.319
Mean Variance	414.421	367712.83	69.070	32.547	2.122	**0.047**
Interaction (df = 18, 11298)						
Mean Events	7.973	4142.612	0.443	0.367	1.208	0.244
Mean Variance	711.136	367712.83	39.508	32.547	1.214	0.239

Overall, the ANOVAs showed no significant effects on the mean number of events, either for the applied or the geomagnetic field . H1a and H2a were therefore not supported.

Several significant interactions were found for the mean variance. For the applied field some exploratory t-tests were performed to determine the direction of the effects. The results are given in table 7. For the applied fields, the 500 mG and 10 mG fields showed significant effects in the predicted direction (the mean variance was lower in the presence of an applied field), and the mid-range field was very close to significance.

Table 7: T-tests looking at Applied field vs. no field effects on variance

Variance of events with field of:	t	p(t) 1-tailed	Effect size (Fisher's Z)
500 mG	-3.843	0.00005	0.036
250 mG	-1.631	0.052	0.015
10 mG	-1.968	0.025	0.019

*N.B. a negative t implies value under field is lower than under no field*To determine an overall effect, the t values were converted to standardised z-scores using Rosenthal's method (Mullen and Rosenthal, 1985) and combined to give an overall z of -4.296, with an associated probability value of less than 0.001 and effect size of 0.028. H1b was therefore supported.

For the geomagnetic field effects, the data were split into two groups - with a K_p index value above the mid point, the other below this - and a t-test performed. The results (see table 8) show that the effect appears to become stronger as the applied field becomes weaker, actually reaching significance for the weakest applied field. This would tend to imply that any effect due to the geomagnetic field will be drowned out in the presence of other, stronger effects, but will show up when the other effects are very weak, as is likely to be the case with psi.

Table 8: T-tests looking at low vs. high geomagnetic activity effects on variance

Variance of events with field of:	t	p(t) 2-tailed	Effect Size (Fisher's Z)
500 mG	0.208	0.835	0.002
250 mG	1.340	0.180	0.013
10 mG	2.522	0.012	0.024

N.B. a positive t implies value under low GMF is higher than under high GMF value

Table 9: Mean events and mean variance for data sets, by geomagnetic field fluctuations

	500 mG data set			250 mG data set			10 mG data set		
GMF K Index	Mean Event	Mean Var	N	Mean Event	Mean Var	N	Mean Event	Mean Var	N
0.4	87.49	43.39	1569	87.49	43.49	1545	87.49	43.31	1570
1.0	87.51	43.41	769	87.48	43.46	809	87.48	43.27	792
1.2	87.48	43.49	1548	87.49	43.41	1544	87.47	43.43	1544
1.4	87.51	43.63	799	87.49	43.80	773	87.50	44.06	748
2.0	87.49	43.40	4346	87.50	43.60	4418	87.49	43.55	4413
2.8	87.49	43.10	743	87.49	43.19	748	87.52	43.16	751
3.4	87.50	43.69	1561	87.49	43.71	1571	87.50	43.90	1506

It is also interesting to note that the direction of the effect, that the overall mean variance is higher when the GMF activity is low, is similar to the findings of ESP research - that psi is more successful when the GMF is relatively inactive. The t values were again converted to standardised z-scores and combined to give an overall z of 2.350, with an associated probability value of 0.02 and effect size of 0.015. H2b is therefore also supported.

In an attempt to find out how the GMF affects the results, the mean variances under each of the measured GMF activity values were tabulated (see table 9) and then plotted on a graph (see figure 1).

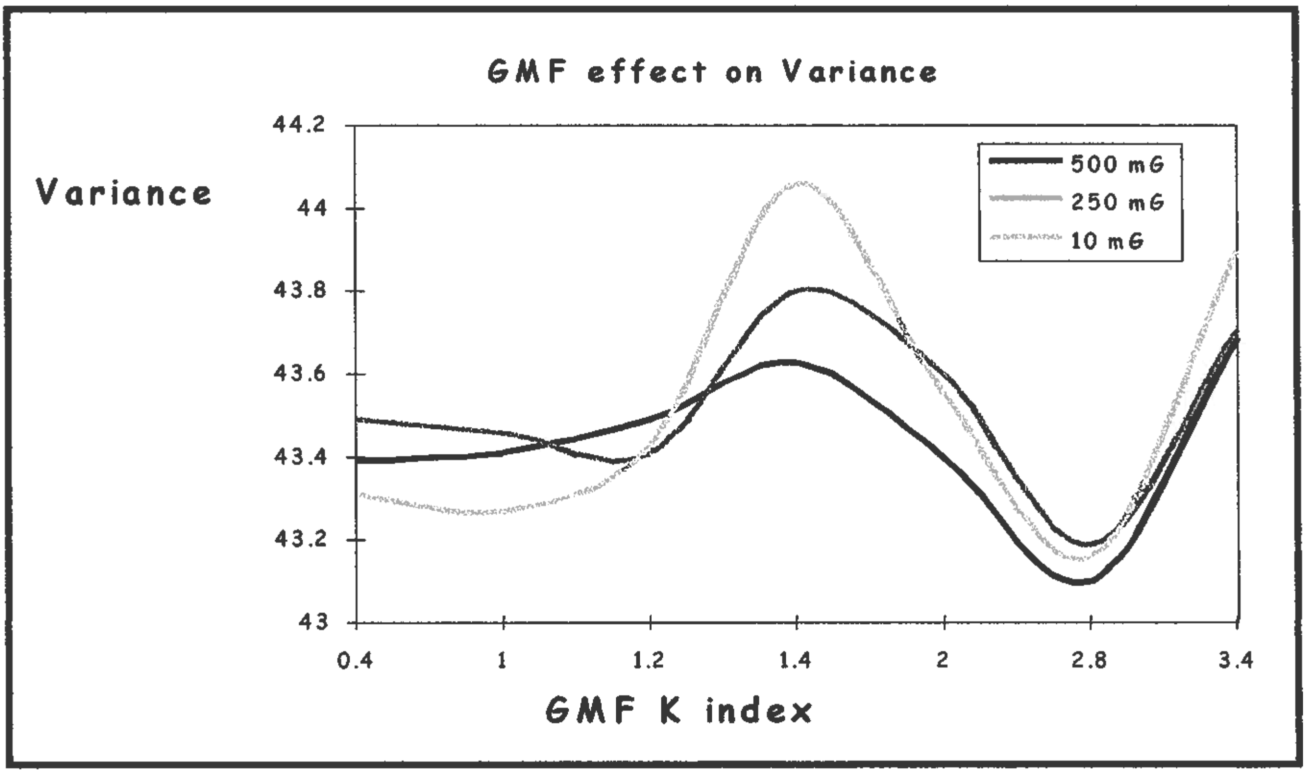

Figure 1: Mean variance versus geomagnetic activity

It is apparent that there was no consistent effects on the mean number of events, as was indicated by the ANOVAs. However, it can be seen that the effect on the variance does appear to be consistent for all the densities of applied field, although the relationship is certainly not linear. This can be seen clearly in figure 1, with the effect of the GMF being stronger for the weaker applied fields.

DISCUSSION

The study described did not find any significant effects of the applied fields or of the naturally occurring geomagnetic field on the mean number of events produced by an electronic REG. This mean shift was also seemingly not dependent on the flux density of the field. Variance of REG output was lowered for the field versus no field case. However, the direction of the shift in variance had some as yet unknown relationship to the frequency of the applied field. For the proposed psi signal, we might therefore expect different PK effects on REGs based on the frequency characteristics of that signal. Consistent PK results would be obtained only if the psi signals in various trials were made as similar as possible. This might be possible if the psi agent(s) were trained to produce a specific pattern of brain activity (e.g. more global alpha) during influence attempts. The results suggest a non-linear decline in effect size with decreasing flux density, so for typical neural magnetic fields of 10^{-8} mG (i.e. 10 million times weaker!) we would expect a decreased effect size from that found here.

A surprising finding was that the geomagnetic field alone was associated with changes in the target system. Although past psi research had suggested a relationship between the activity of the geomagnetic field and success in psi tasks, it has been generally assumed that this was an interaction effect. That is, the geomagnetic field was assumed to interfere with the psi agent or with the psi mechanism. However, results from this study suggest that the geomagnetic field may in itself affect the functioning of the REG. This effect was found to be stronger when the applied fields were weaker. As psi is proposed to be due to a very weak field, the geomagnetic effect would be noticeable in studies where measures were directly related to the REG output, though the effect is as likely to be on the target system as on the psi agent.

To conclude, this study found an overall effect in which a random event generator showed a significant decrease in the mean variance of events when an electromagnetic field was applied. The direction of the effect appeared to have some relationship with the frequency characteristics of the applied field, although the nature of the relationship remains unclear. No overall change was found in the mean number of events generated under an applied field. The aim of this study was to investigate the possibility that the effects seen in psi experiments using REGs based on electronic noise could be due to an electromagnetic mechanism. It is concluded that this approach is viable.

REFERENCES

BECKER, R. O. (1992). Electromagnetism and Psi Phenomena, *Journal of the American Society for Psychical Research*, 86 (1), pp. 1-17.

BELL, G. B. & MARINO, A. A. (1989). Exposure System for Production of Uniform Magnetic Fields, *Journal of Bioelectricity*, 8 (2), pp. 147-158.

BELOFF, J. (1994). Mind and Machines: a Radical Dualist Perspective, *Journal of Consciousness Studies*, 1(1), pp. 32-37.

Dalton, K. and Stevens, P. (1996). Geomagnetism and the Edinburgh Automated Ganzfeld, *European Journal of Parapsychology*, 12, pp. 23-34.

EDGE, H. L., MORRIS. R.L., PALMER, J. & RUSH, J.H. (1987). *Foundations of Parapsychology: Exploring the Boundaries of Human Capability*, Routledge and Kegan Paul.

Ho, M. W. (1993). The Rainbow and the Worm: the Physics of Organisms, World Scientific.

MÜLLEN, B. & ROSENTHAL, R. (1985). *Basic Meta-Analysis: Procedures and Programs*, Lawrence Erlbaum Associates.

PERSINGER, M. A. (1989). Psi Phenomena and Temporal Lobe Activity: the Geomagnetic Factor, *Research in Parapsychology*, The Scarecrow Press, pp. 121-156.

STEVENS, P. (1997). Human Sensing of Weak Electromagnetic Fields: a Possible Relationship to Psi ? *Proceedings of the 40th. Parapsychological Association Convention*, pp.426-440.

STEVENS, P. (1997). *A biophysical approach to psi effects and experience*, unpublished doctoral thesis, University of Edinburgh.