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The Effect of Weak Magnetic Fields on a Random Event Generator: Reconsidering the Role of Geomagnetic Fluctuations in MicroPK Studies

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Abstract

This exploratory study looked at the effect of geomagnetic fluctuations on a random event generator (REG) commonly used as a target system in microscopic psychokinesis (microPK) studies. It is suggested that the geomagnetic fluctuations may themselves be considered as a signal which affect the REG through a process of stochastic resonance. The effect of different geomagnetic activity "signals" on REG output was thus measured during simultaneous application of different levels of magnetic field "noise". As might be expected if stochastic resonance were involved, the REG output (z^2) for each of the geomagnetic activity "signals" showed a maximum at a non-zero level of magnetic field "noise". This level was consistent for 3 of the 4 geomagnetic "signals" used (maximum for K = 0, 2, 3 when noise field was 1 μT), with the highest geomagnetic "signal" (K = 4) showing a separate peak for a 25 μT noise field. As the noise fields were applied in a random schedule over non-consecutive days, this would appear to be a robust finding. The role of magnetic fields should therefore be considered, either as a direct effect on REGs or as part of a microPK mechanism, in any theories attempting to model microPK effects.

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Introduction

Many studies have reported results (see Radin & Nelson, 1989 for summary) which appear to support the existence of microscopic psychokinesis (microPK), wherein a statistical relationship is found between an agent's mental state or behaviour and the activity of a target system . The target system is usually some form of random event generator (REG), the most commonly used type being based on the electronic noise inherent in semiconductors, amplified and digitised to give a output sequence of random numbers. To date, no mechanism has been identified by which such effects might be explained. In the absence of an accepted microPK theory, researchers have attempted to look for physical variables that might affect experimental results. Knowledge of such variables could eventually help theorists identify potential microPK mechanisms, and in the short term might lead to solutions to, or at least explanations for, the lack of replicability that plagues parapsychological research.

One potential physical variable is the amount of activity of the Earth's (geo) magnetic field, which cover a range of frequencies from 0 to 1 kHz (Parkinson, 1983). At one end of this range is the static dipole field generated by the Earth's internal dynamics; at the other are the rapid changes due to interactions between the charged layer of the atmosphere (the ionosphere) and the ground. Between these are the pulsations due to charged particles entering the geomagnetic field from space. The overall activity of the geomagnetic field is monitored using sensitive magnetometers and presented either in terms of the ongoing absolute magnitude[1] or the relative change in a given time period. The most commonly used measures in parapsychology studies are geomagnetic indices (such as the 3-hourly K, Kp and ap indices, or the daily Ap index) which represent standardised local and global disturbance levels of the geomagnetic field.

Many studies have reported a correlation between the effects measured in perceptive psi experiments and geomagnetic field activity, with the general finding that success, however it is defined, decreases as geomagnetic activity increases. For example, apparent extrasensory perception was inversely related to global magnetic activity while the participant was in a dream state (Persinger & Krippner, 1983) and also while in

[1] Technically this is actually a quantity known as *flux density*, but for the purposes of this discussion, magnitude is a close enough concept.

the mild sensory-deprivation Ganzfeld state (Dalton & Stevens, 1996). However, the picture is less clear with microPK experiments. Gissurarson (1992) found a significant negative correlation between the direction of REG output and local field fluctuations, while Nelson and Dunne (1986) reported a non-significant positive correlation between the global activity and REG output.

This relationship, if it represents a real effect, might occur in a variety of ways, but in general it seems that the physical fields (primarily magnetic) associated with geomagnetic activity measures must interact either with the microPK agent, the microPK mechanism or the target system. The first case, that geomagnetic field activity affects the psi agent, has some merit in that there is an increasing body of research showing that weak magnetic fields in the geomagnetic frequency range can alter human behaviour (Stevens, 2001; Bell et al, 1994; Warnke, 1994). However, without knowing what it is the psi agent is doing to bring about a microPK effect, it is difficult to evaluate this possibility. It is also hard to conceptualise how sensitivity to magnetic fields (a receptive ability) might relate to the apparently emissive ability of microPK.[2] The second case, that geomagnetic field activity interacts with the mechanism underlying psi effects is even more difficult to evaluate in that the mechanism has not yet been identified. The third case, that the field interacts with the target system itself is an intriguing idea in that, if a magnetic field can affect the functioning of a target system, then this suggests that such fields could also be involved in the production of microPK effects. In this paper, I will look in more depth at this third possibility.

Magnetic Fields and microPK

That magnetic fields might be involved in some way with microPK is not a widely studied idea, mainly due to the small magnitude of geomagnetic or biologically-generated magnetic fields in comparison to man-made sources. However, there have been a few studies which have addressed this idea. Chauvin and Varjean (1990) found that application of a weak magnetic field to a random mechanical cascade device was associated with a reduced mean during microPK trials. Stevens (1999) conducted a remote microPK study where the REG output showed a

[2]This is true only if microPK represents an action of the agent on the target system, rather than the extrasensory selection process that Decision Augmentation Theory (May et al, 1995) adherents would suggest. However, if microPK is indeed a perceptive ability akin to ESP, then this does not explain why the geomagnetic relationship sometimes shows the reversal in direction.

positive correlation with a 3 hourly global geomagnetic activity index (ap) in both microPK trials and in control data. That both studies found a correlation between microPK success and ambient magnetic activity suggests that there is an interaction between the agent's attempts to influence the target system and that field. However, the Stevens study also suggests that the magnetic field must directly affect the REG, as a significant correlation, albeit weaker, was also found in the control data. To confuse the matter further the two studies found correlations in opposite directions: the Chauvin and Varjean study found decreased means with the applied field, whereas Stevens found increased means for increased geomagnetic activity.

Part of the confusion could lie in the way the interaction occurs. By reporting correlations between (geo) magnetic field activity and REG output, the implicit assumption is that it is a linear relationship. But the lack of consistency could imply otherwise, suggesting a more complex form of interaction.

One concept that may be useful is the phenomenon of *stochastic resonance* (SR) wherein a noisy system is driven by an external signal that would be normally be considered too weak to affect it (Wiesenfeld & Moss, 1995; Gammaitoni et al, 1998). Some characteristics of that signal (such as amplitude, signal-to-noise ratio, coherence, or other measure of performance) are, counter to intuition, actually improved by the presence of the noise. Essentially, the noise randomly boosts the weak signal by sometimes giving it enough extra energy to have a significant effect. This means that, with SR, a system becomes a more sensitive detector of a weak signal as more noise is added, at least up to a point: it is optimally sensitive at some non-zero level of input noise. If some measure of the Signal to Noise ratio is plotted against the input noise, this results in a characteristic profile (see figure 1).

Stochastic Resonance

It should be noted that SR is not an esoteric phenomenon rarely found in nature but one which appears in many physical systems, from the periodic recurrences of Earth's ice ages (Wiesenfield and Moss, 1995) to quantum tunnelling effects (Grifoni et al, 1996). It has also been observed in semiconductor diodes similar to those used as the underlying noise source in many REGs (Jung & Wiesenfeld, 1997).

So how might this help in understanding a relationship between magnetic fields and microPK? As mentioned earlier, we know that mi-

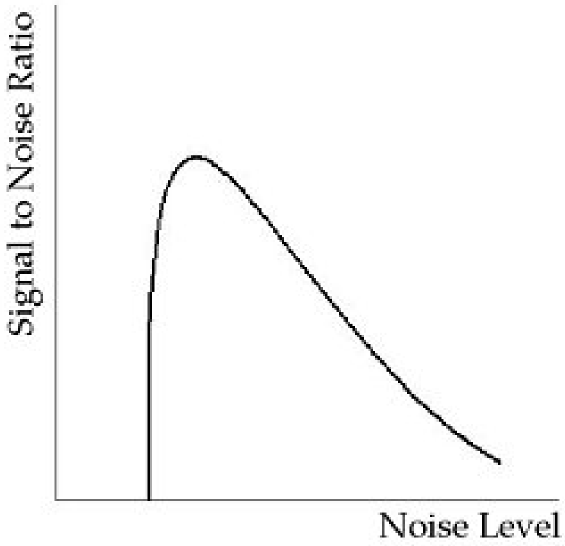

Figure 1. Characteristic profile of a system exhibiting stochastic resonance, showing a maximum value at a non-zero level of noise

croPK effects alter as magnetic field variance increases, whether that field is geomagnetic or artificially generated. A further clue comes from the Stevens (1999) study, which also found a significant, albeit weaker, correlation with geomagnetic activity in the REG control data when there was *no microPK attempt* i.e., the magnetic field alone appears to affect REG activity and so it makes more sense for it to be conceptualised as a "signal"[3] than as "noise" as the latter would not give the observed consistent/statistically significant bias to the REG output. Given the magnitude of variation for the geomagnetic field is extremely small — typically less than 10 nT — we would not expect them to have a noticeable direct effect (e.g., current induction) on the types of REG used. But SR tells us that even small signals can interact with a simultaneous source of noise to produce an effect which would not be seen if only the signal or the noise were present. So if we view the magnetic field variations as our signal, then we need only to find a suitable source of noise to look at the system in terms of SR. Obviously REGs have an inherent amount of noise as this forms the basis of the random event generation, so this alone might give an SR effect to a geomagnetic signal —

[3]The definition of a signal can get complex and to some extent depends on the context in which the term is used. For the purposes of the arguments presented here, a signal may be seen as variations in some physical process which conveys information. Thus the truly random variations generated by quantum processes within an isolated REG would not contain information or be considered to be a signal. The ordered oscillations of the geomagnetic field or of an artificially-generated magnetic field would contain information (e.g., the frequency of the field) and so could be seen as a signal.

something that should be taken into account in future geomagnetic correlation analyses of studies involving an REG. This would mean that, rather than the usual conceptualisation of the geomagnetic field as interference, it could actually be playing a major role in producing the observed effects on the REG under a microPK protocol: some aspect of the changes in the geomagnetic field comprises a signal that the REG system is sensitive to. Any effects are usually small compared to the inherent variability of the REG output, but when a third factor is added — a source of external noise — the geomagnetic signal's effects are enhanced i.e., a good working model might be:

$$Signal\ (Geomagnetic\ variation) + Noise = REG\ output\ measure$$

So what would constitute a source of signal-amplifying noise in the system? It could come from a variety of changes in the natural environment to which the REG is sensitive, such as cosmic rays events or tectonic stress electromagnetic fields; it could also be artificial, due to electrical devices in the vicinity of, or even part of, the study. Of most interest to researchers interested in microPK work, it could potentially be of biological origin — the exogenous fields generated by the ostensible microPK agent's heart, brain or muscle activity (which, for example, generate magnetic fields in the pT to nT range, at a range of frequencies below 100 Hz). Whatever the source, consistent effects will only be seen under the right combination of conditions, where the properties of the noise are resonant with the properties of the signal and the target system is itself sensitive to the amplified signal. It should also be noted that, just because the GMF signal is magnetic in nature, this does not require the noise to be magnetic too, as SR has been observed where signal and noise are dissimilar in nature (e.g., Richardson et al, 1998), but the simplest model would be to start with an all magnetic field interaction, especially as we are concerned with an electronic system.

So this could suggest an alternative way of looking at the effects seen in some microPK studies: the REG essentially acts as a detector of weak magnetic fields. If this is the case, then plotting the output of a REG for different levels of weak magnetic field "noise" in the presence of various geomagnetic 'signals' should at least show the characteristic SR signature shown in figure 2, indicating whether this approach is a useful one to pursue.

Method

Procedure

An Orion serial port REG (Orion Technologies[4]) connected to a PIII 600 MHz PC was placed in the centre of a pair of .20m radius copper-wire wound coils in the Helmholtz condition (parallel coils with the centre-to-centre distance equal to the radius). Coil input currents were produced from twin power supply units (Coutant model LA200.2), with the frequency and amplitude being determined by the signal characteristics from the PC's sound card output (Creative SoundBlaster Live! Value). Control periods involved identical computer operation to experimental periods, but the output to the sound card was an empty file (i.e., zero amplitude). Field strength had been tested prior to the experimental sessions using a flux-gate magnetometer (model 428C, Applied Physics Systems, Mountain View, CA) for all but the pT work, as these fields were well below the sensitivity of the magnetometer.

An earlier unpublished exploratory study had been conducted looking at the possibility of direct effects of a number of artificially generated geomagnetic-magnitude fields on the REG, compared to the null-field control periods. For the current analysis, it was *a priori* decided to use the data from this study which covered fields with a sinusoidally modulated frequency of 40 Hz at magnitudes of 1, 25 and 50 μT. This frequency was originally chosen as it corresponded to a frequency which is present throughout human brain-wave records (the "thalamo-cortical loop") and it was also the first harmonic of the fields used in an earlier study which successfully found effects of weak magnetic fields on human physiology (Stevens, 2001).

For any one session, the PC repeatedly selected (using the Microsoft QuickBASIC v4.5 pseudo-random algorithm) one of four conditions — corresponding to either of the 3 fields or the control condition. Selection probability was weighted so that there were approximately as many control periods as experimental. One session lasted for approximately 10 hours, wherein the PC took 1000 samples each of 175 bits at random intervals (between 1 and 30 seconds). Each 1000 samples (one trial) was reduced to a single mean and this was saved to disk along with information about which field was present. Experimental trials were randomly interspersed with control trials, taken over 7 non-consecutive days chosen purely due to the practicalities of when the experimental

[4]http://rng.interact.nl/

rooms were unused by other studies. Of the 3535 experimental trials, 1155 were in the 50 μT field, 1150 in the 25 μT field and 1230 in the 1μT field. There were 4229 control trials.

As I was also interested in looking at field strengths comparable to those generated by a biological system, further data were collected comparing the REG output under the null-field control condition to a 1 pT (the magnitude of the field generated by the human brain in a normal waking state: Ioannides, 1994) 40 Hz sinusoidal magnetic field. As a much weaker field was used which required a finer degree of control, the PC this time pseudo-randomly selected to turn on or off the input current to the coils. This current was produced from a digital frequency generator, pre-calibrated to produce a 40 Hz 1pT field. This time, one session lasted for 2.5 hours, wherein the PC took 1000 samples each of 200 bits at random intervals (between 1 and 30 seconds), these 1000 samples representing one trial. This trial was then reduced to a single mean value and saved to disk along with information as to whether the field was on or off. Of the 2000 trials recorded over 10 non-consecutive days, 1004 were in the experimental condition and 996 were in the control condition.

Analysis

A measure was needed which would represent an REG response to the effect of the geomagnetic signal. For ease of comparison to microPK studies, it was decided to use the square of the z-score i.e., a measure representing the absolute magnitude of the deviation from expected mean values for the number of events generated by the REG. So for each of the session means for each field type, the mean values were converted into squared z-scores (i.e., expressed in terms of their squared standard deviation). This removed the direction of any effect observed as this was not currently relevant and instead gave an indication of the magnitude of change in REG activity.

Geomagnetic field activity measures were then taken from the British Geological Survey's geomagnetic monitoring station, sited 40 miles away at Eskdalemuir, UK via their website at http://www.nmh.ac.uk/gifs/on_line_gifs.html. The index taken was K, a baseline-corrected measure which represents the largest range of local activity measured in a 3 hourly period. The K index ranges from 0 to 9, with each digit indicating activity which is approximately a factor of 2 greater than the previous digit (Parkinson, 1983). K was chosen rather than any other geomagnetic index as it better reflected changes in the local field activity than global indices.

Results

Columns 3-6 of Table 1 show the squared z-scores representing the mean output of the REG under each type of magnetic field, each of the columns representing the level of geomagnetic field activity (based on the K-index) under which the REG data was collected. The descriptor column gives some indication of naturally occurring magnetic fields which would have the same magnitude as the applied field.

Table 1: Output of random event generator (z^2) for different levels of magnetic field "noise" (nT), split by geomagnetic activity "signal" (K-index)

Magnitude of Magnetic Field "Noise" (nT)	REG Output (z^2)			
	K = 0	K = 2	K = 3	K = 4
0	$5.84X10^{-4}$	$2.22X10^{-3}$	$5.06X10^{-4}$	$2.45x10^{-4}$
0.001	0.00	$3.75X10^{-8}$	$1.08X10^{-7}$	$5.44X10^{-8}$
1000	$1.34X10^{-2}$	$1.56X10^{-2}$	$1.12X10^{-2}$	$7.01X10^{-4}$
25,000	$2.59X10^{-3}$	$7.64X10^{-4}$	$1.50X10^{-3}$	$2.06X10^{-2}$
50,000	$6.49X10^{-8}$	$4.91X10^{-8}$	$1.34X10^{-7}$	$8.64X10^{-4}$

Values in table 1 were then plotted (see figure 2) and found to show multiple peaks at 1000nT and a single peak at 25000nT. The former are found for K values of 0, 2 and 3, whereas the latter peak is found only for the highest K value of 4. Best fit curves have been added purely to aid identification of K-index profiles and should not be taken to indicate continuous distributions.

Discussion

This study suggested that the REG target system used in many microPK studies might be a sensitive detector of geomagnetic fluctuations, possibly through a process of stochastic resonance with intrinsic and/or external noise. To test the basic idea, an artificial source of noise was generated via Helmholtz coils, comparing REG output under different levels of magnetic field "noise" in response to different geomagnetic activity "signals". As might be expected under a case of stochastic resonance, the REG outputs showed maximum deviation at a non-zero level of added noise. This level was consistent for 3 of the 4 geomagnetic signals used (maximum for K = 0, 2, 3 when noise field was 1 μT), with

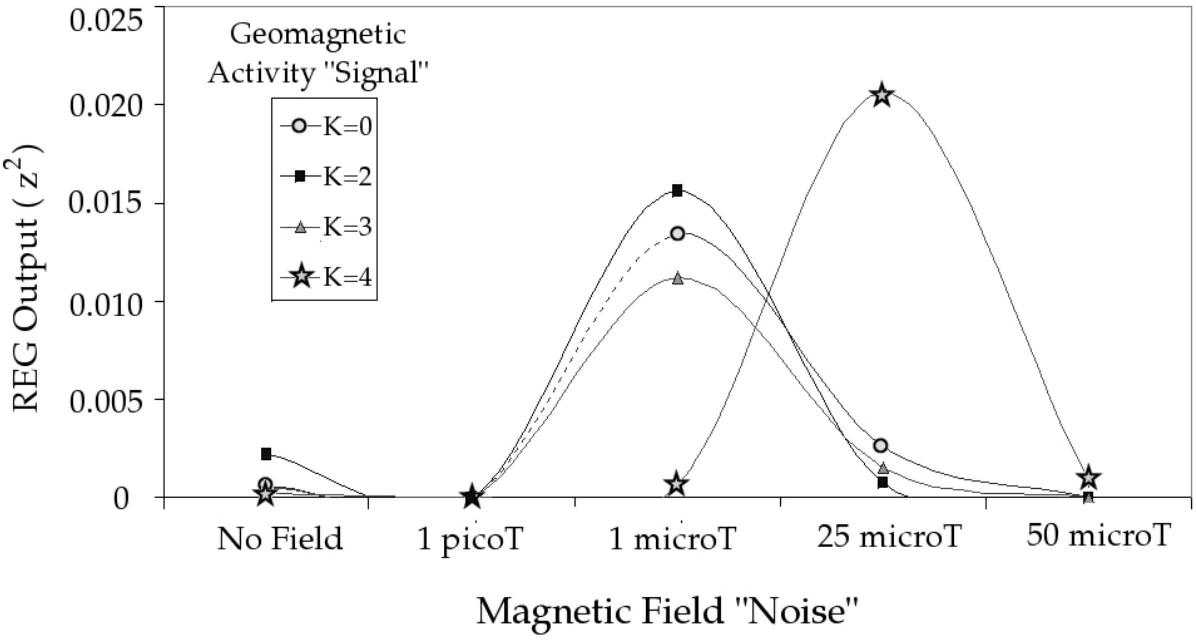

Figure 2. Variation of Random Event Generator output (z^2) as the applied magnetic field magnitude (the *noise*) is changed. Each line represents a different level of geomagnetic field activity (the *signal*) in terms of the standard K-index

the highest geomagnetic signal (K = 4) showing a separate peak at 25 μT. As the noise fields were applied in a random schedule over a number of different days, this would appear to be a robust finding due to a real interaction and not simply due to chance variations. The effect size, based on ($z \cdot N^{-0.5}$), for the largest effect found in this study (the 25 μT field at K = 4) is around 8x$10^{-3.}$ For the 1 pT (the "human brain" magnitude) field, it is 1.3x10^{-5}. For comparison with microPK studies, the meta-analysis by Radin and Nelson (1989) found an overall effect size of around 3x10^{-4}. Thus it does appear that geomagnetic field fluctuations in combination with external field can cause effects of a magnitude comparable or exceeding those seen in microPK studies. Even in the absence of an external noise field, the maximum effect size (for K=2) was 6.9x10^{-4}, presumably (assuming an SR process) based on the signal interacting with the intrinsic noise of the REG itself.

Does this have implications for REG-based microPK work? It certainly indicates that there are physical factors that should be taken into account, and implies that magnetic fields can play a role (possibly including those generated by the human body) in producing REG deviations of a magnitude comparable to those seen in microPK studies. In studies where the independent measure is simply a general biasing of the REG output, it could mean that the effects actually have little to do with the ostensible microPK agent — they just happened to be part of a study that coincided with high geomagnetic activity. This would be especially true of any studies which make use of a theoretical control baseline rather than one empirically determined under similar experimental conditions. However, it cannot be used to explain away the many studies where the REG output shows a correlation with agent intention (Radin & Nelson, 1989) or where the microPK effect is much greater in magnitude than any geomagnetic correlation seen in concurrently-collected control data (Stevens, 1999). However, there remains an option which might be involved in some instance of microPK that has not previously been considered: that microPK itself acts as source of noise to selectively enhance a geomagnetic signal. This is in many ways a simpler proposition than the more obvious choice of considering microPK to be a signal: it would not require any degree of fine control on the part of the agent but would instead need a relatively gross alteration in their emitted noise (which could conceivably be as simple as the magnetic fields relating to cortical arousal). Such a concept may be especially useful in instances where there does not appear to be any intention to cause a microPK effect on the part of the agent (e.g., Stanford, Zenhausern & Dwyer, 1975) but where the REG still appears to be affected when subjects are present.

Alternatively, it would also be possible to incorporate the ideas presented above into a selection model such as DAT. In that case, the selection would not necessarily be just of fortuitous "extra-chance" sequences in the random bit-stream but instead could be the selection of times when the signal and noise fields are suitable to produce the desired output. Alternatively, a blend of selection and influence could operate, with the signal fields being selected for and the noise field generated by the microPK agent.

Obviously this study was exploratory in nature: much of the data was originally collected with the idea of simply looking at direct effects of weak magnetic fields on the REG but, on becoming interested in the phenomenon of stochastic resonance, I decided to look for SR-like effects and added in a further data-set to cover bio-range magnitude fields. Because of this, and as a first foray into a new area of research, the current study has several limitations which should be addressed in any further research. Firstly, the applied magnetic fields all showed fullamplitude variation and so aren't necessarily realistic when compared to natural equivalents. While the magnitudes of the noise fields used are encountered in the environment on a daily basis, the associated frequencies may be different. For example, the main component of the geomagnetic field has a magnitude of around 50,000nT, but this is static. Variations do occur in a range covering 40 Hz, but the associated magnitudes for these are much smaller (.05 nT). Fields of 1 μT are commonly found in an urban environment but are more likelyto be at frequencies of 50Hz (the mains electricity operating frequency). However, remember that the noise field is just that: noise. If SR is involved, then the frequency of the noise field is less important that the magnitude as it is just giving a "boost" to the signal at intervals, whatever those intervals are.

Secondly, the K-index used as a measure of the geomagnetic "signal" is a very gross measure and can really only give a rough indication of the variability of the ambient fields over a large area. Any site-specific variations (man-made or natural) are unlikely to be reflected in this. A better measure where possible would be to take local measurements using a magnetometer.

Thirdly, the design of the REG itself is not ideal for this kind of work. The Orion REG is based on two NAND-gated Zener diodes. This not only drastically reduces the amount of information available about the activity of the source randomness (the variations in electrical currents within the diodes due to electron tunnelling, thermal effects and surface noise) down to a binary digit (i.e., greater than/less than threshold value), but was also specifically designed to minimise the effects of direct interaction with external signals (the NAND gate returns a zero if both diodes show a simultaneous event). Unfortunately, this type of "safeguard" is found in all the REGs commonly used in parapsychology research. Future work of this kind will probably benefit from being based on a REG with an output showing a more direct mapping on to the random source.

However, limitations aside, the findings do offer some new perspectives on microPK research that may further our understanding of the phenomena. The idea that some effects seen in microPK studies may be due to an SR type interaction (with or without the involvement of the ostensible agent) suggests some reasons why previous microPK studies have shown inconsistent results. Hopefully it might also offer new ideas when looking at past research from this perspective. For example, might the old Bio-PK indeed be an interaction effect, as suggested by the adoption of the new DMILS (Direct Mental Interaction between Living Systems) acronym? Perhaps the two people involved could be seen as both contributing to the observed results: one contributing a signal, the other noise.

There is also the idea that some instances of microPK might directly relate to the biomagnetic fields of the people involved. Although in this study the noise fields that were of "human brain" magnitude did not show obvious effects, this could simply be that the combinations of noise and signal were not the right ones (note that the strongest field also showed no effect). That any of the weak fields showed an effect suggests that biomagnetic fields cannot be ruled out of the microPK equation. Future work taking some direct measure of the participant's magnetic output (or at least some related measure such as global EEG activity) might be in a better position to evaluate any effects. There is also nothing to prevent the biomagnetic fields themselves (or some other as yet unrecognised physical field) being the signal if another source of suitable noise is present.

I am not trying to suggest that the ideas presented can account for all microPK effects. In addition to the cases discussed above, it is also hard to see how, according to current knowledge of the physical propagation of magnetic fields, an SR interaction could account for remote effects. Instead, I am presenting these results as a possible area of research that has been neglected but which I feel will help further our comprehension of psi effects. Based on our current understanding of the spatial and temporal parameters that appear to characterise psi effects, current physics seems to offer little chance of explaining the underlying mechanism. However, this apparent lack of explanatory power has lead to a dearth of research looking at possible areas of physical interaction which might affect psi effects. It is often assumed that all microPK effects are the result of some unitary mechanism, whereas it may be that the findings are an amalgam of several different mechanisms. Without investigating the possibilities, even if they only apply to a subset of past results, we are unlikely to progress in our understanding. Such thinking has led to a disregard for the idea that electromagnetism in some form might be involved with psi effects, despite the widely acknowledged psi-geomagnetic relationship. I hope that results such as the above will lead us to reconsider.

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