EFFECT OF AMBIENT MAGNETIC FIELD FLUCTUATIONS ON PERFORMANCE IN A FREE RESPONSE ANOMALOUS COGNITION TASK: A PILOT STUDY.

S. James P. Spottiswoode

ABSTRACT

Retrospective analyses of putative spontaneous psi, or anomalous cognition (AC), events have shown a tendency for these to be reported on days of relatively low geomagnetic disturbance. Studies of past laboratory experiments have produced evidence that scores in successful AC experiments are negatively correlated to geomagnetic field (GMF) indices. Relevant characteristics of GMF activity and of the geomagnetic indices are discussed and a rationale for an experimental test of this effect is presented. A wide range of physical effects are correlated to the GMF indices and it is not presently possible to determine the exact physical parameter responsible for the GMF – AC correlations. In an exploratory experiment subjects were tested for AC in an apparatus where they could be shielded from the relatively large amplitude (> 1 nT) and slow (< 0.1 Hz) variations which are registered by the GMF indices used in the retrospective studies. The apparatus used a Helmholtz coil to generate a magnetic field which could both null out external variations and provide artificial magnetic noise for a control condition. AC performance in a free response task was compared, using a double blind protocol, between the shielded condition and conditions in which three kinds of magnetic noise were imposed upon subjects. In 68 trials the pilot study produced only weak evidence for AC (p = 0.3, effect size = 0.05) and, contrary to hypothesis, AC performance was slightly higher in the magnetically noisy, rather than shielded, conditions.

INTRODUCTION

Since 1985 a number of retrospective epidemiological studies have demonstrated a relationship between the state of disturbance of the geomagnetic field (GMF) and reports of spontaneous paranormal phenomena such as telepathy, clairvoyance, precognition and apparitions.[1,2,3] The most extensively studied effect concerns anecdotal reports of crisis telepathic experiences which have been found to occur on days of relatively low geomagnetic disturbance.[1,4] This effect has been found in all four independent sets of anecdotal reports which have been examined. Persinger's analyses have been criticized by Wilkinson and Gauld[5] on the grounds of imprecise selection criteria and inadequate analysis. However they also find that there is evidence that spontaneous telepathic or clairvoyant experiences occur when GMF disturbance is relatively low. Past laboratory anomalous cognition (AC) data has also been examined for the relationship with variable results. (The term anomalous cognition is used here as an alternative to ESP or psi.) Tart[6] and Persinger & Krippner[7] reported that higher scoring AC trials tended to occur on days of relatively low GMF variation, while Makerec & Persinger[8] found a negative correlation between card–guessing scores and GMF activity. However, the effect was not confirmed by Haraldsson & Gissurarson[9] or Nelson & Dunne.[10] Spottiswoode[11] analyzed six free response psi studies and found a significant negative correlation between trial scores and the GMF index of the three hour periods in which trials occurred. This study also suggested that the effect was absent from studies with a negligible overall AC result. Recently Berger & Persinger[12] showed that yearly averages of scores in forced choice AC studies over six decades were negatively correlated with an annual index of GMF activity.

While the above results are suggestive of an association between AC and low GMF activity, it is not known whether the spontaneous case material constitutes real evidence for AC[13] and there is dispute[14] over what features, if any, of the local magnetic environment are described by the geomagnetic indices used in these studies. A further problem in interpreting these results comes from the range of effects measurable at the earth's surface which are correlated to the GMF indices. Electromagnetic noise over six decades of frequency[15,16] as well as cosmic ray flux[17] are known to covary with the GMF indices. Thus many physical models for the correlations are possible. This paper summarizes some relevant features of the GMF and the indices used to characterize it in these studies and describes a system for creating a controlled magnetic environment for prospective investigations of these effects.

THE GEOMAGNETIC FIELD

The spatial configuration of the magnetic field at the earth's surface approximates that due to a dipole located near the earth's center. The exact mechanism of the field's generation is not completely understood but is thought to be due to currents set up by a self exciting dynamo effect in the electrically conducting core. The field strength at the earth's surface varies between 60,000 nT (1 nanoTesla = 1 gamma = 10^{-5} gauss) near the poles to 30,000 nT at the equator. The field strength also varies spatially on a smaller scale due to differences in the magnetic susceptibility of the underlying rocks. There are also complex variations in time of the field strength at any fixed location with a wide range of periods from millennia to fractions of a second. The secular variations are due to changes within the field generating mechanism. We shall be concerned only with variations occurring over periods of days, or less, and these are due entirely to external causes, namely changes in the near earth space environment caused by solar activity. The interactions between solar activity and the electromagnetic field observable at the earth's surface are very complex.

In general at any location a diurnal variation with an amplitude of some tens of nanoTeslas occurs; additionally magnetic storms cause field variations with amplitudes up to hundreds of nanoTeslas and lasting up to several days, these being more frequent during periods of higher solar activity and of greater amplitude at higher latitudes. There are also many types of small amplitude, semi periodic variations called micropulsations. There is a scarcity of work on the exact spectrum of variations in the GMF in the ULF (<5 Hz) frequency region. Bubenik et al[16] reported an approximately an f^{-1} amplitude spectrum between 2 mHz (1 mHz = 10^{-3} Hz) and 125 mHz. Fraser–Smith & Buxton[18] found an approximately

$f^{-1.25}$ spectrum from 200 mHz to 5 Hz and a minimum in the spectrum between 3 and 7 Hz. Above this minimum the Schumann resonances occur at 8 – 10 Hz. At this frequency there is a resonance of the cavity formed by the earth's surface and the ionosphere. These studies also report that noise amplitudes between 2 mHz and 10 Hz increase with the daily GMF index, *Ap*. This is important in interpreting the correlations between GMF indices and AC performance since it may be power in any part of this spectrum which is responsible for modulating the AC effect.

GMF Indices K, Kp, Ap, ap and aa

The indices *Kp*, *ap* and *Ap* are all derived from the *K* index which is measured at each of 13 worldwide observatories.[15] Each of these stations removes the average diurnal variation from its data and determines the remaining range of magnetic intensity variation along 3 orthogonal axes during each 3 hour period. The range of the most disturbed axis is assigned to one of 28 values on a 0 to 9 scale, with intervals of one third. The *K* scale is individually defined at each observatory and uses an approximately logarithmic amplitude scale. The *Kp*, or planetary 3 hour range index, is defined to be the arithmetic mean of these 13 *K* values. The *ap* index, or planetary equivalent amplitude, is derived by converting *Kp* back to a linear scale in nT. The resulting scale measures the amplitude disturbance of a station for which $K = 9$ has a lower limit of 500 nT amplitude range over a 3 hour interval. The *Ap* index, or planetary equivalent daily amplitude, is the arithmetic mean of the eight *ap* values for the day, starting at zero hours UTC. The *aa* index is a daily linear planetary index which is derived in a manner similar to the *Ap* index but using observations from only two observatories, Greenwich and Melbourne, where readings have been taken almost continuously since 1868. As might be expected from their derivation, *aa* and *Ap* are highly correlated.[15]

The mapping from the measured range of field strengths to the *K* index value is a function taking a continuous variable to a discrete one. In this process information is lost, and in particular any field changes which are much less than the width of the smallest range of the *K* index will be inconsequential to the resulting *K* index value. For instance at the Niermegk observatory the $K = 0$ and $K = 1$ index values correspond to ranges of total field variation of 0 – 5 nT and 5 – 10 nT respectively,[15] larger index values having wider ranges in accordance with the semi–logarithmic definition of the *K* index. Therefore variations substantially smaller than 5 nT can have no impact on the derived *K* index for this station. Other stations have similar *K* index range definitions and it may be concluded that the *Kp* index, and all indices derived from it, are insensitive to variations in the GMF of less than 1 nT. Owing to the reduction in amplitude of natural variations with increasing frequency,[19] the 1 nT cutoff corresponds to an upper frequency limit on *aa* and *Ap* index sensitivity of approximately 100 mHz. The low frequency sensitivity of the *K* index is limited by the 3 hour measurement interval used. Variations which are monotonic across time intervals much longer than this will be attenuated in their effect on the index. Therefore variations slower than around 0.01 mHz will not register in these indices.

Local Measurements of the GMF and Global Indices

Epidemiological studies of the type described above which compare planetary geomagnetic indices with human behavior can be most simply interpreted if there exists a clear connection between the index values and locally measured GMF fluctuations. Persinger & Krippner[7] discussed the relationship between GMF indices derived from different sites in detail and reported that the daily equivalent amplitude index values, *A*, from observatories at Fredericksburg, Virginia and Anchorage, Alaska were highly correlated ($r = 0.85$, $rho = 0.92$) for 6 months of data. However they did not discuss the relationship between the global indices used in the epidemiological studies and field variations at a fixed site.

To investigate this, GMF measurements from a U.S. Geological Survey station operated at San Juan Bautista California were obtained[20] for the period from January 1 to April 1, 1989. This data comprised measurements of the total magnetic field intensity at 10 minute intervals with a least count uncertainty of 0.125 nT. The data were split into subsets corresponding to the 3 hour intervals for which *ap* index data is published. For each of the 720 three hour subsets two quantities were calculated: the range of field changes during the period and the mean of the absolute value of the differences between successive readings. The correlations between these quantities and the *ap* index for the corresponding period were *rho* = 0.52, *r* = 0.78 (Spearman and Pearson coefficients respectively) for the range and *rho* = 0.73, *r* = 0.91 for the 10 min. differences. The data from this station showed a diurnal component with a range of 51 nT, specifically a minimum in field strength at local noon. The *ap* index is derived from data from which the diurnal component has been removed and to test for the effect of this, the diurnal effect was removed from the magnetometer data by calculating the mean value over the 90 days of each of the 144 daily intervals. This average diurnal variation was then subtracted from the raw data and the range and mean differences for each 3 hour period calculated as before. The correlations for the corrected data were *rho* = 0.64, *r* = 0.86 for the range and *rho* = 0.80, *r* = 0.92 for the differences. These correlations with *ap* are slightly larger than those without the diurnal correction, as might be expected. However, it is clear that even with the diurnal component of the local magnetic uncompensated the global *ap* index provides a reasonable measure of local short term field changes at this site. Correlations with *ap* of similar magnitude were obtained from 10 min. magnetometer measurements taken by the author in Los Angeles, California over a two month interval in 1990.

Statistical features of the Indices

The indices *aa* and *ap* exhibit some features which call for caution in their use. Being derived from quantized variables (the *K* and *Kp* indices), their distribution is irregular, this being particularly so of the *aa* index.[21] The *Ap* index has a much more regular distribution, probably because its calculation involves many averages. Additionally the envelope of the frequency distribution of these indices is not normally distributed. Because of these features correlational studies should use a non–parametric correlation function such as Spearman's *rho*. There is also a significant autocorrelation between daily index values over intervals up to about 3 days owing to the persistence of storms over such periods. For instance, for *Ap* data from 1932 to 1990 the Spearman rank order correlation coefficient for one day lag is 0.58, for two days is 0.31, for three days is 0.20 and for four days is 0.14 (author's calculations). Because of this autocorrelation, any variable which is correlated with a GMF index at a given time, will show smaller correlations for earlier and later times. Finally there are periodicities in the index data, primarily a 27 day component at the sun's rotation period due to emissions from active regions which remain at a fixed position on the sun's surface.

FACTORS IN THE DESIGN OF EXPERIMENTAL STUDIES.

If the retrospective evidence for correlations between performance in psi tasks and GMF variations is accepted, then it is reasonable to ask how a prospective experimental test of the effect might be designed. Unfortunately, there are many possible explanations of the observed correlations, each requiring different experimental treatment. The GMF indices reflect events occurring on a global scale and it is logically possible that their influence upon AC occurs at the percipient's location, or at other places where the putative AC channel might be influenced. As a further complication, the GMF indices are correlated with many other physical events that occur during periods of solar activity. For instance ULF electromagnetic emissions at higher frequencies than those registered in the indices themselves,[18] as well as ELF and HF flux[22] and ground level cosmic ray fluxes[17] are all correlated with the GMF indices. Potentially these other physical events could be responsible for modulating AC functioning and if that were the case their correlation with GMF indices would then give rise to the correlations in AC experiments.

In the absence of any theoretical arguments for a link between these other effects and ESP, it seems reasonable to employ Occam's razor and consider how to experimentally test the effects upon AC performance of the specific magnetic field variations to which the GMF indices are themselves primarily sensitive. Given that the geomagnetic indices used in the retrospective studies are sensitive to GMF intensity variations larger than approximately 2 nT, which occur at frequencies less than 100 mHz, a experimental design which allows psi performance to be compared between quiet and noisy conditions in this amplitude – frequency domain constitutes a rational first step. On this basis the design of a facility which would control time variations in the ambient field within ±1 nT for frequencies lower than 100 mHz was investigated.

Shielding of magnetic field variations this slow using a Faraday cage is impractical owing the very great wall thickness that would be necessary. Three alternative methods however have been used: superconducting shields employing the Meissner effect, either alone, or in combination with shields constructed of high permeability metals[23] and shielding by active feedback. This last method uses a system of current carrying coils which generate a field in the test area which counteracts, or bucks, ambient field variations. The degree of control achievable by such a system is dependent primarily upon the resolution, noise level and bandwidth of the magnetometer used to measure ambient field changes. For the frequency and amplitude region relevant here, the active feedback method is the most economical method and it was the one chosen. To cancel, or buck, out arbitrary field variations in a test volume would require a set of three orthogonal coil systems. However the corrections required to buck out natural GMF variations are generally smaller than 1% of the GMF field strength. Under these conditions a single axis coil system can be used to keep the total intensity of the field constant, the consequence being a rotation of the field vector as corrections are made. For instance, at the latitude at which this experiment was performed the field is inclined at approximately 65 deg. to the horizontal and has an intensity of 50,000 nT.[24] A 100 nT field variation, corresponding to a moderate magnetic storm, would result in a rotation of the field vector of 3 minutes of arc when corrected by a vertical bucking field. This is a small angle relative to angular shifts due to a subject's body motions. Spatial field gradients are an important consideration in the design of such a system. Spatial field gradients of hundreds of nT/m are common within steel framed buildings or near automobiles and small movements would then expose subjects to variations larger than the ± 1 nT design criterion. This problem was overcome by situating the apparatus some tens of meters from buildings and roads and ensuring that it was erected in a place with a low natural field gradient. It was also imperative that the coil system used to generated the correctional fields have a low spatial gradient.

Design of the pilot study apparatus

The apparatus consisted of a single vertical axis Helmholtz coil system of square cross section with coils 6.1 m on a side. A schematic layout of the apparatus is shown in Fig.1. The Helmholtz coil consisted of two identical current carrying coils arranged coaxially with the coil centers separated by half the coil diameter. With the two coils fed by equal magnitude currents flowing in the same direction this arrangement produced a horizontal field gradient of 10 nT/m at the center of the system when the coil system generated a field of 100 nT. The vertical gradient of the coil field at the subject's position was less than 10 nT/m. Square cross section coils were preferred over circular ones since they were easier to construct and the penalty in terms of increased spatial field gradient is small.[25] The coil system was erected at a site 35 m from the nearest building and 16 m from local power distribution poles. The background field gradient at the site was surveyed at the level of the coil center (1.53 m above ground level) and a location was found where the field gradient was less than 10 nT/m horizontally. At this location a non ferrous table was constructed some 2.5 m long by 1 m wide and 1.40 m high on which a weather proof tent was erected to house subjects. The base of the tent was heavily padded and blankets were provided inside to ensure the comfort of subjects. The upper coil was supported on wooden poles 3.05 m above ground level while the lower coil lay on the ground. The coils consisted of two turns comprising the two cores of Belden 8428 cable. Deviations from the exact geometry of the coaxial square coils amounted to 0.2 m at most, though this was not critical because the system was calibrated before each run. All the electronics, except for the magnetometer sensor, were located in a hut 27 m from the coil system.

All field measurement were made with an EG&G Geometrics G856AX proton precession magnetometer. The instrument takes readings in cycles of approximately 3 seconds, consisting of alternating polarization and frequency counting periods and an accuracy and stability of ±0.2 nT can be obtained with complete insensitivity to ambient temperature.[26] A disadvantage of this type of magnetometer is that a considerable external field is generated by the sensor and the cable feed to it during the polarization cycle. Because of the requirement to not expose the subject to field variations, the sensor could not be positioned near the subject. Therefore the sensor was positioned 8 m away from the subject's head, to one side of the Helmholtz coil, where the polarization field had dropped to less than 1 nT.[27] An alternative type of magnetometer, the fluxgate (e.g. Applied Physics Systems Model APS520), could have been used. Unlike the proton precession method it generates no external field and has a much higher frequency response, but the long term stability is reduced.

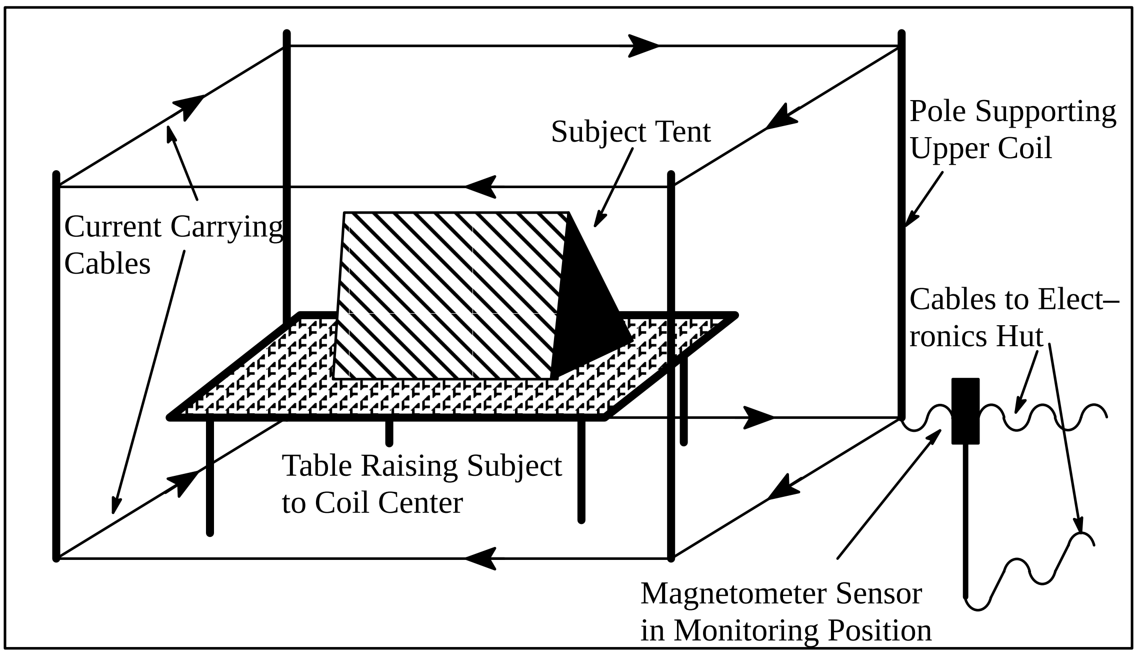

Figure 1. Layout of the apparatus showing Helmholtz coil system and table to support the subject at the coil center (not to scale).

The electronic system consisted of the magnetometer, an Apple Macintosh II computer equipped with a National Instruments Lab–NB input output board and an Hewlett Packard 6824A power supply. These components were connected to form a negative feedback system in which the measured field was compared with the desired field, a correction field was calculated and the current needed to produce this correction field was passed through the coil. The Lab–NB board contained a digital to analogue (D/A) converter, the voltage from which was passed to the 6284A which was configured as a voltage–controlled, constant–current, amplifier. The current from this was passed to the coil system via a low pass filter with a cut–off frequency of 0.5 Hz and a slope of –3 dB / octave as a precaution against passing any 60 Hz, or higher frequency, noise to the subjects.

At the start of each experimental session, a calibration program was run which applied known voltages from the computer to the rest of the electronics and measured the associated field changes with the sensor at the coil center in the position occupied by the subject's head during AC trials. By this means two coefficients were determined, namely the field change produced per volt of output from the computer at the sensors monitoring position, C_1, and that produced at the coil center, C_2. This method of calibration ensured that any changes in the geometry of the coil system or in the gain of the current amplifier or I/O board would be corrected for in each experimental run. In practice such changes were small and the measured values for the coil coefficients across 22 experimental sessions were $C_1 = -1.413 \pm 0.05$ nT/V and $C_2 = 97.09 \pm 1.2$ nT/V. C_2 has a large positive value since it is measured at the center of the Helmholtz coil system, while C_1 is small and negative because the monitoring position was outside the coil system.

During each experimental session the following sequence of events occurred. After starting the program for an experimental run and entering the session information, the program randomly determined which of the two trials in the run was to be in stabilized field mode and which was to have injected noise. The program's operation consisted of repeating a five second cycle of events: first the magnetometer was triggered to take a field reading, then equation 1 was solved for the required output voltage to give the desired field changes, V, and finally this voltage was output to the current source.

$$V = \frac{H_d + H_a + H_{ofs} - H_s}{C_1 - C_2} \quad \text{..........} \quad 1$$

In equation 1 V is the output voltage from the D/A converter, H_d is the desired field variation at the coil center, H_a is the ambient field at the coil center at the start of the session, H_{ofs} is the constant field offset between the monitoring position and coil center and H_s the field measured at the monitoring position. During constant field trials where the system was acting as a shield against external changes $H_d = 0$. During noisy trials $H_d = N(t)$, where $N(t)$ was a constrained random walk, or other noise function. The value V, derived from (1), and hence the correction field generated by the Helmholtz coil was held constant through the five second measurement cycle until V was updated from the next field measurement, H_s. Therefore GMF fluctuations occurring over periods shorter than five seconds could not be corrected. The reasonable assumption was made in the derivation of (1) that GMF field changes at the monitoring position differed from those at the subject's position 8 m away by a fixed offset only, which was found to be 94.1 nT.

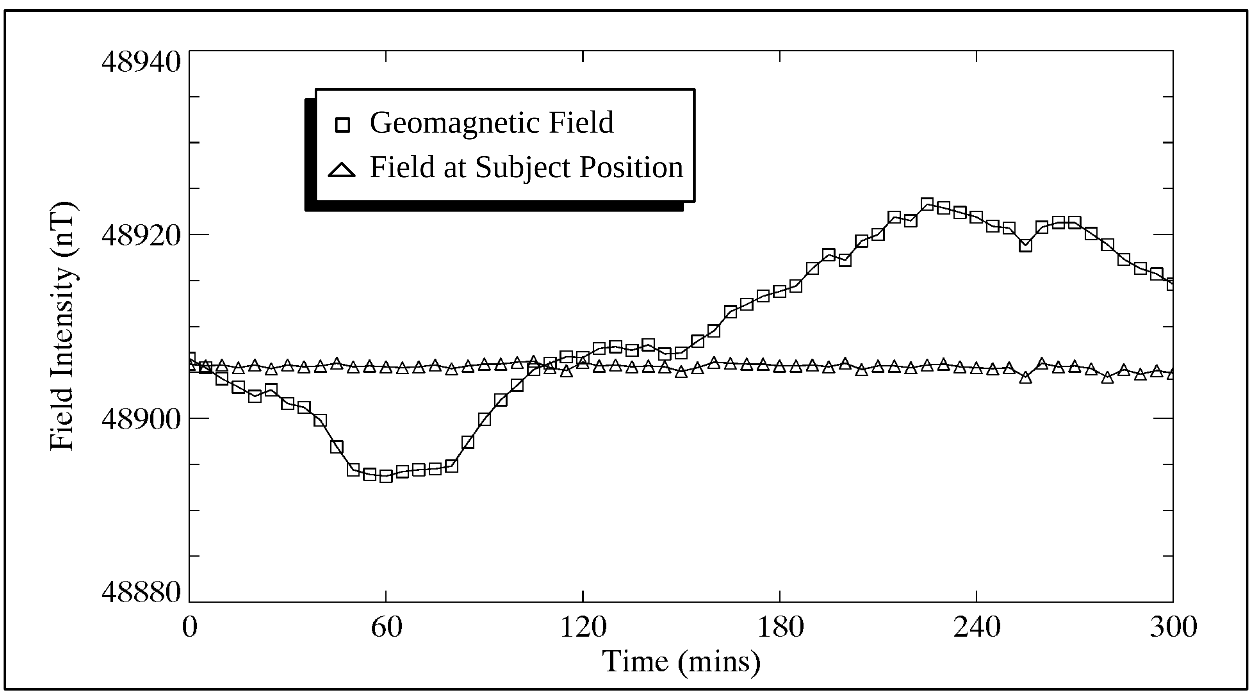

Figure 2. Plots of the geomagnetic field intensity and the field at the subject's location versus time with the system in field stabilization mode.

During experimental sessions the program displayed no information as to the state of the computer and the readouts and dial on the magnetometer and power supply respectively were covered over with opaque tape so that the experimenter was unaware of whether the system was in shielding or noisy mode.

In order to check the accuracy of field control in the shielding mode, a second magnetometer sensor was obtained and the electronics were modified to allow the two sensors to be alternately connected to the magnetometer electronics under program control. The additional sensor was placed at the coil center. Fig.2 shows readings taken from both the monitoring and subject position sensors during a five hour test period. As can be seen the GMF varied by approximately 30 nT during this period while the field at the subject position was held constant with ±1.5 nT. This second sensor at the subject position was not used in any experimental trials because of the external field which would have been generated near the subject. The performance of the system during a typical experimental session is shown in Fig.3. Here the first trial was randomly selected to have superimposed random noise of Type 1 (see later) and the second to be field stabilized. Owing to the fact that there was no magnetometer sensor at the subject's position, the field at the subject was estimated from the monitor sensor's readings and the current fed to the Helmholtz coil.

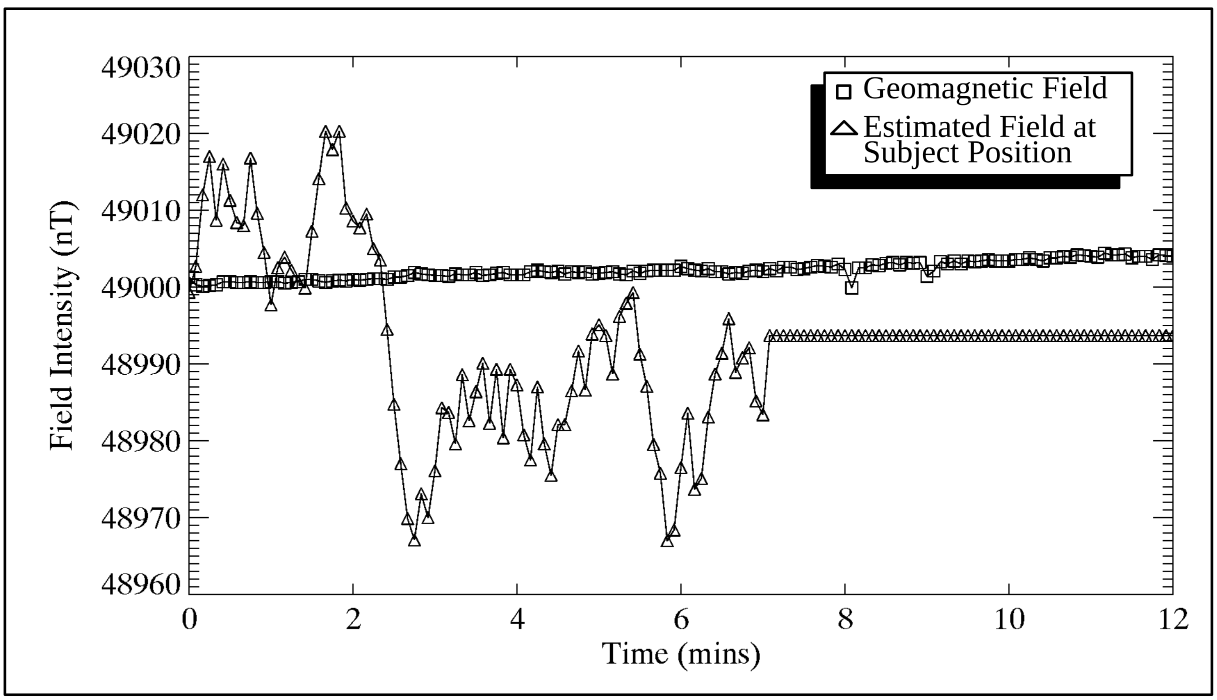

Figure 3. Plots of meaured geomagnetic field intensity and estimated field at the subject position versus time during two trials, the first with artificially generated random noise and the second with field stabilization.

A PILOT STUDY

As discussed above, the retrospective AC – GMF correlation studies do not indicate whether it is the large amplitude field variations directly measured by the GMF indices, or some covarying parameter, that is responsible for the variation in AC scores. Given this uncertainty a pilot study was designed to compare AC performance between subjects in a shielded, or constant field, environment and an environment with several kinds of artificially generated magnetic field noise. It was hoped that if a large difference in performance were observed between one of the noise conditions and the shielded condition, then a formal experiment on that condition would follow. In keeping with the flexibility of a pilot study no formal hypotheses were made. However it was expected that some, or all, of the magnetically noisy conditions would reduce AC performance when compared with the magnetic shielded condition. To minimize other environmental and psychological differences between noisy and shielded trials, it was predetermined that all trials would be held in pairs, one noisy and one shielded, in random order.

Magnetic Field Conditions

To maximize the chance of detecting a possible effect, three types of magnetic field noise were used:

Noise type 1: Randomly varying field with a maximum range of ±300 nT and an upper frequency cutoff of 100 mHz. The function used produced a constrained random walk with a maximum step size of ±40 nT per 5 sec interval

Noise type 2: Sawtooth function magnetic field with amplitude of ±300 nT, frequency 3.3 mHz and an upper frequency cutoff of 100 mHz.

Noise type 3: Randomly varying field with a maximum range of ±400 nT, –3 db / octave amplitude spectrum below 0.5 Hz and an upper frequency cutoff of 10 Hz. In this mode magnetometer readings were not taken.

Noise type 1 approximated an amplified version of the quasi–random variations observed during a magnetic storm. The algorithm used to produce type 1 noise employed a random walk method in which the amplitude of the step size was randomly chosen within the range of 0 – 40 nT while the sign was determined by a biased random decision in order to constrain the output within the ±400 nT range of of the apparatus. For example, if the algorithm's output was +300 nT at a certain time, the probability of the next step being negative was greater than 0.5. In practice this algorithm might produce a sequence of quite small steps resulting in a period of some several seconds during which there was little field change. As the time required for the acquisition of AC data might be quite short, it was thought advisable to try a form of noise that was always changing. This led to the use of noise type 2 which produced a constant rate of change of field, except at the peaks of the sawtooth waveform. Finally noise type 3 was tried which has a higher frequency cutoff than types 1 and 2. The rationale here was to see whether higher frequency variations in 100 mHz to 10Hz might be effective in reducing AC performance.

AC Experiment Design

In a study of this type where AC performance is compared under different conditions, it is clearly desirable to maximize the expected AC effect size. Honorton et al[28] have shown that effect sizes in Ganzfeld experiments are greatest for dynamic free response targets (h = 0.32), and are significantly smaller for static targets (h = 0.07); effect sizes are probably similar for the non–Ganzfeld free response protocol employed here. Forced choice AC targets, such as Zener cards, tend to produce smaller effect sizes (h = 0.02 for Zener cards) and were therefore rejected for the pilot study. Dynamic video targets were also rejected because video equipment could not easily have been magnetically shielded and it was thought desirable that the subjects should observe the correct targets while still in the the controlled field environment. For these reasons, static free response targets were chosen.

Targets

The target pool consisted of 160 color photographs, approximately 13 cm by 8 cm, of a very wide range of objects taken against a black background. These objects were of many types, utilitarian, aesthetic, common and rare, the criteria for inclusion being that the objects should be less than 2 m across, readily identifiable from the photographs and as far as possible interesting. This target pool was assembled in 1982 for other experiments in free response AC. The targets used in all the trials were drawn from the set of 160 with replacement.

Subjects

Six subjects participated, four men and two women, but three of the subjects contributed 60 of the 68 trials. Two of the these three subjects had taken part in formal AC experiments before. No measures of belief in psi were taken, but five of the group expressed a strong belief in AC in discussions with the author. Honorton et al's work[28] has also shown that effect sizes are also greater when the AC sender is a friend of the subject and when the subject has previous experience. These conditions were only partially met in the pilot study. The author was the agent in all trials and was a friend of the three subjects who contributed the bulk of the data. However, of the subjects who contributed most of the data, one had completed an experiment using a novel type of AC experiment[29] where psi performance was not directly assessed, another had conducted many free response trials but had not previously been a subject and the third had no previous experience of AC experiments. Thus these subjects did not meet the selection criteria used by Honorton and should be classified as unselected. The subjects were encouraged to contribute as many trials as they wished during the four month period that the experiment was operating, but because the experiment was considered as a pilot study they were not required to complete a predetermined number of trials.

Protocol

AC trials were performed in pairs, one with field stabilization and one with magnetic noise imposed. The trials were in a random order in each session with the experimenter and subject blind to the order until the end of the session. The sequence of events in experimental sessions was as follows. The computer system was first loaded with information as to the identity of the subject and with a random number, produced by a key press seeded routine in a handheld computer. This number was used as a seed for the pseudo random algorithm in the main computer program which produced the target number and trial sequence. The program then determined the mode for the trial, shielded or noisy, and chose the target number. Subjects were given as much time as they required in the apparatus to produce their mentations and record them on paper. Subjects were also encouraged to sketch their impressions and to annotate them as fully as possible. During this period, which lasted approximately 10 – 15 mins, subjects were alone in the apparatus, usually with the tent door closed. Subjects reported that they found the conditions in the tent comfortable and conducive to the quiet meditative state they wished to achieve. When finished, they signalled for the experimenter to collect their written notes and he returned to the electronics hut, withdrew the trial's target from the pool and took it back to the tent for feedback. Because of the exploratory nature of the pilot study, there were variations from this protocol. In the initial ($n = 24$) trials the target number was only displayed at the end of the subject's period of mentation and no agent was used. In the later set of trials ($n = 44$) the target number was displayed at the start of each trial so that the experimenter could act as agent. These later trials were also judged by the subjects, who were presented with a set of 4 possible targets in randomized order for ranking against their mentations. Care was taken that the target pictures were not visibly marked or smudged by handling, but no more rigorous precautions against cueing by fingerprints were taken.

Analysis

After the pilot study was completed, it was decided that in order to combine the first 24 unjudged trials with the remaining 44 subject judged trials , the whole experiment should be rejudged in a uniform manner. Therefore the data for all trials was submitted to an independent judge who had previously assessed free reponse AC experiments. Responses were edited by the author to remove any notes which referred to targets seen earlier in the session or experiment. The response material was then photocopied. For each trial, the judge was provided with five numbers: the numbers of four alternative targets and the actual target number in random order. Five targets per trial were used, rather than the four targets used in the subject judging during the experiment, in order to increase the statistical efficiency of the ranking method. The alternative targets were produced by a computer program which utilized a previous encoding of the target pool into a system of 36 binary descriptors, in a manner similar to that employed by May et al.[30] This program generated sets of 5 targets, one set for each trial, where the four alternative targets were dissimilar to each other and the actual trial target. The dissimilarity was assessed by comparing the descriptor encodings of the targets in the set. The judge assigned rankings from one to five for each target picture and these rankings alone were utilized in the analysis given here. A comparison of the rankings by the judge with those of the subjects gave a correlation of $rho = 0.23$, $n = 44$. The ranks of the correct targets were converted to z scores by means of an exact calculation of rank probability.[31] The effect size $h = z / \sqrt{N}$ was also calculated.

Results

The overall results summed across subjects are shown in Table 1. Each noise type was tested with equal numbers of trials for the noisy and control conditions. Only the noise type 1 condition reached significance ($p = 0.04$), but this cannot be taken as evidence of AC because of the multiple analyses. However the effect size for the whole series of trials regardless of magnetic condition ($h = .05$) is typical for Ganzfeld experiments with static targets. Both types 1 and 2 noise condtions produced larger effect sizes for AC than their control conditions, though not significantly so. Computing the z score for the difference between AC performance in the shielded control condition versus the noise conditions gives $z = –1.32$ for noise type 1, $z = –1.20$ for noise type 2 and $z = 0.0$ for noise type 3. This is contrary to the expectation that AC performance in some of the noisy conditions would be reduced when compared to the shielded conditions. The same negative conclusion applies when all the noisy condition trials are compared with all the control trials; the subjects were more successful in the noisy trials than in the shielded ones ($z = 1.20$).

Experimental Condition	*N* trials	Effect Size *h*	*Z*
Noise type 1	7	.66	1.74
Control condition for noise type 1 – shielded	7	–.05	–.13
Noise type 2	11	.16	.53
Control condition for noise type 2 – shielded	11	–.35	–1.17
Noise type 3	16	–.02	–.09
Control condition for noise type 3 – system off	16	–.02	–.09
All noise conditions combined	34	.20	1.15
All control condition combined	34	–.09	–.55
All trials	68	.05	.43

Table 1.

Discussion

The overall effect size for AC which was observed is consistent with Ganzfeld sudies using similar targets and subjects. This would suggest that AC similar to that seen in the Ganzfeld work occurred in the pilot study. However, for noise types 1 and 2 the measured AC performance was greater in the magnetically noisy condition than in the control condition, contrary to expectation. The z values for these differences (–1.32 and –1.20) are not large, but in the absence of additional data it is worthwhile considering explanations other than chance. Leaving aside then the possibility that the pilot study's hypothesized result would have been observed in a larger study, there remains the possibilities that the magnetic condtions imposed upon subjects in the pilot had no effect on their AC performance and the possibility that the noisy condition used enhanced their AC. The first of these alternatives was discussed earlier in this paper, namely that the very low frequency magnetic field changes which are encoded by the geomagnetic indices, and which were the manipulated condition in the pilot study, may not be the physical effect responsible for the GMF effect in the anecdotal and experimental AC data. For instance, if magnetic noise in the 100mHz to 10Hz region of the spectrum were responsible for changes in AC performance then a null result would have been seen in the pilot study. On the assumption that the spectral region manipulated in this experiment may be irrelevent to AC performance, the AC scores were examined for evidence of correlation to the GMF index values which were observed during session times. The equivalent z scores for the trials were correlated with the *ap* index values for the trial times resulting in a correlation of $rho = 0.04$. Thus the observed AC performance was not significantly modulated by index values. The last possibility, namely that the difference observed in the pilot was due to a real increase in AC performance in the noisy condition used therein, might be explained in several ways. It might be that some additional magnetic noise was present in the shielded condition, perhaps in a different region of the spectrum. Given the design of the apparatus and the fact that the only difference between noisy and control conditions (for noise types 1 and 2) was the values in the computer program this seems unlikely. However, a weakness of the design of the pilot study apparatus was that no field measurements were taken at the subject's location during trials. Without such measurements it is impossible to rule out this possibility. Another possibility is that AC performance is really enhanced by the noise conditions imposed in types 1 and 2. Neither of these noise conditions exactly reproduced the GMF field changes that occur naturally. The field changes in the pilot study noise conditions were larger in amplitude and of different power spectrum to natural variations. It is not possible to determine which of these explanations, if any, is responsible for the observed AC performance differences.

Given the paucity of physical correlates to AC performance and the ambiguous results of this pilot study, it is worth considering how any subsequent study should be designed. There are two main areas which should be substantially improved. Firstly, the psi aspects of the experiment design should be modified to give the highest possible chance of seeing a difference in AC performance should it exist. Such modifications should include using preselected subjects, with known agents or senders, and dynamic targets. Secondly, an effort should be made to control field conditions over a wider frequency and amplitude range. Methods for measuring and controlling field environment of the subject at frequencies higher than 100 mHz (the high frequency cutoff the pilot study) are readily available. For instance, the enclosures used for magneto–encephelography (MEG) provide considerable shielding from GMF and man–made magnetic field noise in the ULF region of the spectrum. Such an enclosure could be used for an improved version of thjis experiment. However, the cost of such an experiment does pose an obstacle in this field and it is worth considering alternative approaches.

As has been discussed, there are a variety of physical effects which are correlated with the GMF indices and which could produce the observed correlations between GMF indices and ESP. As an alternative to the expensive process of trying all of them, research on other interactions between human physiological and psychological variables and GMF variations may help to narrow the range of possible physical correlates that have to be considered. For instance, Randall[32] reported large correlations between human birth rate and plasma melatonin levels and *aa*. There are also reports[33] of correlations between epileptic seizure frequency and GMF activity. Phenomena such as these may have a larger effect size than the AC – GMF correlation and considerably more is known about the physiological mechanisms involved. Both these factors facilitate research and study of these effects may elucidate the exact physical parameter responsible, which could aid the discovery of the physical mechanism of the AC correlation.

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