18

The Modern Magnetotherapies

MICHAEL A. PERSINGER

Behavioral Neuroscience Laboratory, Department of Psychology
Laurentian University, Sudbury, Ontario, Canada

INTRODUCTION

Magnetotherapy can be defined as the treatment of subjective and objective ailments by exposures to magnetic fields. Historically, the use of magnetic fields in therapy has been remarkably periodic. When the magnetic dream was prevalent, it was pursued with adolescent enthusiasm. Frequently, the magnetotherapies were also paratherapies that were practiced beside and sometimes in opposition to the contemporary medicine.

In many ways, the development of the magnetotherapies has been similar to the clinical history of cannabis. During the last century, hemp or its many variants were used to treat an extraordinary number of complaints that ranged from migraine headaches to "women's difficulties." However the effect upon the presenting problem was rarely consistent and consequently the use of the plant was gradually dropped from the therapeutic repertoire.

The problem lay not in the therapy *per se* but in the failure to isolate the key chemical properties and to discriminate the importance of psychological factors. Now it is clear that the active chemical ingredient is THC (tetrahydrocannabinol). Now it is clear that expectancy about the effects of the drug can produce some of the effects as the drug itself. Furthermore, the personality of the client, his psychological expectancy (demand characteristics) and the drug can interact to produce enhanced effects or experiences.

There is also a sociological aspect to the use of magnetotherapy. Magnets (or other readily accessible devices) have been often described (out of print) as a "poor man's medicine." These procedures allow personal access to the treatment of personal ailments. In this context, magnetotherapy removes the person's dependence upon a complex and sometimes unfathomable medical establishment within which the individual has little control. It is no accident that surges in magnetic and other borderline treatments are often commensurate with problems in access to critical institutions and in the general feeling of social isolation.

The persistence of an interest in the effects of magnetic fields can also be traced to psychological factors. Every researcher's personal environment is a product of language and the processes by which it is generated. Despite maturational (developmental) shifts in the cognitive schemes by which we assimilate information, there are concepts from previous stages that remain. One of them is the fascination with invisible forces (animism). This idea serves as a conceptual core around which cluster ideas of infantile mysticism, paranormal experiences and

sometimes a modified form of omnipotence. It is so closely tied to the concept of self that if care is not taken, magnetotherapies become a personal quest. It acquires dynamics of a belief.

Unfortunately this factor has been ignored, often with arrogant sarcasm, by the very scientists who practice it. However the powerful inertia that ac companies this conceptual core is repeatedly evident. It is manifested by the gradual shift from the use of magnetic fields to treat a specific ailment, to the treatment of all ailments, and then towards mystical or paranormal involvements. Ultimately there is a revelation of transmagnetism where the "critical factor" is contained within the magnetism of the spirit, self, or other word for invisible force. The pattern was conspicuous in the life of Mesmer and has been reiterated many times since.

Scientists are often disquieted by the introduction of these personal variables into technical discussions. However the recognition of these factors is essential for the objective evaluation of magnetotherapy. A researcher may have isolated specific effects but as he or she moves along the Mesmeric progression and loses "scientific respectability" these effects may be indicted as well. They are ignored and a potential discovery is lost.

The problem of the reality and of the strength of magnetotherapy is complex; it is complicated both by methodological and psychosocial variables. This chapter will emphasize a moderate stance whereby methodology rather than theory or feasible mechanism is the criterion of evaluation. The review is limited to those experiments that have been published in journals that are accessible to the author. Claims from Chinese and Russian researchers are not included.

FUNDAMENTAL STRATEGIES OF MAGNETOTHERAPIES

Traditional approaches for reviewing a given area of research have involved organization ac cording to measurement, methodological or conceptual (operational) similarities. However, considering the numerous modes, measurements, and methods that have been employed in magnetotherapies, another approach will be used. It involves the intrinsic metaphor or philosophical strategy of the method. There are four discernible strategies; they will be called: coercive, compensatory, corrective, and concentrative.

COERCIVE STRATEGIES

The coercive strategies involve the application of relatively high intensity, static or time-varying magnetic fields to all or part of the body. Exposure durations are brief (typically 15 minutes with ranges between 5 minutes and an hour). The approach has had a rich and often humorous history. Its serious beginning in the modern scientific literature can be seen with the experiments of Karen Hansen (1). She applied one pole of a horseshoe magnet to human skin and observed the consequent reaction to microinjections of histamine. The strategy can be found today with electromagnetic devices such as the Magnetotron (Germany). The treating solenoid coil is 0.5 m in diameter and 0.45 m in length and generates 50–60 Hz pulsed electromagnetic fields with strengths between 30–90 gauss. The client rests within the coil.

The operating metaphor for this strategy is that the magnetic field influences key target organs (vasculature, brain, etc.). There is usually a presumption that different organs of the body may respond optimally to particular field frequencies,

shapes (square-wave, complex wave, etc.) or presentation patterns (high frequency carriers pulsed at lower frequencies). For pulsating fields in particular the therapeutic effect is argued to be mediated directly to the disease process through the induction of "pulsating magnetic energy." Within this concept is buried an implicit metaphor that disease processes contain undesirable energies that are somehow set free by the coerced application of magnetic fields.

One derivative of the coercion strategy is found in electrosleep-related therapies. Very large intensity electric currents are applied constantly or pulsed through the brain as electronic broad band noise between 5 Hz and 30 KHz at intensities that would be dangerous if given within a pure narrow band such as 60 Hz. Classic examples of such equipment included the Elektrodorm 1 (Austria), the Elektroson 2 (Russian) and the Electrorel GJP (Czechoslovakia). When electrodes are applied over the eyes, the criteria for sufficient current is based upon the report of phosphenes. Often when the electrodes are applied to the forehead, the criterion current is less clear.

COMPENSATIVE THERAPIES

Compensative strategies emphasize the theme that ailments are due to the disruption of normal biological conditions due to modern technology. Fundamental to this approach is that there are natural zeitgebers that maintain the fine-tuning of complex biological clocks. The two most common zeitgebers are the Schumann resonances and geogenic stimuli. Schumann resonances (2) are primarily sharp pulses or sine-wave like extremely low frequency (ELF) electromagnetic signals that are generated naturally between the ionosphere and the Earth's surface. Geogenic stimuli involve the "essences" within the Earth that are propagated to the surface (and to living organisms) by geomagnetic flux lines. The most recent scientific metaphor for geogenic stimuli are the vibrations of rock constituents. These vibrations are mediated to the surface by "soliton waves," a conceptual cousin to Larmor gyrofrequencies and hydromagnetic emissions.

Essential to the therapeutic strategy is that modern civilization has masked these signals. The intensity of Schumann resonances and their harmonics is correlated with local subsurface water levels. They have fallen (in many places) because of heavy cultural demands (3). Steel structures and modern buildings prevent full-time exposure to these natural fields by faradic-like shielding. Asphalt and cement presumably prevent the emergence of geogenic stimuli. Travel across time zones, another consequence of modern civilization, adds a dynamic component to the disruption of the natural signals.

The main idea of compensative therapies is to simulate the natural condition by portable, always-present magnetic field devices. They are usually small "black boxes" that can be carried in the pocket or placed under the pillow. The field frequencies vary with the sophistication of the

manufacturer, but always include the 1–20 Hz range. The simpler devices such as the Relaxit (Canada) generate fixed quasisymmetrical pulses from solenoids. Different devices generate different, fixed frequencies. More engineered devices such as the Mecos (Germany) apparatus emit MHz or KHz carriers that are pulsed at fixed frequencies or at variable frequencies. The latter option accommodates individual sensitivity. Field strengths are usually in the order of 1–10 gauss within 10 mm of the source.

More sophisticated devices have adjustable series frequencies to accommodate personal needs. Presumably clients often speak of a particular frequency as being most suitable. The quasi-theoretical basis of this finding is that the frequency resonates with the client's alpha rhythm. Induced nerve pulses by exterior loops have the greatest effect when they are in phase with each other (4). This explanation is the germinal center of perhaps the most frequent metaphor of magnetotherapy: resonance interaction.

Compensative therapy presumes that magnetotherapy acts as an artificial zeitgeber to correct disrupted body functions. Support for this idea stems from common sense and popular scientific knowledge about shifts in circadian rhythms during travel (jet lag) and the experiments of Rutger Wever (5). He found that human volunteers who were deprived of diurnal cues while living in an underground bunker showed disrupted, drifting and dissociative changes in their complex circadian clocks (temperature, activity). However the system could be "retuned" by the application of artificial 10-Hz electric (presumably with a magnetic component) fields.

Classic ailments that are associated with disruptive circadian rhythms are similar to those associated with deprivation of natural EM fields. They include sleep difficulties, exacerbation of pain complaints, flu-like symptoms, fatigue, problems of concentration and lethargy or other diffuse symptoms. Unlike the coercive treatments, the compensatory strategies involve long-term exposures; the devices are of ten carried for days to months.

Another interesting assumption of the compensatory strategy is that magnetotherapy works only if the person is showing the symptoms. The magnetic field devices will not produce any observable effects in the normal, symptom-free person. This theme is often forgotten in many experiments (including those of the reviewer) that attempt to test these apparatus in the laboratory. If this idea is valid then magnetotherapy may work much like the operation of aspirin. If you do not have a fever, aspirin will not affect your body temperature. If you have a temperature, the antipyretic effects of this simple drug are succinctly powerful.

CORRECTIVE STRATEGIES

These strategies attempt to solve the presenting symptom by correcting excessive, adverse sources. The source may be external (from the environment) or internal (within the person). External adverse sources are of two types: natural and man-made. Natural adverse sources include intense solar-induced magnetic storms and electromagnetic fields generated by extreme weather conditions (like the foehn, Chinook, Santa Anna, or sharav winds). Man-made sources include references to the ubiquitous 60 Hz buzz—from energetic overhead powerlines to the

magnetic fields generated from can openers, blow dryers, typewriters, and terminals.

Corrective strategies for external adverse stimuli involve shielding when possible or masking when it is not. Shielding involves living in special buildings or sleeping in (or under) special copper-containing bags or sheets. One example is Ludwig's (6) report that nocturnal arthritic complaints could be reduced by having susceptible sufferers sleep in special sleeping bags. The masking approach is to drown the adversive stimuli by elevating a more harmonic signal. The most popular technique involves the use of special metal sheets (like a sleeping blanket) that generate a dominant frequency.

A similar idea is to generate static fields around the sleeper by a special sheet (Energon). The field strengths are about three times the magnitude of the earth's static field (about 0.5 gauss). The specific value is based upon the belief that the geomagnetic field has dropped to 30% of its stable value within very recent human history (7).

A variant of the masking approach is a type of "dilution by averaging" procedure. Few magnetotherapists seriously assume that 60 Hz (presumably a disharmonic or adverse frequency) can be totally eliminated as a significant peak in the modern frequency spectra. Consequently this therapy offsets the adverse frequency by artificially adding a large number of conducive frequencies or their harmonics. In this way, the biosystem is less influenced by the single adversive stimulus because of the simultaneous presence of many positive, normalizing fields (8).

Correction of endogenous adverse "energies" is most clearly highlighted in MJRA therapy (8); it was developed by Franz Morell and Erich Rasche (MORA being an acronym). The original insight occurred when Morrell noted that injection of a substance into an *in vitro* system occurred before the lag time required for the chemical reaction. He concluded (as many others have) that the effects of medicines are due to their electromagnetic oscillations. If you can transmit the drug's electromagnetic vibration to the body, it can obtain the same effects without the ingestion of the drug.

The idea was applied clinically. Healthy tissue was assumed to have a different complex electromagnetic spectrum than diseased tissue. Presumably a naturally occurring substance was found that differentially filtered harmonic (H) frequencies from disharmonic (D) frequencies. The latter are associated with disease while the former are correlated with healthy states. By the use of a complicated device, the subject's own electromagnetic patterns are separated (H and D). The H is then amplified and reapplied to the person (usually through a local contact like a bracelet but sometimes whole body exposure) as a positive feedback of harmonic frequencies while the D frequencies are inverted (negative feedback) in order to attenuate the frequencies of endogenous toxins and to help maintain the body's own protecting forces.

CONCENTRATIVE STRATEGIES

The last strategy accommodates two principles: (1) the enhanced efficacy of a force by focusing the area of concentration (the martial arts approach), and (2) the importance of spatial gradients within the body, that is, the whole body is not spatially homogeneous in either its function or effect. The latter, of course, is the fundamental concept of acupuncture. Connected to this strategy is the supposition that fine, focused stimulation of hot spots, trigger points, or whatever term for unique body space, removes or ameliorates disease processes at a distance. Disease is implicitly seen as something that interferes with the homogeneous unblocked flow of life forces. This metaphor pervades the chi force beliefs of oriental medicines. Although many western researchers think that the idea was eliminated along with vital force theorists of the early twentieth century, the idea recurs frequently today, invariably masked by fancy physics.

Application of the strategy ranges from crude to incredulous. The simplest form involves Rutkowski's technique (9) for insertion of needles into muscle in order to treat local pain. Similar forms involve application of electrode plates over tissue where current intensities are raised until paraesthesia (the symptom being treated) is enhanced artificially (10). Still other techniques involved focused magnetic fields applied through electromagnets. There is even one device that can generate focused electromagnetic fields with intensities of several thousands of gauss. Because the skull is transparent to magnetic fields (unlike electric current), focused stimulation of cortical tissue from electrical induction occurs. Stimulation of the motor cortex and induced muscle movements by human volunteers have been reported (11).

A (predictable) developing approach within the corrective strategy taps heavily from the traditions of homeopathic remedies. These folk-based beliefs have been a persistent antagonist of rational medicine. Homeopathy borders between sympathetic magic (found in many cultures) and the structure resonance speculations of Sheldrake. Essentially, certain substances give off energies which are usually intensified by dilution of concentration or by mechanical stimulation (shaking) of the solutions. Because of the fundamental aqueous base to treatment solutions, modern protagonists claim that dilution of homeopathic materials changes the structural configuration of aggregates in water molecules; these different, dominating aggregates generate the varied curative (electromagnetic) properties.

The magnetotherapeutic applications of this approach have ranged from passive to active techniques. One passive technique is the combination of the Energon sheet and the Beena method (7). The latter employs special strips containing beeswax, royal jelly or other substances. Both devices are installed in feather beds as treatments for sleeplessness, rheumatic ailments, etc. Active methods involve placing special homeopathic substances within an iron lattice that is surrounded by a coil; the person's resonances (via MORA-type devices) are passed through the coils and the net reapplied field is a combination of the biogenic patterns plus their modifications by the homeopathic substances within the iron lattice. The operating metaphor contains two parts: (1) amplify the person's harmonic frequencies, and (2) add the electromagnetic oscillations

from special (curative) substances.

The most elaborate and probationary concentrative strategy involves the Indumed tradition that has been developed by Ludwig (8,12). This combines MORA therapy (9) with acupuncture concepts. By using a special ferromagnetic core, an upper transient frequency of 10 MHz is obtained; it is pulsed at, various frequencies called series frequencies of 0.1–300 Hz. Although there is no convincing documentation of the claims, the specific frequencies (in the tradition of matter-as-electromagnetic-patterns) presumably affect particular functions. The hippocampal frequency of 7.8 Hz (also a Shumann frequency) allegedly assists in concentration while 10 Hz has an analgesic effect and 33 Hz facilitates general vitality. Their application is not whole body but focused within the target space (usually the diseased organ).

Although difficult to accept (even conceptually), this magnetotherapy emphasizes an important factor, namely response (personality) profiles. Perhaps they are the moderator variables of all magnetotherapies. Until this decade, the pharmacologically dominated medical model underestimated the importance of personality in therapeutic treatments. The most common personality classification has been borrowed from traditional biometeorological literature. Presumably every person can be designated on two orthogonal dimensions: autonomic type and stability. A person occupies some position between extreme sympathetic dominance and parasympathetic (vagotonic) dominance and as well some position between extreme stability and lability (13). There are many compatible variants of this idea, such as Curry's K (cold) type and W (warm) type (in response to types of air masses); the idea has an uncanny resemblance to Hans Eysenck's (14) two-dimensional personality structure of extroversion-introversion and stable/unstable.

Recent developments of concentrative therapies also emphasize different types of people. Ludwig (8) argues there are at least twelve types, which he categorizes on the basis of their color preference and some other relatively unusual personality criteria. Presumably, the series frequencies that most optimally affect the ailments of people are related to color preferences. Those that prefer red are optimally affected by 8.2 Hz series frequencies while those that prefer purple are influenced by 15.4 Hz series frequencies. Preferences of two similar colors (red-orange/orange) may involve frequency differences of 0.5 Hz. According to the strategy, the optimal treatment frequency is determined by the personality of the client. If this assertion is valid, then the failures of magnetotherapy may have been a consequence of the panacea mentality that ignored the personality dimension.

SUPPORTIVE EVIDENCE: MAJOR EXPERIMENTAL AND CLINICAL STUDIES

Most of the claims of magnetotherapy include disparate and diverse categories of ailments. There are two general clusters of symptoms that appear responsive to several forms of magnetic field patterns. These two clusters involve complaints of pain and relaxation /irritability. Loaded on the latter factor are traditional categories of sleep, depression (in a nonclinical sense) and

anxiety.

TREATMENT OF PAIN

Responses to painful stimuli, nociceptive experiences and the cognitive evaluations of them are difficult phenomena to study. The inseparable interaction between psychological and biological processes in the pain experience has been known for decades; anticipation of an aversive stimulus (whose psychological correlates include references to apprehension or anxiety) can elevate subjective pain estimates quite substantially. It is now clear, from both pharmacological and neurochemical criteria, that pain experiences are not a single factor process. There are probably a multitude of different pain mechanisms that are mediated by various chemical transmitters in response to input from different parts of the body.

No doubt electrical stimulation can influence pain levels. Rutkowski (9) used electroanalgesia for chronic shoulder pain. Over a period of 5 years, 125 patients (76 women, 49 men), aged 38 to 68 years, were given 15–20 minutes of field treatment three times weekly (initially) to once every two weeks (10 to 35 sessions). The treatment involved 2-Hz fields delivered through two needle electrodes that were inserted into the back of the forearms plus a biphasic asymmetric rectangular-shaped spike current with a frequency of 1–10 Hz and amplitudes up to 800 pA. The method employed a concentrative strategy for trigger points. Clear improvement occurred in 80% of the cases and only 4 subjects were discharged without clear improvement. There were no placebo runs but a post-treatment follow-up indicated only 8 relapses during the next 5 years.

Magnetotherapy has been a popular treatment for pain. The most enthusiastic promotion of this treatment has been by Ludwig and his colleagues; they have combined competent engineering with keen marketing skills. Over several years Ludwig (11,15) and his group distributed over 920 ELF generators to over 860 clients; 220 of the generators were used as placebos. Two devices were used, those with fixed 9-Hz pulses and those with selectable ranges of 4–12 Hz. The rise time of the spiked fields was about 10 nsec with field strengths in the order of 0.1 mT. The primary measurement of the efficacy of the treatment was the reduction in the consumption of analgesic drugs over weeks to months of treatment.

The major results of these studies indicate that either ELF device (9 Hz or 4–12 Hz range options) substantially reduced reliance on pharmacological agents to treat chronic headache, migraine, rheumatic pain, and scar pain. Relative success with the magnetotherapy averaged between 87–96%, according to Ehrmann et al. (4). Reduction in reliance on drugs for volunteers who used the placebo devices occurred only about 20% of the time.

Superficially, these results suggest that painful experiences are reduced by magnetotherapy. However, the method of measurement indicates that the clients relied less on analgesics for treatment of their pain or ailments; there is no direct measure on whether the pain was reduced. Effectively, the volunteers may have been substituting one psychological dependency for another one.

There are several other problems with field (clinical) studies of this type; the first is the selection of clients. Readers do not know if the subjects were solicited, volunteered or selected randomly; this would clearly influence the direction of the effect. In addition, the assumption that placebo devices control for placebo effects is not warranted. This reviewer found that clients suffering from pain soon learned which device was placebo or real whenever they talked on a telephone. The actual ELF device generated such intense fields that audible clicks could be heard in the receiver (so much for blind conditions).

Exposures within experimentally controlled contexts have also been associated with the reduction of headache pain. Grünner (16) exposed 59 neurotic patients to either sham-field or field conditions (each subject served as his own control) in a series of blind procedures. The subject's head was placed within three quadratic coils that generated a continuous steady magnetic field of about 0.07 mT. Application of the fields was associated with reports of headache improvement in 85% of the patients while application of the sham conditions generated positive reports in 36% of the patients. Interestingly, Grünner suggested that the field facilitated the placebo effect, an idea certainly worthy of further consideration.

Grünner (17) found other field configurations to be associated with reduction in pain. Hourly exposures to a 225-Hz pulsating field (3.6-msec impulses) of 0.88 mT were associated with a relatively immediate regression of complaints. Another field configuration, characterized by an induction strength of 0.5 mT and a 260-Hz pulse was also successful in treating headache.

Problems with external validity are obviously complicated; usually field-associated alterations in electrodermal skin response or electroencephalographic (EEG) activity are considered inferences of the change in the subjective (pain) state. Ehrmann et al. (4) claim that older patients showed a 50% increase in skin resistance (baseline near 100 Kohm) within 10 to 30 minutes of continuous exposure to 5 Hz or 10 Hz devices; the effect lasted for about one hour posttreatment. However, there was no reported correlation with subjective complaints. Grünner found that increases in electrodermographic resistance on the forehead over time was correlated with a reduction in headache intensity. This elevation was noted in both magnetic field and sham treatments, although increases were more common in the field (85% of the subjects) than sham (35%) condition. Grünner (16,17) has also employed EEG profiles to support his claims, although his approach was primarily visual inspection of the records. He showed that reduction of headache was associated with increased relative proportions in alpha activity and greater subjective relaxation. Again, the effect, although present in both sham and field conditions, was much more frequent during treatment with actual fields.

Grünner (18) has studied symptom-specific populations. He exposed 26 patients who were suffering from vasomotor (tension) headaches to either a stable homogeneous magnetic field (96 gauss), a 12-Hz (66-msec pulses) magnetic field with strengths of about 8 gauss, or sham-field conditions. Each subject received each treatment and each treatment was one hour in duration. Electrical skin resistance from the forehead was monitored before, during and after the treatment. Compared to pre-field values, the electrical skin resistance was elevated for subjects during the

real field conditions; there was no apparent difference be tween the pulsed field and the continuous one. The analgesic effects were coincident with the elevation in skin resistance (indicating a shift to parasympathetic dominance). Exposure to the fields produced reports of a reduction of pain for all subjects; 65% of the patients said the headache had disappeared totally. After the sham treatment only 15% of the patients reported a mild retreat of the headache while 35% of them reported a worsening of the headache pain.

Posttreatment follow-ups to determine the long-lasting consequences of magnetotherapy are rarely completed. Grünner noted that 9 of his 15 patients were symptom-free after a month although they had had chronic headaches for years (17). Grünner also recognized the importance of discriminant validity. He appears to have realized that because headaches have different etiologies they should not respond homogeneously to the same magnetotherapy. In fact, he reported that the 260-Hz pulsed fields were analgesic for tension headaches and for those associated with depressive neurosis (presumably dysthymic disorder). However this treatment was not effective for headaches associated with tumors, anxiety neurosis or migraine (17,19,20).

If there are individual differences in field sensitivities and frequency-specific effects in magnetotherapy, then there should be reports of enhanced pain or headache during treatment. Ludwig and his colleagues depended upon the classic sympathotonic (sympathetic dominance) and vagotonic (parasympathetic dominance) dichotomy to describe such effects. They argued the sleep of vagotonics is facilitated by 8–12 Hz frequencies whereas sympathotonics report sleeping difficulties. They could sleep when pulse frequencies were adjusted to 4–6 Hz. There was also individual optimization with respect to intensity of the fields.

Grünner (19) candidly reported the effects of the Magnetodiapulse device upon 47 neurotic and depressive patients (although symptoms are not specified, they again appear to be dysthymic disorders using DSM III criteria). Subjects were exposed for about one hour to either sham conditions or to 1-msec trains of 27-MHz fields that were presented at nine pulses per second through non-contacting wire coil parietal electrodes. Sixty percent of patients reported the feeling of excitation that accompanies headache; another 25% of the patients reported unpleasant exhaustion or tension; only 15% of the patients reported drowsiness (relaxation). The sham-field treatment was associated with drowsiness or relaxation in 72% of the patients.

Studies to determine construct validity, that is the existence of some process within the body that is both associated with pain and affected by magnetic field exposures, are presented in the literature. Warnke (21) has argued that pain is triggered by the lack of oxygen in tissues and the related acidosis. He found that 5–10 minute exposures to a 3-mT magnetic field within an impulse frequency of 50 Hz, an impulse package frequency of 10 Hz and a resonance frequency of 150 Hz resulted in a 2–3 factor increase in oxygen partial pressure compared to prefield values. The effect disappeared within 5 minutes after the field was removed.

Warnke (21) cleverly demonstrated that the pulsating magnetic field effect evoked dilation of peripheral blood vessels in humans and horses by measuring infrared emissions. He argued that the results indicated a reduction in sympathetic tone (or increase in vagotonic dominance), a

conclusion that is similar to that of Grünner. These results were also reported by Berner et al. (7). These authors state that magnetic foils (Energon) also evoked significant increases in peripheral blood circulation (as measured by thermovision) and arterial oxygen pressure (about 15 mm Hg) but distinctly reduced rheumatic pains. Warnke speculates that there may also be a reduction in activity of pain conducting sympathetic nerves that contain fibers of the A (myelinated) and C (nonmyelinated) category.

The second series of findings that lend credence to the construct validity of magnetotherapy in pain treatment involves the work with reduction in analgesia. A series of studies by Ossenkopp and Kavaliers (22) on rodents, indicate that brief field exposures (30 minutes to an hour) during the night (dark cycle) reduces the analgesia that is normally afforded by morphine. Effectively, rodents that were exposed to time-varying magnetic fields (1 mT , 10 mT) and then exposed to a controlled hot plate behaved as if they were saline-injected controls (no morphine). The effect was produced by rotating magnetic fields and by NMI (Nuclear Magnetic Imaging); however the critical component in the NMI exposures was not the kgauss static field nor the radio frequency component. Apparently, the critical component was the weak, ELF magnetic ripples that are used to enhance the image.

Interestingly, Ossenkopp and Kavaliers (23) found the reduction (abolishment) of nocturnal analgesia in rodents also occurred during a relatively intense geomagnetic storm. They had been suspicious that such factors might be involved on the basis of the high interday variability in nociceptive thresholds. This information is important in light of Grünner's (24) observation that neurotic complaints were enhanced during periods of very quiet geomagnetic activity or very intense geomagnetic activity. Although certainly not conclusive, the Kavaliers and Ossenkopp series appear to demonstrate a conceptual bridge between the mechanisms of analgesia, experimental magnetic field exposures and natural geomagnetic activity. An interface between these three factors would support a central theme of magnetotherapy.

RELAXATION AND SLEEP: ANXIOLYTIC EFFECTS

Considering the intimate relationship between pain and anxiety, it is not surprising that therapies that promise reduction of nociceptive experiences are also associated with anxiolysis. Although anxiety is probably mediated by a neuropeptide within the limbic system, the most well known correlate is muscle tension. In fact, anxious experiences are highly unlikely when muscles are relaxed, a principle that forms the basis of many conventional therapies (e.g., Wolpe's systematic desensitization). Several claims have been made that certain forms of magnetotherapy are also relaxation therapies.

Mantle and Persinger (25) performed one of the first actual double-blind experimental studies with ELF pocket generators. The devices (Relaxit) were manufactured by Electromedia (Rexdale, Ontario, Canada). Four groups of university students (16/group) served as subjects; they were exposed to either control, sham-field, 5-Hz or 9-Hz conditions. The sham devices looked like the devices that generated the 5-Hz or 9-Hz fields; however the sham field devices

did not generate any detectable magnetic field. To insure that any effect was not due to a single device, each Relaxit condition involved two apparatus. The devices were worn (held by a belt) over the area of solar plexus. In the control condition, no belt or device was attached.

The 64 subjects were administered a series of statements before and after the fields were switched on; these statements were Likert scale (1 to 7) descriptions of various vegetative (autonomic) states. During a 10-minute exposure the subjects filled out an anxiety scale questionnaire. Instructions to the subjects were given by tape and the experimenter did not know which subject was receiving which Relaxit condition; the code was broken only after the experiment was finished.

The results of the study indicated that brief exposures did not influence scores on the anxiety questionnaire. However, there was a significant increase in reports of relaxation (or items that loaded on that factor) after 10 minutes of exposure compared to the pretreatment administration for the 5-Hz group. These changes were significantly different from the 9-Hz, sham-field or control groups that did not differ from each other. In addition, there was no difference in scores between members of the two 5-Hz groups that had received exposures from two different apparatus.

Although the Mantle study was one of the more controlled brief exposure protocols in the area, there were several limitations. First, there was no measure of external validity. Statements that “my heart rate is reduced” or “I feel more relaxed” do not demonstrate there actually was a reduction in heart rate or muscle tonus. Secondly, there may have been a pre-test sensitization effect, that is, the subjects figured out that the study was about relaxation (after all, the device was called a Relaxit).

That the 5-Hz groups demonstrated a treatment effect but the 9-Hz and sham-field groups did not (and did not differ from controls) effectively eliminates the possibility of a placebo effect. However, these results cannot exclude the possibility that the 5-Hz effect was due to nonspecific arousal rather than relaxation. In other words, the 5-Hz field may have produced a low-level adrenalin-like arousal but the actual attribution of the experience (relaxation) was determined by the cognitive aspects of the situation; they were determined by the content of the autonomic state questionnaire (pretest sensitization). This effect would be similar to the studies of Schacter and Singer (26). They injected subjects with similar amounts of adrenalin. The emotional experiences of the volunteers were determined by the cognitive aspects (social demands) of the situation. People who were exposed to happy settings experienced joy while people who were exposed to sad contexts became tearful or sad.

Later unpublished studies by Mantle involving approximately 20 male and female volunteers suggested that there was a small change (decrease) in heart rate during 5-Hz field exposures compared to 9-Hz, control or sham conditions. The effects were not statistically significant. However the experiments were designed differently in that the subjects were not required to “think” (answer questions) during the brief field treatments. In addition, electrocardiograph electrodes were attached.

An indirect confirmation that relaxation may accompany brief exposures to 5-Hz Relaxits can be found in a slightly different series of studies. Michaud and Persinger (27) and Persinger and Nolan (28) were interested in the effects of theta frequency fields upon the memory of a three-minute narrative (The Dinosaur Egg Hunt). The basic idea was that magnetic fields applied along the side of the cranium (nearest the temporal lobe) while the subject was listening to a taped story might influence memory consolidation. This would be revealed by consequent discourse analysis. Both studies indicated that there were changes in recall of the narrative, although the type of changes varied. In the first study, there were differences in the form of memory while in the second study there was a reduction in the total amount of detail recalled. The effects of the three-minute exposure to the paratemporal 5-Hz fields were very small but statistically significant.

Although the narrative studies suggest that theta frequency fields interfered with or modified consolidation of memory (because there were no fields applied during the recall) of the narrative, the relaxation hypothesis is equally viable. Decreased arousal and relaxation would also interfere with the university subjects' attention or motivation to remember; the latter was relatively small anyway (optional two-point bonus to the final mark). Grünner noted that the appearance of alpha activity and enhanced reports of relaxation was one of the major features of patients who were exposed to ELF fields, although the frequency and field configurations were markedly different from the Relaxits in the narrative studies.

Grünner (24) also found that when he exposed the heads of his 59 patients to 63-gauss homogeneous fields for one hour the rise in electrodermal response was accompanied by growing parasympathetic tonus and a decline in vigilance, leading in many cases to sleep. The paradigm of the Relaxit studies involved setting the subject in an acoustic chamber during the field exposure; such quiet conditions may have interacted with the ELF fields to have decrease vigilance. However no electrophysiological measures were taken in either the Michaud and Persinger or Persinger and Nolan studies.

There is little doubt that induction of direct currents within the brain can produce sleep in many people. The phenomenon of electroanesthesia has a long history that has been reviewed by Herin (29). The more brutal form of this therapy is often seen today as electroconvulsive shock. Electroanesthesia is mentioned within this chapter because of the conceptual and perhaps even synergistic overlap with magnetotherapies. One example of the combined sleep-inducing magneto-inductive and transtemporal electric currents (TEC) was reported by Photidades et al. (30). Subjects were exposed for one hour to either transtemporal pulsed current (100 pps; 0.1 msec durations and amplitudes of 0.5–2 μA) only or to this current plus a 1000-gauss magnetic field that was pulsed two times per second. The latter field was presented proximal to the face.

A total of 90 sessions, under relatively controlled conditions were recorded for the same 5 subjects; they were not told whether or not the field was present although controls for equipment noise artifacts were not reported. Depth of sleep was determined subjectively according to a 0–3 scale where 0 meant "no effect'" and 3 meant "prolonged sleep." There were 45 sessions of

transtemporal pulsed current only and 45 sessions of this procedure plus the magnetic field exposures. Unfortunately, the authors did not analyze their results statistically but the raw data were presented. Chi-square analyses by this reviewer indicated a highly significant difference ($\chi^2 = 47.29$, df = 3, $p < .001$) between the two treatment conditions. Whereas 38% of the sessions with both conditions were associated with the deepest prolonged sleep, only 8% of the TPC conditions were associated with the deepest prolonged sleep. Close scrutiny of the data indicated that the magnetic field facilitated the shift from deep sleep to deep prolonged sleep only.

However, sleep and relaxation from magnetotherapy may not be dependent upon coercive strategies. Some recent experiments reported by Subrahmanyam et al. (31) indicate that relaxation and anxiolysis can be accomplished by a combination of appropriate geomagnetic orientation of the client and the superimposition of relatively weak ultra-low-frequency fields. Maximum effects were found with pulse frequencies of either 0.01 Hz or 0.1 Hz (rather than 1, 10, or 20 Hz) at intensities of 20,000 or 40,000 gamma. Presumably, there were also correlative changes in autonomic measures.

These studies, if replicated, implicate the role of geomagnetic pulsations and ultra low frequency variations. Exacerbations of irritability, psychiatric complaints and related aversive behaviors have been frequently associated with magnetic storms. The Subrahmanyam results suggest that ailments may be associated with a lack of geomagnetic stimuli. Interestingly, Grünner (19,24) noted that the symptoms of neurotic patients were exacerbated on days when the geomagnetic oscillations were very quiet. The applications of these observations to magnetotherapy remain to be established.

Perhaps the strongest support for the role of magnetotherapies in the treatment of anxiety/irritability is again reported by Grünner (16). He used electronic broad-band noise (20 mA) for the treatment of patients who were diagnosed with endogenous depression, reactive depression, neurotic depression (dysthymic disorder) and anxiety neurosis. The effects were differential according to psychiatric category. Dysthymic patients reported dizziness and nausea while endogenous depressives reported heightened psychic (attentional) activity. There were no reported effects on reactive depressive patients and the treatment was not suitable for anxiety neurosis (although a square-shaped pulsed current of 1 mA appeared more effective). The discriminative nature of this magnetotherapy within a heterogeneous diagnostic population suggests credibility; if the same treatment would have produced similar effects in all four groups, the mechanism would be difficult to comprehend and the validity would be questionable.

There have also been reports of enhanced anxiety during magnetic field exposures. Sweetland et al. (32) exposed 175 volunteers to either MRI (magnetic resonance imaging), sham MRI or control conditions for about one hour. Pre- and post-treatment measures included scales from the Wechsler Adult Intelligence Scale (Block Design; Digit Symbol and Digit Span), the Wechsler Memory Scale of Paired Associate Learning, the Benton Visual Retention Test (Spatial Memory), several other memory indicators and a state anxiety inventory. Compared to the sham-MRI and control conditions, the MR imaging procedure interfered with Digit Span and enhanced

anxiety scores. These authors concluded that the combinations of rf, steady-state and time-varying fields associated with MRI elevated anxiety but did not influence gross cognition.

POTPOURRI STUDIES

A claim for cures of a variety of diverse and etiologically unrelated ailments has been a singular and discrediting trait of magnetotherapies. They are difficult to assess objectively because the data are rarely published or the primary information is written in obscure or eccentric language; most of the time the proofs are single-case clinical examples. In appropriate contexts, they can be very useful (e.g., the single episode of affluent aphasia that allowed accurate location of the lesion in the frontal lobe—Broca's area).

There are many small laboratories and institutes that claim magnetic miracles. To dismiss them as fraudulent simply because they do not have access to traditional forms of expression may be as irresponsible as accepting the claims without question. One such example are the experiments of Charles Turley in Puerto Rico. Turley and his colleagues exposed volunteers to a Japanese manufactured 50–100 Hz pulsating magnetic field with strengths in the order of 100 gauss; exposure durations varied between 15–20 minutes and an average treatment involved between 15–20 sessions over a 5- to 20-day period.

One of the unpublished studies by Turley et al. (clinical report of January 3, 1976) reported a dramatic pre- to post-treatment drop in blood cholesterol of 10 subjects; 10 controls did not show any change. The mean pretreatment cholesterol levels of the treated group was 196 ± 26 mg/100 ml while the control group value was 209 ± 14 mg; whereas this value did not change appreciably (208 ± 12 mg) in the control group, the treated group's mean dropped to 141 ± 13 mg/ 100 ml. The time of treatment varied between 5 and 25 days.

They reported the individual data, so this reviewer analyzed them statistically. A three-way analysis of variance with one level repeated (pre-/post-cholesterol measures) and two main factors (treatment and sex) with covariance for duration of treatment was completed. The results demonstrated an extraordinarily powerful treatment difference ($F = 30.71$, $df = 1,15$, $p < .001$) that was due exclusively to the treatment by repeated measure interaction ($F = 61.80$, $df = 1,16$, $p < .001$) because of the large drop in post-treatment cholesterol for the magnetic-field-exposed subjects. There was no sex difference or significant covariance for duration of treatment.

Unfortunately this kind of data rarely reaches the scientific literature. Indeed there may be incompetent experimenters, fraudulent practitioners or simply unscrupulous promoters who might generate similar results. On the other hand, there may be actual discoveries that have not been expressed, in the tradition of Mendel or even Copernicus, simply because they cannot be published or have been published locally and lost to the general scientific community.

PLACEBO: A PHENOMENON WITHOUT A MECHANISM

A cursory glance at the ailments affected by the Mecos magnetotherapy would include

chronic headache, general body aches, motion sickness, nervousness, fatigue, poor circulation, foehn sickness, and sleeplessness. Claims for the Relaxit are similar. Indupoint and MORA (corrective) therapies would also include allergy-related ailments. Magnetotron claimants would mention the neuralgias, angina, functional gastrointestinal disorders (irritable colon), gall bladder irritation and various paralytic problems. All would claim anxiolysis. The seasoned investigator would recognize this symptom as loading on a single factor: the placebo.

NATURE OF PLACEBO PHENOMENON

Traditionally, a placebo effect was defined as the production of improved conditions by administration of a pharmacologically inert substance. An important part of the placebo effect involves a degree of ritual, expectation, and suggestion. It does not require the ingestion of a substance but may only involve a situation. The "hello doctor, goodbye doctor" effect, where the sick patient suddenly feels better while just sitting in the doctor's office or the person with appendicitis suddenly "feels better" while in the emergency ward, are possible examples.

Disorders which have been found to be most responsive to placebo treatment are pain, headache, anxiety, depression, and fatigue; these conditions require some cortical processing. Peterson (33) lists the most frequent signs or symptoms that have been affected by placebo or expectancy treatments. Percentage of patients (in parentheses) that show amelioration of symptoms have been found for analgesia (28%), headache (62%), sleep disturbances (7%), sea-sickness (58%), neurosis (46%), hay fever (22%), colds (45%), rheumatism (49%), gastrointestinal disorders (22%), and menstrual difficulties (24%). Different side effects following a placebo treatment include (percentage responding in parentheses) headache (25%), sleepiness (50%), feelings of warmth (8%), and relaxation (9%).

The placebo phenomenon is often impugned because it is presumed to be "in the head." Yet a psychological etiology does not alter the power of the phenomenon or the compelling fact that cognitive processes, personality patterns, and traditional medical (biological) ailments are intimately connected. One striking placebo effect was summarized by Rossi (34). A patient with severe lymphosarcoma was refractory to all known therapies; he heard about "krebiozen," a miracle cure for cancer. The physician was dubious but injected the patient on a Friday, expecting a dead patient on Monday. However, by that time, the tumor had shrunk to half its size and ultimately regressed. When the patient read in newspapers that the treatment was "fake," the tumors reappeared and again he entered a terminal state. The physician found "some new remedy" and again the lymphomas shrank only to reoccur (and this time the patient died) when the patient read that this remedy too was worthless.

THE PLACEBO REACTOR

In general, the placebo potency decreases in proportion to the number of doses received; usually by the fourth treatment the effect is substantially attenuated. Continued placebo effectiveness (fixed regimen of administration) is influenced by the personality characteristics of

the patient or client. Placebo reactors have been found to be more religious, older, easier to care for and to get along with, more dependent on outside stimuli, more conscientious, and less mature.

There is a clear relationship between suggestibility (hypnotizability) and placebo responding. Highly suggestible people tend to have rich fantasy lives (35). Their fantasies are so intense that they are sometimes difficult to distinguish from actual events. They show a marked psychosomatic plasticity. This means that many of their body organs have come under control of cognitive processes. Very suggestible people can respond with the triple response of skin injury to mild tactile stimulation; this response involves the release of a histamine-like substance, localized dilation and increased permeability of minute blood vessels.

THE REFLEXIVE USE OF PLACEBO EXPLANATIONS FOR MAGNETOTHERAPEUTIC CLAIMS

Recently Barker (36) concluded that the symptoms affected by current magnetotherapies were due to placebo effects because similar symptoms have been produced by placebo procedures. This approach is popular among debunkers and hinges upon the relatively loose thinking that "similar plus similar equals the same." Using the same paralogical assumptions, Barker would also be forced to conclude that pepper does not make you sneeze (nor does looking at a bright light) simply because having a cold (a more frequent phenomenon) also evokes sneezing.

The actual neuropsychological mechanism of the placebo effect is unclear. Consequently, to state the magnetic effects are due to placebo phenomenon is useless labelling that reveals nothing about mechanism. It is possible, that whatever neuropsychological mechanisms are associated with placebo effects, might also be influenced directly by the application of therapeutic magnetic fields. This possibility has not been pursued.

H.W. Ludwig's older studies, and O. Grünner's earlier work were either double blind or the effects of the treatment were opposite to those of placebo conditions. However, these procedures and results still do not exclude the role of suggestibility. This issue was recently addressed by Ross and Persinger (37). A total of 40 university students were assessed for suggestibility using the procedure of Spiegel (Hypnotic Induction Profile); the characteristics of the population were similar to the norms of Spiegel (38).

The subjects were exposed to 3 minutes of Relaxit therapy (5 Hz or 9 Hz) or to sham-field conditions. They were told that that treatment was associated with relaxation and that they would be asked to recall a narrative after it was completed. The subjects were familiar with the supposition that relaxation interferes with memory consolidation. However, there was no significant correlation between the degree of suggestibility and the amount of recall, although the latter was influenced by the presence of the fields.

CURRENT STATUS, CRITIQUE AND SUGGESTIONS

The existence of valid magnetotherapeutic effects is highly probable. Meta-analyses of published data and pattern evaluation of the types of results that have been presented by the more rigorous researchers strongly suggest that the claims of some magnetotherapies are not due to simple artifacts. Whether or not these effects are of any practical significance beyond the role of a type of adjunct psychotherapy remains to be established. The routine substitution of pharmacological treatments with magnetotherapy is much less probable. However, if Liboff and Thomas' (39) lithium simulation (by bucking the geomagnetic field to half its normal value and superimposing a 60-Hz powerline-intensity magnetic field) shows external validity, then the contingencies will be definitely changed. After all, lithium is one of the simplest and most effective therapies for major bipolar affective disorders (manic depression).

METHODOLOGICAL ISSUES

The single greatest limitation of magnetotherapies is a consequence of the same factor that maintains it: individual interest and innovation. There are so many different types of magnetic field devices that interlaboratory comparisons or even systematic replications are rarely attempted. Because of the lack of standardization in exposure equipment, the types of methodological controls that are essential for understanding the phenomenon cannot be implemented. Science works by systematic replication whereby each new experiment adds to but at the same time reiterates existing data patterns. At this time, it is better to use the same apparatus in different laboratories for several years (at the risk of missing big effects) than to use different apparatus only once.

The following methodological issues must be addressed in magnetotherapy research; most of them are elementary aspects of experimental design. Controls should be instituted for pre-test and post-test sensitization. In most experimental proofs of magnetotherapies there is no reference to the format of the questionnaire by which the subjective reports were obtained. Pre-test sensitization can alter the person's expectations of the treatment. Similarly post-test sensitization can influence the person's recollection of experiences or the assessment of current status by the recondite themes carried by test items. The effects of test formats may appear to be subtle but they are critical determinants in the response by highly motivated clients; most clients in magnetotherapy are highly motivated.

Subject selection is also a critical issue. Magnetotherapy works mostly for people who display symptoms; the effects on symptom-free volunteers are less impressive. This fact is not necessarily a critique. Drug treatment works on the same principle. However, symptoms do not occur in isolation and the client with complaints is also a person with a definite personality, values and belief structure. They are a constant potential source of moderation. A moderating variable is one that must be present before a stimulus (e.g., magnetotherapy) and can evoke a response (amelioration of symptoms).

Double-blind studies are so important to the support of drug efficacy that the pharmaceutical

industry rarely proceeds without them. Single-blind studies (placebo controls) are frequently reported in magnetotherapies; they are never adequate. Few placebo procedures (actually sham-field exposures where the client is exposed to the apparatus without current production) are actually controls. There is no evident attempt to reproduce temperature, vibration or noise artifacts from the equipment. Double-blind studies, where the experimenter is also not aware of the treatment condition, are effectively non-existent in the literature. Considering the importance of the researcher's belief structure in magnetic field research, double-blind procedures are particularly important control measures.

The most likely form of successful magnetotherapy will probably involve the fine focus or concentrative strategies that effectively imitate neuroelectric therapies. Until recently the technology was not available to produce focused, high intensity fields with multiple frequency and complex waveforms. Considering the apparent success of Patterson et al. (40) in treating substance abuse, fine-focus magnetic therapies are a rational extrapolation. They would have the extra advantage of not requiring subcutaneous intervention by needles.

THEORETICAL DEVELOPMENTS

Theoretical developments in magnetotherapy (and for magnetic field effects in general) have been little more than projective tests; they reflect the contemporary fad or scientific metaphor. Many of the mechanisms that are suggested for magnetotherapeutic consequences appear to be obligatory rituals for the Discussion section rather than a realistic appraisal. A naïve reader can be flabbergasted (and that is the appropriate word) to see relatively mundane effects in a Results section transformed into a universal field theory within the Discussion. Often there is not even a rational (let alone empirical) connection between the results and the explanation except for the fact that both are strange. For simplicity, mechanisms of magnetotherapy can be grouped into two camps: single process versus field process.

Single mechanisms highlight or emphasize specific units. They change along levels of scientific discourse, from hemoglobin molecules to major organs; the basic models have not changed since the 1973 review of Persinger et al. (41). Three new advancements deserve attention. The first involves the potential effect of magnetotherapy upon immunological processes (42). As neuroimmunology develops and the cellular mechanisms are elucidated, the effect of magnetic field exposures on these phenomena will very likely become evident.

The second contemporary mechanism is actually a reification of an old metaphor. The pineal gland, primarily because of its unusual geometry and topological position within the brain, was considered to have special mystical qualities. Experiments by Semm (43) and his colleagues show that this structure is electrically and chemically (melatonin) sensitive to changes in near-nature magnetic field intensities. Because the pineal organ primarily inhibits the activity of key endocrine structures such as the thyroids, adrenals and gonads, changes in its activity can produce substantial whole body alterations. The nocturnal analgesia studies of Kavaliers et al. (22) are compatible with this approach.

The third contemporary mechanism involves special tissues within the body; they have organometallic properties that presumably detect or amplify magnetic fields. Some birds are argued to have "magnets" within their brains (44). Magnetite-like granules embedded within neural tissue have been reported in dolphins (45); the material is easily degaussed and demonstrates marked individual variation. The differential existence of such substances within human beings might help accommodate the notable individual variance in responsiveness to magnetic fields.

Another kind of special tissue involves the periventricular structures and circumventricular organs; the latter include the pineal organ, subfornical organ, subcommissural organ, and the area postrema. These structures have poor blood brain barriers and are highly localized vascular, neuronal, and cerebrospinal interfaces. Electrical stimulation of the periaqueductal gray has been reported several times to be associated with pa in relief; there is now corroborative evidence that such stimulation elevates beta-endorphins within the ventricular fluid (46). Whether or not fine-focused magnetic fields can accomplish this stimulation or if magnetoresponsive patients have a particular sensitivity of these brain structures remains to be established.

The second metaphor that is used to explain magnetotherapies (and magnetic field effects) involves the field theories (47-49). The basic theme is that magnetic fields do not act upon an element or a structural unit (e.g., blood cells, pineal organ) but upon the field associated with it. The smallest field perspective concerns the electromagnetic oscillations of the cell. Herbert Pohl's (50) review of the natural time-varying electric fields within and about cells summarizes the theoretical and empirical basis of this contention. Individual nerve cells, for example, have been reported to display 50–500 Hz oscillations. A favorite explanation is that EM fields couple with these oscillations and information (in the form of energy) is transferred (oddly enough only in one direction).

The supreme development of the field metaphors is that consciousness is a field that is generated within (or by) the brain's neuroelectromagnetic matrix (48). Presumably the appropriate magnetic field configuration can directly influence the brain fields and hence modify consciousness. At the metaphysical end of this approach is the assertion that changes in the way we perceive the world (enlightenment) is associated with a restructuring of neural networks (47). The idea has been reinforced by exotic mathematical models, the most well-known being those of Burkhart Heim, where complexity and information are considered more important than intensity of the field or strength of the source.

Wolkowski (49) recently reviewed the role of field theory in biology. As he aptly points out, a field theory is an aggregate that accommodates properties that are not simply the sum of the parts, but it is also a system possessing an infinite number of degrees of freedom. This property makes empirical verification a bit difficult. In addition, most modern instrumentation is based upon digit enumeration of units; few instruments measure field properties of the organism.

The favorite mechanism of the field explanation is usually some type of resonance interaction. Because of the conspicuous graphic similarity between natural ELF (Schumann

resonance) signals and the human electroencephalogram, the resonance model recurs periodically (51,52). Few people apparently realize that those EEG patterns are determined by instrumentation and by the characteristics of skull impedence. As stated by Callaway and Harris (53), the wave-like qualities of the EEG are not likely to be effective carriers of information. A 10-Hz wave needs at least 100 msec to be established and that is too slow a rate to account for the complex information processing of the brain. Interestingly, the appearance of approximately 7–14-Hz waves in the EEG usually reflects a relative absence of information processing.

Despite these limitations the attractive field metaphor may still be vindicated. Cortical activity is dominated by thalamic input and thalamic structures have long been suspected to have special sensitivity to static and time-varying magnetic fields (54), although the causal factors were never determined. Midline thalamic structures contain pacemaker cells that determine the pattern of alpha rhythms; they occur primarily when the cortex is not actively processing. In addition, two types of rhythmic activities are found in thalamic neurons (55). The first is the well-known 7–14-Hz rhythm that consists of repetitive hyperpolarizations interrupted by burst discharges. A slower newly discovered rhythm has a periodicity of 10 seconds (0.1–0.2 Hz). Interestingly, experimental fields of these frequency ranges have been persistently associated with biobehavioral consequences (2).

NEUROCOGNITIVE MODERATION OF MAGNETIC FIELD EFFECTS

Just one decade ago, the possibility that neurocognitive factors might be the primary moderating variables in the magnetotherapies would have seemed unlikely; the zeitgeist has changed. Modern noninvasive techniques for assessing the dynamics of brain activity show an extraordinary complexity and sophistication. Many of these changes, such as regional blood flow, have been shown to be correlated with the type of cognitive activity in process. Evaluation of verbal symbols emphasize asymmetric changes in the left hemisphere while spatial contexts shift vascular activity to the right hemisphere. There is now evidence that electrical coupling between cortical potential shifts according to appositional (right hemisphere) and propositional (left hemisphere) problem-solving (53).

Positron emission tomography (PET) has demonstrated that substantial shifts in glucose uptake (and electrical activity) in the brain occur even in apparent sedate conditions. Perception, voluntary thinking, remembering, calculating, reading, discriminating, and speaking are all conscious activities that are characterized by an activation of the prefrontal areas in conjunction with motor areas or more posteriorly located cortical areas (56). Activation of some areas depends upon what thought processes are involved. For example, the posterior frontal cortex is activated by tasks that involve several degrees of freedom but ultimately lead to a choice.

The metabolic patterns within the brain form three-dimensional and temporal mosaics that are complex but tractable. These patterns respond to the cognitive aspects of the situation; that would include the expectancies, social demands, implicit assumptions and antecedent interpersonal interactions. Other PET studies emphasize the importance of individual differences.

This is particularly appropriate for patients with temporal lobe electrical lability (complex partial epilepsy) where there is no general pattern of intrinsic brain activation across subjects, only within subjects.

Appreciation of these neurocognitive factors in regional and local brain activity changes the types of questions that should be addressed. For applied magnetic fields to have real therapeutic effects must there be specific metabolic mosaics within the brain? Do certain cognitive factors such as expectation, the major component of the placebo phenomenon, generate specific brain mosaics that facilitate the effects from the applied magnetic fields? Do repeated magnetic field exposures alter the operational pattern of brain activity and hence change the cognitive structure of the person?

Are there certain portions of the brain where the metabolic pattern or electrical processes are particularly sensitive to the applied fields or magnetotherapy? PET studies reaffirm the suspected special lability of the temporal lobes, particularly their subcortical components: the amygdala and the hippocampus. Both of these structures are electrically labile and prone to kindling. This is a process whereby the tissue displays electrical impulses (seizures) over time as it is exposed to repeated daily, depth stimulations of minute electric currents. Effectively, because of the repeated exposure to electric currents, the tissue learns to microseizure.

Several studies (57-60) have strongly suggested that certain personality and cognitive characteristics are associated with electrical lability of the temporal lobes. These individuals are more prone to report experiences of floating sensations before they fall asleep at night, hearing one's name called by an inner voice and intense meaningful sensations during early morning hours. The more numerous and frequent these signs, the larger the percentage of alpha activity (that occurs during waking activity) from temporal lobe regions. This temporal lobe factor is weakly correlated but not identical with suggestibility or imaginings.

This temporal lobe factor is a continuum; all of us display some of the symptoms. People at the upper end of the continuum display normal personality profiles without clinical indicators. People who show frequent temporal lobe signs (an inference of temporal lobe lability) are more likely to be anxious, suspicious, aloof, stereotyped in their behavior and ruminative. They are likely to be religious (with mystical overtones) or to experience frequent episodes of "a sense of presence;" they also show remarkable psychosomatic plasticity.

Because magnetic fields penetrate into deep brain space, key temporal lobe structures would be influenced. If the temporal lobe factor is a valid one, then people who di splay these signs would also have an enhanced electrical lability that could be influenced by therapeutic magnetic fields. Deep temporal lobe structures, such as the amygdala, are associated with the same class of phenomena that are most commonly associated with magnetotherapy. The experiences involve affective dimensions (from anxiety or irritation to euphoric relaxation) and the attribution of pain and pleasure to perceptual processing. In addition, the amygdala massively innervates structures that primarily control the immunocompetence, endocrine status and vasomotor tone of the total organism.

CONCLUSION

The magnetotherapies are at the threshold of verification. However, the diverse designs of apparatus and lack of systematic replication have delayed progress. There are strong suggestive patterns in magnetotherapeutic effects that contraindicate simple placebo explanations, even though the phenomena affected by magnetotherapies are loaded by affective and psychosomatic factors. There is a strong possibility that the key moderating variables are personality and neurocognitive conditions at the time of magnetic field application. Despite their intrinsic possibilities, the future of magnetotherapies is still precarious. A major episode of fraudulence or irresponsible attribution of a placebo effect could easily discredit them once again.

ACKNOWLEDGEMENTS

Thanks to Claudette Larcher for typing the manuscript and to Katherine Makarec for constructive comments. Special thanks to Dr. Douglas Goldsack, Dean of Science and Dr. Michael Dewson, Dean of Social Sciences, for obtaining the space and equipment for the Behavioral Neuroscience Laboratory.

REFERENCES

1. Hansen, K.M. Studies made for the end of finding an objective expression of the influence of magnetism on man and of ascertaining whether this influence is carried by way of the autonomic nervous system. Acta Medica Scand. 135:448-457, 1949.
2. Persinger, M.A. *ELF and VLF Electromagnetic Field Effects*. New York: Plenum Press. 1974.
3. Ludwig, W., Mecke, R. and Seelewind, H. H. Elektroklimatologie. Arch. Met. Geoph. Biokl. 16:237-250, 1968.
4. Ehrmann, W., Ludwig, H.W. and Sodtke, W. Influence of alternating magnetic fields (frequencies between 1 and 20 Hz) on psychosomatic ailments. Presented at Second Bioclimatological Colloqium, Munich, West Germany, 1976.
5. Wever, R. Influence of electric fields on some parametrs of circadian rhythms in man. Presented at Biochronometry, AAAS, Washington, DC, 1971.
6. Ludwig, H.W. Wirkung einter nachtlichen Abschirmung der elektrischen Feldstarke bei Rheumatikern. Arch. Met. Geoph. Biokl. 21:305-311, 1973.
7. Berner, H.G., Hauss, R. and Ludwig, W. The energon, beena and indumed therapies. J. Bioelectricity, In Press.
8. Ludwig, W. Biological signals in the ELF and VLF region. Preliminary report. J. Bioelectricity, In press.
9. Rutkowski, B. Electroanalgesia for chronic shoulder pain syndromes, in *Pain*, R. Rizzi and M. Visenthin, Editors. Piccin: Italy. p. 121-124, 1984.
10. Procacci, P. and Maresca, M. Nothnagel-Schultze algoparaesthesic syndrome, in *Pain*, R. Rizzi and M. Visenthin, Editors. Piccin: Italy. p. 35-39, 1984.

11. Barker, A.T. and Jalinous, R. Non-invasive magnetic stimulatino of human motor cortex. Lancet 1(8437):1106-1107, 1985.

12. Ludwig, W. What is indupoint acupuncture therapy? Am. J. Acupuncture 12:153-156, 1984.

13. Persinger, M.A. *Weather Matrix and Human Behavior*. New York: Praeger. 1980.

14. Eysenck, H.J. *Behavioral Therapy and Neurosis*. London: Pergamon. 1960.

15. Ehrmann, V.W., Leitner, H.V., Ludwig, W., Persinger, M.A., Sodtke, W. and Thomas, R. Therapie mit ELF-magnetfeldern. Physikalische Medizin 5:161-170, 1976.

16. Grünner, O. The cerebral application of pulsed magnetic fields. J. Bioelectricity, In press.

17. Grünner, O. The cerebral application of the constant homogeneous magnetic fields. J. Biometeorology, In press.

18. Grünner, O. The effects of stable magnetic field and interrupted electromagnetic field on vigility. Activitas Nervosa Superior 22(2):114-115, 1980.

19. Grünner, O. Application of electronic noise and pulsed magnetic field in the treatment of sleep disorders, in *Sleep: Physiology, Biochemistry, Psychology, Pharmacology, Clinical Implications*, W.K.Koella and P. Levin, Editors. S. Karger: Switzerland, 1973.

20. Grünner, O. Application of electronic noise and pulsed magnetic field in the treatment of sleep disorders. Clin. E Terapeutica (Brazil) 4:15-16, 1975.

21. Warnke, U. Possible physical-physiological pain reducing mechanism in a pulsating magnetic field (PMF), in *Pain*, R. Rizzi and M. Visentin, Editors. Piccin: Italy, 1984.

22. Kavaliers, M., Ossenkopp, K.-P. and Hirst, M. Magnetic fields abolish the enhanced nocturnal analgesic response to morphine in mice. Physiol. Behav. 32:261-264, 1984.

23. Ossenkopp, K.-P., Kavaliers, M. and Hirst, M. Reduced nocturnal morphine analgesia in mice following a geomagnetic disturbance. Neurosci. Lett. 40:321-325, 1983.

24. Grünner, O. Use of natural and artificial changes of magnetic fields in balneopsychiatry. Activitas Nervosa Superior 16:4, 1974.

25. Mantle, E.R. and Persinger, M.A. Alterations in subjective evaluations during acute exposures to 5-Hz but not 9-Hz magnetic field devices. J. Bioelectricity 2:5-14, 1983.

26. Shachter, S. and Singer, J.E. Cognitive, social and physiological determinants of emotional stress. Psychol. Rev. 69:379-399, 1962.

27. Michaud, L.Y. and Persinger, M.A. Geophysical variables and behavior: XXV. Alterations in memory for a narrative following application of theta frequency electromagnetic fields. Percept. Motor Skills 60:416-418, 1985.

28. Persinger, M.A. and Nolan, M. Partial amnesia for a narrative following application of theta frequency electromagnetic fields. J. Bioelectricity 4:481-492, 1985.

29. Herin, R.A. Electroanesthesia: a review of the literature (1819–1965). Activitas Nervosa Superior 10:439-454, 1968.

30. Photidades, D.P., Riggs, R.J., Ayivorh, S.C. and Reynolds, J.O. Electrosleep in man by a combination of magnetoinductive and transtemporal electric currents, in *Th Nervous System and Electric Currents*, N.L. Wulfsohn and A. Sances, Editors. Plenum Press: New York. p. 153-158, 1970.

31. Subrahmaryam, S., Sanker Narayan, P.V. and Srinivasan, T.M. Effect of magnetic micropulsations on the biological systems: a bioenvironmental study. Int. J. Biometeorol. 29:293-305, 1985.

32. Sweetland, J., Kertesz, A., F., Prato. and Nantau, K. The effect of magnetic resonance imaging on human cognition. Magn. Reson. Imaging 5:129-135, 1987.

33. Peterson, E. *Psychopharmacology*. Iowa: W.C. Brown. 1966.

34. Pefferbaum, E. *Psychology of Mind-Body Healing*. New York: W.W. Norton. 1986.

35. Barber, T.X. Changing "unchangeable" bodily processes by (hypnotic) suggestions: a new look at hypnosis, cognitions, imagining, and the mind-body problem, in *Imagination and Healing*, A.A. Sheikh, Editor. Baywood: Farmingdale. p. 69-127, 1984.

36. Barker, A.T. Nonionising electromagnetic therapy: fact or fantasy? Phys. Bull. 36:251-253, 1985.

37. Ross, J. and Persinger, M.A. Suggestibility, temporal lobe signs and ELF electromagnetic field effects. J. Bioelectricity, In press.

38. Spiegel, H. and Spiegel, D. *Trance and Treatment*. New York: Basic Books. 1978.

39. Thomas, J.R., Shrout, J. and Liboff, A.R. Low intensity magnetic fields alter operant behavior in rats. Bioelectromagnetics 7:349-357, 1986.

40. Patterson, M.A., Firth, J. and Gariner, R. Treatment of drug, alcohol and nicotine addiction by neuroelectric therapy: analysis of results over 7 years. J. Bioelectricity 3:193-221, 1984.

41. Persinger, M.A., Ludwig, H.W. and Ossenkopp, K.-P. Psychophysiological effects of extremely low frequency electromagnetic fields: a review. Percept. Motor Skills 36:1131-1159, 1973.

42. Joseph, R. and Sikyta, B. Effects of magnetic field on inflammation. Experientia 31:1411-1412, 1975.

43. Welker, H.A., Semm, R.P., Willig, R.P., Commentz, J.C., Wiltschko, R. and Vollrath, L. Effects of an artificial magnetic field on serotonin N-acetyltransferase activity and melatonin content of the rat pineal gland. Exp. Brain Res. 50:426-432, 1983.

44. Walcott, C., Gould, J.L. and Kirschvink, J.L. Pigeons have magnets. Science 205:1027-1029, 1979.

45. Zoeger, J., Dunn, J.R. and Fuller, M. Magnetic material in the head of the common Pacific dolphin. Science 213:892-894, 1981.

46. Hosobachi, Y., Rossier, J., Bloom, F.E. and Guillemin, R. Stimulation of human periaqueductal gray for pain relief increases immunoreacdtive ß-endorphin in ventricular fluid. Science 203:279-281, 1979.

47. Rascalla, L.M. An electromagnetic field theory of consciousness. J. Am. Soc. Psychosom. Dent. Med. 21:40-51, 1974.

48. Ravitz, L.J. Electrodynamic field theory in psychiatry. Southern Med. J. 46:650-660, 1953.

49. Wolkowski, Z.W. The field concept in physics and in biology. Synergy and Coherence in Biological Systms, University of Paris, 1983.

50. Pohl, H.A. Natural AC electric fields in and about cells, in *Nonlinear Electrodynamics in Biological Systems*, W.R. Adey and A.F. Lawrence, Editors. Plenum Press: New York. p. 87-103, 1984.

51. Direnfeld, L.K. The genesis of the EEG and its relation to electromagnetic radiation. J. Bioelectricity 2:111-121, 1983.

52. König, H.L. ELF and VLF signal properties. Physical characteristics, in *ELF and VLF Electromagnetic Field Effects*, M.A. Persinger, Editor. Plenum Press: New York. p. 9-34, 1974.

53. Callaway, E. and Harris, P.R. Coupling between cortical potentials from different areas. Science 183:873-875, 1974.

54. Barnothy, M. *Biological Effects of Magnetic Fields*. New York: Plenum Press. 1964.

55. Steriade, M. and Deschenes, M. The thalamus as a neuronal oscillator. Brain Res. Rev. 8:1-63, 1984.

56. Roland, P.E. Metabolic measurements of the working frontal cortex in man. Trends Neurosci.:430-435, 1984.

57. Bear, D.M. and Fedio, P. Quantitative analyses of interictal behavior in temporal lobe epilepsy. Arch. Neurol. 34:454-467, 1977.

58. Makarec, K. and Persinger, M.A. Temporal lobe signs: electroencephalographic validity and enhanced scores in special populations. Percept. Motor Skills 60:831-842, 1985.

59. Persinger, M.A. and Makarec, K. Temporal lobe epileptic signs and correlative behaivors displayed by normal populations. J. Gen. Psychol. 114:179-195, 1987.

60. Persinger, M.A. and Valliant, P.M. Temproal lobe signs and reports of subjective paranormal experiences in a normal population: a replication. Percept. Motor Skills 60:903-909, 1985.