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THE EFFECT OF VARIABLE MICROCURRENTS ON EEG SPECTRUM AND PAIN CONTROL

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Abstract

The author proposes a model of spectral smoothing using electroencephalogram (EEG) as a measure of regeneration and pain reduction. Two minute spectral averages of root mean square (RMS) EEG amplitude versus frequency were compared between two groups: 1) an age, sex matched group of normal pain free persons, and 2) a group of pain patients with degenerative joint disease (DJD). Pain-free subjects produced smooth declining spectral curves, whereas the pain group showed many irregularities, and significant "unevenness" in EEG spectral arrays. On the basis of these findings and prior research (Heffernan, 1995, 1996, and 1996b), the author proposes using spectral smoothness as a model to evaluate the effectiveness of differing microcurrent stimulators in safely treating pain patients.

To test three types of stimulators, thirty pain patients, 30-65 years, suffering from DJD were given a five minute test dose of stimulation from three differing stimulators, a 15 Hz, 500 Hz, and 15,000 Hz device (Liss Stimulator), a 0.5 Hz, random, biphasic device (Alpha-Stim), and a continuous 0.5 Hz device for control. Using current limited, 500 microampere stimulation to the wrist, post stimulation spectral smoothing and pain control was found to be superior with the random 0.5 Hz, biphasic device. The regular 0.5 Hz device and the multiple frequency device both produced considerable distortion from the EEG spectrum of normal, pain free subjects. Ordinal pain scales before and after stimulation showed that only the random 0.5 Hz device produced significant pain control with a five minute test dose (4.2 to 2.3).

The author discusses these findings

by proposing a theory of rapid pain control from regenerative restoration of normal cellular electrical fields. This theory of rapid pain reduction by electric field restoration is then contrasted with pain control by stress induction and increased production of endorphins. Finally the author discusses implications of using the spectral smoothing of both EEG and body fields as a model of reversing the negative, carcinogenic effects of externally applied extremely low frequency (ELF) when used therapeutically or delivered inadvertently from human electrical power usage.

Introduction

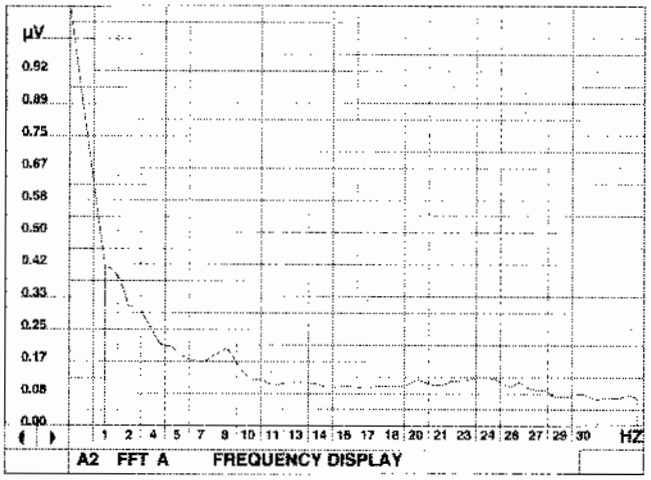
Considerable variation exists in waveform, frequency, pulse duration, and amplitude characteristics of commercially designed microcurrent stimulators, marketed and used for treatment of chronic pain and other disorders. Stimulators have a range from between 0.3 to 15,000 Hz, with amplitudes from 10 microamperes to over 100 milliamperes. Pulse duration ranges of electrical stimulators varies from 20 milliseconds to nearly one full second. The assumption that all stimulators within these ranges are harmless or even beneficial is quite unlikely in view of current research. Extremely low frequency (ELF) electric fields, below 100 Hz, have been found to effect cellular growth and regulation by a mechanism of transductive coupling, involving weak fields as low as 10 microtessla which become amplified at the cell membrane, inducing changes in DNA/RNA transcription, and increases in growth related cellular enzymes (Adey, 1993). Furthermore, evidence has linked ELF fields to unregulated growth or carcinogenesis, thus suggesting a disruption in the normal electromagnetic (EM) field needed for intercellular regulation, and cellular differentiation (Adey, 1992).

While the research on negative effects of ELF pertains to constant frequency exposure, variable or random frequency exposure to ELF may have an entirely different effect. The natural ELF field present in the ionosphere is in fact variable, in the same range as the EEG with a modal frequency of 7.8 Hz. A recent study evaluated the post stimulation EEG spectral changes resulting from a variable, low frequency ELF generator (Alpha-Stim 100), placed on the trapezius muscle. Experimental results showed that a variable ELF square wave generator, operating at less than 1.0 Hz , will cause spectral "smoothing" in subjects who have uneven, irregular spectral FFTs (Heffernan, 1996). The resulting smoothed two minute spectral curves were found to be a declining non linear function of EEG frequency versus root mean square (RMS) amplitude. Other researchers have concluded that the smoothing of the EEG spectrum is an indication of improved function. Specifically, the successful treatment of attention deficit disorder (ADD) by neurofeedback was found to produce spectral smoothing, whereby abnormally high delta and abnormally low sensory motor rhythm (SMR) were balanced toward a lower delta, and an increased SMR (Lubar, 1996).

Pilot studies by the author have confirmed that uneven EEG spectral curves (fast fourier transforms, or FFTs) are consistently present in a great variety of chronic pain patients. These abnormal spectral arrays often take an uneven "saw-toothed" appearance, but are most often smoothed following successful therapy. The smooth spectral curve again becomes a descending, non linear curve, asymptotic with the EEG frequency axis (Heffernan, 1996). These clinical observations led the author to propose the EEG spectral curve as a "tool" and mathematical model for viewing the normal distribution of amplitudes of ELF that exists in health and that probably plays a key role in cellular processes. By analyzing the post spectrum FFT following exposure to ELF, a determination might be made as to whether the field was health enhancing or disruptive to the normal electromagnetic field of the body. A mechanism has been discovered by which weak ELF from intercellular or external fields is able to act as a first messenger on G-protein, increasing ATP and cyclic AMP, and eventual alteration in DNA/RNA transcription (Luben, 1991). Spectral EEG or spectrum from fluctuations in cell membrane potential are measures of the relative amplitude of the various frequencies in which cells are immersed. As thought by this author, such spectra represent an electrophysiologic "signature", or frequency profile of the ELF

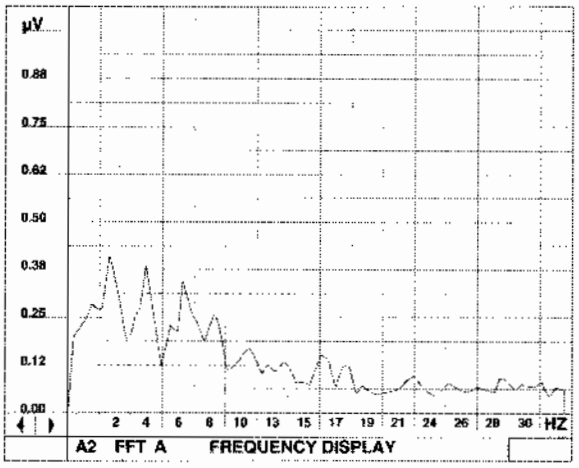
The smooth spectral curve of a pain-free person may be a representation of the normal electric field of the body which developed over evolutionary history as a results of the natural, variable ELF field.

Figure 1



Two minute spectrum of EEG, frequency versus RMS amplitude, for a pain-free normal subject.

Figure 2



Two minute spectrum of EEG, frequency versus RMS amplitude, for a pain subject with DJD.

involved in tissue repair versus cellular disruption transduced at the cell membrane. The spectrum thereby becomes a metric for ELF which can lead to a cascade of cellular effects involved in both regulated cell differentiation and repair, or unregulated cell growth and cancer. Therefore, those ELF devices which increase spectral smoothing were hypothesized to produce the most rapid pain control since such devices would augment the normal and "healthy" EM field needed by cells to regulate cellular differentiation in normal growth and repair. It was further deduced that the spectral arrays of pain-free patients would be smooth, whereas the spectral arrays of pain patients would be uneven, varying significantly from the normal curve demonstrated in pain-free individuals.

Methods

Phase one of the investigation consisted of collecting two minute spectral curves (FFT's) for a group of ten persons without degenerative joint disease (DJD) and associated pain, and a second group of ten patients having the medical diagnosis of DJD with associated joint pain. The spectral averages (FFT's) were compared between both groups for differences. For this phase of the study 20 subjects were age and sex matched. The age range was between 40-65 years, with a median age of 60. Equal numbers of both sexes were represented in the comparison groups. Pain patients were defined as having had DJD as confirmed by X-ray examination of hip, knees, or spine, along with pain lasting for at least eight hours per day, for the last two years. The pain-free group were defined as persons not having DJD nor having pain, and who had been pain free for at least the last two years.

All subjects were evaluated by computerized EEG using an API Neurodata system. EEG electrodes were attached to standard bipolar frontal locations and the subjects were told to sit in a relaxed position, eyes open, without facial movement other than slight eye blinking. Artifact monitoring showed there was no significant interference due to electromyographic (EMG) artifact. FFT spectral arrays for a two minute average were collected on each subject and analyzed for smoothness by computing the deviation from the normal curve in each one cycle per second EEG frequency band. The normal spectral curve was derived by averaging ten normals who demonstrated smooth spectra. The ten curves were averaged to produce a smoother "ideal" spectral curve.

Phase two consisted of evaluation of microcurrent stimulators. For this phase 30 subjects were chosen, half females, half males, aged 30-65 years, who were experiencing pain from DJD of hip, shoulder, knees, or back, confirmed by X-ray, and who's pain was unresponsive to medication, and had lasted for at least eight hours per day for two years or more. Subjects were told "the study was to evaluate the effects of microcurrent stimulators that are commonly used in pain control".

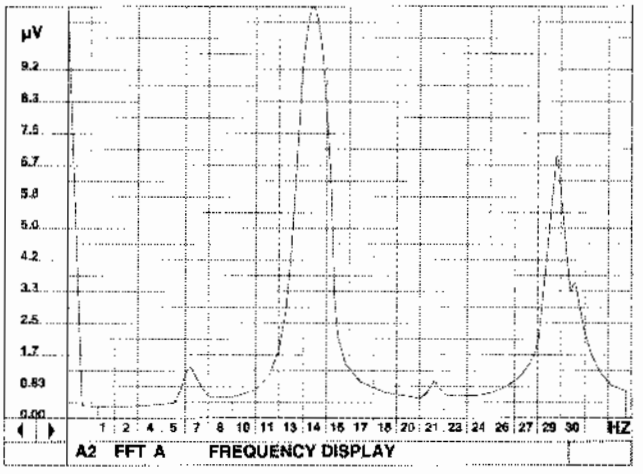
Informed consent was obtained and subjects were randomly assigned to one of three treatment groups, each being given a different stimulation device. Three microstimulators were used, each with widely differing wave parameters. The first device operated at three combined frequencies of 15, 500, and

15,000 Hz (Liss Device by Medi Consultants, Paterson, New Jersey). The second device produced a variable, averaged, 0.5 Hz, biphasic square wave pulse (Alpha-Stim by Electromedical Products International, Inc., Mineral Wells, Texas). Because the efficacy of an electrical stimulator has to do with the complex interaction of all waveform characteristics, the third device was a function generator used as a control, producing a constant 0.5 Hz square wave (BK Instruments of Maxtec, Inc., Chicago, Illinois). All devices were at fifty percent (50%) duty cycle, and therefore the pulse width varied according to the frequency. All stimulators were adjusted to a current delivery of 500 microamperes by use of an in-series, LCD microampere meter.

Stimulation was delivered for five minutes in each group through one inch silver-silver chloride disk electrodes attached bilaterally to the midpoint of the ventral wrist surface. Double blinding was achieved by placing the stimulators out of sight of both the investigator and patient. Three sets of identical wires with electrode leads were attached to the subjects based on subjects stratified, random assignment to groups A, B, or C. After the analysis of the data the stimulators for each set of electrodes were identified. EEG spectrum was evaluated for a two minute period during stimulation with a I400 Neurodata computerized EEG system that produced two minute averaged spectral plots of RMS amplitude versus 2-35 Hz. EEG electrodes were one inch silver-silver chloride electrodes attached bilateral to frontal recording sites. Subjects were monitored with eyes open, sitting upright. Artifact was minimized by having subjects avoid facial, eye, head, or neck movement while taking the two minute spectral test. Two minute spectral tests were taken prior to and immediately following stimulation. An ordinal five point pain scale was orally administered. Pain was rated as none (1), slight (2), moderate (3), moderate to severe (4), or severe (5). Statistical analyses of the prestimulation pain scores among the three groups determined they were not significantly different.

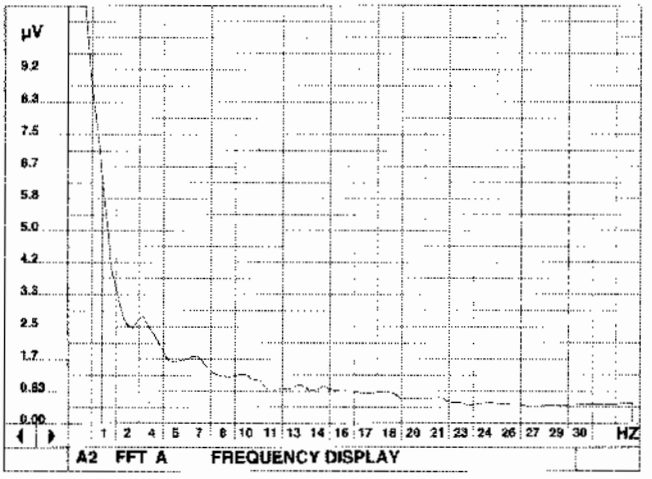
Variations from the normal spectral curve were determined by deviation from a smooth or normal curve. The normal curve was derived for each subject by placing a transparency containing a normal, average FFT curve derived from pain-free

Figure 3



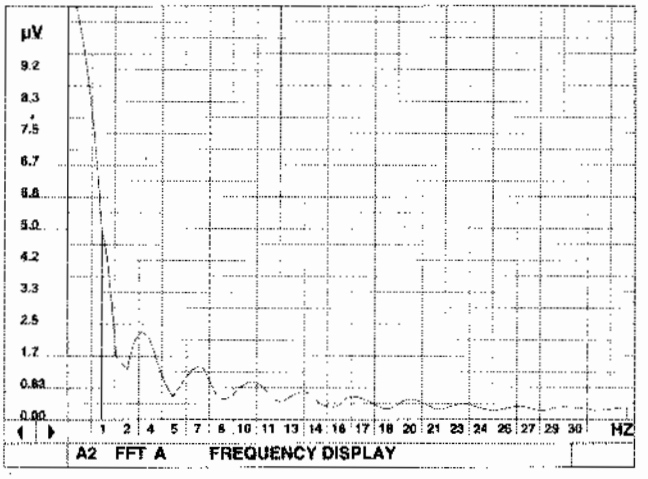
: Two minute spectrum of EEG, frequency versus amplitude, of a subject while being treated with the 15, 500,15K Hz Liss Device.

Figure 4



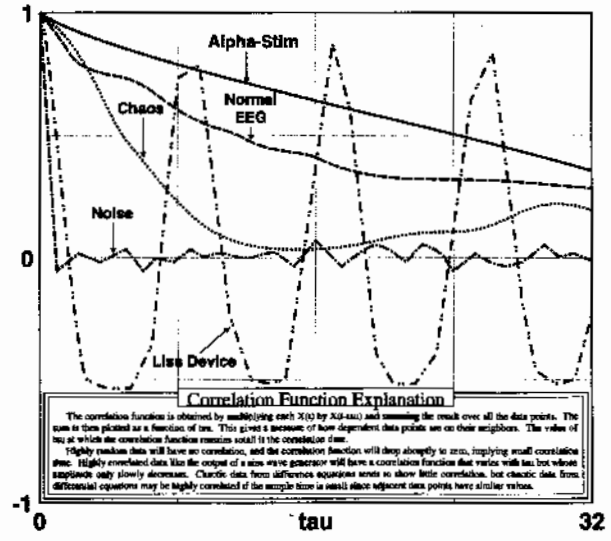
Two minute spectrum of EEG, frequency versus amplitude, of a subject while being treated with the Alpha-Stim 100 device.

Figure 5



: Two minute spectrum of EEG, frequency versus amplitude, of a subject while being treated with a 0.5 Hz, control function generator.

Figure 6



subjects. A standard deviation of the differences between normal and actual spectral curves was then computed to derive an overall variation of the means.

Results

Phase one revealed that normal subjects, free of pain, showed spectral curves that closely followed a smooth mathematical fit of RMS amplitude versus frequency (see figure 1). In contrast, the pain group showed statistically significant deviation from the normal, smooth spectral curve generated by pain free subjects (see figure 2). Table 1 shows the results of the average sum of RMS deviations in the non-degeneration, pain-free group versus the DJD, pain group.

Phase two evaluation of the three differing stimulators showed that all stimulators produced approximately a ten fold increase in RMS amplitude when compared to pretreatment spectral plots. The device producing three constant frequencies (15-500-15K), and the control function generator producing a constant 0.5 Hz frequency, both failed to produce post treatment smoothing in subjects spectral arrays. Only the variable 0.5 Hz device produced a significant smoothing in subjects spectral arrays. The results are shown below in table 2, and in figures 3, 4, and 5.

In order to understand how results could vary so dramatically amongst stimulators, samples of average two minute FFT's were taken during stimulation with each of the stimulators. This was done under the assumption that if a stimulator resulted in post treatment uneven spectra, it must be producing specific frequencies while placed on the body which are either transdermaly or intradermaly conducted along the body to the brain where entrainment would take place. The 15-500-15K frequency device when placed bilaterally at the wrist typically produced a large bifurcated twin peak at 15 and 30 Hz in the EEG spectrum when in stimulation mode (see figure 3). Spectral arrays produced during stimulation with the 0.5 Hz variable device produced normal arrays very much like figure 1 of the normal controls in phase one of the study (see figure 4). Significant deviation from normal spectral arrays were also seen from bilateral wrist stimulation with the 0.5 Hz control function generator, which produced a series of dampening, sinusoidal peaks in the EEG spectrum (figure 5).

Pain scores, taken after stimulation are shown in table 3. Consistent with the extent of smoothing in spectral arrays, only the 0.5 Hz random device produced significant decreases in pain scores. The function generator and 15-500-15k device did not produce any significant change in pain scores following the five minute test dose.

Discussion

Spectral smoothness and fit to a normal or "ideal" spectral curve may be considered a potential characteristic of the pain-free state, as well as a gage or "metric" of a electrical device's effectiveness for treatment. Prior research would suggest this smooth spectra without abnormal peaks shows a lack of potential entrainment frequencies that might cause disruptive cellular effects through the "gap junction", destroying the normal electromagnetic (EM) communication processes within and amongst cells (Adey, 1991). Pain and degeneration seems to be marked by significant deviations from the normally smooth two minute FFT spectral curve. At least some microcurrent devices, operating at a slow random pulse rate, have the characteristic of bringing a pain patient's spectrum back towards normal smoothness, while significantly reducing pain. Pain treatment stimulators which are not variable seem to have little effect in increasing spectral smoothness, but rather appear to temporarily entrain their predominant frequencies in the EEG. These devices if used over a longer period than used in this study are reported to reduce pain and produce an increase in B-endorphins (Liss, 1996). While some pain patients report pain relief from these repetitious, constant frequency devices, they would be expected to cause entrained disruption in the normal cellular EM communication through the gap junction as well as increasing production of cancer producing free radicals like nitric oxide (Adey, 1996).

An additional means of evaluating the "health" of a physiological signal has been described by West

(1990). This method looks at non-linear complexity and the data's fit to a non-linear model. In this view chaotic data from true mathematical iteration is compared with non-complex noise and non-complex sinusoidal generation. A truly healthy electromagnetic signal applied to the body should produce the mathematical characteristic of complexity and not be at all like that obtained with either noise or sinusoidal function.

The author performed a sample correlation dimension check of a normal pain-free subject, via a two minute EEG, of a two minute average of the two commercially available stimulators used in this study (see figure 6). The results were then compared to the data analyzer's memory bank for both noise and iterated chaotic data. The Alpha-Stim most closely matched the pain-free EEG sample, whereas the Liss Device produced a non-complex sine wave function. If a device is to be used on the body it is assumed it might perform better if it recaptures the functional characteristics of a healthy, pain-free data sample. This correlation dimension would suggest that the Alpha-Stim alone accomplishes this goal.

In contrast to pain relief by stress-induced endorphin production, this study suggests there is another mechanism of pain control coming about from the restoration of the normal EM field used by cells to regenerate and communicate with each other. This naturally present cellular EMF seems to be best represented by a smooth, non linear, descending curve of RMS amplitude versus frequency in the band of 1-35 Hz. Electrical devices which induce this form of pain control, due so by stimulating regeneration, and avoid the negative consequences of externally amplified ELF at particular frequency windows.

The smooth spectral curve of a pain-free person may be a representation of the normal electric field of the body which developed over evolutionary history as a result of the natural, variable ELF field. This natural field maintains not only the pain free state, but allows the cells to communicate with each other through gap junctions, thereby maintaining normal cellular controls needed for cellular growth regulation and differentiation. In several hundred post therapy spectral measures taken by the author using the Alpha-Stim device, all pain patients showing the greatest pain relief also showed the greatest smoothing of their spectral curves.

Spectral smoothing is not limited to the brain. The author has taken numerous body microvoltage recordings by putting the standard EEG electrodes on various parts of the body. These systemic recordings, when spectrally analyzed, produce spectra amazingly similar to that of the brain. This is not surprising knowing that all cells of the body retain a mem-

Table 1

Mean deviations in two minute spectral curves from normal curves and one tailed "t" for pain versus pain-free groups.

	Mean Deviation in RMS	t statistic
Pain Free Group	0.2	0.8 P>0.1
Pain Group	2.4	3.6 P<.01

Table 2

Mean sum of deviations from normal FFT with "one tailed paired t" for three treatments.

	Mean Deviations Pre	Post	t statistic
15-500-15K Device (Liss)	2.8	3.0	1.1 P>0.1
0.5 variable Device (Alpha-Stim)	3.1	0.4	3.2 P<.01
0.5 constant Device (control)	2.7	2.6	0.9 P>0.1

Table 3

Mean pre and post pain scores with two tailed paired "t".

	Mean Pain Scores Pre	Post	t statistic
15-500-15K Device (Liss)	4.3	4.5	0.8 P>0.1
0.5 variable Device (Alpha-Stim)	4.5	2.1	3.4 P<.01
0.5 constant Device (control)	4.6	4.8	0.9 P>0.1

brane potential (MP) of around 100 millivolts, and that this MP must fluctuate with cellular function. Therefore, the model of spectral smoothing proposed by the author may apply to the entire body in its response to electric fields .

From the author's model, a patient's spectral curve could be evaluated after treatment with EM fields to determine if additional randomized 0.5 Hz square waves are needed post-therapeutically to establish normal spectral arrays reducing any negative cellular effects caused by constant exposure to ELF. This concept is important since ELF frequencies like 15 and 72 Hz have been used to stimulate regeneration, specifically, increasing osteoblast activity in bone healing, as well as in inducing collagen and cartilage synthesis in soft tissue repair (Luben, 1991). The external EMF may be considered the first messenger in which receptors utilizing calcium ions on the G protein of the cell membrane transduces the EMF by binding, thereafter causing an amplification by adenylate cyclase, guanylate cyclase, and phosphlipase, to induce the second messenger system of cyclic AMP, GMP, and diacylglycerol to produce A, G, and C kinases (Luben, 1991).

These changes may be related to increased healing response, but may also lead to cancer if continued beyond a given "metric" dose (Adey, 1992). The problem is to know how much EMF may be safely used, especially when the frequencies of 1-300 Hz are being used therapeutically. One very effective measure to make this determination might well prove to be the spectral curve obtained from body or brain fields. If the EMF dose has exceeded the safe level, it would be expected to disrupt the normally smooth spectral curve. At this point, a low frequency of 0.5 Hz with random variation could be used as a treatment to normalize the spectral curve and establish proper endogenous ELF to maintain intercellular communication, cellular differentiation, and tissue repair. The fact that pain control is achieved long before the cellular response is complete suggests that smoothing of the spectral curve restores cerebral homeostasis, leading to an endogenous, parasympathetic electromagnetic state in the central nervous system which modulates the internal perception of pain.

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Dr. Heffernan received his PhD in 1970 from University of California (UCLA), while doing EEG brain research at the UCLA Brain Research Institute. Dr. Heffernan has maintained a private practice in Pain Management for 30 years, and now is located in Rockport, Texas. He is a licensed Psychologist in both California and Texas and is a National Health Service Provider in Psychology. Dr. Heffernan has been recently published in several scientific journals for his work in microcurrent technology and spectral and chaos analysis of EEG. In 1996 Dr. Heffernan was invited to discuss his work in microcurrent at the Selye's Annual International Stress Conference in Switzerland.

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