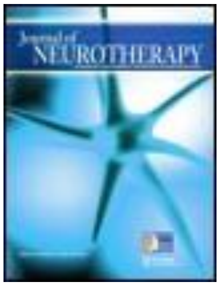

Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience

The Low Energy Neurofeedback System (LENS): Theory, Background, and Introduction

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SUMMARY. This article presents the concepts, operations, and history of the Low Energy Neurofeedback System (LENS) approach as they are now known and as it has evolved over the past 16 years. The conceptual bases and practical operating principles as described are quite different from those in traditional neurofeedback. The LENS, as a behavioral neurofeedback application, often provides the same qualitative outcome as that in traditional neurofeedback, with reduced treatment time. doi:10.1300/J184v10n02_02

KEYWORDS. Neurofeedback, EEG biofeedback, biofeedback, neurotherapy, LENS, low energy neurofeedback system, EEG, brain stimulation

INTRODUCTION

The Low Energy Neurofeedback System (LENS) is an EEG biofeedback system used in clinical applications and research in the treatment of central nervous system functioning. It is unique in the field of neurofeedback in that instead of only displaying information on a computer screen to assist the patient in conditioning healthier brainwave patterns, the LENS uses weak electromagnetic signals as a carrier wave for the feedback to assist in reorganizing brain physiology. The following describes the rationale for the LENS system, as well as subsequent discoveries. Also presented are some suggestions for future research and practical application of the LENS technology.

Evolution of LENS and Relevant Concepts

The major implication of this paper is that both the physically and psychologically traumatized brain has demonstrated vastly greater capacity for recovery than has previously been appreciated. Secondarily, the LENS appears to help the traumatized person achieve clearly increased performance in relatively short periods of time, with a quite non-invasive, low technology procedure. On the other hand, other kinds of EEG biofeedback may be just as effective as the LENS under some conditions. Although no claims are being made here that the LENS is better than any other form of treatment, it is, however quite different from other neurofeedback modalities, as well as from other

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[Co-indexing entry note]: "The Low Energy Neurofeedback System (LENS): Theory, Background, and Introduction." Ochs, Len. Co-published simultaneously in *Journal of Neurotherapy* Vol. 10, No. 2/3, 2006, pp. 5-39; and: *LENS: The Low Energy Neurofeedback System* (ed: D. Corydon Hammond) .

doi:10.1300/J184v10n02_02

neurostimulation techniques such as audio/visual stimulation and particularly transcranial magnetic stimulation, where the intensities used are thousands of times stronger than LENS uses. Lastly, there appears to be no basic science yet revealed to help understand the phenomena described here, thus creating a new area of inquiry in the neuro-behavioral sciences.

The following section is presented for historical purposes to outline the order and context in which the significant components in the development of the LENS were observed including: a description of the instrumentation; the means of measuring and controlling the feedback intensity; the problems and benefits observed in the development of this system; and treatment management problems and how they evolved, particularly with regard to different populations.

History. During the summer of 1990, Harold L. Russell, PhD of Galveston, Texas, telephoned Len Ochs, PhD in Concord, California. He asked Ochs to develop a device which provided fixed-frequency photic stimulation. His interest was based upon the work of Marion Diamond, PhD (1988) in her work on the effects of environmental stimulation on cortical complexity in rats. Russell (Carter & Russell, 1981, 1984, 1993) had experimented with exposing school children with performance problems and high inter-test variability to daily, 20-minute repeated cycles of 10 Hz, for one minute, then 18 Hz for a minute, for six weeks. Russell used bright red flashing lights inside improvised welder's goggles. His idea was to use the flashing lights to stimulate the brains of the school children.

It was my impression that any simple fixed-frequency stimulation would be an inefficient way to provide the desired stimulation to alter brainwave activity. The degree to which a person's EEG (electroencephalographic activity) is influenced by external (e.g., photic) stimulation depends on many factors, including their dominant brainwave frequency from moment-to-moment, and the intensity and frequency of the stimulus used. Although the intensity and frequency of a fixed stimulation frequency could influence the EEG, another factor that might have bearing on entrainability of the EEG is the size of the difference, at any moment, between the stimulation frequency and the predominant energy of the EEG, in which lies the dominant frequency. The dominant frequency is the frequency at that moment at a spot on the person's head which is stronger than any other frequency. With that as a hypothesis, it seemed appropriate to suggest that a treatment approach might be to tie the stimulation frequency to the dominant, or peak, EEG frequency.

Since from 1 in 4,000 children and about 1 in 20,000 adults are estimated to be photosensitive (Quirk et al., 1995), and thus vulnerable to experiencing a seizure with photic stimulation, this could occasionally present severe problems. Photo-hypersensitivity refers to the reactivity to light that is strong enough to elicit convulsions–whether the person is epileptic or not. If, for instance, the person were to have a seizure–whether from epilepsy or the stimulation evoking a photohypersensitive seizure–the frequency of that seizure would become the dominant frequency. In other words, if the stimulation frequency equaled the dominant frequency, the stimulation would further stimulate any pre-existing seizure. Fortunately this could be dealt with easily by programming the software to prevent the software from ever being equal to the dominant frequency. An example of how to do this was to define the stimulation frequency as some percentage of the dominant frequency. It was anticipated that this strategy would begin to displace and disperse some of the energy of any seizure activity to other non-seizure brainwave frequencies. Fortunately, setting the stimulation frequency to some percentage greater than 100% of the dominant EEG might satisfy those in the neurofeedback community (Lubar, 1985) advocating for increasing EEG frequencies for enhanced cognitive control. Further, using a percentage less than 100% of the dominant frequency might satisfy those advocating decreasing EEG frequencies for enhancing emotional integrity and decreasing chemical dependence (Peniston & Kulkosky, 1991). Russell agreed to pay for the programming of the original software according to this conception. Hence, the software was programmed into devices that would be called electroencephalographic entrainment feedback (EEF).

The original EEF software was designed to link together the J&J I-330 EEG module 201 (and afterward the J&J I-400), and the Synetic Systems Synergizer (Seattle, Washington), a light-and-sound generation device which fit inside an IBM-clone computer through software know as BOS, a DOS-based interpreted platform developed by William Stuart, of Bainbridge Island, Washington. As originally conceived, the software was to allow the Synergizer card to set the flash frequency of the lights inside some welder-type goggles, and to continuously reset their speed as the dominant EEG frequency of the person's brain changed on a moment-to-moment basis. The software also set and reset the frequency of binaural auditory tones coming through ear phones, in the same way it set the light frequency. The feedback might pulsate at 105% of the dominant frequency during one 10-second period, then 95% of the dominant frequency during the next, and alternate between the two conditions. The software never let the flash frequency equal the dominant frequency.

The initial system, funded by Russell's AVS group, involved many features that have now been discarded, while the current software now includes many features that were not yet conceived. Discarded features central to the original conception were: the necessary use of visible light feedback, the use of sound feedback, the use of fixed time limits for changing offsets, the use of the same size offsets from the dominant frequency, the necessary use of offsets, the necessary use of alternating offsets, and the necessary use of offsets of arbitrary sizes.

New features include the generation of the feedback signal from within the EEG (the electroencephalograph) device itself, as well as the ability to control the feedback, using the J&J I-330 C2 family of EEGs. The use of the J&J I-330 C2 permitted the portable use of the system from a suitable desktop or notebook computer.

It is important to note that there were many technical inadequacies of the first generation EEF system. Yet the results from this technically "inadequate" system appeared to be better than any other treatment for closed-head trauma. Interestingly, the results were not quite as good when the more technically sophisticated second generation system was introduced. This led those involved to try to duplicate some of the inadequacies of the original system. The major required change was to retard the feedback, which was produced much more rapidly in the replacement unit for the I-330 C2. We had to introduce a time lag between the occurrence of any EEG event and the feedback tied to its occurrence. The critical learning from this experiment was that technical precision does not necessarily lead to clinical efficacy. The current use of the LENS employs extremely weak intensities of feedback and does involve the patient's own EEG driving the feedback, but does not involve any conscious participation or even positive intention.

Differences Between the LENS and Traditional Neurofeedback

The following statements reflect the current status of the EEG biofeedback field at this time.

1. The field of EEG biofeedback or neurofeedback is relatively new. There are relatively few studies with chronic conditions, controlled or otherwise, that offer understandings of what will work, under what conditions, to what extent, and with what time, physical, and monetary costs.
2. Each of the various kinds of EEG biofeedback involves its own set of rituals, with relatively little analysis of what alternatives might be used.
3. None of the forms of EEG biofeedback appear to have ever cured a progressive condition such as Alzheimer's, multiple sclerosis, Parkinsonism, or dementia. However, they probably have increased functioning and quality of life for many people in the earliest stages of any of these diseases, perhaps for at least several years and when applied properly.
4. Each form of EEG biofeedback seems to complement and enhance the effects of all of the others, as well as other forms of therapy.
5. Based on interviews with former patients of nearly each form of EEG biofeedback, each approach seems roughly comparable in effects, no matter how inexpensive or how expensive the treatment was, with some specific differences from treatment-to-treatment to be defined with later research.
6. Nearly all forms of EEG biofeedback work with easy cases and become more

cumbersome and delicate (with satisfactory outcomes) with complex cases, but appear nevertheless at their clinical efficacy limit with the current technologies because of technical problems of managing coherence and other issues.

7. Finally, while each form of EEG biofeedback may appear scientific, the application of each is probably more of a physiologically-based art than science at this stage of the game. Even so, all of the forms of EEG biofeedback seem to offer provocative and interesting hope for many who have been declared to be at the end of their options for improvement.

The LENS differs from traditional EEG biofeedback in that the LENS does not require the person to understand the meaning of, or laboriously attend for a half hour to the feedback in order to influence their brainwave activity and benefit from the treatment. No attentional, discrimination, prolonged stillness, or learning demands are placed on the individual. In addition, the LENS uses a somewhat different conceptual approach to selection of which EEG sites to train. Traditional neurofeedback uses protocols based on either symptoms or on abnormalities found in QEEG brain maps, with both approaches often utilizing only a limited number of electrode sites for training. In contrast, the LENS treatment is also guided by a topographic EEG map, but one which prioritizes electrode site abnormalities based on both EEG amplitude and EEG variability. Unlike other neurofeedback approaches, LENS treatment is then administered at all 19 (or more) electrode sites. Treatment consists of the delivery of a tiny electromagnetic field carrying the feedback signal down the electrode wires for only one second at each of the chosen electrode sites during every session. This input stimulation varies from moment-to-moment, updated 16 times per second based on the dominant EEG frequency changes. Generally between one and seven of the ordinary electrode sites are treated during each session.

Finally, central to the application of LENS treatment is the concept of patient reactivity/sensitivity and the response of the patient's nervous system. We adapt the duration of stimulation, session frequency, and degree to which the stimulus is offset from the dominant EEG frequency to the patient's reactivity, and closely related to their vitality and degree of symptom suppression.

The LENS may be used as a tool to use in a treatment context with other EEG biofeedback or neurofeedback modalities or as a single solution to several problems. The LENS is being studied as a potential treatment of adults and children with CNS-mediated disorders in the USA, Australia, Canada, Germany and Mexico. It has been shown to produce rapid resolution of difficult cognitive, mood, anxiety, clarity, energy, physical movement and pain problems when compared with more traditional forms of psychotherapy or medication treatment. No efficacy comparisons are offered in relation to other forms of EEG biofeedback, or neurofeedback, since no comparative studies have been undertaken.

It is important to note that the LENS does not require the patient's attention, focus, orienting toward feedback, home practice of self-regulation techniques, or, indeed, any conscious participation in any self-regulatory activity (except showing up and not removing the electrodes from the head). The LENS appears to operate on the basis of the biophysical properties of the feedback signals themselves, on the tissues of the brain and related structures such as the vascular system. In addition to not requiring attention, focus, and attention toward feedback, the LENS approach, tolerates gross movement and artifact without reducing efficacy, or inappropriately rewarding maladaptive behavior or physiological reactions.

Feedback signals of different intensities, frequencies, and wave form shapes appear to have different clinical effects. There are only the beginnings of sophisticated research into the properties of the OchsLabs system. It is still too early to draw any conclusions about the mechanisms or properties of the systems used. The LENS can be used with extremely hyperactive patients and still maintain apparent efficacy. The LENS feedback exposures can be as short as one second per session for the appropriate patient and still have apparent efficacy, which means that it demands relatively little cooperation from the patient.

Benefits of LENS

The LENS appears to: (a) increase ease of functioning; (b) increase clarity of functioning; (c) reduce the amplitude and variability (including spiking) of the EEG activity across the 1-40 Hz spectrum at each of the standard 10-20 electrode sites when there is some amplitude and variability to start with; (d) increase the amplitude and variability of the EEG when there is too little variability sometimes to show the full extent of the pathology, before it diminishes the amplitude and variability; (e) reduce or alleviate central nervous system problems as described below; (f) allow new information (psychotherapy, counseling, education, relationship-specific information from a spouse or co-worker, etc.) to be recognized, taken in, used and remembered much more easily without interference or defensiveness.

The LENS appears to shorten the treatment times required for the improvement of some serious cognitive, mood, energy, pain, and motor control impairments. The LENS also appears to offer patients previously considered untreatable a new option for remediation of symptoms. Based on experience with both EEG biofeedback research, and the use of pulsating lights and other energy fields in neurological examinations to study seizure activity, it is hypothesized that the mechanism of action involves altering the person's maladaptive inhibitory neurotransmitter activity. The LENS has been declared a "minimal-risk" device by several independent human subject review boards (IRBs).

Improved functioning has been observed for those patients receiving the LENS treatment who had plateaued in their recovery from motor paralysis and CNS-mediated cognitive and mood impairment after mechanical and psychological trauma. Reported improvements have persisted since data collection was begun in 1994 (and even earlier with antecedent systems).

Improvement has been reported in most of the subjects (N = 2500, in approximately 90,000 sessions as of 2005) who have been treated with the LENS. When the subjects for this research and treatment have fallen within the areas that are known to be particularly treatable such as mild traumatic brain injury, fibromyalgia, and explosive autism, the success rate has reached over 80%. The more the patient's history has been complicated by lifelong problems preceded by an intergenerational history of problems in parents and grandparents, and when the patient's problems have been numerous and complex, it is much more complicated to judge the efficacy of this approach; thus, the "success rate" may drop precipitously.

Side effects from the use of the LENS have been similar to those that result from any change in situation (biofeedback, meditation, moving a household, body work; i.e., disruptive upon over stimulation) but transient and not involving any organ system damage or dysfunction. The three most common side effects when there has been over stimulation have been fatigue, anxiety or hyperactivity, and no improvement in clinical symptoms. All of these situations resolved themselves, usually within a few hours or days, by temporary withdrawal from treatment and decreased exposure to feedback.

Optimal Kinds of Cases. The LENS appears to have its best effects for: (a) mild traumatic brain injury if the person was formerly high functioning; (b) the diffuse pain of fibromyalgia and its associated fatigue and mental fogginess, but leaving untouched any underlying myofascial pain for conventional treatment; and (c) explosive behavior, regardless of its cause, whether it is in an adult, a non-autistic child, or an autistic child.

More Difficult But Positive Cases. The LENS has been shown in uncontrolled, anecdotal experience, to produce less consistent, less reliable, and more difficult-to-obtain–but nevertheless still positive, results in cases of: (a) autism: more sociability, greater affection, verbal skill, more grace and balance; (b) trauma from childhood sexual or physical abuse, work, and war stress; (c) clinical depression secondary to anxiety disorder; (d) bipolar disorder secondary to anxiety disorder; (e) alcohol and cocaine addiction: less craving, less defensiveness and depression; (f) childhood schizophrenia and Asperger's syndrome: less fear, greater independence and achievement; less compliance (not to be equated with oppositional), greater independence, less fearfulness and anxiety, and more self-direction; (g) some types of chronic fatigue syndrome: greater energy and clarity;

(h) attention-deficit disorders; (i) physical head injury symptoms from moderate to severe. In the latter case positive outcomes were found in clinical research that was conducted under Office of Alternative Medicine-National Institutes of Health Grant to determine the efficacy of the LENS on reducing cognitive deficits among people suffering from closed head injuries (Schoenberger, Shiflett, Esty, Ochs, & Matheis, 2001).

It is important to note that while clinical improvement has been noted in all of the conditions cited above, the course of treatment with the LENS alone was often inelegant, cumbersome, involving trial and error and clinical skill. The reasons for the complexity of treatment are reasonably well understood. However we still have not evolved treatment protocols to solve the treatment complexity problems and make them as apparently successful and easy in the discrete conditions that were noted above as areas of application where the best effects have been achieved.

METHODOLOGY AND DISCUSSION

The LENS Treatment Process

The LENS works by continuously monitoring EEG activity and then uses these readings to determine the frequency of very small electromagnetic fields that are "offset" several cycles per second (hertz) faster than the patient's dominant brainwave. This feedback stimulus input is then delivered down electrode wires at generally seven or fewer electrode sites in the course of a treatment session, for only one second per site. This input is much weaker than what the brain receives from holding a cell phone to one's ear.

How can non-perceivable feedback to the brain that is of such minimal magnitude still be influential? While the mechanism of how this happens remains to be determined, it is clear from both the documented effects of these feedback signals on the amplitudes and variability of brainwaves, that (a) this feedback is being processed by the brain, and (b) the impact of these signals, when used correctly, can improve people's functioning in their own experience and the experience of others who observe them. While these effects are clear to the professionals who use the LENS, it remains the job for controlled, double-blind, randomized studies to demonstrate these effects to others. It also remains for basic research to describe the mechanisms that allow these effects to take place, as well as the variables which minimize and maximize the effects.

The current the LENS process involves:

1. Assessing the sensitivity, reactivity, fragility, hardiness, and prior history of problematic symptoms that are no longer present. This is done with a simple questionnaire found in the Appendix B.
2. An assessment looking at the following:
    a. The relative proportion of different frequency band activity within the raw EEG. If there is more delta amplitude, then it is likely there may be an acquired problem such as head injury. If alpha is predominant then there may be more of a pervasive developmental issue such as ADD with genetic influences.
    b. The clinical reaction to a standard dose of stimulation feedback. There is no substitute to putting a toe in the water, experiencing some of the feedback, and then looking at what happens over the next twenty-four hours. Then, despite theoretical ideas about the appropriateness of the dose, the person may find that the dose in that administration is just right, or too much. Signs that it may be too much are that the person is profoundly fatigued, or restless and overly energized, both of which usually disappear within twenty-four hours.
    c. Assessment of which offset frequency from the dominant frequency is most efficacious at which to present stimulation.
    d. If the prospective client appears reasonably sturdy, an offset evaluation is performed to assess these factors.
    e. If the person appears from the evaluation to be vulnerable to over stimulation, a much shorter and less intense evaluation is done, giving all the in-

formation above except a suggestion about which offset to use. The offset frequency is then presumed to be 20 Hz faster than the dominant frequency for the most sensitive-reactive clients.

3. Mapping. Construction of a topographic map of EEG activity, without necessarily providing any feedback, of amplitudes across the 1-30 Hz spectrum across the entire scalp. Electrode site selection in treatment is determined by ranking EEG activity from least to highest in each EEG band, in microvolts amplitude and standard deviation sum for each sensor site. A single channel EEG is used, monitoring each of the standard 10-20 electrode sites in sequence. While amplitude and standard deviation measurements appear to be reliable enough and reasonably correlated with quantitative EEG (QEEG) patterns, measuring correlations among multiple sites is not currently possible since the sites are measured in sequence, and not simultaneously.
4. Treatment providing the feedback in the dose and at the offset frequency as suggested by the above evaluations, in a sequence prescribed by the map.
5. Monitoring the subjective reactions of the patient through self report and the reports of others when available, and the objective changes in the EEG (obtained by periodic remapping) to continue or modify the dosage and site sequences used in the treatment.
6. Involving other tactics to evaluate inferred EEG comodulation (correlated activity in amplitude and/or standard deviation) across the scalp. Comodulation may be responsible for treatment complexity, as well as the duration and stubbornness of their condition.

Most recipients of the LENS input stimulation will have no immediate reaction to the use of this procedure. Some will have relatively short courses of treatment. However, some of those with latent emotional conflicts and intergenerational genetic physiological problems will require longer treatment processes.

Even though this type of stimulation has been found to reduce seizures when they are present, in some patients who have had seizures in the past but where they are not currently present, they have been known to reappear for a brief period of time. Hence the pre-treatment interview is useful in anticipating a complex or problematic treatment. This allows both the therapist and client a chance to review whether the re-experiencing of seizures (or other problems such as anger outbursts, tics, incontinence, or migraines) is something that the client will tolerate.

Reaction Patterns Observed During Treatment. An interesting complexity appears when symptoms become worse during LENS treatment. Many of these patterns we are about to discuss have been considered "side effects." In fact, they may better be considered as stages in treatment that are sometimes experienced in gaining mastery over symptoms. These problems are of five types.

First, vascular type reaction patterns: whether talking about vascular (throbbing pain), periods of anger, rage, sadness, obstinacy, explosiveness, bed wetting (below age six), tics, or convulsions, these episodes become sharper, but shorter in duration, and farther apart in time. As they become increasingly brief, they are experienced increasingly as a fraction of their former intensity, and may not show at all on the surface, in the behavior of the patient. It is often said that as treatment proceeds, the reactions pass faster and have less of a grip on the patient. Finally, their intensity diminishes.

In the end, patients often reflect that circumstances that would have evoked a symptom no longer do. They are completely inarticulate as to what process is happening inside themselves to bring about this change. However, they retrospectively do notice the difference and attribute it to the LENS treatment.

It has been mentioned that the results brought about from the LENS may be either the result of placebo or hypnosis. Yet many of the recipients of the LENS had numerous previous treatments, and many novel ones. Each of these individuals had the opportunity to have hypnosis or placebo work during prior treatment experience. If placebo and hypnosis, either directly or indirectly, have not occurred in the past for these patients, it would seem implausible that the LENS would finally bring them the placebo results that prior attempts had failed to bring. They are involved in receiving the LENS treatment because previous placebos have not worked. Therefore, it is assumed that placebo plays very little part in their current improvement.

Treatment with LENS

It is most important to understand that just starting the use of the LENS does not bring an immediate halt to patient symptoms; in fact, they may appear worse for a while. While these symptoms are ones the patient has had in varying degrees previously and are not caused by the treatment, the change in the way the problem manifests itself and is now experienced is directly attributable to the LENS treatment. The increasing sharpness of these problems, predictable or not, is always of concern for patients, care givers, and referral sources alike. It is also important to know that we expect the therapist to predict and discuss the anticipated changes in how the problems may shift in their manifestations in order to give the patient predictability and confidence in both the treatment process and therapist. A therapist who does not predict this sequence is depriving him or herself of the confidence of the patient. Further, it is important to be considerate of the patient, allowing him or her to choose not to become involved in this approach if the possible consequences are not appealing.

Second, muscular type reactions: muscle contraction pain in non-spastic muscles, and the terrible muscle contraction pain in those with spastic muscles, may occur in head injury, stroke patients, and whenever there is paralysis. Muscle contraction pain of a non-spastic type simply diminishes with time, in contrast to the vascular pattern cited above. There is also pain from the LENS-evoked spasticity reduction that is seen in conditions such as TBI and stroke. This has been in nearly every instance almost intolerable to the patient and those close to the patient. Special care needs to be taken with patients who are hypersensitive to pain medication and are, therefore, unable to use it to alleviate this temporary pain. This intense pain appears to be a function of the decreased bracing offered by non-spastic muscle fibers, which permits the spastic muscles to contract with increasing vigor before they too begin to soften and relax. When this reaction occurs, the intense pain experienced during spasticity reduction typically lasts from three to five days. It is often accompanied by the sequence of uncontrolled muscle contractions, jumping limbs, increases in sensation, and then the return of partial or complete movements. Note: This kind of pain can be reduced or often completely eliminated with the use of a modality called photonic stimulation.

The third type of reaction is the surprise re-appearance of convulsive or tic-related phenomena that may have long since disappeared. This is actually considered a sub-type of the first class of vascular reactions. These problems re-appear after their long absence, to the near-horror and fright of the parents, care givers, and referral sources. Bed wetting, tics, simple or generalized convulsions, and emotional explosions, may suddenly appear for a few weeks before they subside and make way for higher functioning levels not seen before. Anticonvulsant medication has been extremely useful as an adjunct when the severity of the behavior warrants. The advent of more functional behavior after the cessation of these symptoms has led to the speculation that the untoward behavior had been inhibited by the same mechanisms that kept the patient limited in other ways of functioning. When the behavior has reappeared, and then once again remitted, it may be that the brain found another mechanism to control the aberrant behavior while permitting the flourishing of adaptive and useful skills. Nevertheless, everyone involved needs to provide support, care, and safety in the presence of difficult behavior. To date no one has been caught forever in a trap of regressive, destructive, or bizarre behavior, although the behavior has on rare occasion been extreme and frightening to nearly everybody involved in the very unusual instances when it has occurred.

The fourth type of reaction has been the emergence of adaptive but unvalued, or frankly disvalued, behavior in the patient. Examples of this have been: less fearfulness and greater independence of autistic and Asperger's children, which may be outside of the parents and schools value systems (i.e., children who express anger at siblings when anger is felt to be "bad," children and young adults that become more interested in their own and others' sexuality, children who become more independent, adventurous, and exploratory, and, therefore, begin to take risks which frighten parents; children who voice their own points of view and needs may be contrary to what the parents see appropriate; and children who no longer feel compelled to sit still within the constraints of a rigid school system). All of these behaviors have occurred as greater functioning, greater independence, and greater self-control became more prominent. Some parents who have blanched at the changes in their children will usually keep struggling to be supportive, while other parents have done little but glory at the changes in their children. It is advised to avoid treatment if, in discussions with the patient or family, they are unwilling to risk the occurrence of such behavior. In the approximately two dozen autistic or Pervasive Developmental Disorder children I have treated with the LENS, only one has failed to respond at all, for unknown reasons, while all the rest have delighted their parents with their achievements.

Another example of a positive reaction with untoward effect occurred in the treatment of an older man who had experienced a traumatic brain injury more than a dozen years before he entered treatment. As someone from out of town, he had allocated only a week for treatment before he needed to resume his travels. One of the major problems he had experienced since his head injury was rage, which showed itself in verbal and physical violence. Other problems were chronic angina for which he took medication (and frequent drinks of alcohol from a flask always with him), and a loss of three-dimensional vision. After his first treatment he was freed from heart pain and announced that he no longer needed to drink to control the pain. Within 45 minutes after the treatment he announced that his three-dimensional vision had returned. At first he walked uncertainly as if he was wearing his first pair of trifocals. The next day his wife accompanied him to therapy. He was visibly distressed. She had announced to him that she had suffered his abuse long enough and that she was no longer going to take it–since she no longer had to. She continued to hurl invectives at him and he accused her of trying to destroy the good effects of the treatment. She was offered treatment for the post-traumatic stress which she most certainly suffered, but she declined. He was asked to be supportive of her in her anger, considering what she lived with for years. Over the next few days under her relentless attacks he regressed to his former state. At the end of treatment they left: him in pain, his three-dimensional vision again lost, and drinking again, and with her as his long-suffering care taker. This illustrates the importance sometimes of working with the entire social system, rather than narrowly focusing on a particular physiological problem in isolation. It also illustrates the inadvisability of working under fixed time limits.

A fifth type of reaction is the recapitulation of previous symptoms, from the most recent to the oldest. Often patients will re-experience first, recent symptoms, and in the last stages of treatment, re-experience symptoms that they experienced as infants. They will often wonder why, for instance, as therapy is about to be completed, they are experiencing abdominal pain. When questioned, they can often remember having such pain or remembering stories of how they had such pain in childhood. These are transient reactions and often pass in a week or so.

Diagnoses. The LENS is a non-specific treatment approach; that is, treatment planning is not guided by diagnosis, which is seen by some as a weakness of LENS treatment. Part of the problem with treating many conditions that have been resistant to amelioration within conventional medical and psychological circles is threefold. First, there is much misdiagnosis. Many of the diagnoses that are proffered are catch basins and euphemisms, and are substitutes for professional ignorance. The problems of diagnoses of many of these conditions, such as Asperger's, Parkinsonian variants, tuberous sclerosis, attention-deficit disorder, fibromyalgia, bipolar disorder, etc., are often beyond the discriminative skills of many practitioners and the most fashionable diagnoses are often used. Second, many conditions are beyond the discriminative capabilities of the diagnostic systems themselves, or their existence as independent entities is controversial and at the whim of what the medical-insurance system will accept given political (turf) and economic considerations. Third, the diagnostic name itself can say little about the treatment when the individual differences among people with the same diagnosis can demand major differences in treatment strategies.

Considerable heterogeneity of brainwave patterns has been found within the broadly defined diagnostic categories. Replacing treatment guided by diagnosis, LENS treatment is predicated on the fact that many psychological and medical conditions involve various types of abnormal EEG activity (Hughes & John, 1999). LENS treatment is designed to reduce abnormal brainwave patterns and is individualized based on the distinctive amplitude and variability patterns found through topographic brain mapping, as well as the patient's subjective reactions to treatment. Finally, it may be said, considering the vast responsibilities of the brain, that the brain, itself, is a non-specific organ. This means that injuries to it may take this shape or that, without any specific predictable outcomes, associated with a particular location, size, depth, or type of injury. Although some outcomes are certain in a gross sense, the particularities of any injury are always some unique combination for the individual involved. The practices of clinicians using the LENS are often filled with almost nothing but patients who are exceptions to medical and psychological predictions of "no recovery possible."

Differences between the LENS and Conventional Photic Stimulation Systems. The LENS differs from currently available consumer (or professional) AVS devices in the following ways. Most of these devices are considered entrainment devices. They lock the brain wave activity on the frequency used to stimulate. The LENS disrupts the way the brain locks onto frequencies, or clusters of frequencies, hopefully helping to free the brain from rigid patterns so that it can have the flexibility to pursue the tasks that it and the person need it to pursue. Second, most of the AVS devices use light frequencies. The LENS uses various frequencies of electromagnetic energy instead of photic stimulation, with is accompanying small risks of evoking a seizure. Light has not been use in most of our applications for the past seven years.

Third, with the LENS, the person's EEG activity controls the frequency of the pulsations in the energy field. This customizes the pulse rate to the person's own activity as it continuously changes. The stimulation frequency of consumer sound and light systems is both pre-programmed and set; a selection is made on the device's front panel, or programmed to change in a way unrelated to the person's actual brain activity. Thus the input stimulation is not individualized to the unique and ever changing brainwave patterns.

Fourth, the LENS uses electromagnetic energy fields infinitesimal in strength, while other devices use much stronger signals. The LENS may, despite the weakness of its energy fields, obtain its power through sustained resonance between the person's EEG activity and the pulsation frequency of the field returned, which may be received by the brain because of its ability to detect patterns. While much of this is speculation, it has been observed that when the resonant pattern of the feedback is broken (when the link between the dominant frequency and the feedback is broken) there are no longer any beneficial effects from our stimulation. That is, when the feedback resonance is broken, both negative as well as positive effects can still appear, but, depending on the frequencies, intensities, and doses involved, they appear with much less consistency and predictability.

A note on the use of the word resonance: Resonance tends to be used in two ways in current medical parlance. In the phrase Magnetic Resonance Imaging, resonance is achieved by the power of the magnetic field on the electrons adding energy to the electrons to move them into higher order shells. Persinger (1974), Sandyk (1994), Rife (1953) and others use the word resonance to refer to a state in which a stimulus intensity or frequency matches a known or theorized fixed frequency in the body. The word "resonance" is used here in a new way in the history of science: that of the changes in the stimulus continuously matching changes in a physical variable (such as brain waves or heart rate). In this sense the resonance is a dynamic one, rather than a static one. Hence, this is a feedback system. However, unlike other biofeedback systems that feed back informational stimuli, the LENS feeds back physical stimuli, the physical properties of which affects physiological changes.

The LENS Equipment Requirements. LENS requires a brain wave measurement device; a computer fitted with an EEG device that controls the emitted energy-field; software to link the brainwaves with the stimulation radio frequency (RF) carrier wave and a system that can deliver levels of energy field feedback at low but precise levels of intensity. These levels are lower in intensity than the electrical field that surrounds digital wrist watches.

In order to provide feedback, the individual is first fitted with the EEG electrodes. In our previous systems, the patient used to wear glasses with components mounted on surface of the lenses, or sat with the glasses mounted on a stand at some distance in front him or her. The operator monitors the computer screen and controls and intensity and duration of feedback so the person remains comfortable. The continued presence of the equipment operator is necessary to watch the quality of the electrode contact, and to determine that the patient preferably remains motionless for a few seconds before the stimulation is given.

While the final determination on how the LENS works must rest with a great deal of research, we believe that the LENS achieves its results by breaking up the rigid, self-protective way the brain has of responding after psychological (stress) or physical trauma and restoring the inhibitory capacity of the cortex.. There is evidence that during any kind of trauma the brain protects itself from seizures and overloads by releasing neurochemicals that protect it from these dangers. Unfortunately, the protection also reduces functional capacity, not unlike the effect of swelling on joint articulation. Long after the trauma is over and the danger is past, the 'protection' may still remain. The person can, therefore, become stuck in various kinds of disabilities due to the reduced neural flexibility of functioning.

Technology Development of the LENS. There was something wrong with nearly all the LENS design elements and procedures from the point of view of those experienced in traditional EEG recording and EEG neurofeedback. This is acutely evident in relation to:

- the established practical concerns regarding shaping reinforcement contingencies
- using visual and/or auditory, or radio frequency feedback carriers for the feedback of information to the brain
- managing high and low frequency EEG activity
- thinking in terms of under- and overarousal phenomena
- maximizing the amplitudes of some EEG frequencies while inhibiting the amplitudes of other frequencies in relation to particular problems
- locating electrode sites for training
- using topographic maps to provide a treatment plan
- resisting micromanaging the inhibit and reinforcement settings of the EEG in biofeedback treatment
- deferring to subjective reports, rather than quantitative measures of the EEG as either signs of pathology or progress.

There were no clues in the literature for guidance in the preliminary clinical work with the LENS or its predecessors, so the initial treatment guidelines became: Try it on oneself first, always strive to maintain patient's comfort, and cut back if symptoms reflecting over stimulation follow a treatment–even if the post-session discomfort had nothing to do with the treatment.

EEG Site Location. Between 1990 and 1995 the predecessors to the LENS most frequently found success with consistent use of FPZ as the electrode site for the active electrode (with the reference on an ear lobe, and ground at the back of the neck). Depression was typically dispatched in six sessions. This raised the question about the efficacy of choosing any specific site over another at the start of the treatment: one site appeared to be as good as the next when using the precursors to the LENS in the early 1990s. An observation that had no meaning at the time was that delta, primarily, and theta, secondarily, were predominant in the frontal EEG amplitude of nearly all of the patients. In 1995 Ochs wrote a short piece titled *Many Kinds of Depression Are Curable* to spread the good news.

No clear differences in either the way the original light feedback was tolerated or the speed of treatment were found when monitoring the EEG at the sites that were historically popular with traditional EEG biofeedback therapists: occipital locations of O1 and O2, the top of the scalp at CZ, or the site of insult or its contra-coup damage. The central forehead site FPZ was tried because the side effects were minimal, results were as good here as at the other sites, and because it was easier to avoid electrode paste in the hair of the patients during the initial rapport-building session. The frontal site was therefore selected as the point for use at the commencement of treatment. The frontal site has indeed always been more prone to artifact from eye movement, jaw movement, facial expression changes, swallowing, etc. However, since the artifact itself decreased as a function of treatment progression, it seemed plausible to accept the artifact decrease as one of the global indicators of improvement. This suggested the selection of FPZ as an initial starting site. As a consequence, the artifact component of the EEG records was and still is kept, rather than discarded, as is done in conventional neurofeedback treatment.

Another consideration was related to the work of Davidson and Hydahl (1996) and their observation that the left frontal area was less activated in depression. Moving the electrode located at the front-center of the forehead to the left produced, again, no improvement in patients with depressive features. This is not to say that lateralizing the traditional EEG biofeedback might not make a difference in the successful treatment of depression. Using the LENS approach, however, the clinical efficacy of changing the electrode placement to the left frontal area and the practicality of using FPZ overrode all the other considerations pertaining to the selection and use of the more standard electrode sites.

Interestingly, in 1995, with no changes in equipment or software, the selection of FPZ as a site no longer seemed efficacious. In contrast to the delta and theta amplitudes that were predominant in the frontal EEGs of previous patients, alpha now seemed more predominant in the frontal EEGs of those entering treatment. Instead of rapid resolution of depression, irritability and moodiness often resulted from treatment. In contrast to the rapid resolution of depression that had previously been seen, and in contrast to any certainty about how to treat that depression and about placing the active electrode at FPZ, there was no longer any idea about where to place the electrode, either on the basis of the literature or my own experience. This included experimenting with placing the active electrode at C3, C4, OZ, O1, O2, and at CZ. In an unsystematic way the electrode was moved throughout the standard 10-20 sites. At times there was a remarkable response from sites nobody had talked about; at other times there was no response from any sites addressed.

To better understand what was happening, less expensively than with quantitative EEG brain mapping, single-channel data was collected from all the sites, one site at a time, and this data was fed into Microsoft Excel's surface map. An example of the resulting map is seen in Figure 1, which displays an example of a case with high delta amplitudes throughout the right hemisphere.

A histogram (bar graph) was then created, one bar per electrode site. At first the data made no sense when it was simply organized in the order in which the data was collected. But, when rank-ordered from lowest-to-highest amplitudes for each EEG band, it then appeared that it was a picture of the functionality of the sites–that is, the lower the measured amplitude in microvolts, the more the cortex appeared to be inhibiting the subcortical activity from reaching the cortex so that it could be measured. The greater the inhibitory activity exerted by the cortex, the higher the level of functioning. Figure 2 illustrates the data from Figure 1 in this bar graph format, displaying the amplitudes and standard deviations of the data, rank ordering the electrode sites. The rank ordering became the clue about which sites to select for treatment, and in which sequence. A consistent, organized way to select active electrode sites might be to proceed from those with lowest amplitudes to those with the highest amplitudes. This might not have been the only way to select sites, or necessarily the best way, but at least it was empirical and not based on static experience or research based on aggregated data.

The rationale for this was that in starting with the better-functioning (lower amplitude) sites and proceeding to lower functioning (higher amplitude) sites, the better functioning sites might respond more rapidly and stimulate the more poorly functioning sites. By the time the sites with the lower amplitudes were addressed, the higher amplitudes at other sites would have already decreased, lessening the work that would need to be done. This turned out to be true when the amplitudes were among the highest.

FIGURE 1. LENS Map

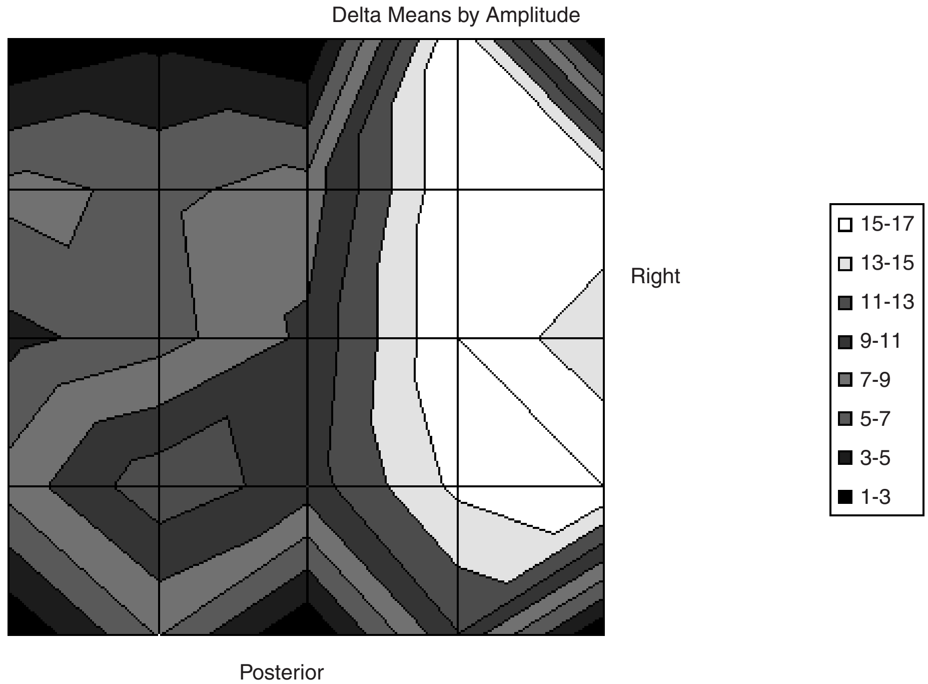
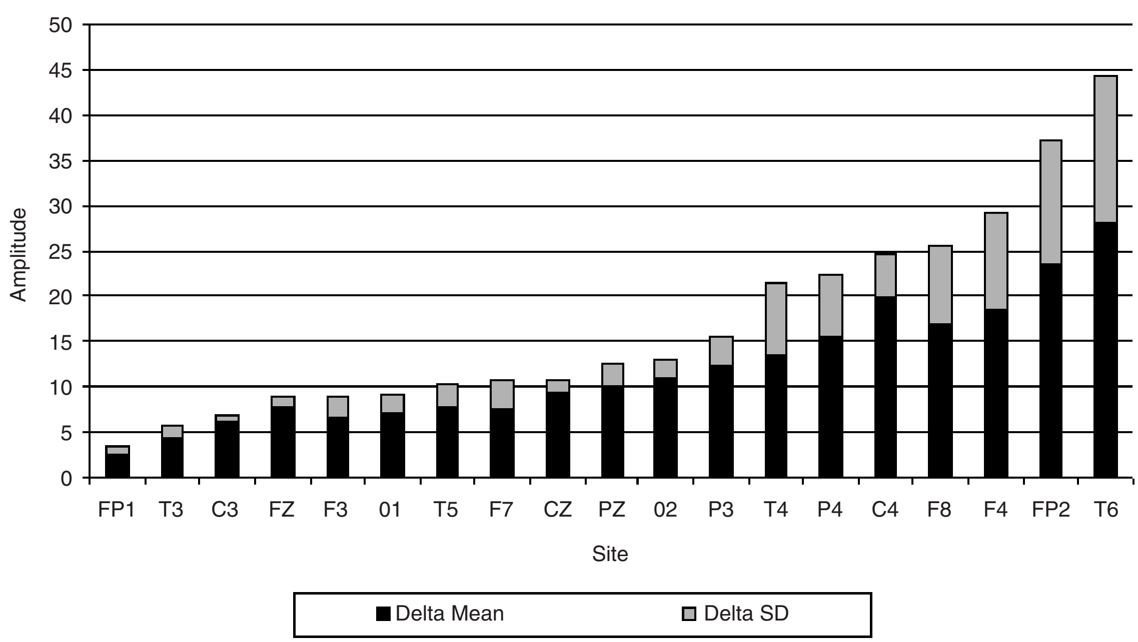


FIGURE 2. Delta Means and Standard Deviations by Sensor Site



The Need for Mapping. A person's performance can be impaired, even though the EEG activity at any one site is low and smooth across the spectrum. It is necessary to see what kinds of amplitudes are at other sites. It thus became necessary to move away from the forehead site and move the electrode to other sites around the scalp without the historical biases about electrode placement. The next stage was to look at each site for evidences of focal high amplitude and high variability activity, and provide stimulation at that site until the EEG activity was low and stable. The activity at each site was assessed and worked with until ideally no high (> 2.0 μV) amplitude/variability activity was observed.

It also became clear that the information used to make the surface maps could be used to generate treatment plans, specifying the order of sites to be used in treatment. This gives the therapist an empirical basis for starting treatment where the cortex is most functional, and working toward points of less functionality, thereby building upon the patient's strengths in developing their discriminatory capability.

The Beginnings of Mapping. Beginning in 1996, performing inexpensive surface EEG maps that showed the relative amplitude and variability of the EEG at each electrode site (as seen in Figure 1) provided an unexpected treatment benefit, in addition to providing graphic pre and post measures. These maps were acquired by measuring the activity at each site in a specified sequence, using a single-channel EEG instrument. Maps constructed in this way do not allow accurate measurements of the relationships among sites. The unexpected benefit of the sequential maps is that they do provide an explicit plan of which sites to treat, and in what sequence. Beginning at the sites of the lowest activity, and working toward sites with the highest activity, is the same as working from where the cortex is most functional to where it is least functional.

Hyper-Reactivity: Alternating the Polarity of the Leading Frequency (Offset). One of the first clear reactions encountered in the use of precursors to the current LENS was hyper reactivity to the visual feedback stimuli. Initial work began in 1990 with two individuals with post-traumatic stress symptoms (PTSD). Neither had been successfully treated with standard psychotherapy, relaxation training, or with biofeedback (including EEG biofeedback). One of the individuals reacted strongly to the visual and auditory feedback. She jumped in her seat, and complained of a headache and backache.

Later, patients complained about some aspects of the feedback. Some expressed dislike of the "flicker" of the lights. Others complained about the color; others, the brightness. Some could not verbalize the quality they didn't like, but reacted physically, or just said that they didn't like it. Others invoked a variety of verbal and non-verbal startle responses. One individual became explosive and frightened staff members in other rooms with the volume of his outbursts.

In each of these cases, the therapist's response was to change the direction of the leading frequency or offset. If the lights were set to flash at +5 Hz faster than the dominant frequency, the polarity was changed to let them flash at −5 Hz (more slowly than the dominant frequency). In nearly all instances of this problem, changing the polarity of the leading frequency, or offset, decreased the immediate uncomfortable reactions. Further polarity changes at the occurrence of these reactions continued to manage and minimize the reactions. Changing the polarity of the feedback offset was the preferred way to minimize these reactions because the software permitted fast and easy changes of polarity. While a brightness control was available, it involved more time and complex manipulation of the controls.

Alternating polarities had so much impact in the early 1990s that the old procedure, then called EEF (EEG Entrainment Feedback) was modified to allow for specific sequences of pre-programmed polarity alternation. Alternating polarities was one of the important elements of the patent. The alternating polarities seemed to decrease the hyper reactivity of patients. One of the major differences between the approaches in the early 1990s and now is that there are few, if any, immediate reactions of discomfort for which the alternating polarities would be needed. In contrast to the measures taken during those early days, today's strategies tend to be much more subtle.

What's in a Name? The LENS process was originally called EEG Entrainment Feedback (EEF), despite the urging of others, who persisted in the argument that the system seemed to be freeing the brain from being locked up (entraining on itself). The ultimate inspiration for changing the name from EEF to EDF (EEG Disentrainment Feedback) was found in *Chaos: Making of a Science*, by Gleick (1988, p. 293). Gleick used the word "disentrainment," referring to the unlocking of a system. This enabled the precursors to LENS to be seen as disentrainment systems. The name of the process was changed from EEF to EDF. After that, the name changed to Neurophotic Stimulation, to EEG-Driven Stimulation, and finally, to the Flexyx Neurofeedback System (FNS), terms that were less theoretically encumbered and more descriptive names.

It should be emphasized that the treatment effects observed were not due to training to increase some components of the EEG band or inhibit others, even though the observable changes in the EEG activity across the 0 - 40 Hz band appeared comparable to those obtained from the traditional EEG biofeedback training. Experienced EEG clinicians and researchers have been observed attempting to truncate the EEG band activity at one end or the other, or at a selected frequency, either based on some theoretical basis, or previous experience. Early EEF work was also done this way (i.e., attempting to "speed" the EEG by using positive leading frequencies). The system is now run by primarily controlling dosage: the duration of the session and the intensity of the feedback signal.

It is important to understand that in no way, as some people think, is the EEG ever "sped" or "slowed," with the LENS. Under most conditions the amplitude and standard deviation across the spectrum is reduced. Furthermore, this effect is accomplished from the biophysical effects of the feedback signal and its resonance with the EEG of the person, rather than from any reinforcement to elaborate or inhibit the activity in certain bands or frequencies.

Subjects' sensitivity to the brightness of the old visual feedback was recognized while working with Dr. Herbert Gross' patients, a neuropsychiatrist who specialized in head injury. The patients' brightness sensitivity became apparent when the brightness of the lights could not be sufficiently reduced to permit patient comfort. Although good results had been achieved using red LEDs, among the most irritating colors one could employ, the protocol was changed to use green LEDs when it was observed that the red LEDs annoyed the head injured population. This change worked well for the group of head injured patients who had been functioning extremely well prior to their head injuries.

Hypersensitivity. An informal survey of "normal" people, in contrast to those with symptoms, using light stimulation devices available to consumers showed that they enjoyed lights at full brightness. At that time, the operating presumption was the brighter the lights, the better the results. Once the idea was grasped that red lights were both too irritating and too bright, the use of red lights gave way to the more tolerable green ones. The desensitization process was developed gradually, slowly introducing the patients to increased light brightness. This desensitization process allowed them to maintain their comfort with lights of increasing brightness. After desensitizing them to the green lights, it was again possible to use the glasses with the red light-emitting diodes (LEDs), and eventually with continued desensitization, at full brightness in that generation of hardware and software, as well.

While the green LEDs, with their decreased brightness, worked for those who had performed well prior to their head injuries, they were inadequate to meet the sensitivities of a second group of patients with heterogeneous diagnoses prior to their exposure to the LENS, including diagnoses of borderline and various anxiety problems. These patients required green LEDs with tissue paper folded over them, or with masking from manila folder material, and even partial covering from vinyl black electrical tape. Only with such masking could these ultra-hypersensitive patients be comfortable, even with the lights at their lowest intensities. This ultra-hypersensitivity was observed even without light.

As clinical work continued with both head injury and non-head injury patients, it soon became apparent that greater incidence of behavioral and physical pathology seemed to correspond with increasingly prominent hypersensitivity to the visual feedback. In other words, patients with depression, energy problems, irritability, explosiveness, violence, distractibility, short-term memory problems, difficulty in organization, problems following conversation, and difficulty reading, may have all had irritable brains as evidenced by relatively large amplitude, low frequency activity, with relatively high standard deviations. This is an entirely testable hypothesis, and to the extent it is determined to be true, is a rather remarkable statement about human functioning and functional impairment. In fact, diagnosis of hypersensitivity might include much lower level light than is usually used in the detection of photo-hypersensitivity, with more sensitive behavioral observations than frank seizure or EEG spike and wave prominence. This discussion of photohypersensitivity refers to pre-1999 work with the antecedents to current LENS work.

Historical note: The following discussion was applicable when LENS feedback was administered for periods of up to 20 minutes per session. Since 1999, the feedback exposure is typically as brief as one second per electrode site, with an average of four sites worked with during any session, which typically occurs once a week. Thus desensitization pre-1999 was quite different from that which has occurred since then through the present. It is placed here, rather than in an appendix, to give the reader a sense of the flow of the LENS development, as well as to contrast the current practice.

Desensitization. Desensitization used to be a cornerstone of our early work linking EEG with photic stimulation. There is no question that for some patients, desensitization of some type may still be important when they appear to have energy and sudden-onset problems. However, as the mix of patient diagnoses and presenting problems became more complex, and more patients showed fatigue as a major complaint, desensitization began to play a smaller part. At this present time, because the feedback signals, even though not visible, evoke EEG changes much more rapidly than they used to be, it is often not possible to expose patients for a brief enough time to the signals to start the desensitization process. The difference between and one and two seconds can be profound to a very sensitive patient.

With the more recent, briefer treatment durations characteristic of the LENS, there does not seem to be enough time or reason to conduct desensitization the way we used to do it. However, desensitization can still be accomplished through the use of the offset settings. Heredity also plays a part. When parents had a history of mood or energy problems, problems were chronic, or slow in onset, desensitization became less helpful and gave way to the application of feedback with only the gentlest touch, the briefest and least frequent application. For this group, the therapist using the old I-400 system might use only green lights, masked glasses, and never raise the brightness above "1" in brightness and 1% in duty cycle during the entire course of treatment. Work has been progressing since 1998 using the profoundly low intensity feedback, and while the electromagnetic stimuli are not visible, this still produces changes in the EEG when the EEG is observed after the feedback stimulus has been given.

Here is an example of how the need for desensitization was discovered in the original systems. Ordinarily, the brightness of the lights was varied frequently during a treatment session and over the course of treatment. Just discussing the brightness of the lights, and none of the other treatment variables such as electrode site, for example, an intensity of "1" may have been used during the first six sessions. As the sessions progressed, symptom intensity decreased. In the seventh through the tenth session, intensity was increased to a brightness of "2." In the eleventh through the thirteenth sessions the brightness was increased to "4." In other words, not only was the brightness increasing, but the pace of increase was coming more and more rapidly as time progressed. Perhaps in the fourteenth session the brightness was increased three times, from "6" to "18" to "36." The brightness ratings are in quotation marks because they are arbitrary in value. No luminosity values were ever formally evaluated for the numerals used to indicate brightness. Yet the brightness values were linearly controlled by current flow; so that relative to each number, a brightness of "2" is half that of "4." Whereas initially going from "1" to "2" would have been uncomfortable for this hypothetical patient, in the end leaping from "18" to "36" would have been quite comfortable. In the meantime, symptom intensities across the entire range would commonly have dropped precipitously.

During one session, by accidentally using new software with a hidden defect, a protocol was loaded that held the light frequency low and constant during the feedback periods, revealing EEG activity which was initially seen when the patient's complaints were prominent. A young woman in her thirties, otherwise high functioning, complained of a post-puberty history of premenstrual fatigue, irritability, racing thoughts and sleeping problems, leaving her with severely restricted professional job functioning fifty per cent of the time each month. She left her job to avoid the continuous, extreme effort needed to fulfill her professional duties two weeks of each month. For two menstrual cycles after desensitization had been completed, her sleep problems ceased, as did her racing thoughts, irritability, and diurnal fatigue. During her third premenstrual cycle, however, her fatigue returned and was ever present. Examination of her EEG spectrum recorded under moderately bright light showed relatively large amounts of high amplitude, low frequency activity when the brightness was consistent across all four feedback periods. The session was constructed using a one-minute, no-feedback pre-baseline, four 18-second periods of feedback (during which feedback stimulation may or may not be given), and a one-minute no-feedback post-baseline, all repeated 17 times. All recording was done eyes closed. The electrode site was Cz, with a left-ear reference.

The high amplitude, low frequency activity was not present when the light brightness was reduced to 10% during the first and third 18-second feedback-possible periods. The informal hypothesis that alternating brightness would have no effect in accelerating change in EEG amplitudes seemed patently wrong. Alternating flashes between the left and right eye succeeded in lowering the amplitude of the EEG more than when we lowered the brightness of the feedback light stimulation, perhaps because there was only half as much stimulation being given.

At the current time, the intensity of the feedback signals (which are no longer photic stimulation) are so weak, their effects so strong, and the treatment times necessarily so short, that issues of desensitization have taken a back seat to dosage. The exposures are now so short that it has been difficult to see how to manage a desensitization program. It has not been until recently that six years of experience with the low power electromagnetic carrier wave feedback has allowed us to understand how to begin to integrate our prior experience with lights into current LENS work. Currently, increasing the number of electrode sites that we work with during each session, decreasing the interval between sessions, and decreasing the offset frequency at which we provide the stimulation are all ways to increase the power of the feedback stimulation and treatment dose.

Desensitization and Level of Functioning. Another past observation, equally testable, was that the level of some patients' functioning consistently increased as their comfort increased with progressively brighter light feedback. This means that depression, irritability, reactions to bright or interrupted light, impatience and explosiveness lifted, non-focal pain decreased, violence ceased, distractibility, anxiety reactions, organization, problems following conversation, and difficulty reading were all markedly ameliorated–without any claim that they were totally erased. The problems were improved enough that friends, spouses, distant relatives, employers, and last, the patients, themselves, were delighted and surprised at the improvement. Academic grade improvements were noticed as well. These observations were echoed by physicians and neuroscientists not involved in this treatment (although no attempt was made to keep them blind to who was involved in the treatment). In retrospect, it may have been that the enhanced ability of the cortex to inhibit electrophysiological reactions from the increased brightness of the feedback stimulation was the sign that the cortex had repaired itself. In contrast, if someone's brain had become re-traumatized, it was very difficult to re-desensitize the person for unknown reasons.

We learned that it was not always possible to desensitize someone. Desensitization was indicated especially when a person was energetic, and less useful when the person often felt fatigued. It is also possible that new techniques will permit successful partial desensitization of those people otherwise unable to tolerate the standard process.

Pace of Desensitization. There was a characteristic desensitization curve, even though the entire desensitization process could take anywhere from five minutes to five months. The initial pace of desensitization was always relatively slow, relative to its much higher rate of change at the end of the treatment process. The desensitization curve appeared to have been an accelerating curvilinear function in which the slope of the rate of change of the light intensity was often imperceptible initially, but its rate of change was geometric at the end. Put another way, the initial brightness changes may be 1% at a time, but increase in units to 20% at a clip occurred in the final minutes of the process.

We found that during a long desensitization process, lasting months, the final 80% of the brightness changes may occur in one treatment session. This pattern was consistent across all patients whenever the need for desensitization was present. The desensitization curve was reminiscent of the logarithmic curves in the Weber-Fechner law of perception, in which brightness increases logarithmically with the absolute value of the brightness of the stimulus. The observation of the adaptation of the brain may cast light on the flip side of the brightness estimation: that is, on the place that the rate of reconnectivity of the cortex plays as it regains competence.

Decreasing Light Intensity After Desensitization. One patient, early in the exploration of the LENS, suffered workplace abuse trauma and re-experienced symptoms formerly minimized by the LENS. She remained free from her former dislike of the brighter lights, however. There was the implication that she had not relapsed into photosensitivity and, therefore, did not need a lowering of the light intensity. Continued treatment with the LENS at high levels of intensity, however, did not lead to a decrease in her new trauma symptoms, which showed themselves prominently as depression, anxiety, and anger. High amplitude and variability in low EEG frequency bands again showed itself in her record. It was hypothesized that the intensity might be re-stimulating her pathology (i.e., perpetuating her re-traumatization). As a test of this hypothesis the intensity of the lights was drastically lowered and almost immediately she reported a decrease in her depression. During this same period, Russell was using the LENS with a few patients who had experienced cerebral vascular accidents. He applied this change in approach to the therapy he was doing and found that motoric and cognitive rehabilitation progress was stimulated and accelerated by lowering the intensity of the lights.

Interestingly, many users of pre-programmed frequency, commercially-available sound and light systems run their systems at full intensity. The colors and patterns are visually interesting at full intensity. The patients most often will seek full intensity, partly for aesthetic reasons, and partly, upon questioning, because they think that brighter is inherently better and that all treatments inherently involve the struggle to tolerate discomfort–which they feel they should do if they really want to improve.

However, it is probably not legitimate to equate the stimulation from fixed or ramping frequencies of the audio-visual stimulation (AVS) systems with that of the LENS and its predecessors. The AVS systems' stimulation intensity may be seen as ambient light, or "noise" stimulation, not nearly so tightly related to the living, dynamic EEG. This may be supported by the observation that AVS users need to use much brighter light intensities than what was ever used in the LENS predecessors. It seems to me that the inherent resonance of the LENS-type stimulation allows the LENS stimulation to remain at very low intensity and still have dramatic physiological and behavioral effects. It is apparently not the case that brighter is always better, nor that tolerating increased discomfort will accelerate recovery. In fact, when comfort is used as a cue for intensity settings, and the feedback LENS intensity is minimized, improvements in energy, mood, and cognitive integrity are often noted. This has been our experience with our older light stimulation system and with the newer versions of LENS.

When the LENS treatment is completed, the cortex may be in a very different state than it was at the start of treatment. Whether or not patients had been desensitized, the patients were, in fact, more receptive to and discriminating about external stimuli, but not hypersensitive or hyper-reactive. Their responses were more flexible and appropriate to the level of feedback present in the moment. In view of the greater sensitivity, is it any wonder, then, that high intensity, strobic feedback would act as if it was overloading the cortex of these individuals and in a sense replicating the internally-produced pathology that once was there? Decreasing the feedback stimulation after the desensitization process might be more effective because the brain has, through the course of treatment, become more responsive to feedback.

The pathology of some brains may require a major change or reorganization at the start of therapy, and trying to work locally at the site of damage may not be useful if the person is very energetic. Once the brain has been globally reorganized by the desensitization process and the patient is comfortable at full intensity, continued feedback at the peak level of intensity may now overwhelm the cortex. This represents a method by which one may safely experiment with replicating trauma and recovery from trauma. After desensitization, by lowering the intensity of the feedback, we may be more able to locally stimulate the cortex–something that we were unable to do at the start of treatment. At this stage in treatment, behavioral changes may be more closely tied to what is commonly thought of as local cortical neuropsychological functions. In other words, local site feedback and local site recovery may be addressable only after global feedback and reorganization has taken place. This might also mean that following LENS treatment, further localized treatment with traditional neurofeedback might have more affect than it would have had previously.

In an interesting side note, a highly functional scientist was put on an older LENS system, and not only felt nothing, but was unable to be overdosed by extremely high levels of brightness. It may be that one of the defining aspects of functioning well is that the brain is able to flexibly respond to high stimulation input, at least in relatively short exposures.

Cortical Permeability. In the early days of using EEG-driven feedback, it was noticed that the EEGs of high-functioning individuals were rather quiet, low amplitude recordings. In contrast, the EEGs of dysfunctional and physically traumatized individuals were typically filled with high-amplitude, low frequency band activity. Recollect that the cortex is one of the last organs to develop both ontogenetically and phylogenetically. The ostensive purpose of the cortex is to provide the integration and inhibition of subcortical brain center activity, which results in the appearance of our higher functioning capabilities.

The appearance of this EEG slowing that is seen as high amplitude delta, theta, and alpha activity, has been, in the view of traditional EEG and neurofeedback circles, considered a problem. Activity in these frequency bands is often inhibited during neurofeedback. Discussion of delta, theta, and alpha excesses was and is often prominent in exchanges of ideas about treatment. Yet delta, theta, and alpha activity may not be the entire problem because activity in these bands is commonly present when higher functions are not engaged.

Occasional high amplitude activity in low frequencies (which is often seen as pathological) may be present in individuals who not only function well, but who are exceptionally creative. These exceptions are not understood. Thus one needs to be careful about glibly pathologizing all EEG slowing, just as spinal anomalies were overly pathologized early in the history of MRI.[1]

In individuals having problems, however, the presence of activity in these slower frequency bands may translate into sections of the cortex, by their impaired inhibitory functioning, permit the delta, theta, and alpha activity to show themselves and be recorded at the scalp. That is, these areas of the cortex no longer function properly, and do not inhibit the low frequency activity. It is the poor functioning of the cortex that fails to inhibit the physiology that gives rise to the excessive EEG activity, which allows the high amplitude EEG activity to be recorded; that is the problem–not the activity itself. The task, then, of the treatment is to bring back the functioning of these impaired sections of the cortex. The sign that these areas are returning to normal function is twofold. First, the EEG amplitudes become inhibited and lower. Second, functional improvement results. The object is to reduce the permeability of the cortex so that it regains its inhibitory and integrative functions. This, in turn, permits higher functioning to return.

Decreases in the Amplitude and Variability of Low Frequency Activity. There were, and are, decreases in EEG amplitude and variability that accompany LENS feedback if the initial amplitudes are high enough. Decreases appear across the entire 1-30 Hz spectrum, but especially in the low frequency 1-12 Hz EEG range, including that activity which is clearly and even probably attributable to artifact.

These decreases are sensitive to the level of intensity of the feedback. There is a window at any time in which the feedback intensity will decrease the amplitude and variability. If the intensity is too low or too high–a Yerkes-Dodgson curve–amplitude reduction will not occur. In fact, if the intensity is (resonant and) too high, the amplitudes may rise, as mentioned above.

The range of intensity in which the amplitudes drop will vary with the phase of treatment. For those with the energy and stamina, higher levels of feedback will decrease amplitudes and standard deviations early in the treatment. As treatment progresses and the patient becomes more sensitive and less hyper reactive, the intensity will need to be reduced in order to continue to reduce the levels of activity. Reducing the level of intensity is necessary to reduce the amplitude and standard deviation, and to increase the functioning the patients.

These evoked (by feedback) amplitude and variability reductions may reflect, on a neuronal level, organic events which parallel the recovery of energy, mood, and cognitive capacities. These alterations in functional reactivity appear to represent the quieting of the brain, and the containing of emotional and attentional impulses in a state of ambient readiness. The recovery of skill was apparent in both those who had clear mechanical and physical trauma, and those who suffered lifelong energy, emotional, anxiety, and cognitive functional problems.

This lowering of the EEG's amplitude using the LENS stands in contrast to other attempts to increase amplitudes of the same EEG bands using traditional EEG biofeedback. Whether it is the feedback itself, the desensitization process, alternate offset polarity, or some other element of the procedure that automatically affects the amplitude and variability decrease, the key point is that these decreases occur in the LENS process without the treatment directing this, which is so characteristic of traditional EEG biofeedback. The implication is that some element(s) in the LENS treatment process triggers a self-organizing/corrective mechanism in the brain which optimizes functioning, and which requires no conscious involvement of the individual receiving the feedback.

In addition to the frequent appearances of EEG slowing, we encounter infrequent instances of patients with EEG suppression, or very low amplitude and low standard deviation EEG activity. These have been most frequently seen in chronic fatigue and fibromyalgia, and usually interlaced with depression. Depression, seen apart from occurrences of chronic fatigue, is most often accompanied by elevation in EEG activity. Ordinarily we have screened out those with unusually low amplitude EEG activity (less than 1 μV) because they have been particularly refractory to our methods.[2]

One more type of EEG activity is important to mention: normal or high amplitude EEG activity, accompanied by standard deviations of below 1. The EEGs of those with these abnormally smooth EEG recordings are often seen to show dramatic rises in elevation following LENS treatment, often accompanied by increases in functioning. This appears to be a due to a treatment-induced lifting of suppression of the EEG. The increase in functioning may be due to the freeing of energy bound by the neurochemistry of suppression. Those with problems functioning speak of the enormous effort it takes to think, organize, plan–in short to compensate for both their symptoms and due to the suppressive effects of neurochemical protection.

Diagnostic Considerations. The LENS has been successfully and reliably used with autism, Asperger's syndrome, post-concussive disorders, depressive disorders, post-traumatic stress disorders, attention deficit disorder with and without hyperactivity, chronic fatigue syndrome, fibromyalgia, and spastic paresis following cerebral vascular accidents. The improvements have been significant enough to have made noticeable differences in the lives of patients, both at home and at work. It may be more useful to think about the above disorders as variations of a single disorder (cortical permeability or insufficiency), in which the cortex is inadequate to the task of inhibiting the bioelectrical activity.

The Potential Central Locus of "Peripheral" Problems. Most pathology is treated peripherally, even when there are known central nervous system mechanisms. To date, peripheral treatment has been attempted though exercise, diet, etc., except where frank neuroleptic or neurosurgical intervention has been involved. For instance, fibromyalgia is typically seen as a muscle problem, since the tender points have been muscular, even though the balance problems, mental fog, and fatigue are typically seen as central problems.

The LENS provides a behavioral way to directly influence central mechanisms versus the indirect means used in traditional EEG feedback. With the LENS, the signals picked up from the brain are ultimately fed back into the tissues of the brain. The information the LENS feeds back to the brain has no graphic or symbolic meaning, as does the information from traditional EEG neurofeedback, so there is nothing to interpret. However, while the information is fed back directly into the brain, it is also not targeted (i.e., certain frequencies are not associated with particular functions) and there is no selectivity of where the feedback signals go in the brain.

It is true, however, that only one site at any one time establishes the resonance source for the feedback and that is the site of the active electrode. So while the feedback is believed to permeate all of the brain tissues and is non-specific in that sense, it remains resonant only with the site of the active electrode, the site whose dominant frequency is generating the basis for the feedback signal (feedback frequency = dominant frequency + offset).

The extent of the promise of this approach can only be imagined. Emerging theories of brain function, specifically with regard to the self-organizing capability of the brain, will find the LENS a significant intervention model for both clinical treatment and pathology simulation studies.

The Corrected Technical Inadequacy Uncorrected: Alternating Hemispheric Feedback. One of the more interesting sides of exploring the LENS has been the extent to which preconceptions about accuracy have been unnecessarily attached to efficacy. There were clear inaccuracy problems in our first generation software, causing the left and right lights to strobe 180 degrees out of phase. It was assumed that they had been flashing in phase synchrony. When the lights flashed at lower frequencies, however, they were observed to flash together only inconsistently. The asynchronously flashing lights were called to the attention of the programmer with the intention of emphasizing how remarkable it was to obtain good results with phase dyssynchrony.

As the second generation software was developed, left-right flash phase synchrony was initially looked at as an imprecise sloppiness, and not included. While the desensitization process seemed identical in the second-generation system, the results seemed to hold less well–until the programmer was persuaded to supply an option for permitting the lights to strobe 180 degrees out of phase. Additionally, it was suggested that alternating hemispheres were stimulated with the left-right alternating feedback. This strategy seemed to inhibit high voltage activity relatively rapidly across the spectrum. The use of alternating light feedback was especially useful later in treatment. Using alternating feedback as the first element of treatment prevented treatment from having the carry-over between sessions that it did when it was used later in treatment, wherein it appears to amplify treatment effects. The transfer of learning value from alteration of phase later in treatment may correspond developmentally with the acquisition of stereoptic vision.

Initially, it looked as if the work with alternating sides flashing might be an example, subject to experimental verification, of the power of accidental digressions from pre-planned designs. Initially it looked as if the left-right alternating stimulation was extremely significant in a number of ways. However, years later, the question changed as to whether this was just another way of reducing the intensity of stimulation, only providing 50% of the intensity at any one time. This question could be resolvable now by doing a thorough analysis of the electromagnetic field emitted by any visual stimulation device so that the concurrent visual and electromagnetic influences can be understood for their individual contribution to any observed phenomena.

Consciousness Is Optional. Psychologists and traditional biofeedback therapists tend to hold to the model of treatment as a conscious process. Yet an unknown percent of patients receive therapy that is primarily conversational for long periods of time with minimal concrete results (even though they may report feeling better). Non-psychotherapeutic psychiatrists, on the other hand, tend to see medication as the primary component in the recovery and symptom alleviation/management process, relegating the patient's conscious participation and learning a secondary, if not functionally irrelevant role.

The LENS appears to offer a behavioral non-pharmacologic, non-surgical and non-psychotherapeutic way to influence behavior, cognitive function, and feeling states, especially with regard to symptoms that result from mechanical and/or psychological trauma. LENS is behavioral and not medical because the signals are profoundly minimal in intensity. It seems likely that functioning, and not structure is directly influenced; the adaptability of the individual and subsystems of the individual are influenced, and adaptability is learning.

Our subjects show significant decreases in EEG amplitude and standard deviation without specific instructions to suppress this activity. LENS, therefore, complements both pharmacologic and psychotherapeutic techniques. Conscious self-development associated with psychotherapy can be valuable, but can proceed better when the patient's consciousness is clearer and thereby more able to process information.

Is It Self-Regulation Even Though It Is Not a Conscious, Deliberate Process? The use of the LENS has been criticized as inducing passive change in the patient, which has little chance of promoting either a sense of empowerment or long-term change in the patient's psychological status. It is here hypothesized that the LENS, instead, shortens treatment by eliminating a major portion of the time-consuming feedback process, clarifies the patient's tendencies to control the inner flow of conscious experience, and still permits the chance to desensitize, drop defenses, and allow neurochemistry to return to productive homeostasis. Further, the EEG disentrainment supports, but does not force, the patient to experience unfamiliar states of consciousness that enhance the chances of recognizing these states with further treatment. While the person receiving the LENS treatment may feel as if they are "not doing anything" and are not involved in a conscious learning process, they have nonetheless brought themselves to a setting that is structured to allow their brain to adapt and learn at a neurological level.

Traditional neurofeedback therapy undoubtedly contributes to the acquisition of self-regulatory skills, as well as operantly conditioning healthier brainwave patterns. However, the elimination of the lengthy and hard work in front of a computer screen with LENS treatment still seems to promote acute patient awareness of the operation of his or her defensive structure and process. The acquisition of a state of passive-allowing of experience seems facilitated by the LENS as it increases the patient's awareness of being drawn into different states of consciousness.

Most of our self-regulatory processes are non conscious, and not voluntary. To take on a mission of micromanaging even a significant portion of these non conscious processes seems to me to significantly reduce one's available conscious resources for tasks usually requiring large amounts of consciousness: learning new skills, and appreciating and enjoying life. It seems ideal to me to find ways to maximize our non conscious skills, so that we can find greater ease and clarity for our conscious lives.

Is the EEG Really Necessary to Drive the Feedback? This question is of central importance. If the EEG is unnecessary to enhance the clarity and ease of our conscious experience, then ways can be found much less expensively to efficaciously use the fixed and/or pre-set frequency feedback in treatment.

There were several inadvertent triple blind studies conducted during the history of the LENS. Triple blind studies are ones where even an experimenter does not know who gets what procedures. Not only were the subjects and machine operators blind to the study, but I knew only in retrospect exactly what happened. Unbeknownst to me or anybody else, during the use of our earlier light feedback system, it was discovered that the EEG had somehow been disconnected from the lights and that the flash rate had remained at 4 Hz regardless of the instrument readings to the contrary. After some investigation it became clear that there was a bug in the program, installed by accident by the programmer after he "upgraded" the software. This bug prevented any change in the LENS programming without effectively disconnecting it from the EEG.

Reviewing the records of the half-dozen patients seen during the time of the problem, all were found to have regressed during the period that the EEG was disconnected from the visual feedback. They were all either more hypersensitive, or more depressed. Patients were provided with enough free treatment to correct the problem and they began to progress again.

This experience yielded several different conclusions. First, it appears that using the EEG to influence the feedback stimulation rate is indeed necessary and useful. Second, programs that were developed that intuitively compensated for the irritating fixed-frequency feedback by dropping the intensity of the light feedback that was originally used further reinforced the utility of very low intensity levels. Third, the default fixed frequency was changed from 4 Hz to 20 Hz, to guard against inadvertent delta and theta feedback occurring in the event of a programming error. Last, considering the actual effects of over stimulation conditions in replicating pathological states and functioning, it may be possible that we can better study central nervous system problems by using the proper kinds and levels of feedback stimulation to experimentally replicate and even temporarily evoke problems in the brain to more accurately study brain functioning, impairment and recovery.

Frequency of Treatments. The optimal treatment schedule is one that leaves the individual refreshed. There is no treatment schedule that affects everybody the same way. Treatments can be effective when delivered on a daily basis if the patient can tolerate this level of feedback. On the other hand, it is possible to leave the patient slightly disoriented, fatigued, and with a headache from sessions which are too frequent or long in duration, or where the offset is too low. While each patient is different, these factors generally underlie clients' reported post-session discomfort. With such patients, much less frequent treatments may be the ones that speed the course of treatment the most. Treatment effects do appear to need a critical mass of treatments to overcome the rigidity of the system that perpetuates the symptom systems and pathology.

The therapist must be willing to rely on the signs of subjective discomfort of the patient, such as fatigue, rigidity, obsessiveness, and depression that will not respond, and be willing to take the risk of giving too little feedback by reducing the stimulation even to such small amounts that it seems ridiculous (i.e., one second per month) if need be. Thus while the range of feedback intensity dose can be enormous (e.g., ranging from three sessions/day to six seconds per week) the primary cues for decision making all come from the patient to the therapist who is willing to risk anxiety and the appearance of being foolish, but who will, to advance the welfare of the patient, reduce feedback intensity.

One of the seductive elements in the use of the LENS is that longer treatment sessions can appear to work well for some treatment populations, such as autistic children. This may fit into preconceived ideas that a therapist may have about the necessity of lengthier sessions. The consequence of longer sessions is that while they work in the short term, on a week-to-week basis they contribute to a slower pace for the occurrence of improvements. The therapists maintain that longer sessions do work for this population. My response is "But have you tried briefer . . . ?"

Duration of Treatment and Factors that Determine Treatment Length. The degree of sensitivity to the LENS feedback, how rapid the rate of desensitization, and the pre-existing duration of the symptoms and efforts to compensate for them are the best determinants of the duration of treatment. For example, the average duration of treatment for a formerly high functioning, multi-tasking patient who had a head injury 2.5 years prior to treatment, is approximately 6 sessions with seven or fewer seconds of feedback during each session. If the person had lifelong problems prior to the trauma, the treatment time ranges from 40 to 70 sessions. If the problem is severe post-stroke or spinal cord bruising paresis, the course of treatment may number into the hundreds of sessions. However, for those with mild to moderate stroke, even with paralysis, shocking relief from paralysis may be seen in between 6 and 14 sessions. An average of three sessions has produced startling results with people who have been overly stressed by work and/or home conditions over several years. No matter if the patient is suicidal, if they were high functioning before the protracted stress their treatment has averaged three sessions.

Reducing Treatment Time with Offsets. The antecedent systems to the LENS were designed with offsets from the start, originally to reduce the chance of elaborating a seizure that might have been triggered by the original bright flashing feedback lights. At that time offsets were called "leading frequencies," because it was thought that they led the dominant frequency to rise or lower. The term "offset" was felt to be more descriptive.

If the feedback signal frequency could never equal the peak, or dominant frequency, two effects were anticipated. First, the feedback frequency might not elaborate seizure activity if there was a tendency toward seizing. Second, the offset feedback frequency might shift energy away from the seizure frequency, which would be the peak EEG frequency at that time. In drawing energy away from the dominant frequency, the amplitude of the dominant frequency would be lowered, corresponding to the effect ordinarily seen.

Defining Frequency Offset. The offset evaluation originated from examining patient data in a typical year-end review. Up to that time we rotated through each of the standard offsets of 5, 10, 15, and 20 Hz at each site we treated. During one particular year-end review of data it was noticed that patients considered more sensitive showed lower EEG amplitudes during the periods when higher offsets (15 or 20 Hz) were used; and patients considered more reactive and less sensitive showed lower EEG amplitudes during the periods when the lower offsets (5 or 10 Hz) were used. If higher functioning levels accompanied lower amplitudes, then it might be wasting time to expose patients to offsets that didn't do much to lower their amplitudes. The task then became to design an evaluation that demonstrated the EEG response to each of the standard offsets. It initially used a baseline of one minute, followed by each of the offsets, structured as follows:

- One second of feedback with an offset of 5, followed by one minute of post baseline monitoring
- One second of feedback with an offset of 10, followed by one minute of post baseline monitoring
- One second of feedback with an offset of 15, followed by one minute of post baseline monitoring
- One second of feedback with an offset of 20, followed by one minute of post baseline monitoring

To reduce the possibility that relaxing during the 1-minute baseline would affect the EEG amplitudes during the stimulation, the baseline was lengthened to six minutes to be sure that the patient had stabilized in relaxation before being exposed to the first offset. If the amplitudes of delta and alpha are measured after exposure to feedback at different offsets from the measure dominant frequency, the amplitudes resulting from each offset can be assessed. The offset that produced the lowest band amplitude would be the one to select during treatment to achieve maximum decrease in amplitude activity.

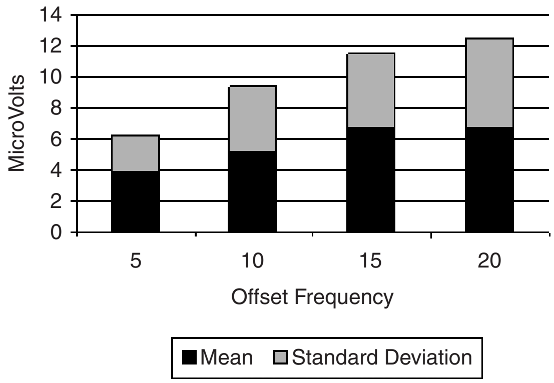
The problem with providing several different offsets in an evaluation, if the offsets are presented in the same order, time after time, is that order effects may be influencing the results. In fact, it is probably true that order effects influence the observed responses of EEG amplitudes to the offsets. To randomize the order of presentation, however, brings its own problems. In order to prevent the patient from being over stimulated, there is limited opportunity to present stimulation during any one session. Offset evaluations ordinarily provide a significant dose of four seconds of stimulation, and are reserved for those patients who are sturdy enough to tolerate them. So it seems inadvisable to do a comprehensive presentation of stimulation with counterbalanced orders of presentation and hope to find the "real" or "right" offset. Rather, the offset evaluation is viewed as a starting place from which to derive the offset.

Interestingly, it was found that the numbers defined as offsets have face validity. A patient who is reasonably insensitive and foggy at the start of the treatment will often have an offset closer to 5 or 10 Hz. If the patient, in later treatment, declares that they are not much clearer and better functioning, one would expect that a repeat offset evaluation will show the offset redefined at a higher number. The patient, then, will also seem more discriminant, less foggy, and more functional. And in fact, the repeat offset evaluation often redefines the offset at closer to 20.

Figure 3 displays an example of an offset evaluation. It shows the response of the delta frequency band amplitude and standard deviation to one second of feedback stimulation at the four different offset frequencies of 5, 10, 15, and 20 Hz. It can be seen that the most effective offset frequency for reducing delta was 5 Hz.

Does the EEG Change with LENS Stimulation? There is usually a question in the minds of both the prospective patient as well as the pro-

FIGURE 3. Delta Response to Different Offsets



spective therapist about whether the LENS actually changes the EEG. After all, therapists using traditional neurofeedback complained that they saw relatively little change in the EEGs of some of their patients. While change in the EEG itself may or may not be correlated with achieving the kind of change that a patient wants, at least it can serve as encouragement that something positive may happen sooner rather than later. The offset evaluation has three purposes. First, as above, it empirically defines an offset. Second, it provides a chance for the non-sensitive patient to put a toe in the water and experience a standardized dose of feedback. If the patient is known to be very reactive (e.g., to light, sound, medications, weather changes, foods, odors, and other people), one can presume an offset of 20, and use a less demanding procedure than the offset evaluation to provide an experience. In either case we use a test dose of feedback stimulation to be as sure as we can that the experience leaves the patient comfortable. Finally, we can compare the baseline and feedback sections of the evaluation to see if the EEG has changed in amplitude and standard deviation.

We have two choices in selecting an offset frequency to use in LENS sessions. One choice is to use the graph of delta responses to the alternative offset frequencies. The other choice is to use the alpha responses. Delta activity has always seemed more responsive than alpha activity, perhaps because alpha activity may be more genetically determined. Therefore, we use the graph of delta activity for selecting our offset frequency. This choice has proven more successful than using alpha offset for reducing elevated amplitudes across the frequency spectrum. In addition, delta offset responses are favored over the reactions to offsets within the theta band because clinical experience has shown that using delta offset data was most effective in reducing both delta and theta activity (in comparison with using theta offsets).

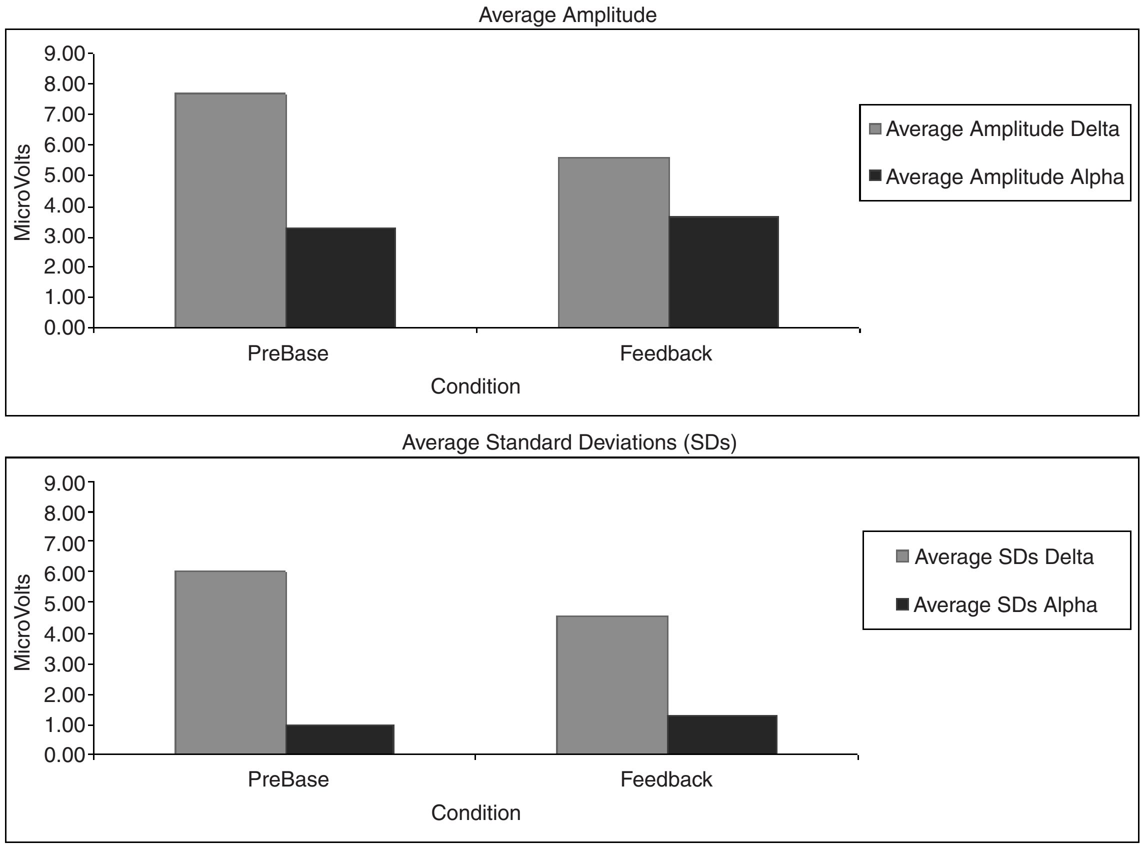
In Figure 4 it is clear that delta amplitude and standard deviation dropped from the baseline following feedback. In contrast to Figure 3, this figure presents the average of data from all four of the offsets. However, it also shows that alpha amplitude and standard deviation slightly increased. This demonstrates that measurable EEG changes can be documented in a brief ten minute evaluation, with as little as four seconds of feedback being given during that time.

Reducing Treatment Time with Brain Mapping. Quantitative EEG (QEEG) was discontinued in the early 1990s because it did not offer clear and reliable guidance in defining which sites to work with and in what sequence. The LENS practitioners were seeking treatment planning answers about patients who presented more complex problems. These problems created uncertainty about how best to bring about progress, and especially in choosing electrode sites. A useful mapping system would graphically specify the order and sequence of sites to treat. The operational definition of an "appropriate" electrode site is one with reduced evoked EEG amplitude within five minutes.

It has been our clinical experience that by simply mapping the amplitude and standard deviation of the EEG at 19 or more electrode sites, we can specify electrode site sequencing and placement. As a basis for treatment planning with LENS this seems to speed the rate of EEG change, wasted treatment time is avoided, and discomfort is minimized by choosing and treating multiple electrode sites during each session, following an order from lowest amplitude/variability to greatest amplitude/variability.

EEG Coherence Issues. EEG coherence is correlated phase activity in a frequency band between different EEG sites. Variability in the form of standard deviations can also be correlated, but is usually not talked about in relation to coherence across electrode sites. Interestingly a major EEG reference makes no mention of coherence in its index (Niedermeyer & da

FIGURE 4. Offset Evaluation: Averaged Frequency and Standard Deviation Changes



Silva, 1999) making the following discussion highly speculative.

The Clinical Side of Coherence. There are patients who are easier to treat, and those who are more complex. "Easier" means that amplitudes reduce and stay low at the sites treated. The easier patients do not suffer an exacerbation of their symptoms after initial treatments. "Complex" means that (a) frequency band amplitude at any site may increase after it lowers, (b) another frequency band may increase in activity at the site monitored, (c) band amplitudes at the same site may see-saw (alpha and delta amplitudes may see-saw), (d) band amplitudes at one site may fall while the same band amplitudes may rise at a different site, and (e) symptoms may flare up after the session. Coherence problems may be recognized by any of these items. On the topographic maps, map areas showing pools of the same color are, in fact, showing areas with the same amplitudes of activity within a frequency band. The sites, then, have correlated amplitudes which may reflect the probability of high coherence. A review of 100 topographic maps, sorted into piles of low-to-high areas of similar amplitude was roughly correlated with patients who were, respectively easy-to-hard to treat. This evaluation was crude and bears systematic and precise investigation.

Hunches About Coherence and Systems. Correlated activity may mean that the activity occurs in a system, an integrated pattern. As with any system, the activity as a whole behaves different than the behavior as the sum of the parts. Changes in the activity at specific sites that are part of a system would be expected to be more resistant to change, and especially to lasting change. Therefore, it is expected that a system would need to be worked with as a whole system, rather than at just at one or two sites.

Components of Systems. There are three major components of systems: (a) sites that are not involved in a system, (b) sites that react to the activity in a system and either amplify the systems activity or dampen the system's activity, and (c) the generators of the system's activity, influenced by the other components. When a site responds to treatment and remains affected without rebounding after the session, it acts as if it is unrelated to the system. If there were no system present, as is sometimes the case, the person would experience a "miracle," a sudden and noticeable reduction in symptoms.

Ramifications of Coherence for the LENS Treatment Planning: A Story. As a metaphor, let's say that there are three types of people in a riotous intersection. First, there are the bystanders. They are the ones who are easily moved by those trying to reduce the noise in the intersection. They are not particularly involved in the activity, and do not contribute to the noise. But their presence does encourage the others fomenting the noise.

Second, there are the collaborators. They have varying degrees of interest and involvement in generating the noise in the intersection. They provide reinforcement and energy for the instigators of the noise and they derive satisfaction from their involvement. The degree of ease with which the collaborators can be moved is a function of their relationship with the instigators, and with the amount of energy they have. Last, there are the instigators. They provide the energy for the crowd.

In any system, there are the energetic sources, the other components that are influenced and in turn influence, and the uninvolved parts. The trick for treatment is to discover how to move the less-involved parts, continue to reduce the overall energy in the system, and to nudge the system toward lower noise and greater flexibility.

It may be said that our job is to reduce the noise in the above intersection: to increase the ease with which messages are exchanged in the brain. If we ask each person in the intersection to move, the ones that first move will be the ones least involved: the bystanders. With the bystanders absent, there is less encouragement for the collaborators and the instigators.

The next to move will be the least motivated of the collaborators. Their absence provides still less reinforcement for the more motivated collaborators and the instigators, making it easier to move more collaborators. In a reiterative fashion, the crowd thins, with more collaborators losing motivation as it does. In the end, the instigators may or may not be moved. However, there is now much more room for traffic to flow and the intersection can be more functional. It is the function of the LENS map to empirically define which of the sites are bystanders, collaborators, and perhaps, the instigator(s)–the generators. Of course this is something of a conjecture and may to a large extent be unnecessary. However, it does provide a methodology for approaching the complex clinical pictures with which we deal. In fact, using the LENS map the way we do may be one of the factors contributing to the relatively short treatment times. There may well be alternative ways of organizing the treatment approach that could result in further reduction in treatment duration, more efficacious results, or both.

The Brain as a System. There are such things as simple problems. These cases generally have a sudden onset of symptoms without an inter-generational or genetic basis to the symptom. The treatments are even simpler for those people who were especially high functioning before their injury or trauma. Treatment of these individuals with acquired CNS problems is often a joy. They may be the cases shared among colleagues, the ones which impress the audiences, and propel the sales of EEG equipment. For these instances, it is quite plausible to apply traditional neurofeedback or the LENS method to one or two of the standard 10-20 electrode sites and watch the miracles happen. Unfortunately, informal surveys of therapists using all of the current models of neurofeedback equipment on the market evoke reports that from 50 to 80 percent of the time the therapists do not feel like they know what they are doing. They feel lost about treatment direction and disappointed at the results they are obtaining.

Achieving success with LENS at any one electrode site (i.e., reducing EEG amplitude and variability) can lead to behavioral rebounds and reactions such as transient hyperactivity or fatigue. When doing topographic maps sequentially at different electrode sites, it is quite apparent when the problems that a person has seem to be occurring within a system or multiple systems of activity as measured across the scalp. The complex cases invariably show many kinds of EEG activity (i.e., unwanted rises in amplitudes and variability) that are caused by isolated successes at the sites that were treated in isolation. If a site or a few sites are treated without recognition of the extant systems, then there are often untoward post-session problems.

This hypothesized activity occurring in systems may be the same as hypercoherence: the same frequency appearing at multiple sites across the scalp at the same time. If these sites are linked together, and if the therapist is treating one or a few of the sites, changes in those few sites will cause a reaction in the rest of the system which may both evoke strong concern or worry in the patient, and create management problems in treatment, as well as cause unnecessarily long and uneconomical treatment processes.

The topographic mapping process that we utilize holds promise to enable the therapist to understand how to approach the areas involved in the pathology in a graded, elegant way, and without any biases based on "known facts" stemming from neuropsychology or literature reports. Mapping reduces the chances that a statistically unusual site plays a prominent part in the functional pathology. It reduces the chance that the unusual site or combination of sites will be missed, delaying the problem's resolution.

The maps show the frequency bands' evoked amplitude undulations shrinking spatially, dampening, and eventually stabilizing in amplitude as treatment progresses. This translates into being able to observe the chaotic energy systems moving around and rearranging themselves across the scalp surface as they become electrically less noisy. The surface maps are transformed into other graphs that specify which sites are to be worked with, and in which sequence (see Figure 2).

Having these maps of evoked activity available also permits the therapist to compare current versus previously measured values. When there is too much of a discrepancy, the loss of accuracy indicates that the map is no longer a faithful guide to treatment and that another map is needed to accurately predict the strategic site sequences.

Sensitivity vs. Hypersensitivity. When patients first enter treatment they tend to see themselves as overly sensitive. In fact, they tend to be quite reactive, but quite insensitive. An extremely reactive individual is so reactive to stimuli and caught up in the emotional, cognitive, glandular, vascular, immunological, and/or motoric elements of the reactions that there is literally no opening for being aware of the stimuli. Hypersensitive individuals are rarely aware of much about their situations or of their feelings. They are aware of their reactions to these situations and feelings, rather than of the situations themselves. For example, they may be overwhelmed by their reactions of discomfort, or overwhelmed by the difficulty of taking things in.

The LENS ordinarily reduces the amplitude and variability of the EEG across the spectrum. In other words, the EEG becomes less hyper-reactive to the LENS feedback. This may be a function of the enormous dynamic range of the feedback intensity, which can potentially be varied by 100,000 gradations from the weakest to most intense feedback intensity levels. Turning the feedback on and off will at times show correlated amplitude and variability changes in the EEG on the screen, even though patients cannot feel the feedback. As the patient's hyper-reactivity drops, the patient tends to experience a subjective increase in ease, greater ability to follow conversations, to understand what is read, and to think more clearly. Clarity is a reflection of greater perceptual acuity and a lessening of mental fog. Often there are reports of increasing quiescence and decreases in restlessness. The intersection, as in the above story, has become quieter and more functional. Another way to put it is that the patient is becoming more sensitive–but less hyper-reactive. The result is that the patient is more aware of the environment and of inner feelings; more aware of likes, dislikes, needs, and satisfactions of those needs. The good and bad news is that while the patient can be happier and unhappier, there is more chance, because of decreased hyper-reactivity, to be more thoughtful about life.

Sensitivity: Its Acknowledgment, Management, and Benefits. The phenomenon of sensitivity to feedback intensity is one of the most intriguing aspects of the LENS. There is an apparent relationship between dysfunction and reactivity to stimulation. Patients express this verbally and/or motorically. This can also be observed during treatment as increasing delta, theta, or alpha activity across a number of sites, without a return to baseline within five minutes. These factors led me and my colleagues to consider alternative treatment models arising from our new views regarding brain trauma and its resolution.

The apparent plasticity of the dysfunction under the feedback of the LENS itself casts considerable doubt on the traditionally held view that much post-trauma dysfunction is attributable to the trauma; perhaps it is largely attributable to the brain's own protective mechanisms. Rather than working with trauma-induced brain damage, in the case of brain injury we may need to be working with the brain's own self-protective neurochemical systems.

What is most important is that we apparently are far more sensitive than we have ever expected, at least when we become injured or in any way dysfunctional. Much of the medical establishment, and to a certain extent the psychological rehabilitation establishment, has taken up the "Jack LaLane" exercise, gain-through-pain approach to rehabilitation. This was the mentality which was originally applied to the LENS work until it was recognized that the opposite was the only approach that consistently produced positive outcomes. It has turned out that the more we take into account sensitivity, making treatment as gentle as possible in previously unimaginable ways, the neuronal strength of the patients has been supported, and recovery follows far more often than not.

This shift in paradigm regarding the units of analysis, intervention and mechanism of action often means that the feedback intensity is kept to a minimum. During the early sessions the therapist needs to know how to be content to make very small interventions until the patient, with decreased symptoms, becomes ready for more pungency in the feedback. It has only been when the patient's sensitivity has been carefully considered that maximum speed of treatment is achieved. Otherwise valuable treatment time is spent recovering from treatment-induced relapses.

Suppression. EEG activity suppression. Almost without exception, all relatively high amplitude EEG band activity drops (even with high beta) following LENS feedback. However, low amplitude and standard deviations can and do rise. When this occurs the low activity is understood to have been suppressed. Prescription medication can cause this kind of suppression. Internal automatic self-medication with perhaps inhibitory neurotransmitters might also cause this kind of suppression.

At first it was thought that the rises in amplitude that occur with the LENS treatments were signs of over stimulation and signs of pathology. However, it has become apparent that most amplitude and standard deviation increases occur in the context of increasingly competent functioning–although not infrequently in the context of some narrowly defined and extremely disruptive symptoms. For example, while the patient is becoming more relaxed and less depressed, there may be an increase in seizures, tics, temper, muscular pain, toileting accidents, and perhaps substance abuse. These are not seen as side effects of treatment now. In contrast, they are now seen as transition states during which short-term compensations and inhibitions have been released. They occur in those with histories of the observed problems. It may be that the very problematic, potentially dangerous, and most likely socially very embarrassing symptoms were intuitively suppressed–and most likely forgotten, until the current treatment.

These symptoms, depending on their pathology and severity, typically last a week, and then remit. They may also re-occur when a virus, other infection, or other body change is still pre-clinical and unobserved. However, after one or two infection or bodily change cycles, they no longer appear.

It is extremely important that each prospective patient be interviewed for such previous historical symptoms. Their presence is not necessarily a contraindication for the LENS approach. But if they were present at one point in his or her life, it is a chance to ask the patient whether the symptoms for which he or she is seeking relief are important enough to out weigh the risk of re-encountering for a short time the intensely problematic symptoms from earlier life. It takes a relatively short while, during treatment, for the brain to integrate–rather than inhibit–problematic pathophysiology, and thus bring marked relief.

The What, Why, and How of the LENS. There are three considerations concerning the LENS and its mechanism: What is happening, why it happens, and what treatment strategies bring about the effect. These can be labeled, respectively: permeability, inhibitory neurotransmitter activity alterations, and applied chaos theory. The statements addressing each area of concern are testable.

What. Changes in cortical permeability: It has been observed that individuals with chronic central nervous system functioning problems have higher levels of recordable low frequency electrical activity at scalp sites. It has further been observed that as the functioning of the individual improves with treatment, the amplitude of the EEG diminishes across the spectrum at each scalp site.

On a descriptive level, the most parsimonious way to picture what happens as functioning improves and as the measured evoked EEG amplitude drops, might be in terms of decreasing permeability of the cortex: the higher amplitude activity probably remains present subcortically. It may be that it is simply not measurable at the scalp surface as the cortex re-assumes its integrative capacity and blocks the appearance of the higher amplitude subcortical activity at the surface. The use of indwelling (needle) electrodes at various depths simultaneously may help differentiate cortical from subcortical activity, and show with treatment, evidence of increased cortical activation as differentiated from subcortical activity.

Why. Inhibitory neurotransmitter activity alternations: Feeding back frequency information that is different from that which is measured, but nevertheless still a function of the frequency measured, may place different neurochemical demands on the synapses which feed the measured activity. If there is post-traumatic inhibitory neurotransmitter activity interfering with cortical function (i.e., making the cortex more permeable) and if the mechanism perpetuating this activity is disturbed and is altered, then the synaptic neurotransmitter mix might be altered to once again permit decreased permeability and proper cortical functioning.

How. Applied chaos therapy: Most neurofeedback treatment focuses on the shaping of activity in one or two frequency bands through voluntary controls at one or two sites. One of the complaints about the duration of neurofeedback treatment is that it takes too long and is too expensive. The sites commonly treated are, as often as not, the ones showing the highest measured amplitudes, making the task from the start a difficult one.

While treatment of acute patients with good premorbid histories may respond to a simpler treatment strategy, such a strategy may not suffice for patients with complicated, life-long histories and symptoms. In contrast, without trying to speed or slow the EEG activity, the LENS addresses all of the of the standard 10-20 system scalp sites as a method to control the feedback in a sequence based on a ranking of site-permeability (irritability) from least to most. By using this method, the activity at both the sites that have problems in isolation, and at sites that act in coherence systems, can be decreased in a predictable manner. This may reduce treatment time and expense in complicated cases, and increase the longevity of a positive outcome.

CONCLUSION

The LENS has shown significant effects in the treatment of a variety of CNS mediated disorders. Ongoing research will be required to fully understand the mechanisms of action and algorithms for directing treatment (e.g., site selection, feedback intensity, duration, etc.). The following are some tentative conclusions regarding the benefits and underlying principles of the LENS.

Treatment benefits include: decreased feelings of irritability, anger, fatigue, anxiety, depression, and decreased angina when caused by cortical problems. Improved mental clarity (decreased "mental fog"), sleep, energy, concentration, attention, short-term memory, improved vision and speech when due to cortical problems, and increased ease of functioning. Tangible clinical improvements are typically noted within three to six sessions. Reductions in EEG amplitude and variability will often be noted within the first five minutes of the first session.

The LENS in the Current Social/Scientific/ Clinical Context. The following are issues of concern expressed by non-The LENS professionals.

Invasiveness

In contrast to traditional EEG feedback, the LENS could be considered minimally invasive.

The field strength of the stimulation is only 10-18 watts/cm2, which is far less invasive than medication or electroconvulsive therapy, and microscopic in comparison to transcranial magnetic stimulation or even in comparison to the stimulation received from holding a cell phone to one's ear.

Other-Directed (Therapist Regulated) vs. Self-Regulation

Two attitudes are interwoven in this controversy. One idea is that consciousness is a requirement for self-regulation. If the regulation that occurs is not conscious and intentional, it is not self-regulation. Yet the spinal cord and lower brain centers are not only responsible for many of our life-support systems, but they also can learn and adapt quite nicely without conscious intervention. In other words, we may be just as smart subcortically (and unconsciously) as we are consciously. So it seems wasteful to devalue non-conscious self-regulation and to throw away resources that can be mobilized for learning and life enhancement. Furthermore, although conscious effort and work is involved with traditional neurofeedback, it is not so much teaching self-regulation as it is facilitating the operant conditioning of healthier brainwave patterns.

The second controversy is the locus of control issue, or who is in control, therapist or patient? This issue seems to be grounded in the naïve belief that traditional biofeedback places the patient in charge, and that he or she is truly engaged in self-regulation. There is, of course, the implication that when a therapist is administering an energy field, the process is controlled by the therapist. In fact, the design of the treatment protocol used in traditional biofeedback is also under therapist control (i.e., whether to enhance a particular high frequency activity and inhibit low frequency activity). Further, the operation of the threshold, which determines which EEG activity gets which kinds of reinforcement, is likewise under therapist control in traditional EEG biofeedback.

Similarly, the therapist is clearly in control of the structure of the LENS session, but is guided by the patient's subjective sense of what is comfortable and uncomfortable. In contrast, when using the LENS protocols, the goal of the LENS treatment is flexibility of neural functioning, and there is no unilateral influence on the brain to either produce more fast-wave activity or more slow-wave activity. The patient's brain is left free to do as it needs to, when it needs to, as the amplitude and variability decrease across the spectrum.

Hopefully, both LENS and general neurofeedback procedures will maximize the ability of the patient to be self-regulating. However, it is naive to hold the premise that traditional EEG biofeedback places the patient in charge of the structure of the treatment, or that neurofeedback is teaching self-regulation in the sense of learning a conscious skill. It seems that the more important scientific concern needs to be: Under which clinical conditions is LENS or traditional neurofeedback most effective and efficient? Each system may have its own domains of applicability.

Physical or Psychological Harm

The Thalidomide tragedy has made everyone aware of the importance of looking at long-term effects of a prospective treatment, and rightly so. It is always worth reviewing the probability that wherever there is change, there is disruption. And whether good or bad, there can always be unpleasant as well as beneficial effects, even if the treatment is "entirely natural." One issue here is not whether there are "unpleasant side effects," but to identify what they are. Side effects or adverse reactions have been noted with traditional neurofeedback technology (Hammond, Stockdale, Hoffman, Ayers, & Nash, 2001) and in fact, if misapplied traditional neurofeedback has the potential to evoke iatrogenic effects, including seizures (Lubar et al., 1981; Lubar & Shouse, 1976, 1977). Once identified, the prospective recipient of the treatment can weigh the benefits against the risks of treatment. The unpleasant side effects of treatment discovered to date echo the unpleasant effects of any other kind of change process, whether it is hypnosis, psychotherapy, biofeedback, yoga, etc. With the LENS system, no patient over the last three years has ever reported a new symptom; that is, one that had never before been experienced by that patient. However, any current symptom, physical or psychological, can be temporarily exacerbated.

Another issue here is to differentiate unpleasant "side-effects" from disruptive signs of health and recovery. As people become clearer about their own reactions to a difficult, unpleasant, and even treacherous world, they are inclined to become more angry, sad, or anxious, and appropriately so. They are apt to become less tolerant of what ought not to be tolerated. However, it is the amount of increased thoughtfulness and productivity about the noxious elements of life that makes these reactions different from the hyper-reactive, blind reactions that characterized their lives prior to the LENS treatment. These considerations need to be made clear when individuals are considering LENS treatment.

Dearth of Literature

It must be acknowledged that apart from this volume, there is only a limited scientific research (Donaldson, Sella, & Mueller, 1998; Mueller, Donaldson, Nelson & Layman, 2001; Schoenberger et al., 2001) on the use of LENS. We know little about the effects of variable-frequency feedback on EEG activity. However, we now have considerable clinical experience in working with a number of diagnoses. As with most clinical areas of application of traditional neurofeedback, adequately controlled outcome studies with LENS are lacking. Therefore, the informed consent process with patients must acknowledge these facts to allow patients to make an informed decision about using a more investigational treatment.

Fear of LENS Treatment Being Too Rapid

Finally we should mention a frequently expressed concern about the LENS producing therapist unemployment because it is too rapid or effective. It is true that the LENS often reduces treatment time, making for more rapid patient turnover, and placing new demands on a'therapist's marketing skills. However, it also often increases a'therapist's effectiveness, opens up treatment as an option to new populations, and makes treatment more affordable and enjoyable. Further, it increases the number of patients a therapist can help in shorter lengths of time.

Summary

LENS is an innovative type of neurofeedback that has evolved over the past 16 years. It involves the use of very weak electromagnetic energy fields which are fed back to the brain based on the brain's dominant frequency from moment-to-moment. This feedback is usually effective in reducing high amplitude activity, in many cases shortening the length of treatment that is required in comparison with traditional neurofeedback. Treatment sessions are brief, and because of the minimal demands it places on the patient it is very appealing to some patients and opens up treatment options for new populations of patients. The nature of LENS technology will also facilitate doing double-blind, placebo controlled studies which can advance our field.

NOTES

1. Some proportion of activity in the different frequency bands seems healthy, with either too much or too little being potentially problematic. Delta, for example, seems to have a functional role in facilitating inner concentration by suppressing extraneous cortical inputs. A delta deficit can correlate with reduced frontal cortical regulation or gating of maladaptive behavioral impulses or extraneous cues, and can be found in conditions such as cocaine addicts, alcoholics, ADD, subtypes of OCD, and schizophrenia (Alper, Prichep, Kowalek, Rosenthal, & John, 1998). Increased theta band activity may be seen in highly experienced mediators, and increased delta and theta EEG activity have also often been found in association with various kinds of cognitive activity, such as performing calculations (e.g., Fernandez et al., 1995; Klimesch, Doppelmayer, Russegger, & Pachinger, 1996).

2. Offsets were originally implemented to reduce the possibility of exacerbating seizure activity and EEG slowing. When amplitudes are unusually low, an offset of zero may help to stimulate the physiology to increase amplitude. However, we have very little experience to state this with any confidence.

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doi:10.1300/J184v10n02_02

APPENDIX A

This article seeks to offer some historical background, an outline of the theoretical basis for how the Low Energy Neurofeedback System (LENS) works, and the approach to treatment which is evolving from the applied clinical work and research being initiated by OchsLabs. The LENS is still evolving at a rapid pace. It is thus impractical to conceive of this overview as being up-to-date for any length of time. The reader is cautioned to avoid any conclusion that this information reflects current practice. The reader is also cautioned to avoid seeing any information presented herein as a claim for the LENS to be efficacious for any condition, medical or psychological. This is the most objective depiction possible of the evidence on hand for its benefits and risks. No claims are being made.

The reader is cautioned that the purpose of this article is to enumerate some of the phenomena, issues, and concerns which were encountered, and not to provide a decision tree about which settings, options, conditions, and choices are to be made in any particular clinical instance. The information about settings, conditions, and treatment options presented are to exemplify the concepts. The actual number of options and considerations in the treatment planning process are outside the scope of this article. Further, there is still not enough concrete research-based information about the particular benefits or drawbacks of any particular setting or settings, or whether such settings are useful or necessary. Component analyses are needed to determine which conditions (protocols) are necessary and useful.

The reader of this article may find more questions being raised than answered. This is the nature of the opening of a new arena of observation and study. In this case, this arena is the area of behavioral biophysics: the interaction of resonant (feedback) physical stimuli on brain functioning. It is possible to ask of most of the statements in this article, "What is the evidence?" "Where are the data?" In fact, after 15 years of this exploration there is still a search for the fundamental questions. Furthermore, after 15 years, how to do research with the LENS is only beginning to clarify itself.

APPENDIX B
CNS Functioning Assessment

Name ______________________ Date of Birth __________ Age ______

Today's Date ______________ Time __________ Diagnosis ____________

Are you able to drive a motor vehicle? Yes Partially No **Are you able to work or study?** Yes Partially No **Are you able to sustain a close relationship with someone?** Yes Partially No

How frequently do you have problems in the following areas? Please pick a number from 0-to-10. "0" means *Not at all*, and "10" means *All the time*.

If one or more of your parents had this, or a similar problem, place a *P* in the column headed by "Parents?"

If the problem came on suddenly, put an *S* in the column head by "Suddenly?"

Sensory	Frequency (0-10)	Parents? Suddenly?
Light, in general, or lights, bother you	__________	__________
Problems with the sense of smell	__________	__________
Problems with vision	__________	__________
Problems with hearing	__________	__________
Problems with the sense of touch	__________	__________
Emotions		
Problems of sudden, unexplained changes in mood	__________	__________
Problems of sudden, unexplained fearfulness	__________	__________
Problems of unexplained spells of depression	__________	__________

Problems of unexplained spells of elation
Problems with explosiveness
Problems with irritability
Problems with suicidal thoughts or actions

Clarity

Feel “foggy” and have problems with clarity
Problems following conversations (with good hearing)
Problems with confusion
Problems following what you are reading
Realize you have no idea what you have been reading
Problems with concentration
Problems with attention
Problems with sequencing
Problems with prioritizing
Problems not finishing what you start
Problems organizing your room, office, paperwork
Problems with getting lost in daydreaming
You cover up that you don't know what was said or asked of you

Energy

Problems with stamina
Fatigue during the day
Trouble sleeping at night
Problems awakening at night
Problems falling asleep again

Memory

Forget what you have just heard
Forget what you are doing, what you need to do
Problems with procrastination and lack of initiative
Problems not learning from experience

Movement

Problems with paralysis of one or more limbs
Problems focusing or converging the eyes

Pain

Head pain that is steady
Head pain that is throbbing
Shoulder and neck pain
Wrist pain
Knee pain
All-over pain
Joint pain
Other pain (specify)

Other Problems

Problems with nausea
Skin problems
Problems with speech or articulation
Dizziness
Noise in ears (Tinnitus)