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Hemoencephalography (HEG)

by
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As so often happens in science, the development of new instrumentation has opened a new field. The new field of hemoencephalography (HEG) studies cortical hemodynamics: vascularity, blood volume, oxygenation, metabolism or temperature in real time. This study is developing information vital to the well being the cerebral cortex.

The new instrument, the near infrared spectrophotometer (NIRS), was first introduced by Jobsis in 1977, a student of Professor Britton Chance at the University of Pennsylvania.

Using these new instruments, NIRS, has led to the discovery that the vascular variables, blood oxygenation and flow, are voluntarily controllable. Voluntary control is leading to further discoveries of HEG's usefulness as a therapeutic exercise agent in neurofeedback. The discovery of voluntary control further led Jeff Carmen to explore a new use for an old instrument, measurement and feedback of cerebral temperature with an infrared thermometer.

In this paper Hershel Toomim and Jeff Carmen present case material derived from their work with HEG. Each has described a successful and an unsuccessful case The purpose of this juxtaposition is to help build criteria for successful handling of cases more difficult to treat with EEG.

Why HEG

HEG has the advantage relative to EEG of being almost immune to muscle artifact. Eye movement, for example, has no effect on the indications. This opens the frontal and prefrontal cortex to treatments very difficult with EEG. Relaxation is no longer necessary to protect the feedback signal from contamination with muscle artifact. Removal of the relaxation requirement allows more usual styles of intense concentration as required to motivate and enhance the effects of the HEG exercise training.

A salient advantages of HEG over EEG is the ease of learning control. The first part of one session usually suffices. The remarkable clarity of the HEG feedback signal simplifies learning and supplies a simple criterion for successful sessions. A 10% increase of HEG average readings in a 10 minute trial has proven to be a good, easily measured rule of thumb for therapeutic effectiveness. The goal, thus established, leads to more effective efforts on the part of the trainee.

New HEG instruments supply useful feedback signals from any placement. Targeting treatment to the affected brain area now becomes simple and fosters more efficient treatments. Treatments no longer must rely on connectivity of cortical areas to bring the treatment to inaccessible brain areas. No longer must we move to the light to look for the brass ring lost in the dark. This factor provides greater efficiency and helps provide for shorter less expensive treatments.

The simplicity of HEG application, and training evaluation makes home training practical. Measurement of gains with the new home based T.O.V.A. PC computer program empowers the home trainer to communicate effectively with a supervising professional.

The targeting possibilities of HEG makes the SPECT or QEEG coherence studies extremely valuable aids in defining the hypoperfused brain areas most likely to underly brain dysfunction. SPECT, QEEG, vascularity and HEG form a science foundation for neurofeedback and make the process understandable to the professional and layman alike.

A recent comparison of SPECT with QEEG promises to make QEEG a less expensive route to effective targeting of the therapeutic exercise.

I, Hershel Toomim, find the label "ADD" unhelpful in determining the course of therapy for its bearer. I find targeted treatments to those brain areas most involved in the functions limiting the child's development. more effective than my earlier work with generalized EEG. HEG makes targeted treatments convenient. Figure 1 shows the vascular effectiveness on Fpz of training at Cz to be approximately 10% as effective at Fpz as similar training at Fpz.

History

The technique of HEG rests on extensive investigation of the optical properties of cerebral tissue. The scientific and medical literature on NIRS contains more than 200 peer reviewed papers in premier journals of science and medicine. The field of optical examination through the skull of living cerebral cortices was introduced by Jobsis (Jobsis FF 1977), a student at the time of Professor Britton Chance of the University of Pennsylvania, showed that radiant energy, light or heat, easily penetrates the skull and carries information about cerebral tissue oxygenation.

It's not dark in there!

From that modest start extensive work through the years has made great progress. The NIRS instrumentation has since been brought to a high state of development by Prof. Chance, his students and collaborators. For a review see Elwell, C., Hebden, J. (1999) "Near Infrared Spectroscopy" This excellent discussion of NIRS can be found on the internet. It is now possible to see pictures of vascular brain events as they occur To see the latest imaging development see .Chance et al (1998) "A novel method for fast imaging of brain function, non-invasively, with light".

. Jeff and I are now engaged in modifying these events with **HEG neurofeedback.** I, Hershel Toomim, illuminate the brain with light and present the colored reflections to the client. Jeff presents cortical temperatures via infrared energy emitted by metabolically warmed brain blood. Both techniques are yielding efficient interventions in the alleviation of brain dysfunctions.

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Hershel's Cases

The following study compares outcomes of two 13 year old boys, George and John, initially similar in intelligence and attention as measured by MicroCog™, (General Cerebral Functioning and General Cerebral Accuracy) and T.O.V.A™ (Omissions, Impulsivity, Reaction Time, and Variability).

	George		John	
	MicroCog™	T.O.V.A™.	MicroCog™	T.O.V.A™.
first session	84,77	<40, 82, 110, 48 70, 71 ADD ----	98, 97,102, 45	ADD ----
10th session	85, 84	61, 90, 115, 102 ADD ---	89, 82	104, 120, 112, 104 ADD 2.69

Figure 2: MicroCog™ is normalized for 18 years and older. It is used here as a tracking device for youngsters 10 yr. and up. Scores shown in order: General Cognitive Proficiency, General Cognitive Functioning

T.O.V.A™. Scores in order: Attention, Impulsivity, Reaction Time, Variability

Differences:

Note the similarity of the two boys ten session MicroCog™ scores. MicroCog™ is a test of intellectual ability and both boys gained in the 10 sessions. T.O.V.A™. scores reveal another view. T.O.V.A.™ is more direct physiological measure than MicroCog™. It shows a marked difference in gain in the Attention score, from <40 to 61 for George and from 98 to 104. for John.. George was significantly impaired and failed to reach normalcy. John was normal in attention from the beginning.

Careful histories revealed significant facts:

George, a "crack baby", was adopted at age 3 from a drug addicted mother. He is a ten year member of his very caring aware adoptive family. His mother felt he had no conscience. He feels no guilt. She was afraid, before the birth of her new child, that George would harm the newborn child. Instead, George developed a caring, affectionate relationship with his new sister, Carla, and loves to be assigned for her care. George's history revealed he had had a severe trauma to the bridge of his nose at age 5 and has been subject to short episodes of feeling "weird" ever since. His school mates tease him about it. His mother was unaware of this result of the injury. With the history of maternal cocaine addiction and suspected seizures a SPECT study and Coherence QEEG study were ordered

John, an engaging youngster with a charming smile, is a juvenile actor earning significant sums toward his college education. His main difficulties were distractibility and trouble focusing on his homework. He was recognized as ADD by a neighbor who saw characteristics in John which were present in her ADD child. John's father, also suspected of ADD, is an authoritarian who expects perfection in his son. This is a source of continuing stress in the family deflecting the child's development .

Neither boy exhibited florid symptoms of hyperactivity although each showed some evidence of restless legs during testing. John reached a very high score for the T.O.V.A™ ADHD while George had yet to reach a measurable value.

Discussion

The initial MicroCog™ and T.O.V.A.™ tests revealed nothing unusual for ADD children in these two youngsters although John's lower MicroCog scores suggest he would fare less well than George.

The HEG ability for targeting treatment gives the SPECT study great usefulness. The SPECT location of hypoperfused areas mark brain areas with below normal activity which can be activated with intense neurofeedback exercise.

George's SPECT study showed significant hypoperfusion in the anterior poles of the temporal lobes, hypoperfused foci on the anterior poles of the prefrontal cortex, more severe on the right than the left. There is mild hypoperfusion on both cortices above the Sylvian fissure, Werneke's area on the left and the visual comparison area on the right. In addition, the right occipital pole shows significant hypoperfusion as does also the right basal ganglia. Significantly, the orbito-frontal cortices, in sagittal section views, show significant hypoperfusion. This area, as shown by Allan N. Schore, is the seat of emotional control and it's hypoperfusion is likely a residual of the neglected first 3 years of this young man's life. Kleist (1931, cited in Starkstein, Boston & Robinson 1988) considered the orbito- frontal cortex to be the center of emotional life, and to be implicated in ethical and moral behaviors. It is noted that there is some evidence of increased perfusion on the edges of these areas in George's SPECT study. One can speculate this is evidence of a repair process at work, probably attributable to his 10 years with his present family. It offers hope that such neglectful injury is not permanent. George, at present is a delightfully responsive playful youngster who took to his treatment with appropriate seriousness. There was no hint of hurt in his recall of his early life.

These considerations guided the selection of HEG treatment areas. Training was for ten minutes at each site, three to four sites per session. For both boys most of the ten session treaning time was shared among Fp1, Fp2 and Fpz while for George time at F7 and F8 was included and for John T5 and T6 were added.

The simplicity of HEG use makes home training practical. George lives in northern California where there are no known therapists using the HEG technology. His Mother mastered the use of the instrumentation in two days and began the study of the brain anatomy involved in George's

injury. She is now using a home HEG trainer to complete George's therapy. This course of therapy is expected to require 3 months of three hours weekly.

George's initial course of therapy at the Biofeedback Institute of Los Angeles was accomplished in ten consecutive days. This highly intensive exposure is considered to be less than optimally efficient. There have been no adverse effects noted. Time between sessions is required for vascularity to develop the capacity to supply more oxygenated blood to the exercised cortical tissue. Time for growth between sessions will require fewer sessions..

The treatment plan for George involves continued effort at Fp1, Fpz, Fp2, F7, F8, and Oz until the T.O.V.A™. normalizes.

George's brain, so clearly impacted by the bump on the bridge of his nose as shown by the hypoperfused prefrontal areas under Fpz and the contra coup area at Oz, will require upward of 40 targeted HEG sessions, far more than the projected 20 sessions for John. Without the targeting capabilities of HEG there would have been no use for the SPECT study. There would have been no guidance toward these critical areas.

No treatment is planned for the basal ganglia which is beyond the depth limit of current HEG instrumentation

John's HEG treatment plan focused on the prefrontal area where the initial T.O.V.A. showed excess impulsivity errors. These impulsivity errors maximized in half two The target, rare in half one becomes common in half two of the T.O.V.A. test.. John knew each time he made an impulsive error and noted each one with a gasp or body movement. This fact signaled that the inhibitory prefrontal cortex made the proper decision each time but failed to inhibit the button press. The inhibitory neural impulse failed to reach the critical brain area in time to inhibit the, by now, habitual button press. The frontal cortex was too slow!

Further, John's difficulty in retaining read material could not be traced to working memory since the MicroCog working memory sub test was his best score. Careful questioning revealed his spatial memory was also intact and his difficulty lay in Werneke's area where translation of the perceived word is translated into understanding.

These considerations led to specifying HEG targeted exercise at Fp1, Fpz, and Fp2 for frontal cortex speed improvement. Eye movement artifact would have precluded this choice if EEG were the instrument used. T5 was targeted for word translation area exercise while T6 maintained brain symmetry.

The validation of these choices is shown by the follow-on testing with T.O.V.A.™ and MicroCog™. After 10 sessions John measured in the normal range for T.O.V.A™. Even though he is only 13 years old he scored in the MicroCog™ normal range for 18 year olds boys.. His mother is happy with his progress in his studies and his teachers report significant improvement in reading. He no longer has to read everything twice.

John is continuing HEG therapy for a projected total of 20 sessions, even though his objective measures are in the normal range. This is mainly because his mother and I have no way to predict the eventual outcome.

George, on the other hand, still shows deficits in QEEG, SPECT and T.O.V.A.™. His mother reports he has been caught stealing and shows no guilt or remorse. His brain injuries clearly suggest continued training with no clear end as yet in sight.

Summary

HEG, in the two cases above illustrates a progression toward more efficient neurofeedback therapy made possible by the simplicity and targeting capabilities of the new instrumentation. HEG enhances the value of SPECT and QEEG coherence studies in shortening and clarifying objectives of the neurofeedback process.

Jeff's Cases

For several years prior to learning about Hershel's work with HEG, I had been using infrared technology to monitor migraine activity. I had also made some unsuccessful attempts at making the infrared data work within a feedback paradigm, eventually giving up on the idea. Once I realized that Hershel had succeeded in using vascular information for feedback, I tried some things in a different manner than before. Perhaps based as much on serendipity as anything else, the system worked.

My hope was to be able to gain enough control over vascular behavior to directly impact migraine activity. In monitoring the effects of this system however, I think the mechanism is a little different. I have been using it in exclusively an Fpz location, picking up data from a circle about 1.25 inches in diameter. This appears to activate the prefrontal cortex in a manner that improves neurovascular regulation. What appears to be happening is that the system responds to increased frontal perfusion. The perfusion is an effect and possibly also a cause of increased neural activity, which then improves regulation throughout the brain. It has not been a surprise that it has produced migraine prophylaxis. It has been a surprise that it can stop a migraine midstream, because migraine researchers have considered this stage to represent a kind of vascular paralysis.

I have actively used this system only since 10/1999, so there is no long term data. I have used it on migraine, attentional disturbances, depression and emotional control problems. Migraines tend to respond rapidly and consistently. Attentional problems respond rapidly but sometimes the effect holds and sometimes not. About 50% of the depression cases have improved rapidly and held with the other 50% showing no effect at all. I have only limited and variable data on emotional control problems so I am unable to say much at this point.

Although it is very easy to learn to increase the display on the meter, my impression is that unlike Hershel's 10% criteria, learning and possibly physiological growth occur only after the easy increases have been achieved and it has started to become difficult to produce further increases.

Time spent in this condition represents “exercise” of the prefrontal cortex. That usually occurs after an increase of about 3 degrees. That is the usual starting point for setting the thresholds to operate a video. This requires a combination of sustained mental effort with a relaxed affect. Thresholds are then changed upwards to maintain continued effort. Sessions are 45 to 50 minutes in length with 30 to 40 minutes of actual time connected to instruments.

I have selected two cases because they are both interesting and both completed. The first represents a success, the second less so.

Case #1:

This is a 40 year old woman, college graduate, professionally employed, married, referred by her neurologist for medication resistant severe migraine like headaches with aura (scotoma). The headaches had increased in frequency over a period of 6 years from occasional to daily. MRI and sleep deprived EEG were normal. There were no correlations with external variables such as time of day, day of week, month, weather. None of the standard prophylactic medications had helped. Prednisone stopped one headache but not subsequent ones. Imitrex in various forms reduced pain but did not eliminate the headache. She had a positive family history for migraine. She also had a tentative diagnosis of Systemic Lupus Erythematosus, which complicated the headache diagnosis due to the possibility of the pain being generated by vasculitis rather than migraine. Raynaud like spasms often preceded headache onset. Mental confusion occurred as an intermittent variable, without warning, lasting several minutes, and leaving without warning. Fatigue was chronic.

This is not an optimistic scenario. Some of the features present as migraine and some as vasculitis. Based on my experience with Lupus patients, my suspicion was that the headaches represented vasculitis, a disorder that is not responsive to biofeedback or neurofeedback. I was wrong.

Headache activity improved after the first HEG session, was gone completely after the fifth session and has not returned. The patient had a headache during the first and second but not subsequent sessions. HEG training had no impact on the Raynaud symptoms, nor did subsequent peripheral thermal training. None of the other symptoms changed.

Discussion: This woman has a migraine condition, now probably resolved. She also has probable Systemic Lupus Erythematosus that appears to be getting worse. In this case the headache activity really was migraine activity, probably familial, and probably not directly caused by the presence of an inflammatory disease process. It is likely that the disease process served as an aggravating variable possibly influencing the increased frequency of migraines. It is likely that the Raynaud symptoms were inflammatory as they did not respond to peripheral training.

Case #2:

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This was a highly intelligent 12 year old boy. He was referred by his pediatrician for dysfunctional patterns of attention at home and school with accompanied hyperactivity, meeting DSM IV criteria for 314.01 (Attention-Deficit/Hyperactivity Disorder, Predominantly Hyperactive-Impulsive Type. These patterns had existed since birth. No prenatal factors were identified, but a strong family history for similar behaviors was present. Unlike many children diagnosed with ADHD, he had a pleasant disposition, and presented no behavior problems. School performance was erratic through elementary years, but had deteriorated to a level of consistent borderline failing by middle school. His WISC III scores were in the 95th percentile range.

He could not sit still at home or school. Squirms per minute while trying to sit still averaged 60 per minute. Typical sustained attention by self report and also as measured with skin conductance responses was 5 to 10 seconds, while trying to maintain attention. He was easily distracted under all conditions and all locations, including home, school and my office. The short attention span and easy distractibility maintained even when engaged in activities that for him held high interest. He had an excellent response to Ritalin, but due to a coexisting migraine condition could not continue with it as it produced a rebound migraine at the end of the day. Even when not taking Ritalin, severe migraines would occur 1 or 2 times per week, accompanied by photophobia. The headaches were not a target of treatment.

Treatment combined a primary emphasis on HEG at Fpz for increased focus, along with a secondary emphasis on skin conductance for general arousal reduction training. He was a willing and active participant in the process. Improvements were noted in the first session, with all measures normalizing. Squirms per minute reduced to an average of 1. Measured and reported shifts of attention were only occasional with sustained attention typically exceeding 60 seconds. Skin conductance levels reduced from an average of 16 to 5 micromho's, with increased stability. His skin became less sensitive and less ticklish. I saw him at 8:00 in the morning for the first session. He had an abnormally excellent day at school.

I worked with this young man for 8 months, incorporating 20 sessions, primarily HEG with some skin conductance. Two response curves developed.

The first relates to his attentional patterns. Normalization occurred gradually over a period of 3 months. At the end of that period, his behavior was as well managed as when he was on Ritalin. Then it slowly reversed itself. By the end of 8 months, his behavior had essentially returned to baseline. It still normalized as soon as he was connected to an instrument, but deteriorated again as soon as he was "free" of the instrument.

The second relates to his headache activity. By the end of the initial 3 months he noticed that he was no longer getting migraines. This was a non-targeted symptom. The migraines have not returned.

Discussion: It is very difficult to say what happened here. The normalization of a neurological condition such as migraine suggests that there has been some neurological reorganization. The initial improvements in his ADHD related behaviors also suggests that, but the subsequent

deterioration is a curiosity. One hint as to the source of the problem comes from the young man himself. He stated that he likes himself much better when he is "hyper". He doesn't like the feeling that comes with being "steady". It seems that we may have ultimately entered the realm of personal choice.

Summary:

We have reported two sets of case studies using two different HEG systems. For the sake of perspective, each of us has chosen to report one case in which HEG was very effective, and one case in which it was less than optimally effective. The typical response to both systems has been a relatively rapid improvement in symptoms that often take longer to resolve with EEG and peripheral based formats. We have both found that HEG's freedom from eye movement artifacts and EMG artifacts makes working with the frontal regions of the brain easy rather than frustrating. Also, because of that freedom from artifact, it may be producing data for feedback that is more reliable and valid than EEG based systems.

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