EEG or HEG ? That is the question

by Hershel Toomim

The advent of blood oxygenation or its corollary blood flow as the prime source of feedback for training dysfunctional brain problems1, 2, 3, 4 has raised the question: Is there a reasonable foundation to make a choice between Electroencephalography (EEG) and Hemoencephalography (HEG) ? This paper considers the characteristics of each in an endeavor to make sensible choices.

The question can be approached from the examination of the effects on the brain of various brain exercises. With the experimental scientific literature as a guide some useful concepts arise.

Animals in enhanced learning environments compared to those in simple physical motor exercise environments develop different brain characteristics 5, 6, 7. Physical exercises tend to increase density of capillary density while mental exercise such as solving mazes emphasize synaptogenesis relative to angiogenesis. It is well known that physical exercise makes people feel sharper. Recently, the physical exercise has been shown to increase brain derived neurotrophic factor (BDNF) in humans 8, 9. BDNF is a brain protein essential to the development of neurons. It has been established that part of Einstein's brain had more than the normal complement of glial cells per neuron. This suggests that brain exercise activates human angiogenesis. A study of Einstein's brain by Diamond et al. states13 "The results of the analysis suggest that in left area 39, the neuronal: glial ratio for the Einstein brain is significantly smaller than the mean for the control population (t = 2.62, df 9, p less than 0.05, two-tailed). Einstein's brain did not differ significantly in the neuronal glial ratio from the controls in any of the other three areas studied." Glial cells supply the connection to brain capillaries to supply nutrients from the blood stream to neurons.

Learning to cope with difficult problems tends to emphasize synaptogenesis, the development of new synapses and enhancement of existing ones. On the other hand, simple repetitive tasks that are easily learned contribute mainly but not exclusively to angiogenesis, development of higher capillary density in the brain. The development of either tendency emphasizes one but does not does not exclude simultaneous development of the other.

EEG training as originally applied to treatment of epilepsy by Sterman and of ADHD by Lubar simply required learning to enhance the sensory motor rhythm at the top of the head, 12 to 14 hertz (hz) 10 or higher frequencies11 and suppress theta activity at 4 to 8 hz.

This paradigm has been considerably expanded by the work of the Othmers11 and many others to include selecting specific frequency bands and bandwidths for enhancement and/or suppression. The choice of such parameters often varies during a single session to help develop desirable brain states. Adapting to changing parameters constitutes new learning and is an important part of the training experience. This type of training that depends on the development of synapse arrays is best characterized as operant conditioning.

Today, HEG training is marked by simple repetitive brain exercises. Poorly functioning brain modules may be determined by a careful history, a properly designed questionnaire and objective tests.

Then the most dysfunctional areas are selected for training. The simple headband with the white disk sensitive area over the first training site is strapped in place. Training sites are distributed across the exercise session. From the standpoint of the trainee, the process from here on is merely repetition of the same activity during each of several training sites in a session. The trainee is encouraged to apply the greatest effort to increase the fedback brain blood flow and oxygenation. Very little learning is needed. The learning process is usually completed in the first session. Thereafter, sessions are repetitions of the previously learned activity. By demanding increased blood oxygenation, flow increases, limits are stretched, angiogenesis is encouraged and predominates in this simple process That some synaptogenesis occurs is attested to by the gains made in intelligence tests after sessions of HEG.

With these factors in hand, it is a simple concept to assign EEG nearer to the beginning of a synaptogenic region and HEG near the end of an angiogenic region of a synaptogenic - angiogenic brain exercise continuum. The construction of the continuum provides that no point on it represents pure synaptogenesis or pure angiogenesis, merely that a position can be found that suitably emphasizes one or the other activity. Between the ends of this theoretic continuum, there is a graded region of overlap. Thus, starting from the synaptogenic region and surveying toward the angiogenec region, synaptogenesis decreases while angiogenesis increases as the other end is approached. It seems highly unlikely that a brain exercise can be devised that will reside at either extremity.

Existence of such an efficiency distribution is buttressed by the recent finding2 that both EEG and HEG are useful in training ADD/ADHD, usually an inherited disorder. HEG that is closer to the angiogenic end of the continuum, will be more effective in such a structural disorder. HEG is twice as efficient as EEG in this training.

Our brains use about one fifth of all ingested calories and accounts for only one fiftieth of body mass. Brain energy per pound is ten times greater than that of the rest of the body. In HEG training oxygenation increases of twenty percent are common. Highs of sixty percent have been measured. Twenty percent increase indicates an energy use of over two and a half times the normal value. Supplying such extraordinary amounts of energy is limited by furnishing the extra energy only on active module demand. Haier12, with PET, studies has measured increased metabolism in specific brain areas of students playing the hand held computerized game, Tetris. Encouraged by this paper Toomim measured three degrees temperature rise over the brain motor strip when a colleague played Tetris. Carmen8 reports 3 degree F. temperature rise when training with pirHEG, the passive HEG version, for blood flow feedback. Of necessity, the brain is very parsimonious in its use of energy. If all the brain was used continuously the extraordinary energy consumption would fire a conflagration.

When demand exceeds the energy supply, brain growth is led by angiogenesis. Increase in the number of capillaries is a more efficient way of delivering blood to tissue than is increased pressure.

According to this theory a tentative list of learned disorders points to: age related issues, anxiety, insomnia, over arousal, mood disorders, pain, PTSD, relaxation, states of consciousness, addictions, open focus, life relationships, and flexibility of attention.

A similar partial list of primarily developmental and injury disorders points out: autism, Aspberger’s, learning disability, ADD/ADHD, traumatic brain injury, memory loss, distractibility, Tourette’s Syndrome, schizophrenia, bipolar disorder, stroke, and brain ischemia.

The gradient from learned to developmental suggests the efficiency of training is best developed by the location of the disorder on the continuum tempered by the recognition that either choice is viable for most disorders. It is highly likely that a combination of both can be better than either when the choice is not clear.

Further contemplation reveals a pathway to a better result overall that is independent of the choice of EEG or HEG.

Brain exercise during and between training hours has motivation as a major issue. According to the theory developed so far there are modules operating below the level of the general intelligence level of the trainee. One can expect the best overall results from the training program if the client is motivated to exercise these lower functioning modules.

The first and simplest direction is to target these areas for training in the therapeutic hour.
But what about the many hours between? The therapist's job becomes much more complex if he assumes responsibility for properly exercising the delinquent brain areas during the client's pursuit of happiness between sessions. Accepting brain exercise as an efficient way to develop brain capabilities, it becomes useful to consider how exercise of the lower productivity brain areas can best be accomplished.

Consider, as an example, poor reading capacity. Aversion to reading can often be traced to the excessive work required. When the work required to decipher written material exceeds the reward in reading it, reading becomes a chore to be avoided. Such reading disability is often traceable to poor working memory. A disability requiring repeated rereading a sentence destroys motivation as the quote below from Heidi's case study shows.

"We tried numerous reading and phonics courses to no avail. The same word repeated in a paragraph was always a new word for her."

She suffered with frequent headaches; word reversals when reading, saying "on" instead of "no"; and letter and number mix-ups when writing them down. When her math program changed from a hands-on and visual approach to conceptual, she lost her ability to comprehend it… the concepts of multiplication and division would not stick."

Here is a list of her difficulties:

- Recognizing, remembering a word when it appears again (Heidi.... "I see a word, and I know I've seen it before. I have little squinty workmen in my head, who start frantically searching through the file drawers in my brain, hunting and hunting for that word.")

- Decoding words: Heidi... "I know the word, the meaning, and the sound, but I can't get it out of my mouth, or it comes out wrong. It's like I'm trapped in my own body."

- Very difficult to read and answer questions: Heidi... "In my brain a little delivery man, with thick, foggy, bottle glasses, takes my words, which are in a package, and drives them in his truck towards my mouth, but he always takes the wrong road and gets lost! Then I have road repair men, wearing helmets, which go searching for him, but he's gone."

- Recognizing written musical notes, she has to decode it again...very difficult to sight read

- Reads slowly: Her self-esteem took a beating at times by children who would tease her, or adults who were ignorant of her disabilities and thought she was being uncooperative.

The difficulty Heidi encounters is a failure of working memory. Words fade from memory before the series of words make sense. Note also the failure of Broca's area to properly control the muscles of articulation and the inversion of letter symbols typical of dyslexia. The brain areas controlling these functions are primarily at Fp1 and F7 for working memory, Broca's area between F3 and F7 and the area between T3 and T5 for the dyslexia.

It is easy enough to prescribe training of these areas with Neurofeedback EEG or HEG. The times between training sessions can be used productively to improve the functionality of these areas. Assigning exercises to be performed between sessions is also easy enough.

The real challenge is to be sufficiently in touch with the life and desires of the client to design these exercises so they are attractive and fun.

Clearly a reading assignment is called for. What can the client read that will be fun, engrossing?

Reading aloud can exercise Broca's area. Mistakes in pronunciation will occur. Can we make this a game?
Children have fun with the absurd. How about an exercise reading aloud trying to make sequence errors? This can be fun and also heighten sensitivity to errors of sequence?

Dyslexic errors will also occur in writing and arithmetic. Words like "pad" and "bad", or "pat" and "bat" can bring absurdity to reading These are dyslexic errors of shape. Sometimes "q" and "p" are mixed. Descenders get confused with ascenders as in "d" and "p" or "b".

How can we make this entertaining? We must learn to think and feel like children.

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