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Explaining Neurofeedback

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In this handout, a review of the brain's activity from both structural and electrical perspectives will be presented. This is intended to give a lightly technical review to provide a model of brain function, including a brief description of behavioural interventions to change the structure and function of the brain.

The brain controls it's own blood supply through the dilation and constriction of the blood vessels. The blood flow is directed to areas that are active through this self-regulation. The blood supply's flow, along with the utilization of the oxygen the blood carries is measured as "perfusion", a measure that is clearly seen in some of the modern imaging techniques, such as Positron Emission Tomography (PET) and SPECT technology. Though these techniques are invasive, requiring the injection of small amounts of very short half-life radioactive materials, they do give good resolution of the perfusion due to the emission of the positrons, which are emitted from where the brain utilizes the oxygen and burns the glucose the blood carries.

A research project performed at UCLA by Ian. A. Cook, et al. in 1998 showed that the brain's electrical activity, or electroencephalogram (EEG), also has specific correlates of the perfusion. This is useful in that the EEG is capable of showing when the perfusion is low, as seen frontally in ADD / ADHD. In these situations, the EEG shows a resting or idling rhythm of alpha and/or theta, which are two frequency specific patterns in the EEG which have rhythmic waveforms.

In ADD / ADHD a large study of over 400 children showed that there were generally findings of alpha and/or theta in the frontal lobes (Chabot, et al., 1996), which corresponded to the frontal hypoperfusion seen in ADD / ADHD with the PET or SPECT perfusion studies. The frontal lobes are executive areas in the brain, which control attention, emotions (affect) and impulsivity, as well as regulate (inhibit) the motor areas of the brain.

The Robert Chabot study (1996), with analysis performed at NYU, also showed that the EEG could be used to differentiate those with ADD / ADHD from normal children, as well as differentiating ADD / ADHD from those subjects with a learning disability (LD). The LD children were shown to have a slower pattern, called delta (1 to 3.5 Hz) over the central and parietal lobes (posteriorly at the crown of the head). These areas are responsible for integrating raw sensory stimuli into perceptually interpretable activity.

These studies used a particular form of EEG, which is a quantitative analysis of the EEG, or QEEG. The QEEG, or quantitative EEG, is now being used to assist in differentiating these disorders, as well as in showing any comorbidity, or simultaneously occurring problem.

The brain’s electrical patterns are a form of behaviour, which are subject to behavior modification through "operant conditioning", a fact discovered in research done in the late 1960s by Doctor Barry Sterman, now a professor emeritus at UCLA. His work was originally in animals, though it was replicated in humans starting in the 1970s. The technique of operantly training the brain to behave in a new and different way is now called Neurotherapy, or Neurofeedback.

With this approach, the brain frequencies that are in excess are reduced, and those with a deficit are increased. The technique uses the EEG, amplified from the minute voltages and hooked up with special instruments to control a computer game. The person’s EEG is the "joystick" they use to operate the game. Over a series of sessions the person learns to use the EEG to operate the game, which the instructor slowly adjusts to "shape" the behaviour of the subject[1]s brain into a more normal pattern.

The QEEG data may also be used to predict which medication should be used if that approach is preferred. The QEEG pattern of frontal theta responds better to methylphenidate (Ritalin), whereas the frontal alpha type responds better to antidepressants. If the alpha is shown to be slower in frequency than normal, the amphetamines are the drugs the subjects will respond to best. If a specific statistical measure called Ocoherence is too high, the subject may require an anticonvulsant (Suffin and Emory, Clinical EEG, 1995).

There is no behavioural difference between these groups, which the physician may use to predict the proper medication choice. Physicians generally find the proper medication the old fashioned ways by trial and error. The "best guess" medication selection method requires more doctor office visits, medication trials, and has the possibility of significant side effects. All this is generally avoided with the more objective QEEG based method, which is based on the person’s physiology, not the behaviour.

It is not too hard to see why this is the case. The medication treats the physiology, hoping to effect the behaviour. The measurement of the physiological indicators should logically be more related to the proper choice, since this is what is actually being treated.

The choice of medicating the client requires continued treatment, as it is merely a temporary change, due to the drug’s effects. Neurotherapy is a treatment, which changes the way the brain works, and once the skill is learned, (unlike medication) it appears to be permanent. Follow-up studies show long term seemingly permanent change in the brain’s function following Neurotherapy.

Both of these methods (Medication and / or Neurotherapy) improve the client's attentional and behavioral states. The choice of which method to use is merely a personal choice. The medications, when used long term, end up being more expensive than the Neurotherapy. The Neurotherapy has less likelihood of having side effects than does the medication, but it takes a number of training sessions before the effect is noted and becomes more permanent.

The stimulant medications typically decrease appetite, with weight loss commonly noted, as are sleep problems. Long term use of stimulants have been known to cause teeth grinding (Bruxism), cardiac rhythm changes, blood pressure increases, changes in sleep patterns, anxiety / nervousness and even "psychotic" symptoms (such as hearing voices or other sensory hallucinations). For those with adverse side effects, it is fortunate that a non-medication intervention is available.

There are medical contraindications, or arguments against using stimulants, such as heart problems, gastro-intestinal and blood pressure problems and other more rare complications, which preclude prescribing them. In these individuals, as in those with complications from taking the medications, the presence of an alternative treatment is essential for proper behavioral adjustment and scholastic achievement.

It is no surprise that the brain can learn, but what may surprise some is that the brain changes structurally when it learns. This morphologic change is microscopic, the forming and reinforcing of small connections between a part of a neuron, called "dendrite", but it is a structural change, never the less.
This highly changeable connective nature is referred to as "neural plasticity", based on the original definition of plastic, not as a substance, but as a descriptor of the malleability or change ability of materials or structures.

The brain has a method of developing and expanding the pathways that are used, and "pruning" the connections that aren't utilized. This process is most dramatic early in life, but continues throughout life. We are born with about twice as many neurons as are present when we become young adults.
The pathways that are more consistently utilized are protected from the pruning process through a mechanism still unknown to science, though the fact of the change is irrefutable.

Another time when this is evident is following damage (head injury), or disuse of an area (as when hearing is lost). Then, the surrounding functions may take over an area not utilized, occasionally causing some phenomenal changes, which may be uncomfortable. One example of this is tinnitis, or ringing in the ears, following loss of hearing; another is "phantom pain" when a limb is severed and is no longer present, but sensations seeming to come from the missing limb are felt. The functions adjacent to these areas in the brain merely grow into the area and the person misinterprets these new signals as the older inputs.

These examples are dramatic, but "growth-through-utilization" is the process we want to focus on. This process is how we build additional capacity for the nervous system to do its work. Analogous to exercise building muscle mass, the utilization of the brain builds the mass of the brain's dendritic connections.

Certain intense negative experiences may change the body's chemistry, increasing the stress hormone released from the adrenal cortex of the kidneys. This chemical, Cortisol, is a healthy response to stress, though with chronic or overly intense stressors, the cortisol has deleterious effects on the brain, specifically attacking a temporal lobe structure, which has immune receptors, the hippicampus. This structure has important non-immune system functions as a memory comparitor, required for both comprehension and recall.

The implication for this latter process where stress deteriorates the brain's ability to comprehend and recall has large implications for education. A child with a stressful existence may never reach his or her true potential due to the damaging effects of the stress hormones. If the stress was experienced during pregnancy from the mother[1]s hormonal balance, the newborn will have a disproportionately intense reaction to stress, causing inordinately large amounts of strain (and thus more cortisol) and ultimately more extensive deterioration of the brain's capacity.

The ability to teach a new response to the situational stressors is capable of changing the life course for these children, creating a much more favourable outcome. The operant conditioning technique (Neurotherapy) mentioned earlier is one such method of intervention. Similarly to the stress response, there is a relaxation response, which can be trained to counteract these deleterious effects.

The technique requires time to learn, and varies depending on the state the individual starts with. In general, the more severe the starting condition, the more learning has to occur to correct the state. Simple relaxation may take as few as 10 sessions to learn; though with more severe cases, a longer training course may be needed, such as with generalized anxiety disorder, or panic attacks.

The learning curve for EEG has been described in research done at Langley Porter Neuropsychiatric Institute, of San Francisco. They showed that the curve is a fifth order curve, which contains an initial increase, followed by a dip, a second increase, followed by the exponential increase at the end of the training. This corresponds to the subjective states reported in some individuals. They are initially presented in a slightly anxious state, which gets better when they habituate to the training situation corresponding to the initial increase in the curve. The individuals then report that they "try hard to relax", a counterproductive attempt, which corresponds to the dip. They give up trying hard (active volitional attempts), corresponding to the second increase, which is then followed by the learning of the passive volitional state, which is the final exponential increase.

In some cases, the individuals may need more peripheral forms of intervention, such as muscle relaxation or training of temperature or the electrodermal responses. These will depend upon whether their individual response profile shows their stress in these areas as well. The peripheral training often requires less training time, though the source of the difficulty is universally central, as these modalities are all under the control of the central nervous system. Training peripherally may be all that is required in more mild cases, but in many individuals, the central training is the only method that will have a permanent result. In these more severe cases, there may be symptom substitution without the central intervention.

In cases with mild stress, the peripheral intervention is often a complete intervention, though when additional complaints such as attentional problems, depression, or hyperactivity are noted, the central intervention is usually the first choice, to minimise the total number of sessions, by getting directly to the source of the problem.

Prior to starting work with an individual, their existent brain function must be known, in order to design an appropriate operant conditioning intervention. Optimally, this would entail a full recording of their EEG, with quantitative analysis and comparison of the individual’s brain activity to an age matched database. These databases are commercially available from a number of sources. Following such a comparison, areas that deviate from normal may be identified, as well as the direction of deviation. This shows whether an excess or a deficit of any frequency pattern exists, as well as the location on the brain's surface.

Following this evaluation, an appropriately customized operant training may be designed which optimizes the training time by focusing on the areas of deviation. The training will take time, with 30 to 40 sessions being quite common before a permanent result is established, and even more are required for more severe or complex cases. There are commonly reported behavioural changes long before this end point of training is reached, with the early signs of change showing themselves at 5-10 sessions for most individuals, though some have strong changes even after their initial session. It is also common for an individual to not notice the change, as they are occasionally not self-aware, though the changes are easily seen in objective testing and reported by those observing the individual’s behaviour.

Commonly reported success rates of 60 to 80% are seen in the scientific literature, with up to 90% reported in QEEG based intervention (C. Wright, 1998). Using strict criteria (total remission of complaint) the percentage range from 50 to 60%, with those reporting positive results, though with less stringent measurements of success, such as "feeling like you got a positive benefit", ranging in the 80 to 90% rate.

Many therapists are not aware of this application of operant conditioning, being more familiar with more easily observable behavioural operant training, though not the operant training of "internal states". The literature in this area is most well accepted in the area of operant training of EEG in epilepsy, with well controlled studies showing the technique can assist in cases where medication alone was shown to be inadequate at controlling the electrical discharges associated with the epilepsy. A review of this application is published in Clinical EEG, in the January 2000 issue, authored by Barry Sterman, Ph.D., Professor Emeritus, U.C.L.A.

If the EEG in epileptics can be taught to stop the abnormal discharges, or to eliminate the behavioural manifestations of the epilepsy, the technique should be easily accepted in less severe neurological changes such as behaviourally based disorders such as ADD/ADHD, depression or anxiety. All these areas have been shown, in a large number of studies, as valid applications for this emerging technologically based operant training technique.

The operant conditioning of the EEG was first demonstrated in cats, where placebo effects are assumed to be absent. Those studies done with control groups have shown the technique to be a robust and valid intervention. Many more studies are of a case series variety, without control groups. Though this latter category is not held in high regard, now with the newer studies using some randomization and controls, perhaps this is changing. Recent New England Journal of Medicine reviews of research design have cast doubt on the need for placebo controlled designs. Their review has shown that when there is a preponderance of case series reports, the concordance between those results and those of the "gold standard" (double blind placebo controlled studies) was very high. Many in the field are now arguing against doing a double blind study due to the lack of proper humane treatment of those in the control group (receiving no treatment), an approach which is also now considered unethical by the World Health Organization when known treatments exist.

There are two national professional organizations dedicated to the study of this technology and these applications. The Association of Applied Psychophysiology and Biofeedback (AAPB) and the Society for Neuronal Regulation (SNR) both have annual conferences and often sponsor workshops.

There are also many state organizations, often affiliated with one or the other of these national organizations. SNR has international chapters in other countries. Both organizations have web sites (aapb.com and snr-jnt.org), and SNR sponsors a professionally published journal focussed on Neurofeedback, The Journal of Neurotherapy, which has abstracts on-line at the SNR web site.

For more information on both the QEEG and Neurofeedback please visit the following websites:

- Q-Metrx Inc

  www.q-metrx.com

- The Association of Applied Psychophysiology and Biofeedback (AAPB)

  www.aapb.com

- The Society for Neuronal Regulation (SNR)

  www.snr-jnt.org