Brain Training Against Stress
Theory, Methods and Results from an Outcome Study

“The literature, which lacks any negative study of substance, suggests that EEG Biofeedback Therapy should play a major therapeutic role in many difficult areas. In my opinion, if any medication had demonstrated such a wide spectrum of efficacy it would be universally accepted and widely used.”

Frank H. Duffy, MD
Associate Editor for Neurology,
Clinical EEG Journal, 2000

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Erik Hoffmann
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1. Introduction

The number of stress victims is growing at an alarming rate with millions of people on stress relief medication. As a result there is much loss of work time and increasing medical expenses with huge financial losses for individuals as well as for companies.

The National Institute for Occupational Safety & Health finds that stress-related ailments cost companies in the US about $200 billion a year in increased absenteeism, tardiness, and the loss of talented workers. Between 70% and 90% of employee hospital visits are linked to stress.

The epidemic of stress keeps escalating and there is no sign that it is going to stop. Individuals, companies and society at large have to face that fact and do something radical about it. Talking about stress and giving good advices on stress-seminars do not suffice.

Stress is not only dependent on the external pressure such as long working hours, many dead lines or a job shift. Most important is it how you handle the stress and how your brain responds to the pressure. Stress occurs when the organism fails to adapt successfully to changes in the environment which confront the individual with new challenges. Most stress occurs when we resist – mentally or emotionally – the new challenges we are faced with. Resistance, negativity and worried thoughts about situations and persons are what really stresses us. However it is possible to train the brain not to respond habitually and resist new challenges seen as threats. And it is possible to train the individual to go into a flow state without resistance and negative thinking.

This report describes a new groundbreaking method in stress management called Neurofeedback Training. Neurofeedback is a new effective form of attention training which has bearings on meditation. However, while meditation is a very subjective method, neurofeedback training is objective and based on scientific principles and measurements. Brain training with neurofeedback changes the brain’s neurophysiological and biochemical set up and eventually changes the brain’s responses to stress. The training actually teaches you to control your attention and thinking and to go into flow states without resistance to what is.

In this report some of the neurophysiological mechanisms involved in the stress syndrome are described as well as the different brain wave patterns and the brain’s responses to stress. We have over the past few years trained more than 40 adult subjects with stress who were all having at least 10 sessions of neurofeedback training. In 20 of these subjects clinical ratings, QEEGs and brainmaps before and after their training were available for a statistical study. The results of this outcome study including a few cases with brainmaps are also included in this report.

The human brain and nervous system is the most advanced communication system we know of. Each second around the clock this system regulates behaviour, thoughts, feelings, organ functions, the blood’s chemical composition, etc. Most of these activities take place automatically without our conscious interference. However in times of stress, the system is upset which may lead to many physical symptoms.

Figure 1

Most of the automatic functions of the body are regulated by the Autonomic Nervous System (ANS). The ANS is divided into a Sympathetic and a Parasympathetic system based partly on anatomical and partly on functional differences. Most organs in the body are stimulated both by sympathetic and parasympathetic nerve fibres. The effects of this stimulation are different and most often antagonistic. The sympathetic system usually facilitates the processes necessary during various behaviours and in dangerous situations where the organism has to prepare for fight or flight.

A sudden danger will give rise to an increased sympathetic activity which will result in dilated pupils, increased pulse and blood pressure, faster breathing, higher concentration of blood sugar and an increased blood flow to the brain and the muscles. Since the brain is also activated, the brain wave frequencies will accelerate from slow Alpha and Theta waves to fast Beta frequencies.

The parasympathetic system, on the contrary, will tend to facilitate processes taking place during rest and relaxation. In this case more blood will be directed to the inner organs, the stomach and intestines are stimulated, pulse and blood pressure are lowered and the pupils are constricted. During parasympathetic dominance in the ANS, the brain waves are slowed down from Beta to Alpha wave frequencies and during excessive parasympathetic activity to Theta waves.

In a healthy person without stress there is a fine balance and flexibility in the ANS. When this person is busy and wants to achieve something, his autonomic system is dominated by sympathetic activity and his brain is generating Beta waves. On the other hand, when he comes home after a busy day and relaxes, the balance will change to parasympathetic dominance and his brain will start producing Alpha waves. This is a healthy reaction pattern showing flexibility in the system. However, many people are unable to relax after a hard day’s work. They find it difficult to let go of the stresses and tensions accumulated during the day, and they will still show sympathetic dominance in the ANS. These people often suffer from chronic sympathetic over-activity with a fast pulse, high blood pressure, tense muscles and a restless brain dominated by fast Beta waves. In this...
case, training the brain to produce more Alpha waves has a beneficial effect on the autonomic balance. It will reduce stress and make the ANS function more properly.

3. The measurement of brain waves (Electroencephalography)

There is a general consensus that rhythmic electrical waves recorded from the surface of the scalp (the EEG) are summed synaptic potentials generated by the pyramidal cells in the cerebral cortex. The EEG represents responses of cortical neurons to rhythmic discharges from the thalamus. The frequency and amplitude of the EEG are determined by a complex arrangement of excitatory and inhibitory interconnections within the thalamus itself and between the thalamus and the cerebral cortex. The spontaneous fluctuations of the brain electrical activity (EEG), picked up on the scalp surface by electrodes, vary from moment to moment in both amplitude (voltage) and frequency (cycles per second or Hertz).

The brain consists of about 20 billion neurons which all generate electrical impulses. When these neurons work together in synchrony, tiny alternating electrical potentials occur in the synapses which are specialised junctions between the neurons. The more neurons that work in synchrony, the larger the potential (amplitude) of the electrical oscillations measured in microvolts. The faster the neurons work together, the higher the frequency of the oscillations measured in Hertz. These two parameters: amplitude and frequency are the primary characteristics of brain waves.

These weak electrical signals can be measured by electrodes placed on the scalp using some conductive paste. After amplification by an EEG-amplifier, the signals are fed to a computer and analysed for amplitude and frequency. This is called electroencephalography (EEG).

3.1 Five types of brain waves.

Brain waves may be divided into 5 categories depending on the frequency: Delta waves (0.5-4 Hz) are dominant during coma and deep sleep. Theta waves (4-8 Hz) are associated with drives, emotions, trance states, and dream sleep. Alpha waves (8-13 Hz) reflect the brain’s idle state and are found in most people in the awake condition with closed eyes. Alpha waves are the prime indicators of conscious attention, and they represent the gate between the outer and the inner world. Beta1 waves (13-20 Hz) indicate an aroused, mentally alert and concentrated state. Finally, the fast Beta2 frequencies (20-30 Hz) mostly correlate with tension, stress and anxiety (Table 1). Thus, both Delta and Theta waves reflect unconscious states, whereas Alpha and Beta waves indicate awake, conscious states (Table 1).
Table 1. Brainwaves, Frequencies and Functions

<table>
<thead>
<tr>
<th>Unconscious</th>
<th>Conscious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>Alpha</td>
</tr>
<tr>
<td>0.5 – 4 Hz</td>
<td>8 – 12 Hz</td>
</tr>
<tr>
<td>Instinct</td>
<td>Emotion</td>
</tr>
<tr>
<td>Survival</td>
<td>Drives</td>
</tr>
<tr>
<td>Deep sleep</td>
<td>Feelings</td>
</tr>
<tr>
<td>Coma</td>
<td>Trance</td>
</tr>
<tr>
<td></td>
<td>Dreams</td>
</tr>
<tr>
<td></td>
<td>Awareness of the</td>
</tr>
<tr>
<td></td>
<td>body</td>
</tr>
<tr>
<td></td>
<td>Integration of</td>
</tr>
<tr>
<td></td>
<td>feelings</td>
</tr>
<tr>
<td></td>
<td>Perception</td>
</tr>
<tr>
<td></td>
<td>Thinking</td>
</tr>
<tr>
<td></td>
<td>Mental activity</td>
</tr>
<tr>
<td></td>
<td>Tension</td>
</tr>
<tr>
<td></td>
<td>Anxiety</td>
</tr>
<tr>
<td></td>
<td>Excitement</td>
</tr>
</tbody>
</table>

It is obvious that the brain’s activation or arousal level is positively correlated with the EEG frequency. Thus, the faster the brain waves oscillate the more active the brain is and the higher the arousal level. When attention is directed towards the outer world, the brain waves oscillate fast (Beta waves), while they oscillate slowly (Alpha and Theta) when attention is directed towards the inner, mental world. Thus, the brain wave frequency also reflects the direction of attention.

3.2 The brain’s response to stress.

The brain’s natural response to stress is a decrease of Alpha and an increase in Beta activity (Fig. 2). The higher the stress level, the faster the frequency. Thus, severe stress levels are normally reflected in the baseline EEG by high amplitude Beta2 frequencies.

**Figure 2. The brain’s responses to stress**

According to Canadian pioneer in stress research, Hans Selye (Selye, 1956) the General Adaptation Syndrome (GAS) has three phases in the development of stress and burn-out: 1. Alarm reaction, 2. Resistance, and 3. Exhaustion. During the first two phases, the organism tries to adapt to an external stressor, Alpha activity decreases and Beta increases in the brain. If the stress condition lasts for a long time, the organism and the brain is exhausted, the Alpha waves slow down in frequency and diminish in amplitude, and will sometimes disappear completely. In the exhaustion phase 3, the EEG pattern usually shows very little Alpha, some Beta and an increasing amount of slow Theta.
activity. This pattern reflects chronic stress, especially the increase of Theta indicates that the brain is in a state of chronic fatigue and burn-out (Fig. 2).

So when you are stressed, the brain is working at a high speed producing fast Beta waves. A stressed person often has problems relaxing after work. He/she is not able to lower the brain’s speed, decreasing Beta and increasing Alpha activity.

4. Neurofeedback training

The principle of neurofeedback training is based on a direct, immediate feedback signal to the subject reflecting the state of his/her brain. The brain wave frequencies are measured, analyzed and converted into auditory and visual signals which are fed back to the subject via loud speakers and a computer screen.

Figure 3. Neurofeedback technical setup

The feedback signals, in the form of sounds, music and animations, tell the subject what to do and what not to do in order to get into the right state. In the course of training the person will gradually learn to go into the desired brain wave state and stay there for longer and longer periods of time. In classic learning theory this method is also called operant conditioning.

4.1 The practical training

When we see a client for the first time, an interview is performed and the client fills out a questionnaire. Then we take a so called quantitative EEG (QEEG). This is analyzed for frequency, amplitude etc. on a computer, and a brainmap is printed out (see later). The client gets a copy of the brainmap with a written evaluation, and the meaning of the brainmap is also explained to him/her verbally. Following this, the client has a test training session.

On the basis of the interview and the brainmap, it is decided which type of training the client should have – where to put the electrodes and which frequencies to train. When we are dealing with stress in a person with low Alpha, we usually start with Alpha wave training. Small sensors (electrodes) are mounted on the head and ear lobe and the client is seated in a comfortable resting chair. Brain wave signals from the electrodes are fed to the computer, stored on the hard disk and displayed in real time on the computer screen.

During the Alpha session the client is resting with closed eyes and every time his Alpha amplitudes exceeds a certain threshold a pleasant sound is automatically released from a pair of loud speakers. The subject is instructed to turn his attention inward and let go of all tensions, feelings and thoughts. When he does that successfully he hears the sound from the speakers telling him that he is in the right state producing Alpha waves. This is a systematic learning process in which the subject is taught to go into the high Alpha state and stay there for longer and longer periods of time up to 40 minutes. After 10 sessions
most people are able to go into the Alpha state without feedback and thus start to use it in their daily lives.

4.2 Alpha waves and Alpha wave training

Alpha waves reflect the brain’s idle function in the awake condition. When we relax with closed eyes, most people produce a certain amount of Alpha waves. The moment you start doing something - concentrating, thinking, listening, etc. - Alpha waves are blocked or reduced in amplitude (Fig. 2). On the other hand if you get drowsy Alpha activity will also drop down. Thus, in order to stay in the high Alpha state you must keep a certain balance between relaxation and alertness. Alpha is pure consciousness or being without any doings. It represents a gate between the outer and the inner world – between the conscious and the unconscious.

In order to produce Alpha waves you must control your attention and direct it toward your inner body ignoring all outside stimuli. If any thoughts appear in that state you should not follow them but observe them passively as you would observe drifting clouds in the sky.

Alpha waves reflect a calm, open, balanced mind with a free flow of energy and a good connection to the body and its feelings. During stress, a blocking of energy will result in low Alpha or no Alpha activity, and in the long run this may lead to various stress symptoms and burn-out.

During Alpha training you consciously let go of your inner tensions thereby dissolving blockages. The energy follows your conscious attention and the process is accompanied by increasing Alpha activity. When you are training Alpha waves you stimulate the free flow of energy. The blood supply to the brain increases and the immune system is strengthened (Nagata, 1986).

How you relate to your work and how much resistance you have toward your work determines how much energy you spend and how much stress you accumulate over time. The amount of work is not crucial as long as you at certain intervals during work remember to go into the Alpha state, maybe just for a few minutes, thereby neutralising accumulated stress and blocked energy. Going into Alpha is making a conscious space for recharging the brain with new energy.

Sports, physical fitness and relaxation exercises may reduce stress and increase the energy level. However, in both these disciplines there is no systematic, conscious direction of attention. Alpha training, on the other hand, is conscious and systematic focusing of mental energy. It is a recharge of the brain with energy which is then available for intellectual and creative activities.

Alpha wave training is effective against stress because the training attacks the problems at their roots. It removes or reduces the habitual tendency to tense, resist and block the energy in response to stressful situations. While other methods of stress management usually try to establish new behaviour patterns, Alpha wave training focuses on eliminating the old inappropriate patterns and habits which lead to the stress condition. While other methods try to re-program you, Alpha wave training will actually de-program you. The training heightens consciousness and makes you more aware of yourself, your body and your environment. It also teaches you to stay relaxed and focused in times of stress.
A person with a high Alpha level has an efficient brain and goes without effort from one task to another. This person is aware and present in the moment, his or her energy flows freely and no stress accumulates. The goal of our Alpha training is to advance the ability to perform most tasks in Alpha.

### 4.3 Training of synchronized Beta waves

It may seem contradictory to train Beta waves since too much Beta activity (in the baseline condition) usually indicates stress. However there is no contradiction. Beta training is in many ways similar to Alpha training and has some of the same positive effects. Both the high Alpha and the high Beta state are synchronized focused states without thoughts. In case of the Alpha state, focus is directed toward the body, while in the Beta state focus is directed toward the outer world. As a matter of fact you should be able to use all of your brain wave frequencies in the proper situations: Delta waves during deep sleep, Theta waves during dreaming, Alpha waves for the dissolution of stress and Beta waves when you need to work hard (see table 1).

Beta waves are the muscles of the brain, and it is good to have strong muscles. However, you should not always walk around with tense muscles and neither should you have a tense brain producing Beta waves all the time. The EEG signature of a healthy person resting and recuperating is Alpha not Beta. On the other hand when work has to be done and you need to concentrate Beta waves are a must. This is why we also do Beta-training.

**Figure 4.**

**Synchronization depends on neurological coherence**

It is important to discriminate between synchronized and desynchronized Beta waves (fig. 4). Synchronized brain waves appear when a large number of neurons work in coherence, which incidentally seems to be a necessary precondition for consciousness to emerge. During high neurological coherence, electrical potentials from perhaps millions of neurons are summed to form high amplitude mono rhythmic waves with a frequency depending on the neurons firing rates. The neurons may synchronize at many different frequencies and form e.g. Theta, Alpha and Beta waves as we know them from our EEG recordings.

**Figure 5**

**Brain Structures, Brain Functions and Brain Waves**

Synchronized brain waves reflect attention, awareness or consciousness - without any motor activity in the brain. The moment the brain starts doing something, neurological coherence is diminished since the neurons start doing different things – and thus the brain waves are desynchronized and reduced in amplitude. When the brain waves syn-
chronize at low frequencies (Delta and Theta) it reflects awareness at an unconscious level, and when they synchronize at higher frequencies to form Alpha and Beta waves, awareness at a conscious level emerges (fig. 5).

We always train synchronized Beta waves (as well as we train synchronized Alpha waves). There are both similarities and differences between Alpha and Beta training. Alpha waves we always train with closed eyes from the back of the brain where they are most abundant. Beta waves, however, we train with open eyes and usually from the frontal area.

In cases of stress in a client with low amplitude Alpha activity, we initially use the Alpha protocol. When the client has learned to increase his Alpha significantly, usually after 5-10 sessions, we often move on to frontal Beta training. Alpha training is superior in reducing stress since it relaxes the subject, quiets his mind and improves his body awareness. Beta training, on the other hand, increases focus, concentration, energy level and mental clarity. The two forms of training supplement each other and may be used in combination in cases of stress.

Figure 6. Growing box animation for Beta training

Since Beta waves are trained with open eyes we can use both auditory and visual feedback. Some clients prefer only auditory feedback but others want to sit in front of the computer screen watching an animation controlled by their brain waves. In the animation in figure 6 the green box will grow in size when the client succeeds in increasing his Beta level. When his Beta is above a certain threshold, set by the trainer, he will also hear a sound. The red box is controlled by his Theta waves. If the client gets inattentive or drowsy at any time, his Theta waves tend to increase.

When Theta exceeds a preset threshold, the feedback tone will automatically be inhibited. Thus, in order to hear the feedback tone two EEG criterias have to be met: Beta waves should be above and Theta waves below specified thresholds.

In order to generate a high Beta level, the client is instructed to focus intensely on an object on the wall or on the computer screen without any distractions. The object of his focus should be the only existing thing in his mind. No thinking, no reflections, no images, are allowed, since it will immediately desynchronize the Beta waves, reduce their amplitude and inhibit the feedback signal.

4.4 High Performance Training

Many of our customers are business men and women who want High Performance training. They may or may not suffer from stress but they all want to have optimally working brains. In these cases we often start with Alpha training and after 5-10 sessions when they master the Alpha we go on to more advanced neurofeedback training which will stimulate and increase focus, concentration, creativity and stamina (energy and will power).
One interesting exercise we use for stimulating creativity is called ‘In and out of Alpha’. When the client has learned to master his Alpha, he can go in and out of the Alpha state on command. This is an opportunity to creatively work with an idea or a problem the client has in his private life or in his business. When he is out of Alpha he analyzes the problem he wants to work with by writing ideas down on a blank sheet of paper. After two minutes the feedback tone is switched on and the client is instructed to close his eyes and go into the Alpha state. Now he is told not to think about the problem any more but focus on the body and the feedback tone. Following two minutes in the high Alpha state he is again asked to open his eyes and focus on the problem at hand. This alternating back and forth between Alpha and no Alpha, between analysis and intuition and between the conscious and the unconscious stimulates creativity and the free flow of ideas from the unconscious. Every time you go into Alpha you erase all thoughts and reset your brain so you can then open up to new ideas. This exercise may go on for 20 - 40 minutes and has been shown at our Center to stimulate creativity. We have had several business men and women who after this type of training have come up with new ideas which they have later implemented with success in their businesses.

Beta training from the brain’s prefrontal area, as described earlier, is also part of our High Performance training program. Beta training sharpens the mind and increases focus and concentration. Over the last year we have developed a more advanced form of Beta-training called Gamma-training. While Beta frequencies go up to 30Hz, Gamma frequencies are even faster and go from 30 – 42 Hz. Sometimes, however, Gamma is defined as frequencies from 38 - 42Hz.

The 40Hz Gamma activity was originally studied at the Neuroscience Unit at the University of Birmingham. The scientists there found these frequencies to be associated with higher levels of brain organization ‘binding’ information from all the senses together for a higher level of awareness of unity of the objects of our perception. Gamma rhythms seem to be associated exclusively with higher mental activity, including perception and consciousness – since Gamma activity disappears with general anesthesia. Gamma frequencies seem to be primarily associated with the frontal part of the brain which is the seat of the executive functions integrating the activities in the rest of the brain.

From our own work we have gathered evidence that Gamma waves are associated with will, intense focus, and ‘binding’ of sensory information. In a number of subjects we have found that Gamma training is the most effective way to increase a person’s ability to focus. Also we have found indications that this training increases the person’s energy level and will power. People with a sharp mind and intellect tend to show higher Gamma levels than the average person. We have had top athletes and scientists in training who showed very high levels of Gamma and who were also able to increase their Gamma further through neurofeedback.

4.5 How neurofeedback works

Neurofeedback facilitates intensive attention training. During the training the brain’s activity is controlled by both conscious and unconscious direction of attention.

Conscious learning occurs when the client realises how the feedback signal is connected to his attention and state of mind. As the client becomes aware of how he/she can control
and maintain the feedback signal by staying calm, alert and present - producing the right brain wave pattern – he/she can choose to stay in this state for long periods of time – usually up to 40 minutes.

Most of the learning, however, takes place at an unconscious level, where the brain gradually tunes in on the feedback signal intuitively. The consciously and unconsciously acquired new skills are internalised during the training and automatically transferred to the person’s daily activities.

On the physiological level the intensive training of attention seems to stimulate and promote neurological coherence, growth and maturation processes in the brain. This occurs during training when the neurons are stimulated to create new synaptic connections improving brain functions in the concerned areas.

There is evidence that both Alpha and Beta training increase blood flow to the brain. Nagata (1986) found a negative correlation between Delta/Theta activity and blood flow, and a positive correlation between Alpha activity and blood flow to the brain. In other words, when the client succeeds in maintaining a high Alpha state for some time, his/her brain receives more blood and therefore more oxygen and nutrition. This also stimulates impaired neurons to regenerate and improve their conduction of electric signals.

Neuroplasticity is the term for neurons’ ability to create new synaptic connections and pathways in the brain. An example of this is when a new area in the brain takes over the damaged functions of another area. Presumably the brains neuroplasticity comes into play during neurofeedback training.

The American neuropsychiatrist Jeffrey Schwartz argued that the mental effort practised by the training of attention releases a 'mental force' influencing brain functions with the ability to create new synaptic connections. Using PET scans Schwartz has demonstrated that attention training increases blood flow to certain areas of the brain (Schwartz and Begly, 2002).

From a psychological point of view, neurofeedback training is a process increasing awareness of both body and mind. For example, during Alpha training the stressed client becomes more attentive to his body, feelings and impulses. Gradually the client learns to confront and observe his inner impulses of stress and restlessness without responding to them. If you give up your resistance toward these inner impulses and observe them with full attention, they will quickly fade away. This is a process which learning psychologists call 'de-conditioning' or 'extinction'.

5. Methods

5.1 Brainmapping

Before the training starts we always take a QEEG and construct the client's brainmap. This gives us an overview of the brain’s functional state and indicate the level and type of stress we are dealing with. When the training is terminated we record another brainmap in order to see the effects of the training on the brain and evaluate if the client needs more sessions.

Our brainmaps are based on the recordings of 8 channels of EEG. The following electrode placements are used according to the international 10-20 system: Fp1, Fp2, T3, T4, T5, T6, O1, O2, and Cz. The EEG is recorded during three different conditions: 1) Resting with
eyes closed, 2) Resting with eyes open, and 3) Mental calculations with eyes closed. After editing the records for artifacts (removal of signals caused by muscle activity and eye movements) the computer performs an FFT frequency analysis of at least 60 seconds of artifact free record from each of the three conditions. Based on these analyses three brainmaps showing the distribution of Delta, Theta, Alpha, Beta1, and Beta2 frequencies are constructed.

**Figure 7. Brainmap and electrode locations**

The brainmap above shows five coloured ovals displaying the distribution in the brain of five types of brain waves. Each oval shows the brain seen from above, and the little tip at the top indicates the location of the nose. Each of the five ovals only displays one type of brain wave, however, all five types of waves are measured at the same time and at the same locations on the brain. Thus, the brainmap splits up brain wave activity on five different displays in order to give a better overview.

The vertical, coloured scale to the left shows the power of the brain waves. Blue indicates low power, green and yellow medium, and red high power of the brain waves. The red colour in the oval in the middle, for example, indicates that Alpha waves are the most dominating waves in this brainmap, and is most predominant in the posterior (rear) part of the brain.

**5.2 Examples of brainmaps showing stress**

**Figure 8**

The above figure 8 shows examples of different patterns of stress. To the far left is a normal brainmap with dominance of Alpha activity most prominent in the rear part of the brain. Number two from left is a so-called ‘blue brainmap’ from a person with almost no...
Alpha. This is a common pattern in some people during the initial phase of stress. A ‘blue brainmap’ usually reflects poor integration of upper and lower levels of brain functions, and the person is often detached from his body and feelings. Number three brainmap from the left is from a person with severe stress who have had several blood-clots in the brain. Notice that Alpha activity is low and beta1 and beta2 are very high in certain areas of the brain. The last brainmap to the far right, showing dominance of Theta activity, is from a burnt-out person who suffered from poor concentration and memory and episodes of depression. Notice that all these brainmaps are based on eight channels of EEG recorded over approximately 100 seconds during rest with eyes closed.

5.3 BrainFitness Index

Figure 9

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUPER (10-15)</td>
<td>15</td>
</tr>
<tr>
<td>NORMAL (6-10)</td>
<td>8</td>
</tr>
<tr>
<td>POOR (4-6)</td>
<td>5</td>
</tr>
<tr>
<td>CRITICAL (2-4)</td>
<td>3</td>
</tr>
</tbody>
</table>

A BrainFitness Index (BFI) is supplementary to a brainmap. It is easier both to measure and evaluate. The BFI is based on only one channel of EEG, usually taken from the back or top of the head. The BFI reflects the amount of Alpha activity in the resting EEG relative to other types of brain wave frequencies. The BFI is based on the hypothesis that a healthy brain without stress generates high Alpha and low Theta and Beta waves in the resting condition with closed eyes. When opening the eyes, the Alpha waves should drop down to a minimum indicating a proper response to the visual input.

Thus the BFI is constructed from the following parameters:

1. Alpha/Theta ratio (with closed eyes)
2. Alpha/Beta ratio (with closed eyes)
3. Alpha/Alpha ratio (Alpha closed eyes/ Alpha open eyes)

The sum of these three ratios constitutes the BrainFitness Index. The BFI varies between 3-15 and these ratings are divided into four categories (fig. 9). This index makes sense because when people are stressed, their Alpha activity is reduced, beta activity tends to increase and, in case of burn-out, Theta activity increases. All these changes will make the BFI go down.

The BFI does not reflect stress itself but rather it indicates the brain’s adaptability to stress and its ability to recuperate after stress. Following a stressful impact, the brain should immediately return to the Alpha state in which it relaxes and integrates the stress. People with a high BFI can do that while people with a low BFI cannot. Thus, the BFI also indicates the brain’s resilience or toughness to stress.

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**Fig. 10. BrainFitness Index from 40 IT Executives**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>7 subjects</th>
<th>8 subjects</th>
<th>23 subjects</th>
<th>2 subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical</td>
<td>17%</td>
<td>20%</td>
<td>58%</td>
<td>5%</td>
</tr>
<tr>
<td>Poor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUPER</td>
<td></td>
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</tbody>
</table>
Figure 10 shows the results from BFI measurements of 40 IT executives from a large Danish Company. Seven subjects (17%) fell in the critical, red category while eight subjects (20%) fell in the gray category. This makes a total of 15 subjects or more than one third (37%) falling in the two lowest categories suggesting that it is time to do something serious about their stress problems.

5.4 Equipment and training protocols

Mental Fitness & Research Center uses training equipment (hard- and software) developed by Thought Technology in Montreal, Canada. This equipment is by experts believed to be the best on the market and is presumably the most widely used, professional neurofeedback equipment. The recording amplifier is a Procomp+ with two EEG channels and six other channels for biofeedback of peripheral physiological variables such as muscle activity (EMG), finger pulse, respiration, skin temperature and skin conductance. Biograph is a very flexible and comprehensive software that enables the user to build his own training screens and protocols. You select the ‘instruments’ from the software that you want to use on the screen, define the frequencies, sounds, music and animations you want to use for feedback.

For quantitative EEG (QEEG) and brainmapping we use a Danish product (PCEEG8 from KHEPRI) with 8 EEG channels and software for artifact editing, FFT frequency analysis, calculations, and construction of brainmaps. Furthermore, we have a Mindset, 16 channel EEG machine developed by Aqua Thought in the USA which we also use for research.

Our basic training protocol for stress is an Alpha protocol with a Theta buzzer. When the Alpha amplitude is above a preset threshold, a pleasant sound is automatically released from a pair of loud speakers. We have constructed an index (Theta/Alpha) of sleepiness which sounds a buzzer whenever it is above a preset threshold. If the subject gets drowsy during training, his Alpha waves drop down and his Theta waves increase thus activating the Theta buzzer in order to keep him awake.

Many clients get some complementary training in the form of frontal beta training. If for some reason the client gets drowsy during training or has difficulties raising his/her Alpha, we may use frontal Beta training as a supplement. Beta training is done with open eyes and it tends to make the subject more alert and focused. Following Beta training we have observed that Alpha activity tends to increase with closed eyes.

Thus, the protocols for stress management we use most are:

1. Reward Alpha (8-13Hz) and inhibit Theta with closed eyes from Cz-T6 or Cz-O2
2. Reward Beta (16-24Hz) and inhibit Theta with open eyes from Fp1-Fp2 or Fp1-F7

6. International Research

6.1 History of neurofeedback

In the mid sixties neuroscientist Joe Kamiya at the Langley Porter Neuropsychiatric Institute in San Francisco showed how ordinary people were able to learn to control their Alpha brain waves by means of neurofeedback. They listened to tones representing their Alpha
waves and gradually learned to control them. Kamiya’s subjects described the Alpha state as a pleasant, mentally relaxed state characterized by inner tranquillity and body awareness.

The first scientific paper applying EEG operant conditioning (now called neurofeedback training) to the treatment of a clinical disorder was published by Sterman and Friar in 1972. This report was a case presentation of a 23 year old female with a 7-year history of generalized epileptic seizures of unknown origin. The patient had proven refractory to numerous drug combinations. However, following 24 neurofeedback sessions where 11-15Hz activity was reinforced, the patient’s seizures essentially ceased. Following the treatment, a QEEG showed a decrease of slow theta waves and an increase in 11-15Hz activity. A follow-up study confirmed that the patient had stayed totally free of seizures.

Professor Joel Lubar, University of Tennessee, is one of the leading scientists in the field of neurofeedback training for attention disorders. Lubar adopted Sterman’s methods in the 70’s and discovered that when he trained epileptic patients they became more attentive and focused after training. These observations led him to test neurofeedback training on children with ADD (Attention Deficit Disorder) and ADHD (Attention Deficit/Hyperactivity Disorder). Lubar has since 1975 researched this area using neurofeedback methods and has published his positive results extensively in scientific papers (Lubar, 1995).

During the seventies the technology was primitive but the claims for the efficacy of neurofeedback were high. The expected scientific research results, however, did not materialize, and the scepticism toward the method was growing. Then around 1990 there was a turning point. Following new advanced technology (e.g. fast computers, new software for brainmapping and improved neurofeedback protocols) more solid research results started coming in. One such important study on the benefits of neurofeedback training on chronic alcoholics was published in 1989 by Peniston and Kulkosky (see later).

Over the past decade, brain wave training has expanded rapidly both in the U.S.A and in Europe. In the US there is presently more than 1500 professionals practicing neurofeedback training in the treatment of a variety of clinical dysfunctions such as attention and behaviour disorders (ADHD), anxiety, depression, post traumatic stress disorder, substance abuse and mild to moderate brain damage. In several of these areas science has documented excellent results.

### 6.2 Treatment of stress-related disorders

Hardt and Kamiya (1978) assessed 100 college male volunteers with the MMPI Welsh A anxiety scale. The 8 subjects who scored highest and the 8 who scored lowest on the trait anxiety scale participated in an experiment where they learned to enhance and suppress their Alpha (8-13Hz) brain wave activity over seven sessions of neurofeedback training. Statistically significant negative correlations were found between Alpha and anxiety levels. Alpha enhancement reduced both state and trait anxiety but only in the high-trait anxiety subjects. The authors conclude that Alpha feedback training can be effective in case of anxiety disorders and they recommend at least five hours of training.

More studies of Alpha enhancement training in anxiety patients were done in the following decades (Garret and Silver, 1976, Rice et al., 1993). Their results supported the hypothesis that alpha enhancement training can reduce anxiety.
One break through study of neurotherapy treatment of chronic alcoholics was published by Peniston and Kulkosky in 1989. Ten experimental subjects with established chronic alcoholism and multiple past failed treatments completed 15 30-minute sessions with eyes closed EEG alpha-theta biofeedback. Compared to a traditionally treated alcoholic control group (n=10), and non-alcoholic controls (n=10), alcoholics receiving brain wave biofeedback showed significant increases of both alpha and theta rhythms in their EEGs as well as reductions in Beck Depression inventory scores. Control subjects who received standard treatment alone showed increased levels of circulating beta-endorphin, an index of stress, whereas the experimental biofeedback group did not. Thirteen-month follow-up data indicated significantly more sustained prevention of relapse in alcoholics that completed the alpha-theta brain wave training as compared to the control alcoholics.

Peniston concludes: ‘Successful outcome results included a) increased alpha and theta brainwave production; b) normalized personality measures; c) prevention of increases in beta-endorphin levels; and d) prolonged prevention of relapse. These findings were shown to be significant for experimental subjects who were compared with traditionally treated alcoholic subjects and non-alcoholic control subjects.’ (www.aaets.org/article47.htm).

In another study (Peniston and Kulkosky, 1991) 29 Vietnam veterans with a 12-15 year history of chronic combat-related posttraumatic stress disorder (PTSD) were treated with alpha-theta neurotherapy. They compared EEG alpha-theta enhancement training of 15 patients with traditional medical treatment of 14 patients. The experimental subjects first received eight 30-minute hand warming biofeedback sessions followed by 30 30-minute alpha-theta enhancement training sessions. The 15 experimental patients improved on all 10 clinical MMPI scales such as depression, paranoia, social introversion, etc. while the control group only improved on one scale. A 30 months follow-up study showed that only three had relapsed from the experimental group while 12 were still maintaining their improvement. In the traditionally treated control group all 14 patients had relapsed.

7. A Danish Outcome Study
7.1 Introduction
In 2003 we published the report ‘Neurofeedback Training of Children with Attention and Behaviour Disorders’ on our website www.mentalfitness.dk. This was a clinical outcome study of 16 children with ADD/ADHD who had on the average undergone 30 neurofeedback training sessions with excellent results. Quantitative EEG with brainmaps done before and after the training showed significantly reduced theta activity in the children with concomitant improvement of their clinical-behavioural condition.

The present report is also a clinical outcome study of 20 adult persons with a variety of stress symptoms such as headache, high blood pressure, sleep disturbance and moderate anxiety and depression. Some of the patients had been referred to our training by a psychiatrist and others have applied for the training via our website.

As this is not a scientifically controlled study our results, however promising they seem to be, need to be verified by more extensive and carefully control studies.
7.2 Methods

At the first consultation patients were interviewed about their problems and they filled out a stress-questionnaire. They then had a QEEG and a brainmap with a written evaluation and a suggestion as to which training protocol should be used.

We included 20 subjects in this study for whom we had clinical evaluations and QEEG’s before and after the training. Most subjects completed 10 sessions of training, however a few had up to 20 sessions. Mean age was 42 years with a range from 23-64 years.

All the subjects were initially trained with an Alpha protocol which rewards EEG Alpha frequencies from 8-13Hz and inhibits Theta from 4-8Hz (see section 5.3). Electrodes were in most cases placed at Cz-T6 and in a few patients, who initially had low levels of Alpha, they were placed at Cz-O2 with the left ear lobe as ground. In two subjects, who initially had symptoms of depression and low frontal arousal, the Alpha training was followed by Beta enhancement training of the left frontal lobe (Fp1-F7).

The QEEG were recorded at 8 different locations on the scalp before and after the training period. The EEG were measured at Fp1, Fp2, T3, T4, T5, T6, O1, O2, and Cz under three different conditions: 1) Resting with eyes closed, 2) Resting with eyes open, and 3) Counting backwards with eyes closed. After editing the records for artifacts (removal of signals caused by muscle activity (EMG) and eye movements) the computer performed an FFT power spectrum analysis of at least 60 seconds of artifact free record from each of the three conditions. After that, the power distribution within the Delta, Theta, Alpha, Beta1, and Beta2 bands was computed. On the basis of these data, three brainmaps, one for each condition, were constructed.

We only report here the EEG data from the resting condition with closed eyes where the Alpha activity is most abundant. Our primary hypothesis, of course, was that Alpha activity would increase following training. And, we predicted, that Alpha activity would not only increase at the training sites but in all or most locations of the brain due to a generalization of the brain’s relaxation response.

After termination of training, all subjects were clinically re-evaluated by the neurotherapist, while the EEG data were scored by the research director. The clinical evaluation was done through interviews and questionnaires. Little or no improvement was rated 0, some improvement was rated 1, good improvement was rated 2, and large improvement was rated 3.

7.3 Results

We divided the subjects into two groups according to their clinical ratings. Subjects with ratings of 2 or 3 (good or large improvement) were referred to group I, while subjects with ratings of 0 or 1 (no or some improvement) were included in group II. Group I consisted of 15 subjects with an average clinical rating of 2.6, while there were 5 subjects in group II with an average rating of 0.6. Thus, there was a substantial difference between the two groups in the evaluation of their clinical benefits from the training. Fifteen out of 20 subjects had a substantial improvement which gives a success rate of 75%.

Table 2 shows that group I had a mean Alpha increase of 89% while group II only had a mean Alpha increase of 8%. Table 3 shows that this difference between groups in Alpha
enhancement after training is statistically significant according to the Mann-Whitney U Test (p<.01). This means that the subjects who showed the largest increase of Alpha activity following training (group I) also had the best clinical outcome. The #A3 subject in group II who showed an Alpha increase of 100% actually only increased his Alpha from 3 to 6 micro-volts which is still a very low level.

We analyzed the changes of Alpha activity following training for four different electrode locations (T3, T4, O1 and O2 all referenced to Cz) and for the mean of all eight electrode locations. The results for group I can be seen in figure 10a. This figure shows that the increases for the mean and for T3 and T4 are more statistically significant (p<.01) than the increases for O1 and O2 (p<.05). There are nearly 100% increases of Alpha in the temporal areas (T3 and T4) while the increases for the occipital areas (O1 and O2) are only 30%-40%. These figures reflect a tendency for the Alpha activity to spread after training from the occipital toward the temporal and frontal areas.

Figure 10b shows that for group II with poor clinical outcome there are no significant changes of Alpha activity after training.

7.4 Summary and conclusion

Following 10-20 sessions of Alpha neurofeedback training, 20 subjects suffering from a variety of stress symptoms were clinically evaluated and their QEEG’s were recorded. 15 subjects with good clinical improvement showed a statistically significant 89% increase of their mean Alpha activity, whereas 5 subjects with little improvement did not show any increase of Alpha. The difference between groups in Alpha enhancement after training was statistically significant, indicating that Alpha enhancement is a predictor of clinical outcome.

With a success rate of 75% after approximately 12 hours of treatment, Alpha wave feedback training could be a promising method for treating the escalating epidemic of stress. However, scientifically controlled studies of the beneficial value of Alpha enhancement training in counteracting stress must be completed.
7.5 Graphs

Table 2. Comparison of much improved (group 1) with little improved (group 2) subjects

<table>
<thead>
<tr>
<th>Group 1. Much improved (n=15)</th>
<th>Group 2. Moderately or not improved (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subject</strong></td>
<td><strong>Age</strong></td>
</tr>
<tr>
<td>#1</td>
<td>40</td>
</tr>
<tr>
<td>#2</td>
<td>39</td>
</tr>
<tr>
<td>#3</td>
<td>32</td>
</tr>
<tr>
<td>#4</td>
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<tr>
<td>#14</td>
<td>64</td>
</tr>
<tr>
<td>#15</td>
<td>35</td>
</tr>
</tbody>
</table>

**Clinical evaluation:**
0 = no improvement, 1 = some improvement,
2 = good improvement, 3 = large improvement
Table 3. Alpha increase after training predicts the clinical outcome

<table>
<thead>
<tr>
<th>Stress group</th>
<th>Alpha Increase</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (n=15)</td>
<td>89%</td>
<td>2.6</td>
</tr>
<tr>
<td>Group 2 (n=5)</td>
<td>8%</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Significance
(Mann-Whitney U test) P< .01

Figure 10a. Mean Alpha changes in group I after training

** p<.01, * p<.05 Wilcoxon two-tailed test
7.6 Cases with testimonials

1st case. 58-year-old female engineer with own consultancy.

LF underwent 20 sessions of High Performance training with the aim to gain control of a racing mind and improve concentration and mental acuity. During Alpha-training LF was asked to analyse a current problem and try to find a creative solution to that problem. After two minutes she stopped thinking completely and was guided into Alpha by the feedback signal opening up mentally to new creative ideas. She went in and out of Alpha several times and after the session she came up with four different solutions to a difficult problem she had been stuck with for a long time.

After the training LF stated: 'I experienced a distinct improvement of my concentration in my everyday life. My mind is sharper with less disturbing thoughts and I am more present in my body. In addition I am much better at stopping up and paying attention to my intuition as well as to other people.'

Lise Fredslund
Manager, DIDA Consult
Analysis of brain wave activity for Lise Fredslund before and after training.

Before training               After 20 sessions

| ![Brainwave Maps Before Training](image1.png) | ![Brainwave Maps After Training](image2.png) |

Strongly increased Alpha and Theta activity after training reflect greater inner peace and awareness as well as improved contact with body and feelings.

2nd case. 38-year-old male store manager

Before training FN had severe difficulties with concentration, he had a racing mind and was suffering from stress. FN underwent 10 sessions of neurofeedback training to overcome these problems. He received a combination of Alpha and Beta training to learn to maintain focus and control his thinking. After 10 sessions of Neufodfeedback, FNs brainmap showed a tripling of Alpha waves during rest with closed eyes in the frontal area of the brain. This indicated that he was more present, better balanced and in control after training.

FL stated: "Already after my second session I experienced a dramatic effect of the training. I felt euphoric and far more focused, and I was no longer tormented by my racing mind. This effect lasted for the rest of the day and was noticed by my family. The training, in general, has taught me a lot about how to relax, handle my stress and get a grip of my thinking. I have no longer a racing mind. My concentration has improved, my energy level has increased, and I am feeling a lot better."

Flemming Nielsen
Store Manager

3rd case. Arne Nielsson, 10 times world champion in canoe and author of the best seller ‘The Will to Victory’, said after Gamma power training at Mental Fitness & Research Center:

"After about 10 minutes of training I experienced an intense narrowing of my focus on a motive on the wall… I practically merged with that motive… Following 20 minutes of training I was in a state of ‘flow’ which was comparable with the state I was in the last few meters before the goal line in an important race."

Arne Nielsson
8. References


