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**The effect of infra slow frequency neurofeedback on quantitative
electroencephalogram and autonomic nervous system function in
adults with anxiety and related diseases**

by

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Abstract

Over the last decade it has been observed in clinical practice that Infra Slow Frequency (ISF) training alters clients physiological state during training. Peripheral body temperature, pupil size and breathe rate are a few examples of autonomic nervous system (ANS) responses regularly observed during ISF neurofeedback training.

ISF electroencephalographic (EEG) biofeedback focusses on the low energy signals produced by the brain. This includes frequencies of less than 0.1 Hz. Evidence suggests that these slow oscillations play a role in synchronizing faster activity and modulates cortical excitability. The origins of these slow oscillations are not yet well understood but studies have indicated the involvement of the thalamus and other subcortical structures.

The ANS is an important role player in maintaining sympathetic-parasympathetic and cardiovascular homeostasis. It includes vagal cholinergic and sympathetic noradrenergic nerves that supply the heart and sympathetic noradrenergic nerves that enmesh arterioles. Therefore, clinicians and researchers have long sought valid, non-invasive, quantitative means to identify patho-physiologically relevant abnormalities of these systems.

Heart Rate Variability (HRV) is one of the most well-known measurements. There is increasing research pointing to the clinical application of HRV in training and exercise due to its apparent result in strengthening sympathetic-parasympathetic balance. Achieving an increased HRV while doing ISF training should be a good indicator of firstly reaching a clients' Optimum Frequency (OF) and secondly achieving a sympathetic-parasympathetic balance.

This study hypothesizes that ISF training has a measurable physiological effect on an individual by measuring certain autonomic functions viz. HRV, muscle tension, skin temperature, skin conductance, heart rate, respiration rate and blood pressure. Also, to demonstrate how ISF training impacts the resting state EEG.

Methods

Thirty adults between the ages of 18 and 55 with primarily anxiety will receive a Quantitative Electroencephalogram (QEEG) to get a baseline value before training. The participants will then receive ISF neurofeedback training for 10 sessions while

continuous monitoring of ANS changes will be done to determine if there are measurable changes. After 10 sessions we will repeat a QEEG to determine what changes occurred. The same process will be completed for a control group. The control group will receive one channel power training where Theta and High Beta activity will be inhibited at 3-7 Hz and 22-30 Hz respectively and Lo Beta 12-15 Hz activity enhanced at the C4 location on the head.

Results

Significant changes were seen in the skin conductance ($p < 0.0001$), electromyography ($p = 0.01$), very low frequency and low frequency of HRV ($p = 0.004$ and $p = 0.05$) and blood pressure (systolic change $p = 0.049$; diastolic less significant $p = 0.083$). Changes are also noted in heart rate ($p = 0.22$), and blood volume pulse amplitude ($p = 0.25$). These are less significant but do indicate change. In the heart rate and blood pressure a large change is noted in the standard deviation indicating a non-linear change and regression towards the mean. No significant changes were seen in the control group.

Conclusion

The study demonstrated that autonomic functions are affected by ISF neurofeedback training and that changes occur in the resting state EEG of participants trained.

Keywords: neurofeedback, infra slow frequency, electroencephalogram, autonomic, blood pressure, electromyogram, skin conductance, breathing, heart rate variability, inter beat interval, autonomic function.

Declaration

I, Karlien Balt, hereby declare that this research dissertation is my own work and has not been presented for any degree at another University.



Signed:

Date: 30/10/2018.....

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List of Abbreviations

Abd	Abdominal
ADHD	Attention Deficit Hyperactivity Disorder
ADD	Attention Deficit Disorder
ANS	Autonomic Nervous System
BIS	Behaviour Inhibition System
BP	Blood Pressure
BVP	Blood Volume Pulse
CNS	Central Nervous System
DSM	Diagnostic and Statistical Manual of Mental Disorders
DC	Direct Current
EDA	Electro Dermal Activity
EEG	Electroencephalogram
EMG	Electromyogram
FFT	Fast Fourier Transform
f	Frequency
fMRI	Functional Magnetic Resonance Imaging
GAD	Generalized Anxiety Disorder
GAD	Generalized Anxiety Disorder
HRV	Heart Rate Variability
HRV	Heart Rate Variability
Hz	Hertz
HF	High Frequency
ILF	Infra Low Frequency
ISF	Infra Slow Frequency
ISOs	Infra Slow Oscillations
IBI	Inter Beat Interval
kOhm	Kiloohm
LE	Linked Ears
LZT	Live Z score Training
LF	Low Frequency
LF/HF	Low Frequency to High Frequency Ration
Loreta	Low Resolution electromagnetic Tomography
LH	Luteinizing hormones
MRC	Medical Research Council
µV	microvolt
mV	millivolt
NIN	Neurofeedback Institute of Netherlands
Nr	Number
OCD	Obsessive Compulsive Disorder
ODD	Oppositional Defiant Disorder
OF	Optimum frequency
PNS	Parasympathetic Nervous System
PZOK	Percent Z scores OK
PAG	Periaqueductal Grey

PH	Phase Coherence
PPG	Photoplethysmography
QEEG	Quantitative Electroencephalogram
RAD	Reactive Detachment Disorder
RSA	Respiratory Sinus Arrhythmia
RAS	Reticular Activation System
s/s	Samples per Second
SMR	Sensorimotor Rhythm
Ag/AgCl	Silver/Silver Chloride
SCP	Skin Conductance
SCP	Slow Cortical Potential
SD	Standard Deviation
SDRR	Standard Deviation of the R-R Interval
SARA	Standardized Artifact Rejection Algorithm
	Standardized Low Resolution Electromagnetic
sLoreta	Tomography
SNS	Sympathetic Nervous System
ULF	Ultra-Low Frequency

Chapter 1: Introduction to infra slow frequency neurofeedback, quantitative electroencephalogram and the autonomic nervous system

1.1 Introduction

There is increasing evidence that some mental and physical problems experienced by individuals are not just from structural deviances in the brain but that the functional connectivity of the core networks can be flawed. This is one of the reasons why pharmacological treatment has failed in many conditions and calls for an integrative perspective that considers the neurochemical and bio-electrical domains. (1) This has led to the continuous development of other forms of non-invasive treatments like Infra Low Frequency (ILF) and Infra Slow Frequency (ISF) electroencephalogram (EEG) biofeedback. (1,2)

The development of more commercially available direct current (DC) coupled amplifiers led to researchers being able to explore bandwidths outside of the traditionally defined analog limit of 0.5-50 Hz in neurofeedback. More and more the low frequencies were explored going as low as 0.003 Hz. These very low frequencies were later defined as Infra Slow Frequency by Mark Smith due to the interaction of frequency and DC potential shift. (3)

1.2 Background to Infra Slow Frequency neurofeedback

ISF EEG biofeedback focusses on the low energy signals produced by the brain. This includes frequencies of less than 0.1 Hz. (3) Smith, with the help of others like Tom Collura at Brainmaster Technologies in the United States of America developed specific training protocols to train these low frequencies in clients. Evidence suggests that these slow oscillations play a role in synchronizing faster activity and modulates cortical excitability. (4) The origins of these slow oscillations are not yet well understood but EEG and imaging studies have indicated the involvement of the thalamus and other subcortical structures. (5) A recent study was done by Bazhenov, where the EEG was recorded in subjects practicing mindfulness for about an hour. Analysis of these recordings indicated near DC activity that ranged from approximately 10-35 minutes in all subjects coming from mainly the frontal midline and inferior areas

1.3 The Role of the Autonomic Nervous System

The autonomic nervous system is an important role player in maintaining sympathetic-parasympathetic and cardiovascular homeostasis. It includes vagal cholinergic and sympathetic noradrenergic nerves that supply the heart and sympathetic noradrenergic nerves that enmesh arterioles. These play a role in peripheral resistance to blood flow in the body and therefore blood pressure and that is why clinicians and researchers have long sought valid, non-invasive, quantitative means to identify pathophysiologically relevant abnormalities of these systems. (7)

Heart Rate Variability (HRV) is one of the most well-known means of measurement and is measured as the beat to beat variability in the sinus rhythm over time. There is mounting research which points to the clinical application of HRV in training and exercise due to its apparent result in strengthening sympathetic-parasympathetic balance. (5) Achieving an increased HRV while doing ISF training should be a good indicator of firstly reaching clients OF and secondly achieving a sympathetic-parasympathetic balance. (8,9) Measurements of high frequency (HF) and low frequency (LF) power as well as their ratios are good indicators of changes in HRV. It has been shown that HF mainly reflects respiratory sinus arrhythmia. (7) Low frequency is not as well understood but it is believed that it indicates baroreflex functionality and cardiac autonomic outflow. (7)

Studies by Levenson et al. (10) have shown that certain autonomic functions correlate with different emotions, for example temperature, heart rate and skin conductance. This shows that these functions can be used to track an individual's emotional state with a relative amount of certainty. (10)

Many people suffer from neck and shoulder pain especially in higher states of anxiety and, more specifically, the trapezius muscle is a good indicator of physical release of this pain or tension. (11,12) Other autonomic functions include heart rate, blood pressure and respiration rate as can be seen in Figure 2.

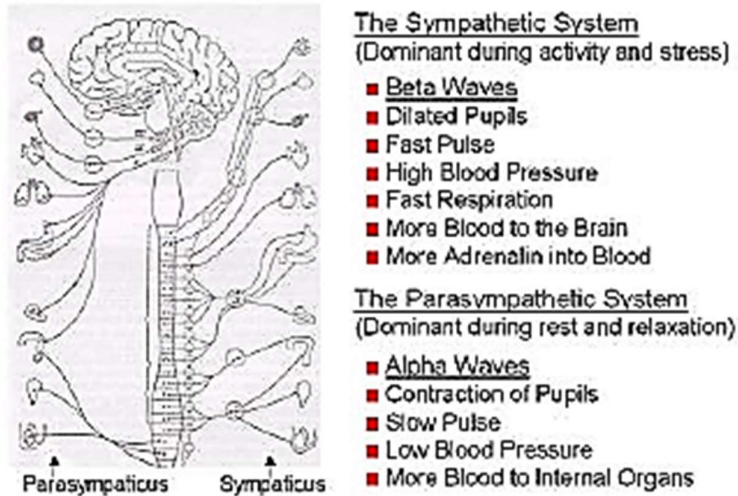


Figure 2: The autonomic nervous system. (13)

1.4 The Quantitative Electroencephalogram

A QEEG is used to assess the functionality and physiology of the brain by looking at the different brainwaves as seen in Table 1. (10)

Table 1. Brain wave frequencies and basic functions. (13,14)

Delta	Theta	Alpha	Beta	High Beta	Gamma
0.5 - 4 Hz	4 – 8 Hz	8 – 12 Hz	12 – 18 Hz	18 – 30 Hz	30 - 45 Hz
Instinct	Emotion	Consciousness	Concentration	Stress	Consciousness; perception
Survival	Drives	Awareness of the body	Perception	Tension	Binding
Deep sleep	Feelings	Integration of feelings	Thinking	Anxiety	Perception
Coma	Trance		Mental activity	Excitement	Learning
	Dreams				Information processing

It was originally developed as an affordable outpatient method to test for attention disorders in individuals and included measuring EEG at different sites one channel at

a time and comparing and quantifying the data from different sites. (15) It has been demonstrated by numerous of peer reviewed journal articles that the QEEG is a valid and reliable method of analysing EEG by its high standards of reliability and validity that have been met. It is, however, still criticized by many who prefer to classify it as experimental. (11) Still it has shown higher standards of reliability and validity in comparison to results obtained from just visual inspection of EEG. (11) A typical full-cap QEEG consists of nineteen active leads, a ground and two reference leads. Each active site is referenced to the linked ears references. The data is then analysed to produce brain maps that indicate where deviances are present. This is done by means of computer algorithms that allows EEG to be displayed quantitatively. (16)

1.5 Motivation for this study

ISF neurofeedback training is such a new field that very little literature and information is currently available. The full impact on the body is not yet well understood and we are unsure of the systems involved. Understanding its effect better will help future trainers to be more educated and will help them optimize their clients quicker which can in turn bring relief from anxiety and other symptoms faster. Another goal would be to identify the measurable responses that show the most sensitive or fastest indication that your client may be optimized or at least near their optimum frequency. This could further contribute to the methods' scientific validity and eliminate speculation, especially when working with a client who either under reports or over reports symptoms.

1.6 Aim of the study

The aim of the project is to assess whether ISF neurofeedback training leads to an overall improvement or change in brain function and whether physiological changes can be measured (either positive or negative) during ISF training in a session while doing training and throughout the study by comparing the results from session to session and from session one to ten.

1.7. Research Objectives

- Determine if there is any significant change in brain functionality by comparing the percent deviance in the QEEG prior to the neurofeedback training to the percent deviance after training.
- Determine which autonomic measurements taken during ISF neurofeedback training showed the most significant change.
- Determine if the same changes are seen in another group of participants who were doing amplitude neurofeedback training (Focus/Sensorimotor Rhythm (SMR) training) instead of ISF neurofeedback training.

1.8. Research Procedures

The procedures are summarised in Figure 3. The subjects will first complete an evaluation questionnaire to determine the current problems they are experiencing. The questionnaire is being used by all ISF practitioners when doing their training and was developed to evaluate a broad range of information (Appendix B).

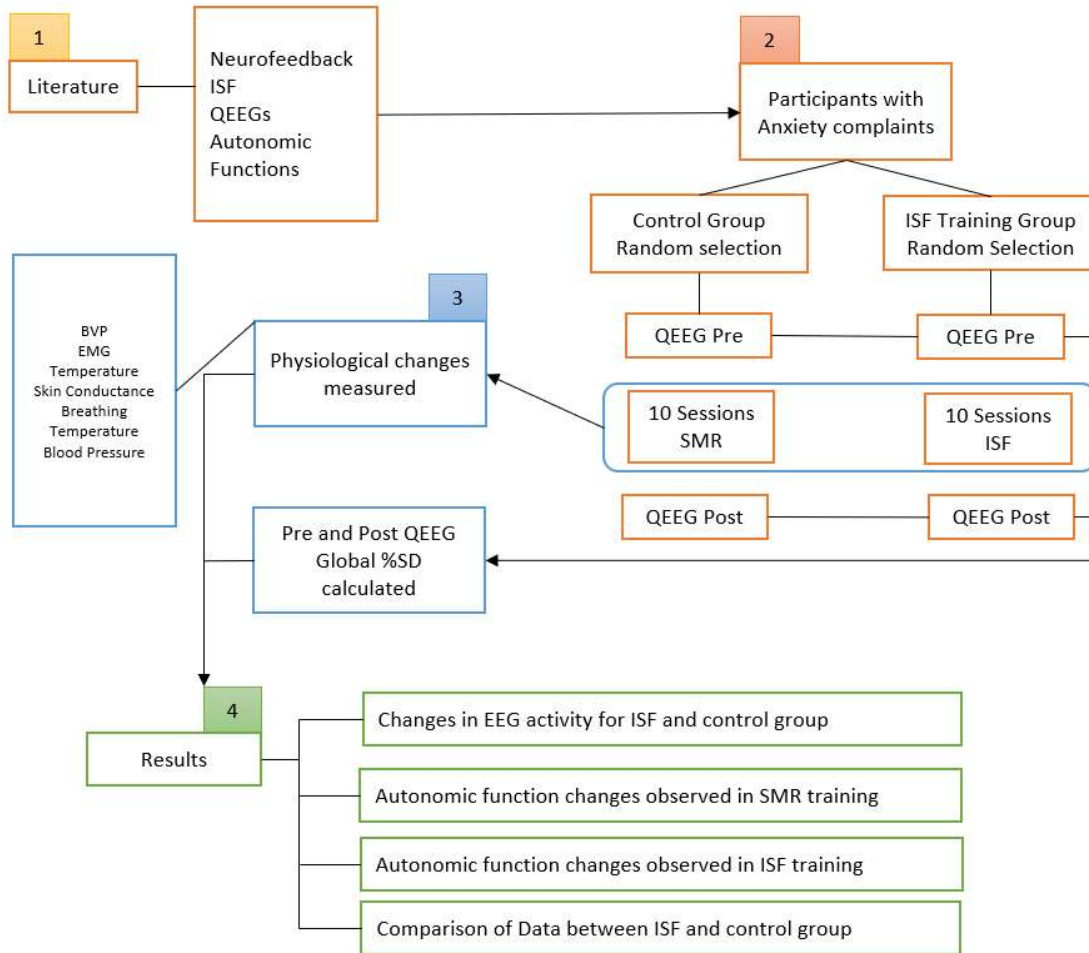


Figure 3: Summary diagram of research procedures.

After completion of the questionnaire a QEEG will be completed by each participant. This will involve recording of the EEG data at 19 sites on the subject's head. The raw EEG will be visually expected for any abnormalities like epileptiform activity. The EEG will then be uploaded to the QEEGPro™ website where data will be processed. Once the processing is complete the full reports will be downloaded.

Neurofeedback training (will then commence bi-weekly for 4-6 weeks. This involves 1 session of 1 Channel power training at C4 to serve as a control. The protocol for the session of power training will be Focus. This Protocol enhances 12-15 Hz activity and inhibits 3.5-7 Hz and 20-30 Hz activity. The following ten sessions consist of 30 minutes ISF neurofeedback sessions 2 or 3 times per week. Physiological data will be recorded during the control and the ISF sessions. All data will be saved on the computer hard drive as well as backed up with a cloud-based service.

After 10 sessions of training a QEEG will be repeated in order to compare pre-and post-training changes.

1.9. Hypothesis

The following hypotheses were formulated for this study:

1. The QEEG will show significant change when comparing the pre-and post-percentages deviance.
2. The autonomic functions measured in the ISF training participants will show significant changes when comparing the 10th to the first session.
3. The autonomic functions measured in the participants who did amplitude training will show less significant changes.
4. There will be no significant difference in QEEG pre-and post-percentages deviance.
5. There will be no significant difference in any of the autonomic functions measured during ISF training or amplitude training.

1.10. Ethical Clearance

Approval from the University of Pretoria Health Sciences Ethical Committee was obtained prior to the start of the study (216/2018) (Appendix A).

1.11. Overview of Chapters

Chapter 1: Introduction to infra slow frequency neurofeedback, quantitative electroencephalogram and the autonomic nervous system

Chapter 2: Literature Review

- Discusses the literature background of this study. Specific focus is placed on firstly discussing the QEEG – the development of QEEG, the development of the databases used in QEEG, the validity of QEEG and the different phenotypes that have been identified in recent years of research. The following focus point is Neurofeedback training where we briefly discussed the different forms of training that have developed over the years. ISF training is discussed in more detail focusing on the physiological origin of these slow rhythms in the brain and the development of the technique itself. Lastly, we briefly discuss the

different autonomic functions that we measured and how these functions typically play a role in the anxiety response.

Chapter 3: Research Procedures

- Outlines the study design and research methodology, while discussing in detail how the QEEG assessment was done and the different training methods. The chapter also includes a description of the methodology used to measure the autonomic activity as well as the different equipment and sensors used. Our population demographic and statistical analysis were also discussed in this chapter.

Chapter 4: Results and Discussion

- Reports the results for all analytical data obtained from the study. The QEEG descriptive data was reported in table format and graphical format. All the descriptive data for the different autonomic functions is individually represented in a table format, while also being graphically displayed looking at the trend and confidence intervals. The data from the ISF training group (hereafter referred to as the Experimental group) is displayed separately from the amplitude training group (hereafter referred to as the Control group). The chapter includes an integrated discussion of the results with special focus on the changes in the sympathetic and parasympathetic nervous systems, the balance of these systems and their role in anxiety.

Chapter 5: Conclusion, Limitations and Recommendations

Concludes the findings of this study, discussing the significance of the findings and how this can impact the development of the field. Study limitations and future recommendations are also addressed in this chapter.

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Chapter 2: Literature review

2.1. Neurofeedback

2.1.1. Introduction

One of the most important role players in human performance is self-regulation. Neurofeedback is a very promising non-invasive tool for the modification of human behaviour. It aims to teach an individual to modulate his/her own behaviour with the use of a technical interface. The learning of control over specific neural substrates has been shown to change specific behaviours. Its effectiveness has been evaluated regarding application in clinical populations as well as the enhancement of performance. (1-6)

The field of Neurofeedback involves psychiatrists, neurophysiologists, researchers and a variety of other disciplines used in both experimental and clinical paradigms encompassing neuro-scientific, neuro-engineering and learning-science. (2, 3)

As cognitive enhancement is very important for individuals wanting to perform better it has become a very popular topic in recent years. These higher cognitive functions are involved in various aspects of daily life and have also been associated with behavioural and psychiatric impairments when dysregulation occurs. It is of high social, individual and economic relevance to help with the improvement in these executive functions. (7) Neurofeedback protocols which increase the ratio of Theta to Alpha waves has also shown enhancement of mood, music and dance performance. (8,9)

There have been clinical trials for epilepsy, migraine, stroke, chronic insomnia, attentional-deficit hyperactivity disorder (ADHD), autism spectrum disorder, major depressive disorder, anxiety disorders, addictive disorders and psychotic disorders. (10) In cancer survivor's neurofeedback has also been shown as an effective tool in combatting ongoing symptoms such as fatigue and cognitive impairment. (11,12)

Recent developments in functional magnetic resonance imaging (fMRI) has led to the ability to monitor task related changes in neural activity which offers feedback on simple and complex neural signals. FMRI neurofeedback can give feedback on more regions such as the cerebellum and brainstem. This has shown promising results in

treating stroke and Parkinson's disease. (10) The use of this form of training in clinical trials has still to be explored. (10,11,13)

The development of low-resolution electromagnetic tomography (LORETA) and its application in neurofeedback has also broadened the use and specificity of neurofeedback training. The ability to target more specific and deeper cortical and subcortical structures has shown promising results in memory impairment and other cognitive faculties such as attentional processes and short-term memory. (14)

Another branch of neurofeedback training involves the training of slow cortical potentials (SCP). This involves the utilization of unipolar electrode placement, randomized bidirectional signal regulation feedback and discrete feedback rewards. Training is done at around 0.1 Hz. It has been shown to also be effective for the core symptom reduction in ADHD individuals. (15)

2.1.2. Types of Neurofeedback

2.1.2.1. Amplitude or Power training

Sterman et al. (16) were the first researchers to study the practice of EEG operant condition on cats in the 1960's. Sterman et al. (16) placed electrodes on the sensorimotor strip and rewarded them with milk or chicken broth when they produced 12-19 Hz SMR rhythms. When injected with toxic rocket fuel the cats who had SMR training took twice as long as those who did not receive training to exhibit expected seizure activity from the toxicity. (16) With amplitude training EEG activity is recorded from a single scalp electrode. A reference and a ground electrode is typically attached to the earlobes. The recorded signal is filtered, and the activity extracted into the frequency bands of interest via a Fast Fourier Transformation (FFT). Changes in activity are relayed back in real time to the trainee via visual and/or auditory feedback. The trainee is rewarded for producing desired changes in patterns. Over a course of several training sessions the trainee learns to self-regulate the EEG activity. Typical protocols include rewarding 15-18 Hz frontally for attention or rewarding 8-12 Hz Alpha activity occipitally for relaxation. (17)

2.1.2.2. Z score training

Z score training is based on a computation using a normative database to produce multiple targets. Simple feedback is given to the trainee, but it reflects a complex set of relationships between the amplitude and connectivity metrics. Relatively wide thresholds are set, for example -2 and +2 and the text is displayed of all Z scores lying within these thresholds or outside and the clinician can adjust the percent of time the trainee is rewarded. The trainee gets auditory reward sounds when his Z scores lie within the set thresholds. For a 4-Channel training session 248 Z scores are trained and can be viewed by the clinician while doing the training. The percent of Z scores achieved is a “proportional” feedback variable rather than a simple “on/off” feedback signal. The most important factor in doing Z score training is setting correct target range for the standard deviations as a different effect will be produced. (Figure 4) If the target range is too small too many outliers will be missed. If it is too wide, it ignores too many outliers. (18)

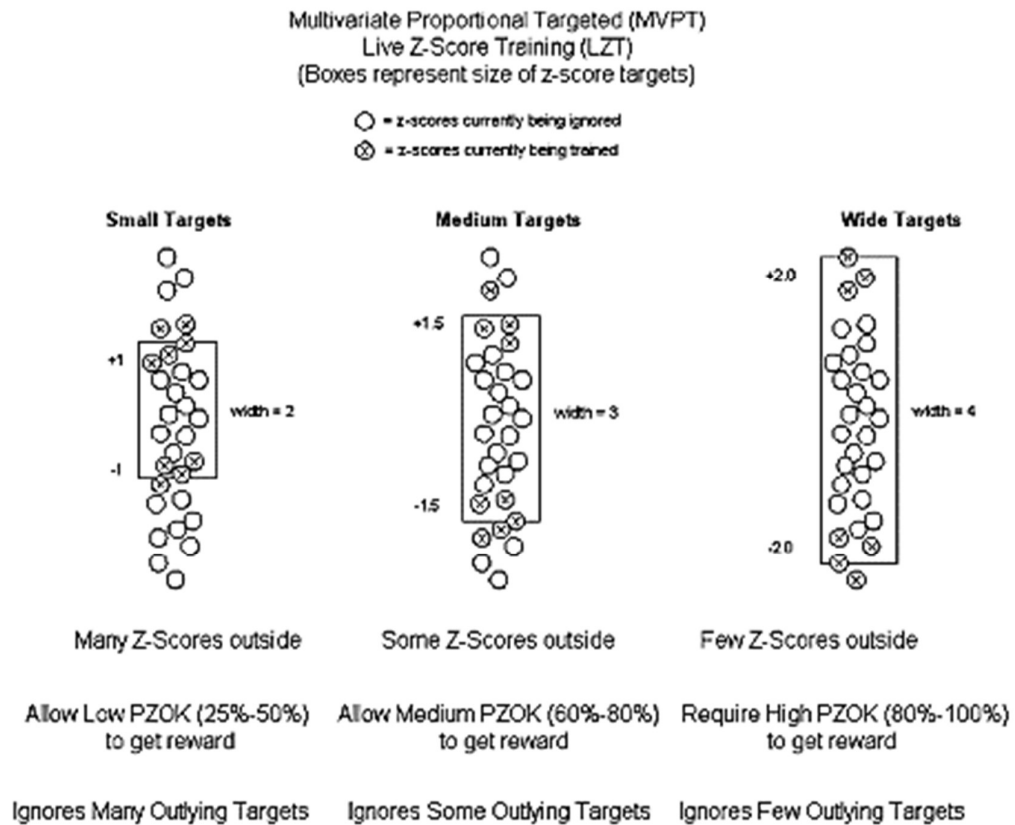


Figure 4: Relationship between the size of LZT targets and the establishment of reward criteria. (19)

The brain is allowed to decide how it meets the strategy of normalization by allowing a percentage of Z scores to be outside of the target range. (19)

Advantages of real-time Z score biofeedback includes:

- Simplification of data by reduction of different metrics to a single common metric. (20)
- Simplification by the provision of a threshold and direction of change.
- Improvement of linkage between the complaints and symptoms of the patient and localization of functional systems found in the brain. (20)

2.1.2.3. Low-resolution electromagnetic tomographic analysis and Standardized low-resolution electromagnetic tomography analysis Neurofeedback training

LORETA was developed by Pasqual-Marqui. (21) Scalp data from the whole head is mathematically applied to compute the estimation of the cortical electrical activity that gave rise to the surface potential. It uses approximately 2300 7-millimetre voxels – values calculated for thousands of spatial regions. Standardised low-resolution electromagnetic tomography (sLoreta) includes 3 additional features that distinguishes it from LORETA - 6239 5-millimetre voxels are used, a function of smoothness is incorporated into the solution and the algorithm has zero localisation error. It allows the training of selected brain regions of interest (Figure 5) and for example allows training of the anterior cingulate or insula rather than just training at Fz or Cz. (21,22)

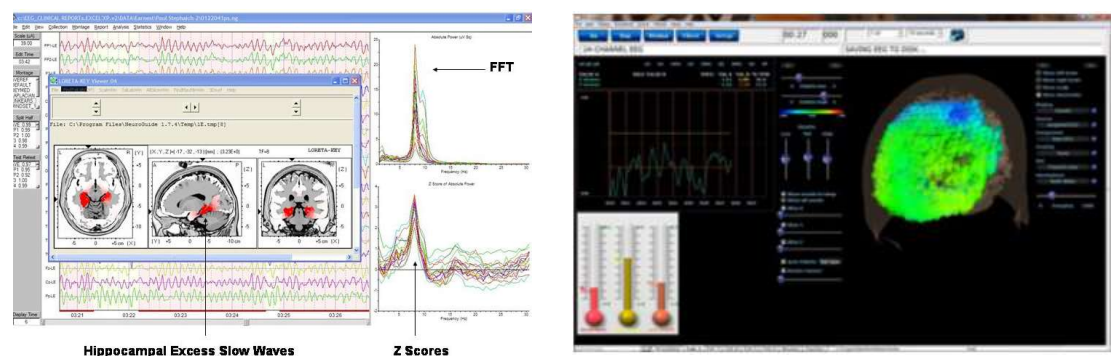


Figure 5: Example of LORETA (left) and sLORETA training screens. (23,24)

2.1.2.4. Slow cortical potential training/Infra-Low frequency training

The Slow cortical potential (SCP) is defined as the slow, event-related, direct current (DC) shifts of the electroencephalogram. It originates from the upper cortical layer of the brain and last from 0.3 to several seconds. (18) It is not oscillatory and occurs therefore to external events. A shift in the negative direction reflects the depolarization of large cortical cell groups and this reduces the excitation threshold. The SCP is due to a large depolarization in layers or sheets of neurons. This means that a positive or negative DC shift has a physiological meaning. A negative shift reflects activation and the rhythm of the EEG on the other hand reflects the momentary excitability cycles in populations of neurons. The main source of these slower potentials is the glial cells. These cells regulate and support the neurons as part of the global system. They have been closely related to overall brain activation and have also been connected to stability in the brain. (18) Compared to neurons there are almost ten times more glial cells. Glial cells are known to be related to general cortical arousal, intention and are very relevant in epilepsy and other abnormal processes such as what is seen in ADHD. SCP training has been used successfully in ADHD and epilepsy. (18,25,26,21)

Training frequencies range from 0.01 Hz to 0.5 Hz and training is done using a monopolar placement. (27,28) SCP training is not traditional amplitude training. (29) With SCP training there is rather a monitoring of the shifting of brain potentials relative to a standard reference and makes it possible to either shift this potential up or down. The polarity of the training is important as this is what dictates whether the potentials will be trained in either an activating or deactivating manner. (21)

2.1.2.5. Infra Slow Frequency training

Infra Slow fluctuations (ISF) are also known as the ultradian rhythm and is a frequency of less than 0.01 Hz. Training is done only with sintered silver/silver chloride electrodes for stability of the signal. (30) ISF training is discussed in detail in section 2.2.

2.2 Infra Slow Frequency neurofeedback training:

2.2.1. Background

There are many neuroanatomic pathways that relay a direct and indirect interaction between the hypothalamus and the neocortex. It has been demonstrated that slow periodic fluctuations are superimposed on the time series of EEG power and that significant infra-slow oscillations occur distributed in a broad range between 50 and 320 seconds. The role of infra slow frequencies has been demonstrated in the release of luteinizing hormones (LH) where the onset of LH pulses is accompanied by a transient positive DC potential shift that commences shortly before the LH pulse onset. (31) It has also been found that infra slow frequencies are likely to reflect a superstructure of interacting and transiently oscillatory infra slow signals that play a role in both the integration within and the decoupling between concurrently active neuronal communities. (31-33)

As with SCP training glial cells are suspected to play a large role in the production of these slow signals. (21) Glial cells are recognised as having a large role in communication within the CNS in partnership with neurons. One of the large differences is however that unlike neurons, glial cells continue to undergo cell division into adulthood. This is particularly noticeable after brain injury. The two major types of glial cells include the microglia and the macroglia. Microglia are involved in the removal of debris resulting from injury, infection or disease. Microglia arise from macrophages outside of the nervous system and have no physiological or embryological relation to other neural cell types. (34) Macroglia (Figure 6) can be divided into three types of cells namely the oligodendrocytes, Schwann cells and the astrocytes. The first two are involved in myelination of axons in the CNS and peripheral nervous system. Astrocytes include fibrous astrocytes mainly found in white matter and protoplasmic astrocytes which is mainly found in grey matter. These cells play a role in various functions such as involvement in the blood-brain barrier junctions maintaining the appropriate concentration of ions and neurotransmitters. (34)

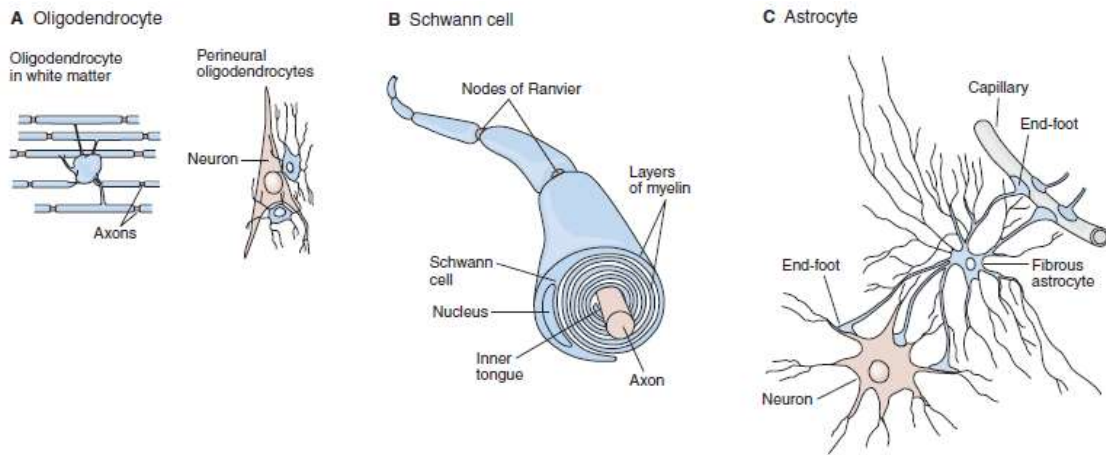


Figure 6: The macroglia in the central nervous system. (34)

2.2.2. Technical specifications

The three cardinal oscillator model was proposed by Crunelli and Hughes (21) which identifies 2 thalamic and one cortical source of Infra Slow Oscillations (ISOs). More recently astrocytes have also been identified as a source of ISOs in the 0.003-0.1 Hz range. The low frequency band is embedded in the direct current (DC) potential shifts in amplitude. (21) This fluctuation takes place on the millivolt (mV) scale. It has been observed that the DC fluctuations drive the microvolt changes in the slow frequency regime and this is what is targeted for feedback. The DC is measure in millivolts and the ISF signal in microvolts. (35) Even though it is possible to quantify the system response as a frequency it can also be considered as a time constant. This is based on a linear systems theory where for any filter there is a direct trade-off between the frequency response and the time response and that the time and frequency can be considered as equivalent alternative ways to view the system. (21) The lower the filter is set the slower the response to a change in input, thus the input must be larger to show a change in output. (21) These low-frequency cut offs can be set as low as 0.001 Hz and frequency adjustments can be made as low as 0.0001 Hz. The filter acts to block all but the largest transient shifts. This means that with a range of 0.001 to 0.0014 Hz the low cut-off brings the signal back to zero with a long time constant while the high cut-off ensures that only significant shifts will be passed through the filters. (21,30)

To perform ISF neurofeedback one needs sintered silver/silver chloride (Ag/AgCl) electrodes and a DC coupled amplifier. In the Brainmaster Atlantis amplifier first-order

Butterworth filters are used. This utilizes quadrature methods with an implicit envelope detection method and so provides information faster than conventional methods that uses a method of peak-to-peak detection. (35) As previously discussed, depending on the low cut-off frequency applied, the resulting filter will have a corresponding time constant. This means that if it is set at 0.002 Hz for example, the associated time-constant will be 175 seconds/2.92 minutes. This indicates that when there is a shift in the baseline the amplifier will require approximately 3 minutes to move the bulk of its recovery back to baseline. This means that the amplifier “holds” onto the DC level of the value for a long time in comparison to the occurrence of each fluctuation or shift in baseline. (35)

The frequency at which training is set, known as the OF is reflected to the client with two reward sounds. The higher tone is given when there is an amplitude increase of more than 15% and a lower tone is given when the amplitude decreases by more than 15% compared to a damped average of the signal. (35) The reward is given to the clients the instant the parameters are met and continues for the duration of the condition. There is also no refractory period between rewards which allows for rapid transmission of information to the client. In addition to the ISF reward band, the basic protocol includes inhibition of the 1-40 Hz bands in the EEG. It is set up to inhibit these frequencies 3% of the time by making use of an auto-thresholding function. This is an additional feedback parameter and the client receives this feedback via a dimming of the video that they are watching. There are more advanced protocols available that allow for greater flexibility and can include combinations of ISF and synchrony training and ISF with referential enhancement. (30,35)

2.2.3 Procedure discussion

It has been reported that the best response is when the optimum frequency OF for each individual client is determined. (35) This is done by starting at one of two 10/20 site options. Either starting at T3 and T4 or at T4 and P4. It can take several sessions of neurofeedback to determine the clients OF but once it has been identified it rarely changes. (35) Frequency adjustments based on the OF can then be made based on the cortical areas trained and the hemisphere involved (Figure 7).

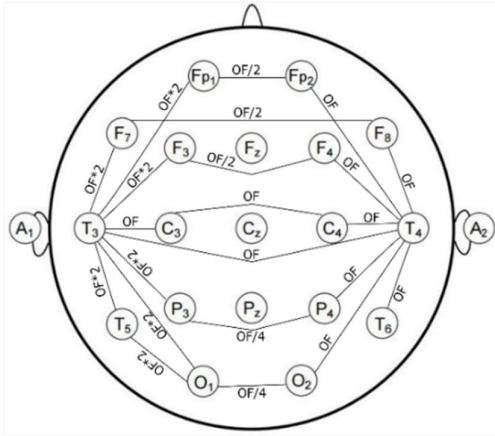


Figure 7: Cortical and hemispheric frequency adjustments based on OF (ISF Manual).

The process of optimization involves the client and therapist working together discussing what the client is experiencing so that the client can reach a state of optimal affect and arousal in session. The aim is to achieve a state of autonomic balance and is determined by the feedback from the client about their perceived changes. (35) It is important to evaluate the brain functionality before training as the comparison of pre- and post QEEG assessments can be helpful in determining if efficient training is taking place.

2.3 Quantitative electroencephalogram

2.3.1. Background

The human brain consists of hundreds of billions of neurons that use chemical messages to regulate the activity throughout the brain. This leads to measurable electrical changes. The measurement of these electrical changes is known as an EEG that can be understood by their frequency content. (36) In 1965 the FFT algorithm was invented which played a large role in the early progression of the field due to its simplification of the computation of spectral coefficients. (36) The Quantitative EEG commenced in 1932 when Dietsch (37) applied the FFT to seven EEG recordings and is still a very popular analysis method in the field today. (37)

Digital EEG has since been defined as the digital samples of the electric potentials produced by the brain and is known as the electroencephalogram. (38) The American Academy of Neurology defined Quantitative EEG as: "the mathematical processing of

digitally recorded EEG to highlight specific waveform components, transform the EEG into a format or domain that elucidates relevant information, or associate numerical results with the EEG data for subsequent review comparison.” (38) The comparison to normative values of developed databases was defined by Nuwer (38) as:” group statistics to determine whether a parameter (or parameters) measured on an individual patient lies inside or outside the range of normal values. Statistical techniques employed may be simple thresholds based on the mean and standard deviation of a “normal” distribution.” (38)

Whatever approach is used to analyse raw EEG, the most important factor which remains is that it should not be too far removed from the visual record. In EEG spectral analysis voltage amplitudes converted into frequencies as it is believed that mental processes are better reflected in the periodicities than in the raw value. One should however be able to observe these periodicities by inspecting the raw EEG otherwise it can become empirically meaningless. (37) In QEEG assessment it is assumed that each behavioural and mental state is reasonably homogenous in nature and that the underlying perceptual and cognitive operations occur in like quantities and qualities when a state occurs. It is also assumed that these perceptual and cognitive operations exhibit a distinct and reliable profile of the activity in the brain. An example of this is chronic alcoholics who typically show less Alpha activity than most people. (37) As mentioned previously, the goal of neurofeedback is to improve self-regulation and the QEEG can help to identify areas of dysregulation. (37)

A QEEG involves computer assisted imaging and statistical analysis of EEG. It includes many advantages such as offering an ideal temporal resolution in the millisecond time domain characteristic of neuronal information processing and there is no ionizing radiation as in other imaging methods. It can also image both excitatory and inhibitory cortical neuronal activity noninvasively, is portable and is relatively inexpensive. (39)

2.3.2 Database comparison

The QEEG is based on the determination of EEG abnormalities by comparing the individuals to a “normative” or “reference” database. Statistical deviations from the mean values in the database is used in combination with other clinical information to determine abnormalities or deviances in brain function. A number of databases (Table

2) are available for evaluation. They mostly differ in sample size; screening criteria and EEG features normed. (40)

The predictive accuracy and error rate are dependent on the data that makes up any given database and the sensitivity and specificity is directly proportional to the adherence to established statistical principals. (41) The Four Daubert Factors (41) for scientific standards of admissibility in Federal Courts that have already been met for several databases are:

1. Inclusion and exclusion criteria
2. Error estimates of reliability and validity
3. Peer reviewed publications
4. General acceptance.

It is important to know that these databases contain EEGs of medication free subjects. One must be able to recognize the influence of psychoactive medications when interpreting QEEGs. (40,42)

Table 2. Comparison of the most well-known QEEG databases. (40,43)

	Neurometrics+ B1:12 (John&Pritchep) (40)	Neuroguide (Thatcher) (40)	SKIL (Stern&Kaiser) (40)	NeuroRep (Hudspeth) (40)	Eureka3 (NovaTech) (40)	International Brain Database (Brain Resource Company) (43)	BrainDx (BrainDx) (43)	qEEG-Pro (EEGprofessionals, B.V.) (43)
Number of cases								
Adults	N=426	N=155	N=135	N=55+30 replicates	N=84	N=1284	N=464	N=1482 EC N=1232 EO
Children	N=356	N=470	None	None	None	N=607		
Age Adjustment	Yes - Regression Equation	Yes - age subsets 16<n<45	No - Adults only	No - Adults only	No - Adults only	Yes - Non-linear regression	Yes	Yes
Screening for Normalcy	Questionnaire screening for significant medical history	Questionnaire, WISC, WAIS IQ, WRAT, School grade point	Questionnaire screening for significant medical history, life events	Luria - Nebraska, medical history, life events	Questionnaire, interview for medical and clinical histories, negative for substance use	23 different questionnaires and scales, for medical and neurological history, cognitive screening2	Discriminant Function for certain conditions	Questionnaire, Client based, regression analysis
No of EEG channels	19	19	19	19	19	26	19	19
EEG Frequency Range	EEG spectra banded as Delta, Theta, Alpha, Beta (5-25Hz)	EEG spectra banded and in 1 Hz bins (0-32 Hz)	EEG Spectra in 1 Hz bins (1-24 Hz)	EEG spectra banded as Delta, Theta, Alpha, Beta (0,5-22 Hz)	EEG spectra in 1 Hz bins (2-32 Hz)	EEG spectra banded as Delta, Theta, Alpha, Beta, Gamma (0-40 Hz)	EEG spectra banded as Delta, Theta, Alpha, Beta, High Beta (0-40 Hz)	EEG spectra banded as Delta, Theta, Alpha, Beta, High Beta Gamma (0-40 Hz)
EEG Features used	Absolute and Relative Power, Coherence, Frequency, Symmetry	Relative Power, Asymmetry, Coherence, Phase	Absolute Magnitude, Comodulation	Absolute Magnitude, Relative Power, Frequency Ratios, Coherence, Phase, Symmetry	Absolute and Relative Power, Power ratios, Loreta	Absolute Power, Relative Power, Absolute Magnitude, Phase, Frequency, Symmetry, ERPs, Coherence, Frequency ratios, Loreta	Absolute Power, Relative Power, Coherence, Phase, Symmetry, sLoreta	Absolute Power, Relative Power, Absolute Magnitude, Phase, Frequency, Symmetry, Coherence, Frequency ratios, sLoreta, Burst metrics, Alpha peak, Comodulation, Fluctuation
Recording conditions	Eyes Closed	Eyes Closed, Eyes Open	Eyes Closed, Eyes Open 2 Tasks	Eyes Closed, Eyes Open	Eyes Closed	Eyes Closed, Eyes Open Task Battery	Eyes closed, Eyes open	Eyes Closed, Eyes Open
Reference electrode	Linked ears, Selected sequential Pairs	Linked Ears, Average, Laplacian	Linked Ears	Linked Ears	Common Average	Linked Mastoid (Also average reference in analysis)	Linked Ears, Average, Laplacian	Linked ears, Laplacian

Table by Karlien Balt

2.3.3. Medication consideration and effect in QEEG

It is always highly recommended that an individual be off medication when recording EEG. This is however not always possible and is always the decision of an attending physician. The other problem is that certain drugs like selective serotonin reuptake inhibitor (SSRI) type antidepressants have a very long washout time which makes the best clinical course of action to record the EEG while on medication. (40)

Even though there is a response stereotype for each medication it must always be considered that there are individual responses which may vary. It can also be impossible to evaluate when an individual is on a mixture of medications. Table 3 summarises some of the known effects. (42)

Table 3. Summary of known effects of medication on EEG. (42)

Substance/Medication	Effect on EEG
Marijuana/ Hashish/ THC	Increased frontal Alpha Increased frontal interhemispheric hypercoherence and phase synchrony Effects on evoked potentials
Lysergic acid diethylamide (LSD- 25)	In an EEG with a normal background -Decreased Alpha; Increased Beta In an EEG with a slower background – Increased Alpha and fast activity In a low voltage fast EEG – Little change observed May cause convulsions at higher doses
PCP Phencyclidine Angel dust	Increased slow activity Paroxysmal activity Extreme voltages
Barbiturates	Rhythmic 18-26 Hz activity frontally (can spread to entire cortex with long-term exposure) Increased dose – Increased slowing Further increased dose – Decrease in fast activity with predominant slowing and decrease in voltage Iso-electric pattern in barbiturate coma
Morphine/ Opiates/ Heroin	Increased Alpha initially Slowing Alpha during euphoric high stage Increased slowing with increased dose Iso-electric pattern can be noted Increased REM sleep
Alcohol	Ethanol at high doses leads to slowing In a low voltage fast EEG – initial exposure leads to sudden increase in Alpha

	In severe chronic alcoholism periodic lateralized epileptiform discharges (PLEDS) can be seen with obtundation
Neuroleptics Tranquilizers (chlorpromazine) Thioridazine Clozapine/Clozaril	Increased coherence, decreased Beta, increased temporal and morphologic sharp Theta transients. Reduced Alpha blocking (memory disturbance) Increased fast activity Typical neuroleptic pattern with increased epileptiform discharges
Anxiolytics Meprobamate Benzodiazepines (Valium/Ativan)	 Increased Alpha, increased Beta over 20 Hz, slightly increased Theta Decreased Alpha, increased Beta 20-30Hz, sinusoidal hyper-rhythmic spindling Reduction in paroxysmal and epileptiform discharges
Hormones (Vasopressin) (Cyproterone acetate)	 Increased high Alpha Decreased frontal Alpha and increased Beta
Antidepressants Imipramine Amitriptyline Iproniazid MAO Inhibitors SSRIs	 Increased slow activity, decreased Alpha and high Alpha, increased Beta 20Hz and above More increased slow activity decreased Alpha and high Alpha, increased Beta 20Hz and above, increased paroxysmal discharges in epileptics Slightly increased slow activity marked increase in fast activity Wider response variation. Some increase 20-30Hz activity and decrease slow activity. Others have a more typical effect but with more variation. Fewer changes in slow activity, mild fronto-central Beta increase on 18-25Hz range, decreased Alpha anteriorly
Stimulants Amphetamines Methylphenidate Caffeine Nicotine Cocaine	 Increased activity in the RAS – release of norepinephrine, increased Alpha peak frequency Decreased slow activity, increased Beta 12-26Hz Decreased Delta and Theta activity, posterior Alpha increase, increased low Beta Theta and frontal Alpha increase in withdrawal – suppression with resumption Theta and frontal Alpha increase in withdrawal – suppression with resumption Low to moderate doses – increased Alpha and Beta Increased doses – desynchronization of the EEG with dominant fast activity Chronic abuse – decreased Delta (“burned out” dopamine system); Slow Alpha
Antimanics	Increased Theta, mild decrease in Alpha and increased faster activity; strong potentiation of latent epileptiform activity. Overdose shows marked slowing with triphasic discharges
Tuberculostatics	Burst of paroxysmal activity noted
Methanol	EEG shows marked slowing
Solvents	EEG shows marked slowing

Mercury	Initial exposure leads to increased fast activity. Increased concentrations shows increased fast and slow activity with paroxysmal activity of an epileptiform nature
Organo-phosphates	Slowing of the EEG with paroxysmal bursts
Chlorinated hydrocarbons	Bi-temporal sharp discharges and anterior slowing. Convulsions
Lead, organic	Cerebrotoxic effects with drop in IQ, dementia and convulsions Diffuse slowing of the EEG with paroxysmal discharges after increased exposure
Aluminium	EEG shows slowing with excessive fast activity

2.3.4. QEEG components analysed

2.3.4.1. EEG

Commonly, the Neurotherapist focuses on rhythms and activity within defined frequency bands. There might be minimal changes in how these bands are defined but commonly Delta is defined as 0.1-4 Hz activity, Theta 4-8 Hz, Alpha 8-12 Hz, Lobeta or SMR 12-15 Hz, Beta 15-18Hz, High Beta 18-40 Hz and Gamma 40 Hz and above. The extent of cortical engagement is identified by measuring the mix of slow and fast activity across the head. (36) The mix of activity is also present at different amplitudes which is also important in analysis. Typically, high frequency oscillations have smaller amplitudes compared to the lower frequencies. The relationship between amplitude and frequency can be seen in Figure 8. (44)

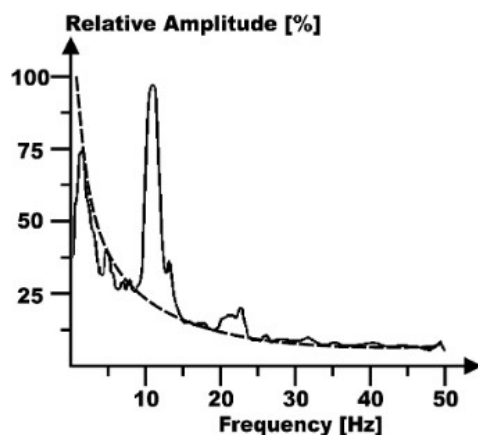


Figure 8: The relationship between amplitude and frequency. (44)

The electrical activity is measured over 19 active sites on the head and it is detected as the difference in potential between two electrodes in a grounded system. (36) When all electrodes are paired to the same physical reference such as the vertex (Cz) or the ears it is known as a referential montage. This is different from a bipolar recording where electrodes are paired in series without a common reference. The linked ears montage, which is used by the most known databases, provides a non-lateralized reference when it is properly connected (Figure 9). (36)

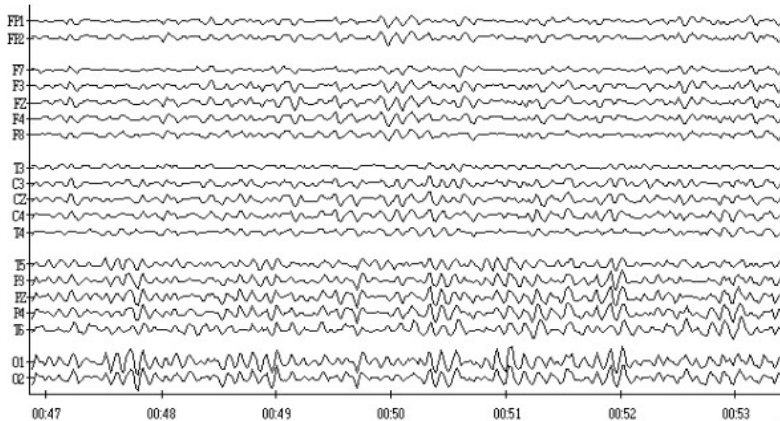


Figure 9: The EEG data recorded from 19 channels in a linked ear montage for an adult. (36)

When looking at a QEEG analysis there is two types of data available. The first is the activity at a scalp location and with this the examination of different frequencies is done in terms of measurements. This includes amplitude, relative power, peak frequency and peak amplitude. Secondly, the quantification of the association between locations is quantified. This includes phase and coherence analysis. (45) See Figure 10.

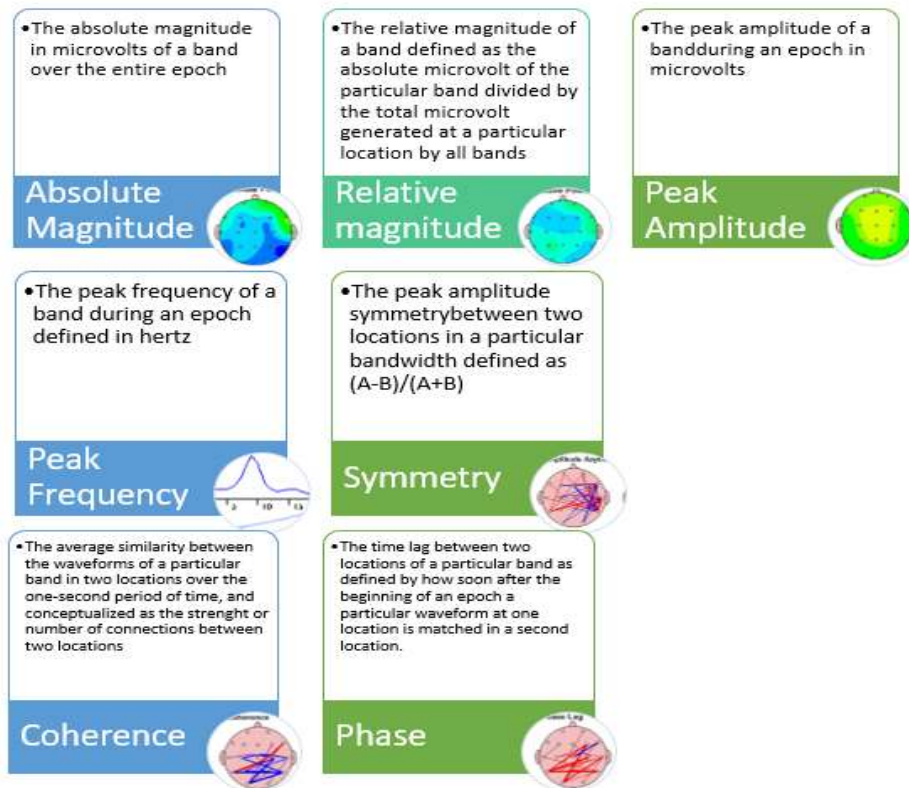


Figure 10: Summary of the components of a QEEG analysis. (45-47)

2.3.4.2. Functional connectivity

Network abnormalities can be evaluated by looking at functional connectivity. This includes determining whether there is excessive or deficient shared activity between brain areas. (36) By looking at a coherence or comodulation analysis the clinician can also determine functional homogeneity, differentiation or topographic reciprocities. (36) The coherence analysis is defined as the quantification of phase consistency between signals, whereas comodulation quantifies the magnitude of the consistency. (36)

2.3.4.3. Data review and selection

Artefact management is very important, and it is essential to identify and remove this before QEEG analysis can be performed. This is usually activity generated by muscle movement (such as the eye, face, neck or heart); changes in skin conductance; or even equipment problems. Some software contains filters that can automatically detect artefact by making use of algorithms and low- or high-pass filters. (36) The rest needs to be done via manual deletion or at least requires human intervention. (36)

The most popular analytical approach which reduces EEG to a manageable number of coefficients is frequency analysis. This allows the information to be presented in various formats such as numerical tables, histograms, line graphs or brain maps. The brain maps convert the numeric data into colours and in this way a user-friendly depiction is provided from a large set of data. (37) The end goal of a QEEG analysis is to identify the deviations in the underlying electrophysiological measures so that interventions directed towards these can improve the clinical condition or chief complaints. (48)

2.3.5. EEG and QEEG phenotypes

This can also be defined as a QEEG profile or a neurophysiological “phenotype” that is variably representative in one or more disorders defined behaviourally. (40) It is however important to realize that even though an individual QEEG profile may contain elements of several phenotypes it may be more complex and can contain elements of several patterns. It can also be a manifestation of both the genome and behaviour and these phenotypes are highly heritable and not isomorphic with DSM categories. This can have implications on the therapeutic level. (40,49)

2.3.5.2 Commonly seen QEEG phenotypes

The following phenotypes have been identified:

Diffuse slow activity, with or without low frequency Alpha: Commonly seen when there is a decrease in CNS activation and usually involves the reticular activation system (RAS) and the thalamic projection system. (40) This can lead to a decrease of Alpha and an increase in slow activity. It can be due to specific neuropathology and is often seen in pervasive developmental disorders, dementing illness and other disorders of consciousness. The slow activity is usually seen as a mixture of diffuse lower voltage Delta and Theta and low frequency Alpha can be seen separately or coexistent. (40) Diffuse slow activity is also seen in cases with probable post-concussive syndrome. (46)

Focal abnormalities, not Epileptiform: Focal slowing can be from a tumour, ischemia, stroke, trauma, inflammation or another medical condition. (40) It can also involve focal low amplitudes across different frequencies and regions as has been

observed in attentional and affective disorders where there is a general amplitude minimum in the frontal areas.

Mixed fast and slow: In this profile there is usually a decrease in the traditional Alpha band frequency of 8-13 Hz and in the lower Beta frequencies in conjunction with increased higher Beta and slow activity. (40) It can be seen with either an anterior or posterior emphasis. It is more commonly associated with the use of medication but can be due to encephalopathy. (40)

Frontal lobe disturbances: The frontal lobes play a large role in the general regulation of the brain and disturbances in these areas are associated with various disorders. This includes attentional and affective disorders as well as motor dyscontrol. Frontal Alpha and/or Theta excess or even Beta excess is commonly noted in ADD/ADHD. (40) Midline frontal irregularities are often noted in Obsessive Compulsive Disorders (OCD), Oppositional Defiant Disorders (ODD), Reactive Detachment Disorder (RAD) and Generalized Anxiety Disorders (GAD) and can be due to dysfunction in the cingulate, marginal gyrus or supra-marginal gyrus. (40)

Frontal asymmetries: Various literature has mentioned the importance of asymmetries in the frontal lobes. (40) The interhemispheric ratios of Alpha and Beta are often implicated with right hemispheric dominance commonly being associated with a lower mood state or depressive symptoms. Bilateral increased Alpha is sometimes noted but a right frontal excess is typically noted in anxiety or agitated type of depression but is also seen in autism. (40,46)

Excess temporal lobe Alpha: An increase in temporal lobe Alpha usually suggest decreased function in this area but it may also be an effect that is seen in response to decreased activity by the ipsilateral frontal lobe as the decreased stimulation frontally allows the temporal lobe to be idle. (40)

Epileptiform: Epileptiform activity in any area of the brain indicates significant dysregulation and areas of origin usually do not communicate well with other areas. The application of neurofeedback in epileptiform abnormalities is the most thoroughly validated application with various double blind and randomized trials. Careful attention is required to determine the location of onset. (40,46)

Faster Alpha variants, not low voltage: Sometimes the Alpha frequency can be faster than usual, and this can correspond with anxiousness or hypervigilance. (40) There is usually a complaint of attention difficulties in conjunction with anxiety as the

hypervigilance can act as a source of distraction. It has also been noted 1-2 years post injury in areas where there has been acute trauma. (40)

Spindling excessive Beta: More commonly this is due to a medication effect but if no medication is involved it can be because of dysfunction or encephalopathy. (40) Focal excessive spindling has been associated with pre-epileptic auras and may be associated with cortical “irritability”, viral or toxic encephalopathies or epilepsy. Focal excessive Beta spindling has also been reported in ADD/ADHD and bipolar disorder. (40)

Generally low magnitudes (fast or slow): When the low voltage EEG is fast, it is considered as a normal variant. If it is slow it can be a diffuse and non-specific abnormality. It can be related to drowsiness but can be an indication of metabolic, toxic, degenerative or post hypoxic etiologies. (50) Low voltage slow EEG has also been reported in the early stages of dementia. Low voltage fast Alpha has been associated with alcoholism. (50)

Persistent Alpha with eyes open: In the eyes open state Alpha generally drops by 50% or more in amplitude or magnitude. (40) This is due to the specific projection system of the hypothalamus. If this system is failing it is suggestive of reticulo-thalamic activation problems and can lead to under-arousal. In anxious individuals’ Alpha can attenuate in the eyes closed condition. (40,51)

2.3.5.2. QEEG, sLoreta and fMRI deviances found in anxious individuals

The QEEG of an anxious individual typically shows various abnormalities. One of the most common traits seen in an anxiety disorder is a decline in Alpha activity. (52) In a study conducted on 100 patients with an anxiety diagnosis conducted by Gurnee (2003) (52) six QEEG subtypes were identified as seen in Figure 11.

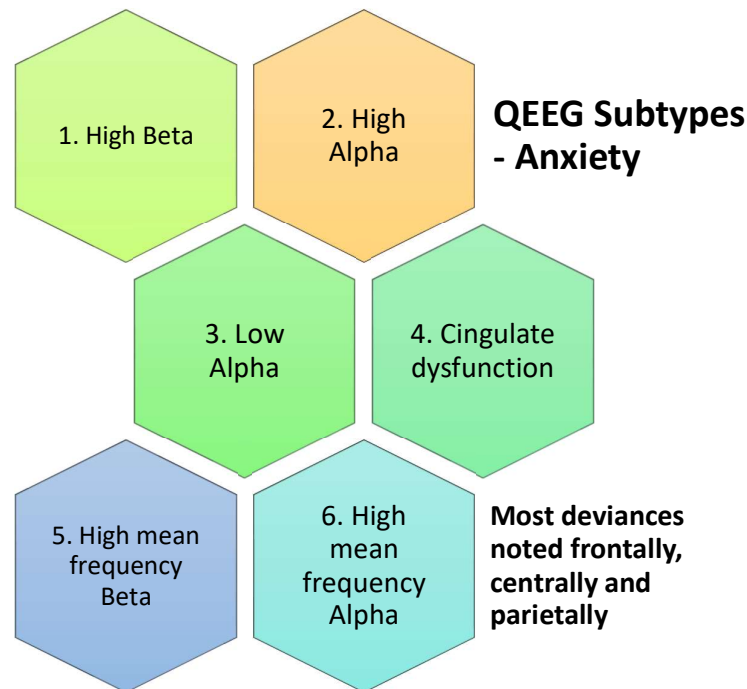


Figure 11: QEEG anxiety phenotypical subtypes. (52)

Some individuals also show a significant decrease in connectivity for the brain regions associated with emotion processing. This includes the insula, and adjacent regions, the hippocampi, the parahippocampal and entorhinal cortex, the right amygdala, the brainstem near the substantia nigra, the temporal pole, superior temporal sulcus, thalamus and the fusiform gyrus. Increased connectivity has also been noted in the prefrontal areas associated with emotional regulation and cognitive control. This includes the right lateral prefrontal cortex, and the bilateral portions of Brodmann's area 8. (52,53)

2.4. Physiological measurements of autonomic response

2.4.1. Background

Autonomic nervous system function is a response system which is normally not under the control of an individual. This makes it a more accurate measure of stress in an individual as it is not easily manipulated. This makes it free from self-report biases. This suggests that the autonomic reactions might be related to another type of stress response that is out of the conscious control of the individual, namely the defence mechanism. The greater the stress, the greater

the need for defence will be and thus should be related to heightened physiological arousal. This can protect the individual from the conscious experience of anxiety although arousal on the physiological level can continue. (54)

Symptoms of autonomic activity is often reported in different conditions such as anxiety, headaches, chronic levels of anxiety and depression are associated with altered activity of the autonomic nervous system. (55) This commonly includes symptoms such as nausea, vomiting, diarrhoea, pallor changes, vasodilation, piloerection and diaphoresis. Individuals may experience increased heart rate and blood pressure, dilation of the pupils, trachea and bronchi and changes in body temperature. In the absence of a real threat, as in the case of anxiety, these physiological changes can be a great source of discomfort. (55) A lot of these symptoms include both hypo- and hyperfunction of both the sympathetic and parasympathetic nervous systems (Figure 12). (56) The understanding of the ANS and the homeostatic changes that occur remains a challenge for neuroscientists to understand as it is a fundamental component in the treatment of anxiety, stress and emotional disorders. (57)

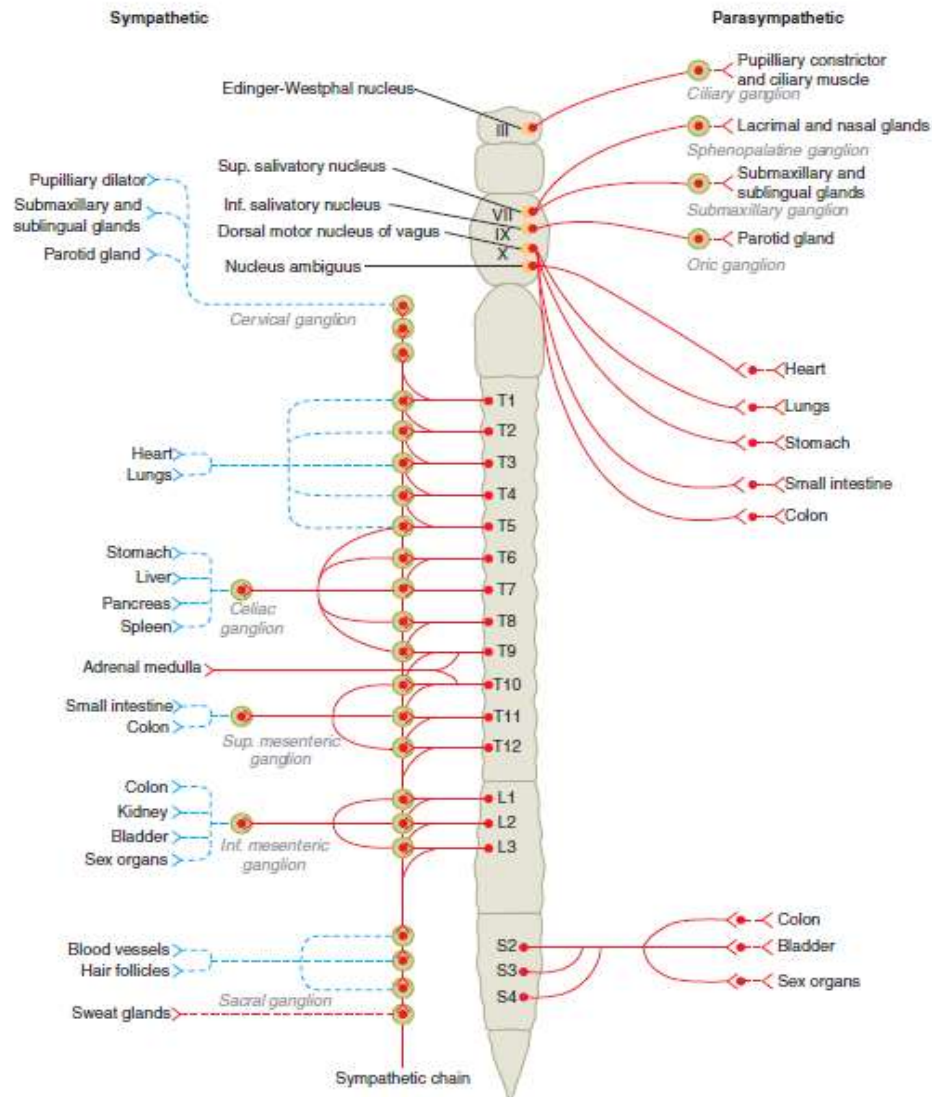


Figure 12: The organization of the sympathetic and parasympathetic nervous systems with cholinergic nerves indicated in red and adrenergic nerves in blue. (34)

It has been suggested that breathing techniques for example can be used as a first-line and supplemental treatment for stress, anxiety and depression as it affects both the body and brain where medications just effect neurotransmitters in the brain. (57) There are widespread changes in homeostasis during stress and anxiety and this makes treatments that can shift the ANS from a sympathetic to parasympathetic state a very promising component in the treatment of these diseases. (57,58)

There is a variety of symptoms commonly reported by individuals suffering from anxiety. This includes trouble falling and staying asleep, fatigue, headaches, muscle tension, pounding and racing heart and purposeful exclusion of people and places in order to avoid anxiety provoking situations. (53)

2.4.2. Heart Rate Variability and Breathing

Heart Rate Variability (HRV) is a measurement of autonomic function and is defined as the characterization of the short time fluctuations of Heart Rate (HR) in a time series. A large HRV is considered as a sign of good health in medical practice. (59) Numerous publications have demonstrated biofeedback and neurofeedback training as being efficacious in the management of a wide range of medical and psychological disorders. (57-60) The regulation of HRV occurs via neural input from both the parasympathetic and sympathetic nervous systems. The predominant effect being from the parasympathetic division by either an input or withdrawal effect. A study by Prinsloo et al. (60) found that when analysing HRV values, chronic psychological stress lead to a low HRV and a decrease in the HF component is seen which is indicative of a decrease in vagal activity. (60) The increase in plasma cortisol associated with chronic stress furthermore results in impaired memory and impairs general cognitive function. (60) In contrast to this a higher HRV is associated with increased executive functioning, faster reaction times and improvement in cognitive tasks. (60)

Negative mood states such as stress, anxiety and depression can lead to sympathetic activation due to widespread depolarization throughout the brain and the body. (57) Slow deep breathing and meditation leads to an inhibition that causes hyperpolarization and, in this way, parasympathetic activation. (57) From reviewing the literature, it is blatant that anxiety has almost unanimously been characterized by sympathetic activation and vagal deactivation together with faster and shallower breathing. (61) Other physiological changes that have been researched include increased heart rate, decreased HRV, increased LF and LF/HF, increased electrodermal activity. (61,62) Aggression, anxiety and depression have all been associated with low levels of resting respiratory sinus arrhythmia (RSA). (63) Low tonic RSA typically reflects rigidity or a diminished

capacity for flexibility in responses and has thus been associated with a host of emotion-related problems. (63)

HRV spectral analysis uses the pre-defined frequency bands for analysis and these bands reflect independent SNS and PNS components. This includes the Ultra-Low Frequency (ULF), Very Low Frequency (VLF), low frequency (LF) and High Frequency (HF) bands and the LF/HF ratio which is considered as a key indicator for sympathetic-parasympathetic balance (Figure 13). (59,63,64) See table 4 for a summarised detail of the different frequencies.

Table 4. The different HRV frequencies and their main functions. (65)

HRV Frequencies			
Ultra-Low Frequency ULF	Very Low Frequency VLF	Low Frequency LF	High Frequency HF
- <0.0033 Hz = 300 seconds/cycle Minimum > 24-hour recording Circadian Not commonly used in clinical assessments	0.0033-0.04 Hz = (300-25) Seconds per cycle = (0.2-2.4) cycles/min Minimum 5-minute recording Strongly predictive of all-cause mortality and inflammation Origins unclear Intrinsic (pacemaker) predominantly SNS activity Not baroreflex Low power from parasympathetic influence at normal respiration	0.04-0.15 Hz = (25-6.7) seconds/cycle = (2.4-9) cycles/min Minimum 2 min recording Baroreceptor range during rest Power from SNS, PNS and baroreceptors SNS not above 0.1Hz In slow respiration – vagal parasympathetic influence increases PNS dominant to 0.07 Hz due to baroreflex activity	0.15-0.4 Hz = (6.7-2.5) Seconds/cycle = (9-24) cycles/min Minimum 1-minute recording Respiratory band Parasympathetic activity HR variations related to respiratory cycle may not reflect vagal tone Respiratory Sinus Arrhythmia (RSA)

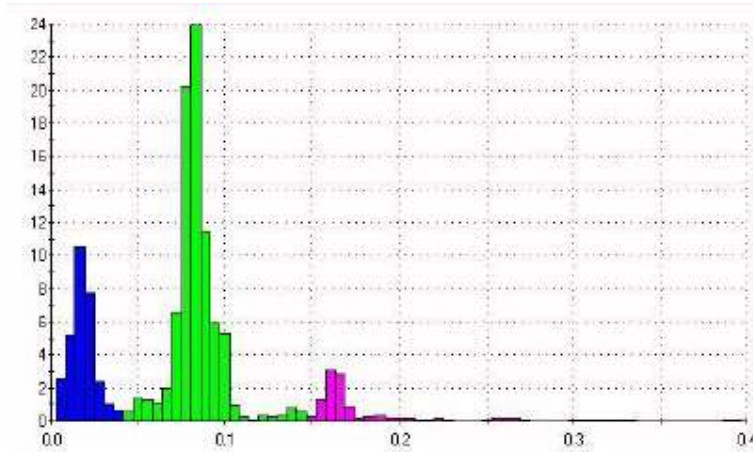


Figure 13: Ideally the highest amplitude should be in the LF range as this indicates good balance between sympathetic and parasympathetic activity. (66)

Slower respiration rates correspond to increased levels cardiorespiratory synchronization and this leads to a shift towards parasympathetic dominance via widespread hyperpolarization and inhibition of both the amygdala and thalamic cells. (68) During stress one sees decreased levels of cardiorespiratory synchronization and this leads to an increased heart rate in irregular breathing. This effect is alleviated by meditation where a parasympathetic dominance is seen, and increased levels of cardiorespiratory synchronization is seen. (57,67, 68)

2.4.3. Physiological basis of Electrocardiogram and Blood Volume Pulse

This delivers oxygen and nutrients to the organs and the muscles. The contraction of the heart is controlled by natural pacemakers – the sinoatrial (SA) and atrioventricular (AV) nodes. Contraction of the heart involves a series of electrical events. (69) It involves depolarization and repolarization of the muscle fibres which triggers the contraction in the atria and secondly in the ventricles. The inter beat interval (IBI), commonly known as the R-R interval, is the time between two heartbeats and is the source of the HRV data. (Figure 14)

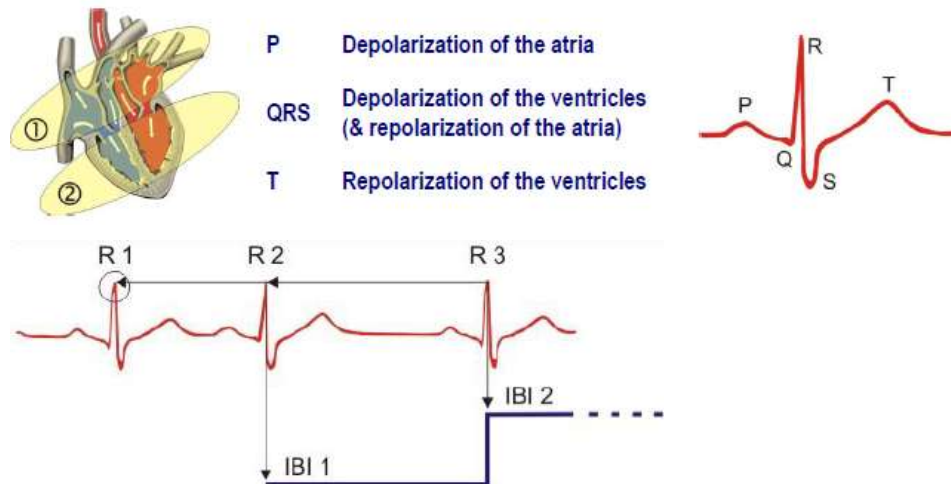


Figure 14: The inter beat interval (69)

2.4.4. Temperature

Greater relaxation is associated with an increase in peripheral finger temperature. This is due to a decrease in vasoconstriction where blood pressure and heart rate also decreases. (70) This has been associated with lower anxiety and a lowering in pain. (70) A decrease in peripheral temperature is associated with sympathetic arousal and research has indicated that it is responsive to stress induction. (71)

2.4.5. Skin Conductance

There is considerable evidence that indicates that individuals disposed to use defensive emotion-inhibiting strategies show increased electrodermal reactivity (EDA) when they are faced with stressors while those who are less exposed will show less reactivity. (54) EDA, and more specifically skin conductance (SC), is a marker of the sympathetic nervous system and the behaviour inhibition system (BIS). (72) This is a neurophysiological motivational system that can increase arousal and attention for support in risk assessment and can inhibit impulsive behaviour in potentially threatening situations. (72) It is considered to be a direct and undiluted representation of sympathetic (cholinergic) activity. (58) Increased EDA is commonly associated with higher trait anxiety, anger, depression and somatic symptoms. (73)

2.4.6. Muscle tension

Muscle activation is controlled by the CNS. (74) There has been evidence that sympathetic muscle activity is associated with anxiety and depression and that muscle over-activity is often associated with anxiety. (75,76) In anxiety disorders muscle relaxation has become a very important technique used as a treatment modality. (77) It is also used in various other psychiatric disorders but lack of proper studies as evidence has negatively influenced the use of it in treating these disorders. (77,78)

The diagnostic criteria for GAD include excessive anxiety and uncontrollable worry accompanied by at least two additional symptoms. This includes restlessness, becoming easily fatigued, difficulty with concentration, irritability, muscle tension and restless sleep. (79) Further investigations have shown that only muscle tension shows a unique and substantial correlation with pathological worry. (79)

In previous studies it was found that the action potentials in the neck muscles of patients with anxiety and stress were much higher than in healthy controls. (76) Over activity in electromyograms (EMGs) has also been recorded in the neck and scalp muscles of anxious individuals. (76)

The underlying physiological mechanism involves the γ -motor neurons. (76) These neurons are regulated by descending tracts from a number of areas in the brain and also control α -motor neurons. This mechanism plays a role in the sensitivity of muscle spindles and the threshold of the stretch reflex. In anxiety disorders an increased discharge is noted which can lead to hyperactive tendon reflexes. (76)

2.4.7. Blood Pressure

Hypertension has become a very prominent public health issue with approximately 1 in 4 adults in the United States being affected. It is a risk factor for death and disability related to coronary heart disease, heart attack, stroke, kidney disease and vascular complications. (80) A high systolic blood pressure has also been linked to decreased cognitive performance, memory loss and the loss of healthy brain tissue. An increased activation of the sympathetic-adreno-

medullary axis and increased levels of circulating adrenaline and noradrenaline is seen in chronic psychological stress and chronically high levels of adrenaline has been implicated in the progression of hypertension. (80) Behavioural interventions aimed at reducing stress and sympathetic arousal has been shown as effective interventions leading to reduce stress and sympathetic arousal leading to a decrease in blood pressure. (80)

The arterial baroreflex is important for homeostatic control of blood pressure. In humans psychological stressors can suppress the capacity of the arterial baroreflex to control short term fluctuations in blood pressure and this is reflected by reduced baroreflex sensitivity. Analysis of fMRI data have implicated that a reduction in baroreflex sensitivity covaried with greater activity in the brain systems important for central autonomic and cardiovascular control. (81) This includes the cingulate cortex, the amygdala, insula and the midbrain periaqueductal gray (PAG). Many animal and human studies also link these brain regions to the generation of acute cardiovascular reactions to stressful stimuli. (34, 81) This reflects their influence on brainstem nuclei that control autonomic nerve traffic to the myocardium and vasculature. (81) This is a key mechanism whereby the processing of psychological stressors evokes acute cardiovascular reactions that involves the suppression of the arterial baroreflex. (34, 81)

An increase in blood pressure that expands vessel walls of the carotid arteries and the aortic arch leads to an increase in the firing of baroreceptors. This is relayed centrally along the vagal and glossopharyngeal nerve bundles to the nucleus solitarius. (81) Baroafferent signals are then relayed to the parasympathetic and sympathetic source nuclei which in turn decreases heart rate, cardiac contractibility and vascular resistance. (81) This serves to return the arterial blood pressure towards a regulated set-point in a homeostatic control loop fashion. During psychological stressors there is however a suppression of the baroreflex to regulate blood pressure and this is apparent in the relationship between heart beat interval and blood pressure adjustments following successive beat to beat changes in blood pressure. (81) This can become exaggerated and pathogenic in some individuals. (81)

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Chapter 3: Materials and Methods

3.1. Participant information

Sampling was randomized and consisted of a population group that had already decided out of their own volition to do neurofeedback training. These individuals were randomly assigned to either the ISF or control group. See table 5 for a summary of participant demographics.

3.1.1. Inclusion criteria

- Reports of high anxiety.
- Reports of daily problems with concentration and memory.
- Complaints of sleep problems.
- Reports of emotional or anger control problems.
- Subjects that come for at least two training sessions per week.
- Subject that complete a minimum of 10 sessions of ISF neurofeedback training.

3.1.2. Exclusion criteria

- Subjects using recreational drugs.
- Subjects using benzodiazepines will be excluded as this drug is known to have a negative outcome on neurofeedback training.
- Subjects using any new form of medication during the study period that may influence the outcome.
- The effect of various drugs on the EEG have been published. We will be looking for any of these known effects and any participants showing possible signs of drug use will be excluded.
- Subjects not doing a minimum of 10 training sessions.
- Subjects not coming for at least two training sessions per week.

Table 5. Summary of participant demographics. C= Control group, S= experimental group

Subject	Sex	Handedness	Age (Years)
C1	M	Left	36
C2	M	Right	39
C3	M	Right	26
C4	F	Right	36
C5	M	Left	19
C6	M	Right	55
C7	M	Right	18
C8	F	Right	55
C9	M	Left	26
S1	M	Right	35
S2	M	Right	22
S3	F	Right	23
S4	F	Right	24
S5	M	Right	49
S6	F	Left	36
S7	F	Right	23
S8	F	Right	23
S9	M	Right	37
S10	M	Right	24
S11	M	Right	48
S12	M	Right	49
S13	F	Right	38
S14	M	Right	22
S15	M	Right	55
S16	M	Right	38
S17	F	Right	49
S18	F	Right	34
S19	F	Right	27
S20	F	Right	18
Total Male	17		
Total Female	12		
Mean age	33,9		
Mean age Control	34,4		
Mean age Experimental	33,7		

From clinical interviews on completion of the questionnaire at intake it was determined that the 5 main complaints that most participants had in common were:

- Anxiety/panic attacks
- Either falling asleep or staying asleep
- Irritation/anger problems
- Executive function problems (concentration/focus/memory complaints)
- Constipation and or irritable bowels

3.2. Procedures

3.2.1. Data Collection

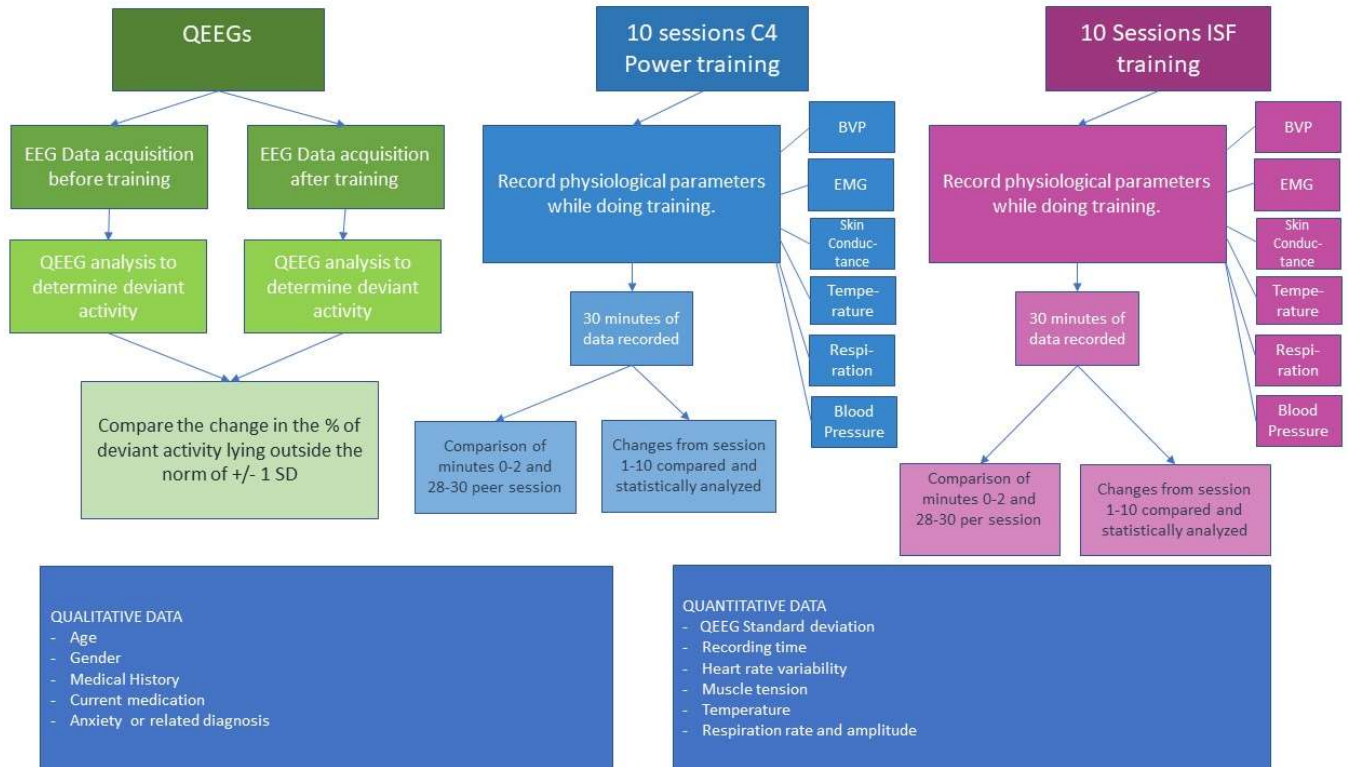


Figure 15: Summary diagram of data management and analysis.

3.2.1.1. Questionnaire

The subjects will first complete an evaluation questionnaire (Figure 15) to determine what current problems they are experiencing along with a clinical interview. The questionnaire being used is given to all ISF practitioners when doing their training and was developed to evaluate a broad range of information. (Appendix 3) This also helps to determine the best starting placement for ISF training as discussed in chapter 2, at either positions T3/T4 or T4/P4. (1,2)

3.2.1.2. QEEG

The Discovery 24 Channel EEG amplifier (Brain master Technologies, USA) is a physiological monitoring and feedback system (Figure 16). It offers monitoring and

feedback of brain signals and include the measurement of EEG, direct current and slow cortical potentials (DC/SCP). (2)

The recordings are made from the surface of the body using standard tin, gold, or silver chloride sensors. In our study, sintered Ag/AgCl sensors were used. This provides a visual or auditory signal corresponding to the status of a patient's EEG (e.g. brain Alpha wave activity) for the patient to undergo operant learning.

Signal processing and feedback are provided by a PC running the software provided by BrainMaster Technologies Inc USA (BrainAvatar 4.6) and information is derived from spectral analysis of the EEG.

The Discovery uses optical and magnetic isolation/coupling technology to provide a safe, low-noise interface to the user's PC and provides EEG biofeedback monitoring, analysis and reports using a Windows PC with the supplied software. (3,4,5)

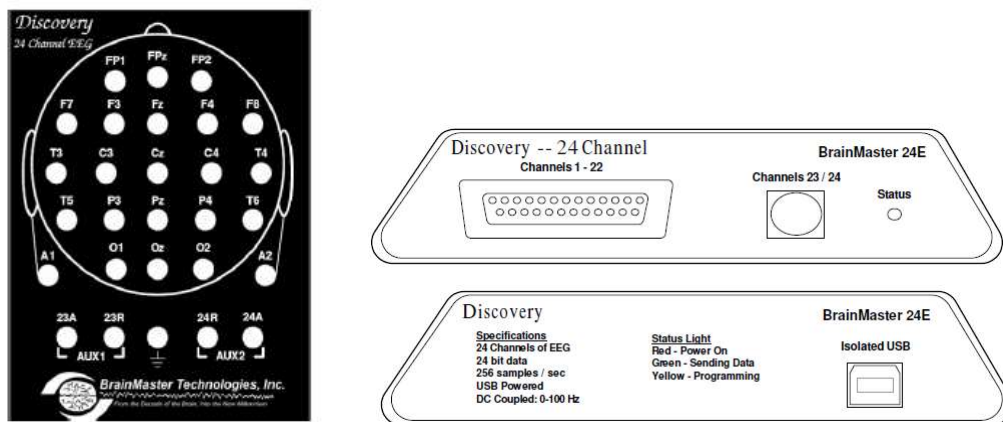


Figure 16: The Discovery 24 channel amplifier. (4)

With the BrainAvatar software, 19 channels of EEG can be recorded simultaneously (Figure 17). It can also display the sLoreta analysis visually in different brain areas while the recording is being done (Figure 18).

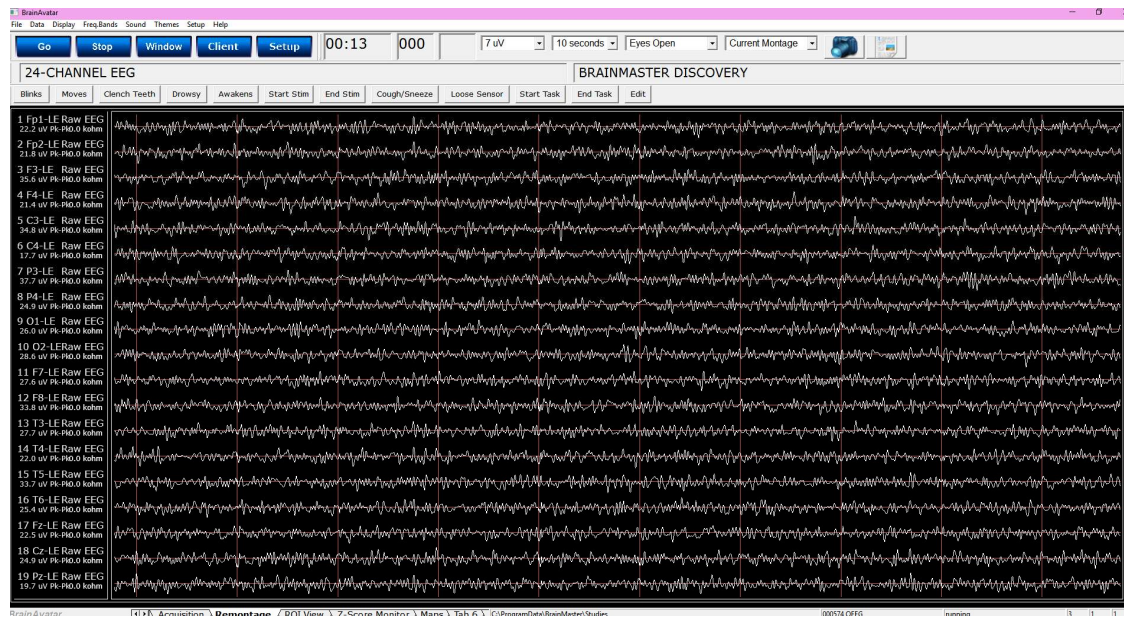


Figure 17: Example of a BrainAvatar acquisition screen (BrainMaster Technologies Inc.)

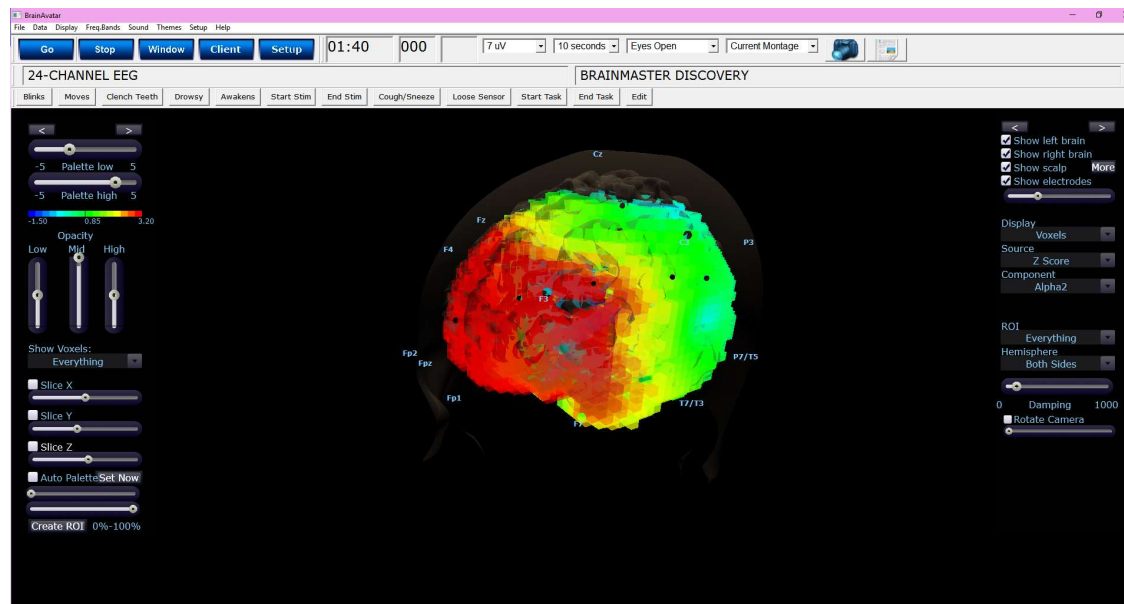


Figure 18: Real-time EEG monitoring visualized in BrainAvatar software during acquisition (BrainMaster Technologies Inc.)

The QEEG is a standardized evaluation which requires recording EEG from 19 active electrodes in a linked ear montage as seen in Figure 19.

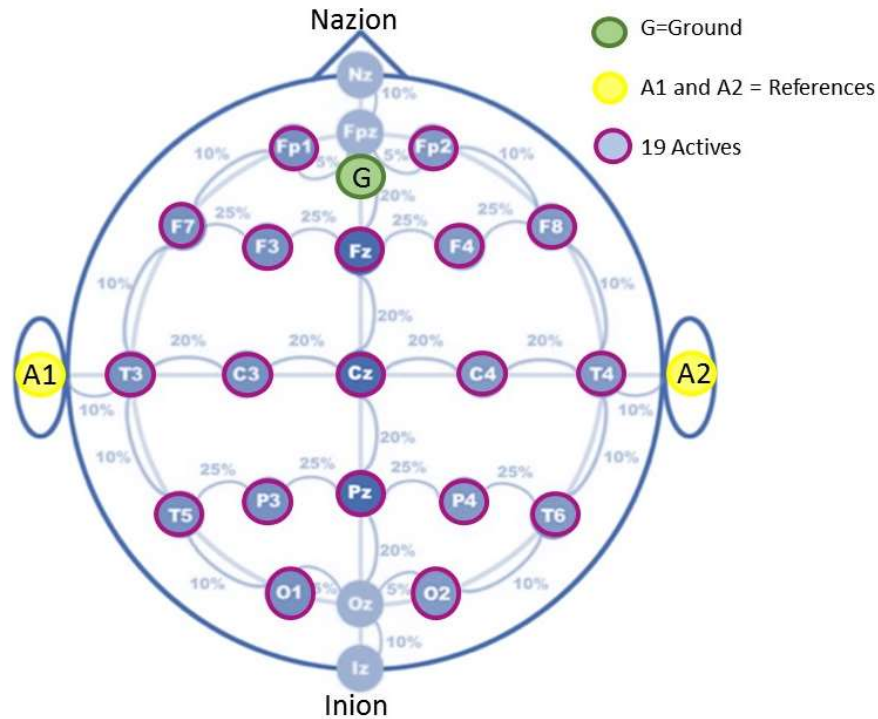


Figure 19: Placement of electrodes for QEEG as based on the 10/20 placement.

Each area on the scalp is cleaned using NuPrep skin preparation gel. This is an abrasive gel that removes any dead skin. Electrodes are then pressed onto the cleaned area using 10/20 conductive paste. Surrounding hair helps to keep electrodes in place. If there is not any hair surrounding the area as with Fp1 and Fp2, a piece of micropore tape can be used to help keep it in place.

Once an impedance of less than 5kOhm is obtained the data can be recorded. The subject is instructed to sit relaxed with minimal movement for 10 minutes – 5 minutes with the eyes closed and 5 minutes with the eyes open while the EEG is recorded. Once recorded the data can be uploaded in to the QEEGProTM™ database to be processed.

The QEEGProTM™ database consists of resting state EEGs recorded from clients. Each client in the database filled out an extensive diagnostic and statistical-based questionnaire and by making use of statistical regression psychopathology was removed. The EEGs were recorded in the Netherlands between 2008 and 2014 and

is updated yearly. It currently consists of 1482 eyes closed and 1231 eyes open recordings made using modern high-end amplifiers.

A Standardised Artefact Rejection Algorithm (S.A.R.A.) developed by Dr Andre Keizer was used for all the recordings in the database. It evaluates the raw EEG for eye blinks, horizontal eye movements, low and high frequency artefacts and epileptiform activity. All EEGs are processed anonymously and stored on the QEEGProTM™ server for 6 months, after which it is deleted.

The following aspects can be compared (Figure 20, 21 & 22):

- Absolute power: This is the amount of power at each electrode site for each frequency band that is compared to a database mean value.
- Relative power: This is each score relative to the total power of all the frequencies. The percentage of power in any band compared to the rest of the patient's EEG.
- Amplitude Asymmetry: The average difference between signals measured compared to normative database
- Coherence: Coherence is the communication and coordination between two areas of the brain. Coherence focuses on Hyper (excessive) or Hypo (too little) connectivity between two sites. Hypercoherence denotes functional rigidity. Hypocoherence in network sharing denotes functional isolation.
- Phase: A measure of the temporal relationship between two signals. Reflects the speed of information sharing between two sites, or between two sites and a third (or more) sites. Two sinewave signals are said to be "in phase" (have zero phase difference) when their peaks and valleys are aligned in time. (QEEGProTM, 2016)

For experimental purposes we identified absolute power and coherence as the two main measurements to be used for comparison as these are the most well-known and commonly used variables in QEEG analysis (Figure 23).

Client ID: 000444
Test Date: 2016-05-18
Age: 9.21
Gender: Male
Montage: Linked Ears
Eyes Closed



Summary of the Z-score analyses

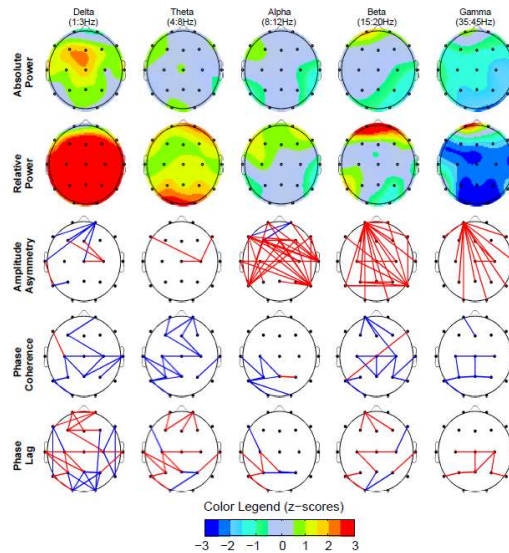


Figure 20: Example of a QEEGPro™ report summary indicating absolute power, relative power, amplitude asymmetry, phase coherence and phase lag for the different frequencies (QEEGPro™, 2016)

Tables: Amplitude

Absolute Power (μV^2)									
Ch	Delta	Z-Delta	Theta	Z-Theta	Alpha	Z-Alpha	Beta	Z-Beta	Gamma
FP1	57.3	-0.5	30.3	0.4	14.8	0.0	9.1	1.8	1.5
FP2	52.1	-0.9	28.1	0.2	13.6	-0.2	8.2	0.7	0.8
F7	50.1	0.8	29.8	1.0	20.2	0.9	5.7	0.7	0.4
F8	75.9	1.8	41.3	0.0	28.1	0.0	6.9	0.2	0.4
Fz	79.6	1.8	42.8	0.3	25.5	0.3	5.9	-0.0	0.4
F4	94.5	1.1	36.1	0.2	22.7	0.1	6.3	0.0	0.4
F8	50.7	0.5	25.8	0.7	15.2	0.3	5.5	0.5	0.4
T3	38.8	1.5	20.9	0.5	12.7	-0.0	4.4	0.1	0.6
C3	55.1	1.1	37.6	0.1	33.0	0.3	5.5	-0.0	0.3
Cz	84.0	1.9	60.2	0.6	34.1	0.0	5.7	-0.1	0.4
C4	49.0	0.5	30.4	-0.4	20.8	-0.6	4.5	-0.6	0.3
T4	34.6	1.2	14.9	-0.2	7.1	-1.2	2.6	-1.0	0.3
T6	32.3	-0.4	23.7	-0.5	14.7	-1.2	4.8	-0.5	0.5
P3	61.5	0.8	47.7	0.4	32.7	-0.4	6.1	-0.2	0.3
Pz	69.3	0.9	50.0	0.2	48.2	-0.2	5.3	-0.5	0.3
P4	63.4	0.8	45.9	0.3	35.3	-0.4	4.4	-1.0	0.3
T6	36.6	-0.2	24.0	-0.5	14.5	-1.3	3.1	-1.6	0.3
O1	70.6	0.5	68.1	0.8	71.7	-0.2	6.7	-0.7	0.3
O2	70.2	0.3	68.4	0.4	72.3	-0.3	5.4	-1.3	0.3

Tables: Amplitude Asymmetry

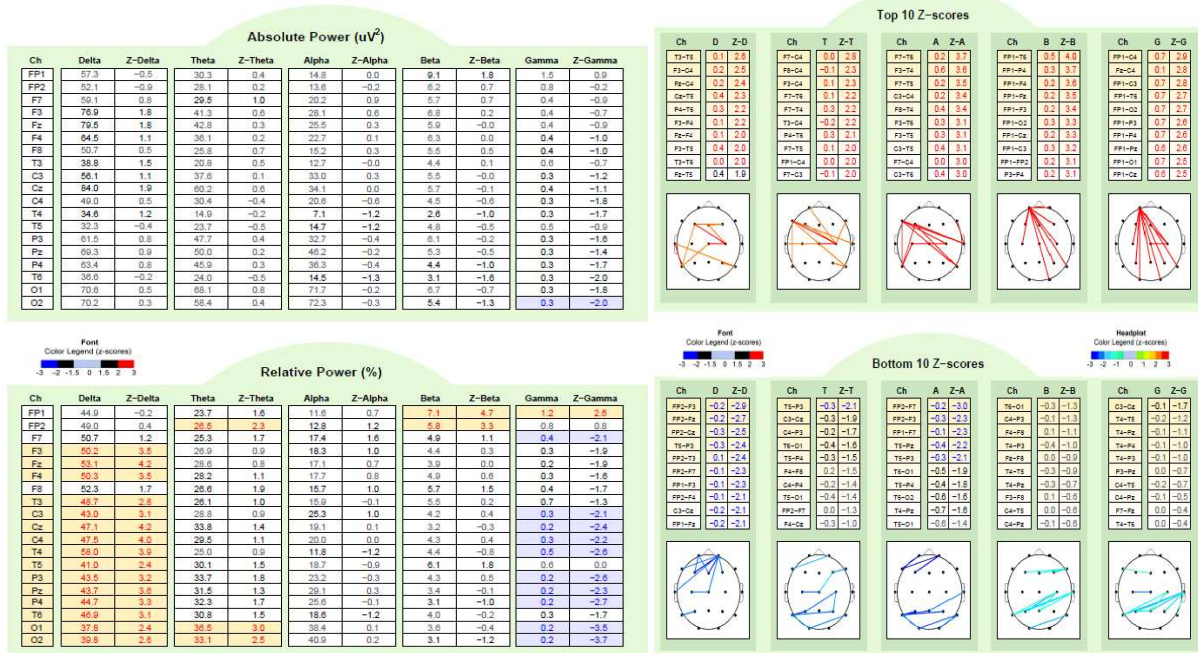
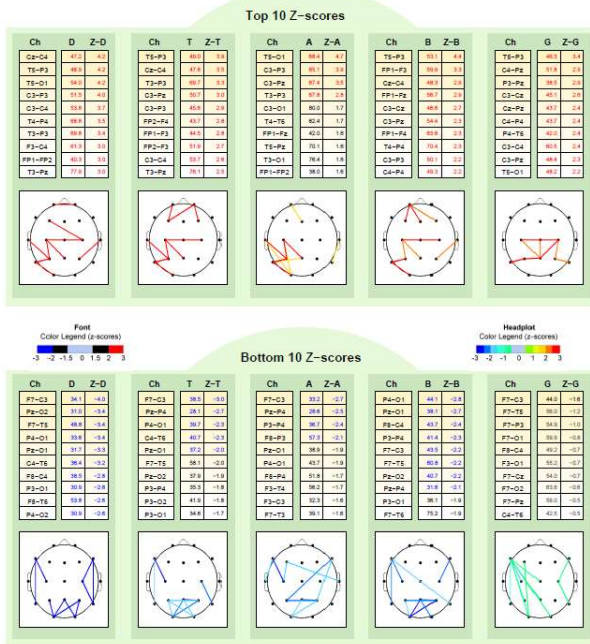


Figure 21: Example of summary values obtained for amplitude, relative power and amplitude asymmetry.

Tables: Phase Lag



Tables: Phase Coherence

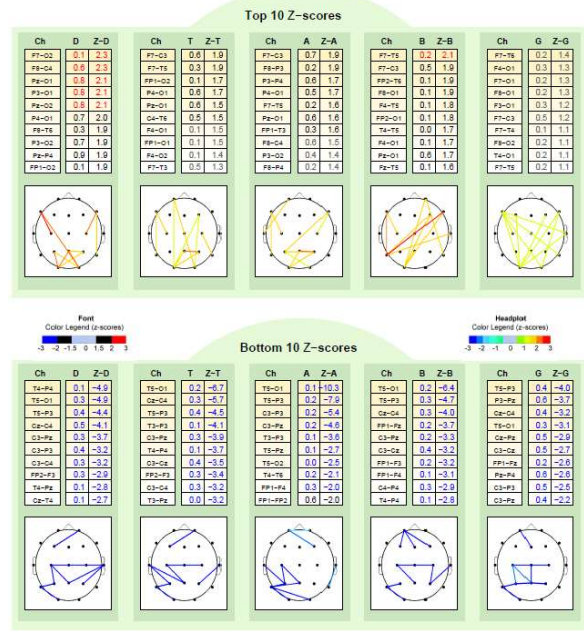


Figure 22: Example of summary tables obtained for phase lag and phase Coherence.

QEEG COMPARISON REPORT
SURFACE AMPLITUDE



Figure 23: Example of comparison report that will be used to compare the 1st and 2nd QEEG.

3.2.1.3. Physiological data monitoring

The Thought Technology ProComp Infiniti (Canada) was developed for the intended purpose of biofeedback, relaxation and muscle re-education (Figure 24). It is an 8 channel multi-modality device and gives real-time computerized biofeedback and data acquisition. The sampling rate is 2048 samples per second in two of the channels and 256 samples per second in the other 6 channels and can be used to render a wide range of physiological signs to be used in clinical observation as well as biofeedback. The encoder connects to a computer via USB with a fibre optic cable and uses four alkaline “AA” batteries as power supply. The data is received in optical form and converted into USB format to communicate with the software.



Figure 24: Thought Technology ProComp Infiniti. (6)

The active electronic sensors meet exacting standards for instrument accuracy, sensitivity, durability and ease of use. They are non-invasive and little, or no preparation is needed for use. The following can be measured with the correct type of sensor connected (Figure 26):

- Electromyography (EMG)
- Electroencephalography (EEG)
- Skin Conductance
- Skin Temperature
- BVP, heart rate, and amplitude

The system design allows inputs to accept any sensor type which allows for wide variety and easy configuration. The only sensor that is channel specific is the EMG MyoScan sensor which is specific to channel A and B. (6)

The BioGraph Infiniti software version 6.0 allows simultaneous monitoring of the above mentioned various physiological parameters (Figure 25). (v 6.0 BioGraph Infiniti 6 Feature Set – Manual) (6)

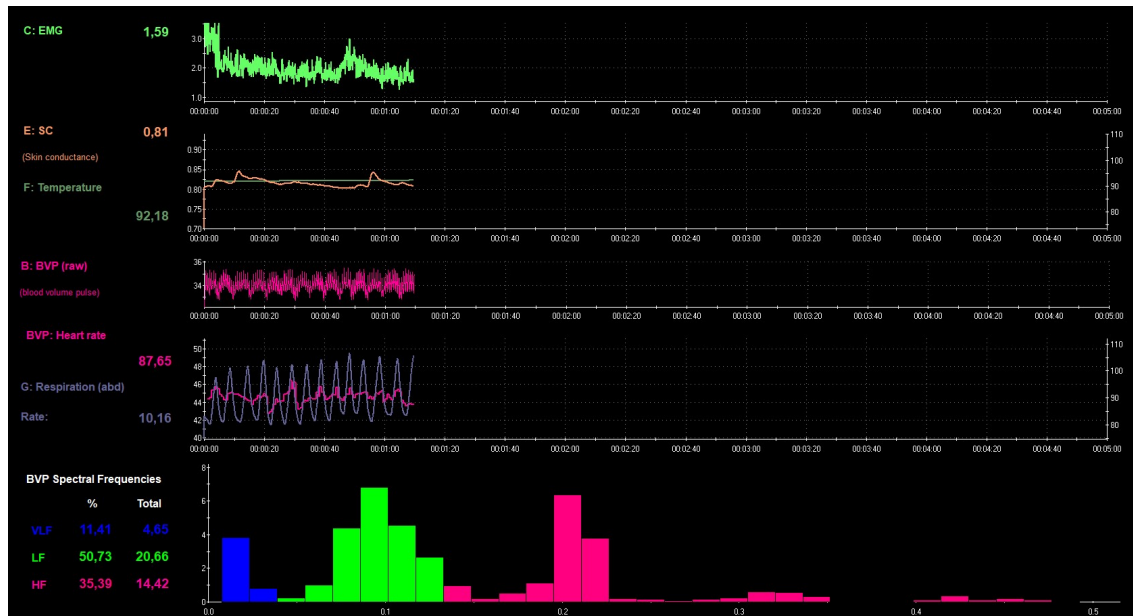


Figure 25: Example of BioGraph Infiniti software session trends screen. (6)

The EMG triode sensor was placed on the trapezius muscle on the right shoulder. The temperature sensor was fastened to the right thumb with a Velcro strap for all clients. The skin conductance sensor consists of two sensors that were placed on the second and third fingers. The BVP sensor was placed on the ring finger also with a Velcro strap. With every beat as the heart pushes blood through the arteries and veins it causes a wave which travels from the heart to the peripheral areas of the body and then it returns to the heart. This distributes oxygen rich blood through a finer set of arteries and deoxygenated blood is again removed via capillaries, venules and veins. The pulse wave that causes a sudden increase in engorgement in the tissues followed by normal tissues perfusion makes it possible to determine the heart rate at peripheral areas. (Figure 26)

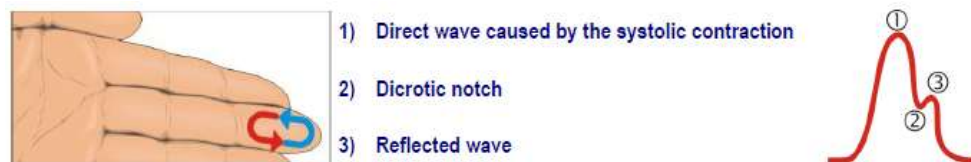


Figure 26: Peripheral measurement of heartrate. (6)

No biofeedback training was done, and the client never saw the physiological measurements so that they were never cognitively aware of any changes taking place. The measurements were recorded for 34 minutes, of which 30 minutes is the length of an ISF training session and 2 minutes pre- and post-session.

The resting blood pressure was measured before and after each session while the participant remained in a seated position by making use of a wrist cuff and the values for systolic and diastolic blood pressure were recorder in millimetres of mercury (mmHg). (6)

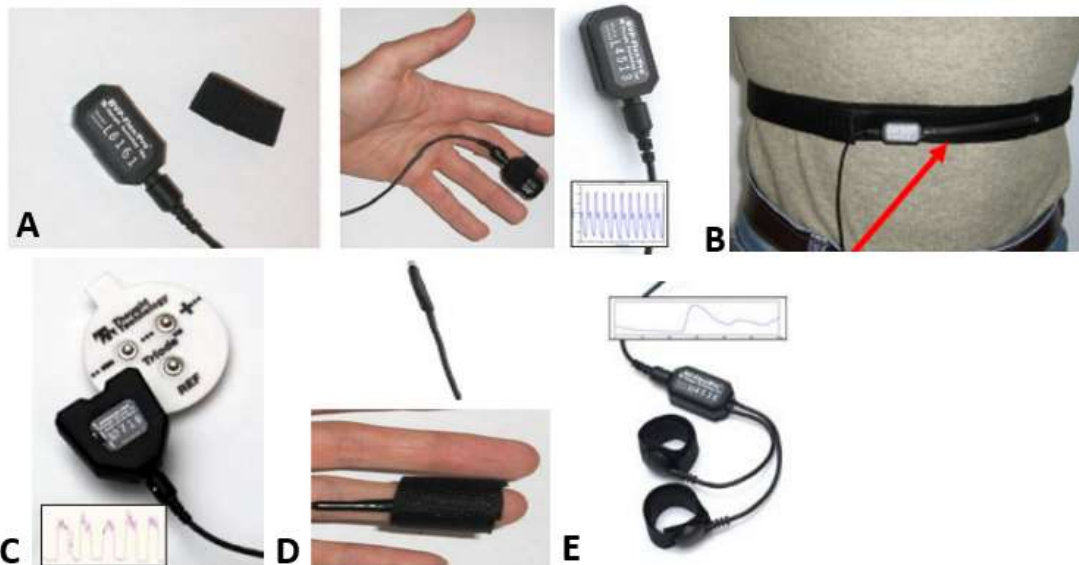


Figure 27: The different Thought Technology sensors used. A: Blood Volume Pulse, B: Respiration, C: Electromyogram, D: Temperature and E: Skin Conductance. (6)

3.2.2. Training equipment

The Discovery 24 Channel EEG amplifier is a physiological monitoring and feedback system (Figure 16). It offers monitoring and feedback of brain signals and include the measurement of EEG, direct current and slow cortical potentials (DC/SCP).

The Brainmaster Atlantis 4x4 (Brainmaster Technologies, USA) is a 4 channel EEG amplifier and physiological monitoring and feedback system. Just like the Brainmaster Discovery it offers monitoring and feedback as described above.

3.2.3. ISF training methods

Each area on the scalp is cleaned using NuPrep skin preparation gel. Electrodes are then pressed onto the cleaned area using 10/20 conductive paste. Electrode placement is extremely important when doing ISF training. Poor cleaning and placement can lead to ineffective training as such low frequencies are being measured.

Training is done using a bipolar montage. This allows for monitoring of Z scores while doing training (Figure 28). This means that 5 electrodes are used. Two actives at either T3 and T4 or T4 and P4, two references, each placed on the mastoid bone behind the ears and one ground placed centrally at the Cz position according to the 10/20 placement. The duration of a session was 30 minutes.

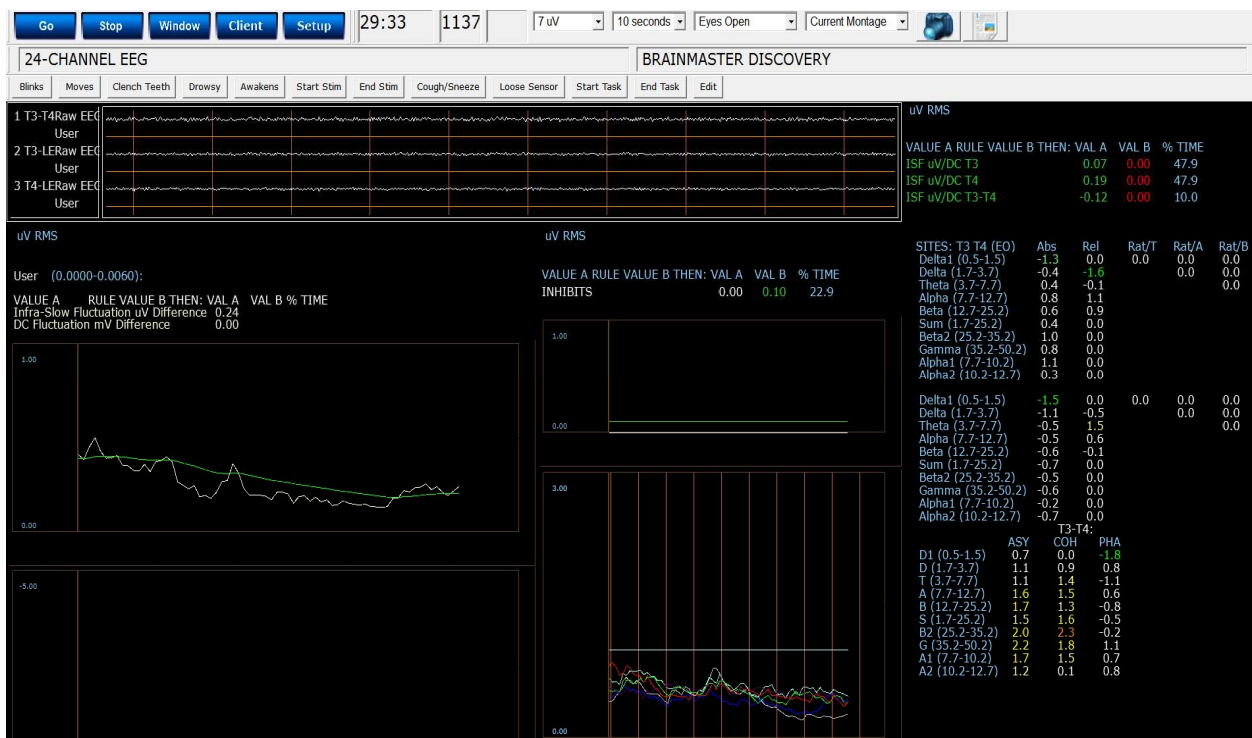


Figure 28: ISF training screen.

Training is done via visual and auditory feedback. The subject hears two reward sounds – a low tone when the amplitude decreases more than 15% and a high tone when it increases more than 15% compared to a damped average signal. It is an instant reward and continues for the duration of the condition. There is also no

refractory period between rewards which allows for rapid transmission of information to the subject concerning changes in the amplitude of the ISF signal. (7)

The objective is to find the frequency where the client feels most relaxed and focused. This is known as the subjects OF. Changes in frequency are guided by the symptoms that the subject experiences.

During the ISF training sessions we will be making use of a BVP sensor to monitor changes in HRV. The sensor is a photoplethysmography (PPG) sensor and is placed on the finger of the client with a small Velcro strap. It uses an infra-red light to measure changes in blood volume in the arteries and capillaries. It thus measures the changes in perfusion of the blood in the tissue below the sensor. This can indicate not only vasodilation and vasoconstriction but also changes in the elasticity of the vascular wall which can reflect changes in blood pressure. (1) Muscle tension will be measured using a triode electrode that is placed on the shoulder. Skin conductance is measured by using a sensor that measures the amount of perspiration on two finger tips. A normal temperature probe is used. It is also placed on one of the fingers with a Velcro strap. Breathing rate and amplitude will be measured using a strap around the abdomen as was previously described.

Recorded data is stored to later be statistically analysed to track changes that occur in session and from session to session. Blood pressure readings will be taken before and after every session by making use of a wrist electronic measurement cuff.

3.2.4. SMR training method

Each area on the scalp is cleaned using NuPrep skin preparation gel. Electrodes are then pressed onto the cleaned area using 10/20 conductive paste. Three electrodes are used. One active placed at the C4 site, one reference placed on the left mastoid and a ground placed on the right mastoid. The duration of the training session is 30 minutes. The client will watch a movie as with the ISF training. In the background they will hear a tone which will sound when all parameters are met. This will be the auditory feedback. To aid as visual feedback the screen will also dim when the client is not meeting the required thresholds set and light up when they do. The protocol for the session of power training will be a SMR training protocol It enhances 12-15 Hz activity and inhibits 3.5 - 7.0 Hz and 20 - 30Hz activity.

During the SMR training sessions we will be making use the exact same physiological measurements as described for the ISF training in 3.2.3. It will also be recorder for the 30 minutesute duration of the session with an additional 2 minutes pre- and post-session.

3.3. Methods

3.3.1. Study Design

The aim of the study was to measure the effect of ISF neurofeedback on a high anxiety population. This was done in an analytic experimental study design where there was a control population added for a comparative study between two modalities of neurofeedback.

3.3.2. Setting

Participants were assessed, and Neurofeedback training was be done in a clinical office setting.

3.3.3. Sample Size

The study consisted of 29 participants, ranging in age from 18 to 55. It included male and female subjects from any ethnic group. The ISF training group included 20 participants and the control group included 9 participants. Each participant voluntarily participated and understood the nature of the study. Any risks involved were explained and informed consent was obtained from all participants. Approval was obtained from the institutions Research Ethics Committee (Appendix A).

3.3.4. Measurements

First a QEEG was done. This involved recording of the EEG data at 19 sites on the subject's head. The raw EEG was visually expected for any abnormalities like epileptiform activity. It was then be uploaded to the QEEGProTM™ website where data was processed. Once the processing was complete the full reports were downloaded.

ISF and SMR neurofeedback training (section 4.6.2) commenced biweekly for 4-6 weeks. This involved either 1 Channel amplitude training at C4 as described previously to act as a control or ten sessions of ISF neurofeedback training 2 or 3 times per week.

Physiological data was recorded during the control and the ISF sessions. All data was be saved on the computer hard drive as well as backed up with a cloud-based service.

After 10 sessions of training a QEEG was again performed to compare pre-and post-training changes.

3.3.5. Data Management and Analysis

The QEEG data was recorded and analysed by the investigator who is a Board Certified QEEG technologist. The investigator also did the neurofeedback training sessions with the help of another qualified neurofeedback practitioner. The investigator then analysed and compare the quantitative data to the qualitative data.

The quantitative data consisted of all the raw data recorded during the pre- and post-analysis and during the neurofeedback training sessions. The questionnaires filled out by every participant was studied by the investigator to assess the qualitative data from the participants before the study commenced.

3.3.6. Statistics

Statistical support (Appendix B) was provided by Charl Janse van Rensburg from the Biostatistics unit of the Medical Research Council (MRC).

The following measurements will be taken and statistically analysed to determine which changes show the most statistically relevant results:

BVP amplitude, BVP IBI, BVP HR from IBI, BVP HR (Smoothed), BVP IBI peak frequency, BVP VLF % power, BVP LF % power, BVP HF % power, Respiratory Amplitude (Abdominal), Respiration rate, HR max - HR min, BVP amplitude mean, BVP HR mean (beats/min, BVP peak freq. mean (Hz), BVP IBI std. dev. (SDRR), BVP VLF % power mean, BVP LF % power mean, BVP HF % power mean, BVP VLF total power mean, BVP LF Total power mean, BVP HF total power mean, BVP LF/HF (means), EMG mean (uV), Skin conductance mean (uS), Temperature mean (Deg), Respiratory rate mean (br/min), BVP IBI Peak amplitude, BVP IBI pk ampl trigger, BVP IBI NN Intervals, BVP IBI pNN Intervals, BVP IBI pNN Intervals (%). The reason why such a vast amount of statistical data was because there are still many unknowns about the impact of the training. By including all statistics, we were able to determine which physiological functions show the most significant change. This can be very

useful in future studies in helping clinicians practising ISF Neurofeedback optimize their clients faster.

Brain Avatar and the Biograph Infiniti software captures data in real-time and all such data is stored on the computer it is connected to. All electronic data was be stored on a laptop of the investigator and daily backups were made to a cloud storage account.

All EEG data can be displayed and processed using the BrainAvatar software package. This allows for artefact removal before it is uploaded to the QEEGPro™ database for further processing. The QEEGPro™ software will again check for any artefact using a mathematical standardized method. This will make sure that all the data is processed in the same way. This excludes any concern of the effect of operator bias.

All other physiological data gathered in the BioGraph Infiniti software will also be scanned for any artefact and this will be removed before raw data is analysed statistically.

The mean, median, standard deviation and inter-quartile range will be used to describe the statistical findings. To test for differences in pre-and post QEEG values we will use the t-test or non-parametric alternative. To determine if there are trends in the ISF parameters over the 10 sessions a linear mixed model will be used where random intercept and slope effects as well as the difference between pre-and post-sessions will be evaluated. The test will be evaluated at a level of 5% significance and all analysis will be done using STATA 14.

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Chapter 4: Results

4.1. Introduction

Twenty participants completed the pre-QEEG, ISF neurofeedback training sessions and post-QEEG and 9 participants completed the pre-QEEG, Amplitude/Power training and post-QEEG and met with the inclusion/exclusion criteria. There was one exclusion based on incomplete data.

4.2. Results of the autonomic function analysis

The descriptive statistical analysis was done by making use of STATA14 statistical software. A within group analysis was performed to determine the mean, minimum and maximum values, standard deviation, median, 25th percentile and 75th percentile for all the variables. An independent sample t-test was done with the significance set at $p < 0.05$ which indicates that the slope is significantly different from 0. Figure 29 includes a summary of the different variables and their significance. Each variable is discussed independently following the summary.



Figure 29: Summary of variables analysed and their statistical significance for the experimental group (n=20) (left) and control group (n=9) (right).

4.2.1. Blood Volume Pulse Amplitude

The BVP amplitude is derived from the BVP signal. It is a relative measure and indicates an increase or decrease in blood flow. BVP amplitude can be indicative of peripheral blood flow, tissue engorgement and elasticity of the vascular bed which can be indicative of vasoconstriction or vasodilation. BVP amplitude can be influenced by the autonomic nervous system. When the BVP amplitude increases the blood flow increases (vasodilation) which is indicative of parasympathetic activation. A decrease of BVP amplitude indicates vasoconstriction which indicates sympathetic activation. (1,2)

Table 6. BVP amplitude summary statistics experimental group.

BVP Amplitude mmHg		N=20					
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	0,62	7,95	3,51	2,01	3,10	1,99	4,91
Session 10	0,39	13,67	3,90	3,61	2,03	1,29	5,90

p-value: p=0.63 for comparison of session 1 to session 10

Table 7. BVP amplitude summary statistics control group.

BVP Amplitude mmHg		N=9					
Training Session	min	max	mean	SD	p50	p25	p75
Session 1	2,01	14,24	7,25	4,25	6,54	3,72	9,87
Session 10	0,68	9,63	4,73	2,69	4,58	3,22	5,46

p-value: p=0.92 for comparison of session 1 to session 10

The t-test did not show any significant change for either the experimental or control group (table 6,7). In the experimental group an increase was noted up to session 8 which can be seen in Figure 30 and 31. Although it was also not significant (p=0.25) it was a change in the positive direction and could be interpreted as increased parasympathetic activity. To understand the decrease after session 8 will require further research.

There are many factors that can influence BVP readings. Temperature of the hands for example – was there a significant temperature difference in the environment? As this study was conducted in the winter, there would have been large differences between a participant coming for a session at 8am and one coming at 1pm. Other factors that influence the values are age and blood pressure. This increases the

stiffness of the arterial walls can give less responsive values. Ideally one should have a larger study group, where one will be able to separate participants firstly according to age and one should also be able to separate those with hypertension from the rest of the group. That will possibly give more accurate values in determining if there is a significant effect on BVP amplitude when doing ISF training. (3)

Due to so many variables having a possible influence on the results, especially in such a small sample, it cannot be determined with certainty that optimal and accurate results were obtained for BVP amplitude. (Figures 30,31)

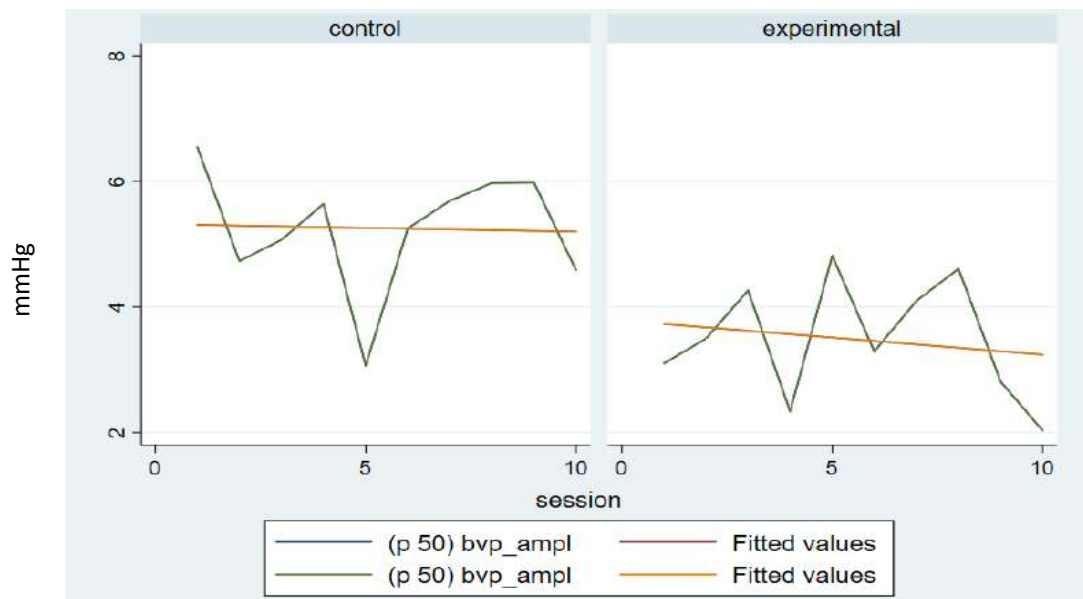


Figure 30: BVP Amplitude with p50 fitted regression line.

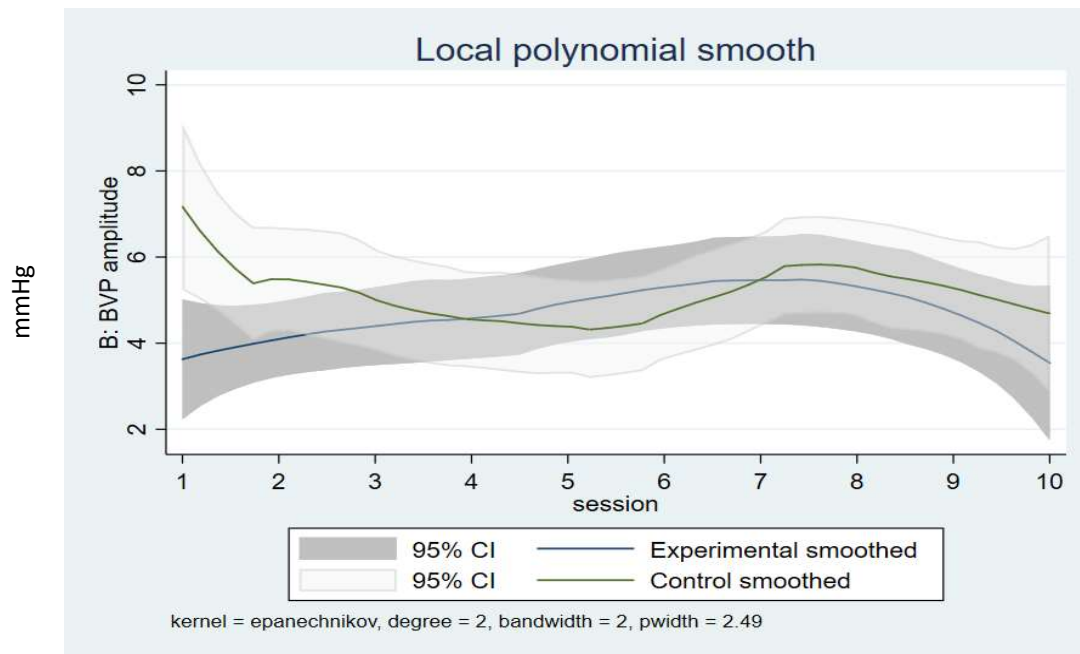


Figure 31: BVP amplitude smoothed values with 95% confidence interval.

4.2.2. Heart Rate Variability % power of the VLF, LF and HF

By making use of an FFT allorhythmia the heart rhythm can be decomposed into different frequencies. This can be graphically represented and distinguishes HF, LF and VLF. The amplitude of these frequencies is usually very different for an individual in a high stress state and one who is relaxed. (Example -Figure 32)

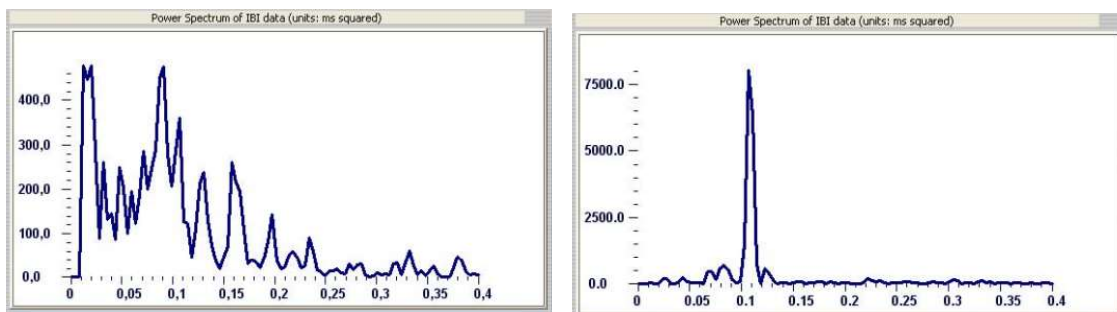


Figure 32: Comparison of HRV frequencies a stress state (left) compared to a relaxed state (right). (1)

HRV depends on the activity of the ANS. The VLF has been found to be a major determinant of physical activity and it has also been proposed as a marker of sympathetic activity. It is also said to affect the vascular tone loop of the baroreflex system, thermal regulation and activity of the renin-angiotensin system. A decrease in the VLF is hypothesised to be an indication of sympathetic blocking. (4)

The LF is an indication of both sympathetic and parasympathetic activity and is indicative of activity of the baroreflex function. The HF is indicative of parasympathetic activity. (4) A decrease in HF is indicative of decreased vagal activity which shows decreased parasympathetic activation. (5) It is important to look at the balance of LF to HF as this is believed to be a measurement of balance between the sympathetic and parasympathetic nervous systems. The summary of the results are seen in table 8 and 9.

Table 8. Very low frequency, low frequency and high frequency % power summary statistics experimental group.

BVP VLF Power % N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	4,28	62,52	25,94	19,88	21,58	8,84	36,63
Session 10	1,04	45,52	16,17	14,23	10,22	5,73	23,08
BVP LF Power N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	15,12	85,93	37,19	16,54	34,78	27,07	43,60
Session 10	11,07	61,20	43,36	13,54	45,72	38,77	51,34
BVP HF Power N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	8,02	72,74	34,04	19,78	30,68	17,20	44,43
Session 10	6,97	57,75	35,76	13,60	35,85	31,51	46,74

VLF p-value: p=0.05 **LF p-value:** p=0.004 **HF p-value:** p=0.51 for comparison of session 1 to session 10

Table 9. Very low frequency, low frequency and high frequency % power summary statistics control group.

BVP VLF Power % N=9							
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	6,96	45,42	28,51	11,67	27,48	22,46	36,07
Session 10	6,73	65,28	37,34	18,60	37,30	31,99	45,13

BVP LF Power N=9							
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	27,22	65,72	51,11	10,99	52,16	46,63	56,93
Session 10	7,74	85,62	49,03	22,01	52,06	38,62	58,77

BVP HF Power N=9							
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	6,64	49,51	19,50	13,15	15,80	11,06	25,57
Session 10	4,04	44,88	12,01	14,12	5,38	5,12	6,97

VLF p-value: p=0.302 **LF p-value:** p=0.985 **HF p-value:** p=0.12 for comparison of session 1 to session 10

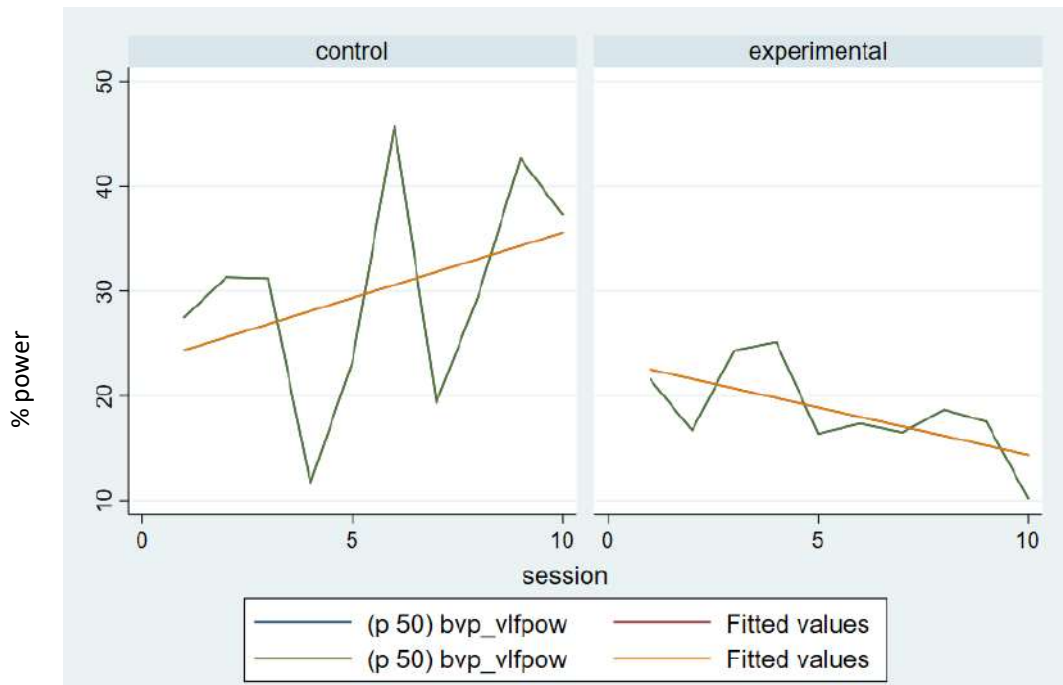


Figure 33: VLF power with p50 fitted regression line.

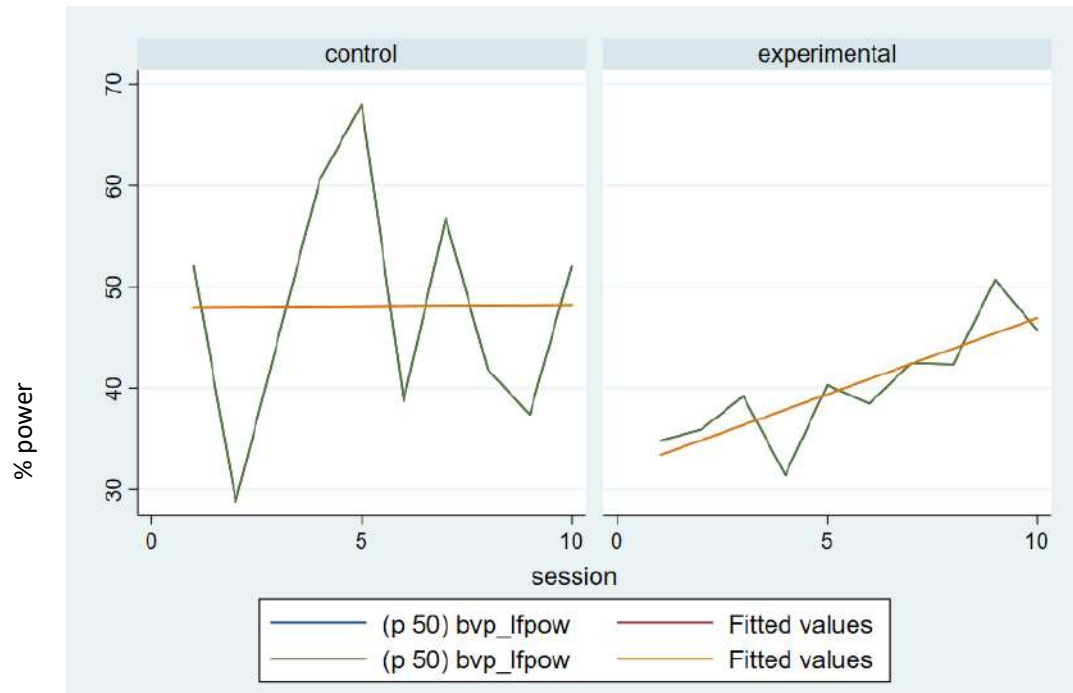


Figure 34: LF power with p50 fitted regression line.

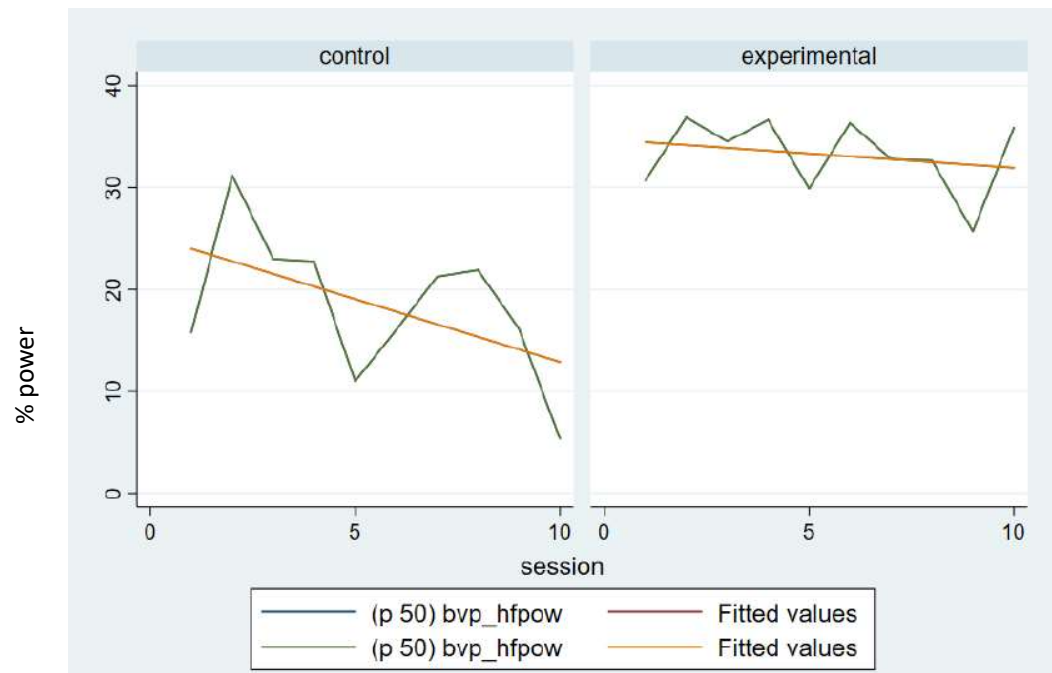


Figure 35: HF power with p50 fitted regression line.

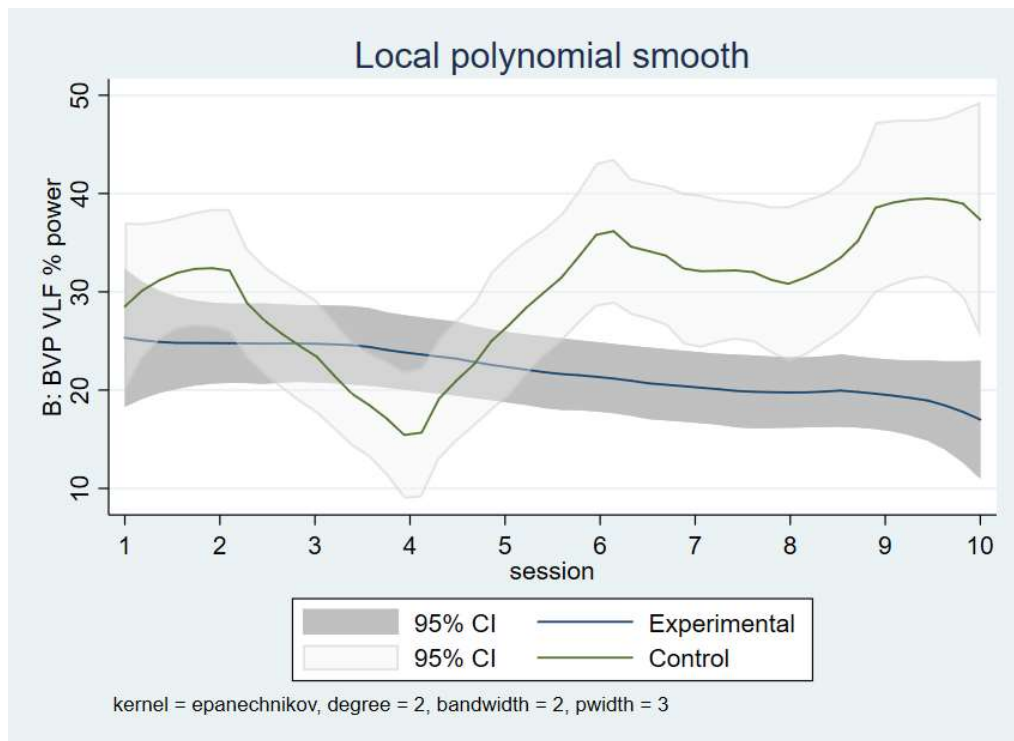


Figure 36: Smoothed curve for VLF % power with 95% confidence interval.

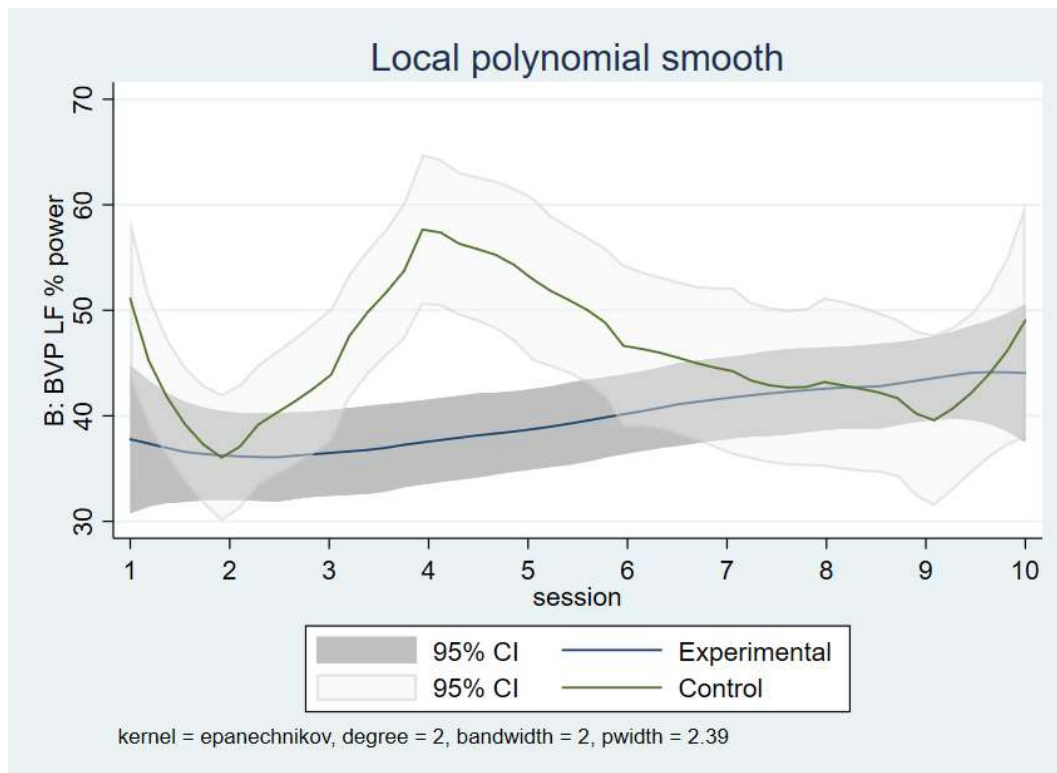


Figure 37: Smoothed curve for LF % power with 95% confidence interval.

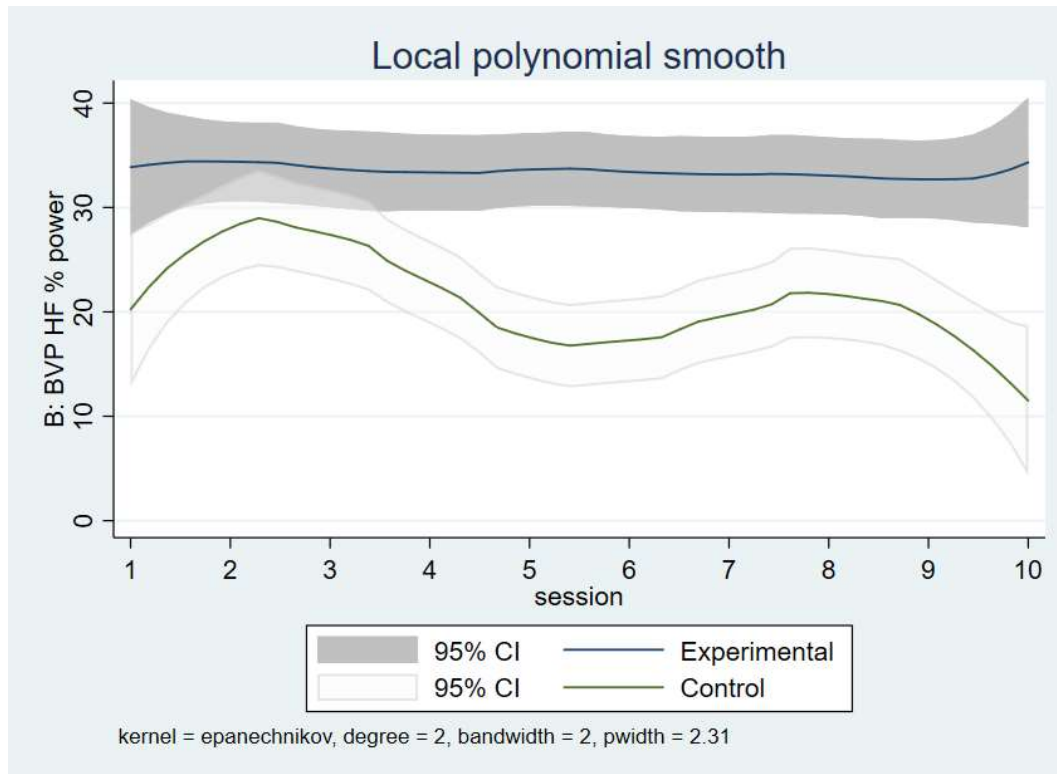


Figure 38: Smoothed curve for HF % power with 95% confidence interval.

When looking at the t-test results for the different components when comparing session 1 to session 10 the following values were obtained:

- VLF $p = 0.05$. This indicates a significant decrease in the VLF % power. This can be an indication of decreased sympathetic activity as it is hypothesized that increased VLF represents sympathetic blocking (Figure 33). (6)
- LF $p = 0.004$. This indicates a significant increase in the LF % power. It reflects sympathetic and vagal influences on cardiac control via baroreceptor-mediated regulation of blood pressure according to some theories. Others do suggest that it is a marker for sympathetic modulation. (6) The range for LF frequency is 0.04-0.15 Hz with PNS dominance believed to be from 0.04-0.7 Hz. When looking at the BVP peak mean frequency measured the mean peak frequency measured at session 1 was 0.1 Hz and this decreased to 0.08 Hz at session 10. Due to it appearing insignificant the data was not further included in the larger results, but it does however indicate a possible shift towards being more parasympathetic dominant. (Figure 34)

- HF $p = 0.515$. This indicates no significant change in the HF % power. There is however an increase noted which can indicate more parasympathetic activation. (Figure 35)

When looking at the LF to HF ratio of both the experimental and control groups no significant change was noted.

4.2.3. Heart Rate

The normal heart rate is around 70 beats per minute when at rest. During sleep bradycardia occurs and tachycardia can occur due to emotion, exercise, fever and various other stimuli. In a normal healthy individual, HR varies with the phases of respiration. An increase is seen during inspiration and a decrease during expiration. This is called the respiratory sinus arrhythmia (RSA) and results from the 10th cranial nerve known as the vagus nerve. The heart rate itself is also regulated by parasympathetic and sympathetic activity, causing a decrease and increase in heart rate respectively. (7) A summary of the results is seen in table 10 and 11.

Table 10. Heart rate summary statistics experimental group.

BVP HR from IBI Beats/Minute N=20							
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	47,21	145,77	76,97	23,72	73,10	61,71	87,03
Session 10	53,61	86,72	72,00	10,55	73,29	62,88	80,13

p-value: $p=0.44$ for comparison of session 1 to session 10

Table 11. Heart rate summary statistics control group.

BVP HR from IBI Beats/Minute N=9							
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	57,61	82,19	76,63	7,49	79,23	78,52	79,84
Session 10	61,26	89,96	72,89	9,28	75,71	64,10	76,46

p-value: $p=0.703$ for comparison of session 1 to session 10

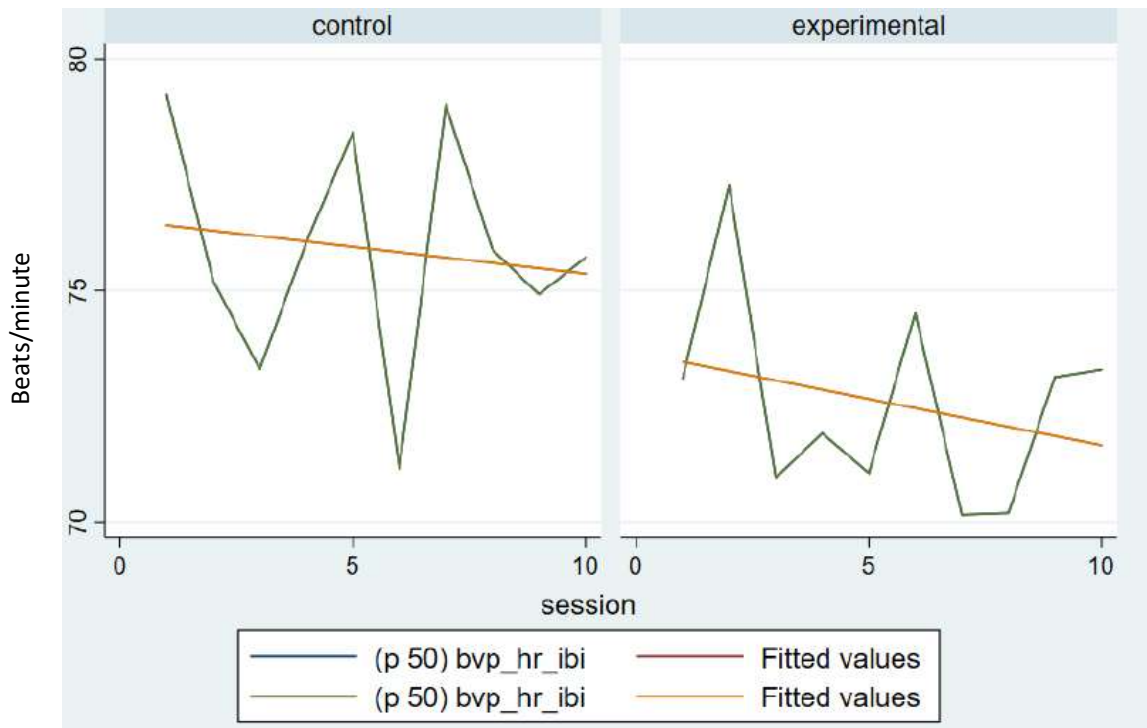


Figure 39: Heart rate with p50 fitted regression line.

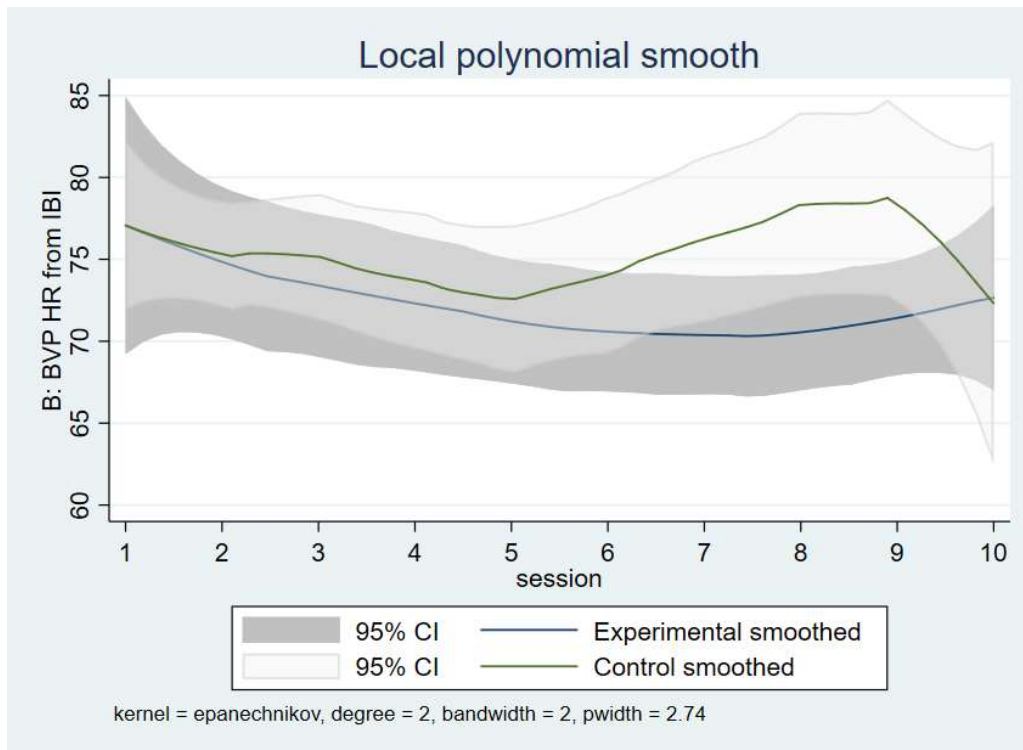


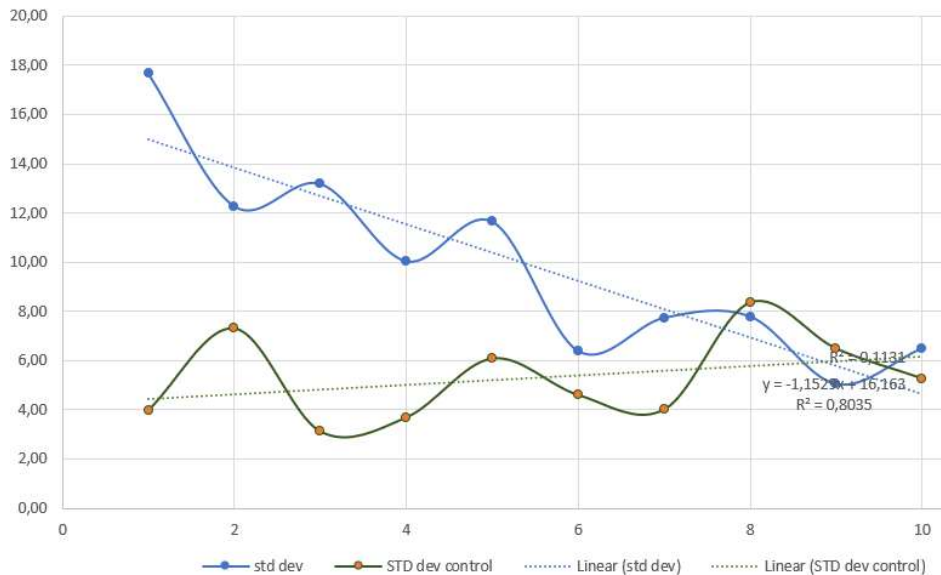
Figure 40: Smoothed curve for heart rate with 95% confidence interval.

When looking at the mean heart rate the p-value for session 1 to 8 is $p=0.16$ and for session 1 to ten $p=0.443$. This indicates that there was no significant change. If the data is however analysed further and individual heart rates are compared to what is considered normal for the subjects age there is a change towards the norm where those participants with very high resting heart rates showed a decrease and those with very low heart rates had an increase in their resting heart rates. This is also reflected in the standard deviation of the group.

Resting heart rate chart for men							
By Age	Heartbeats Per Minute						
	Athlete	Excellent	Good	Above Average	Average	Below Average	Poor
18-25	49-55	56-61	62-65	66-69	70-73	74-81	82+
26-35	49-54	55-61	62-65	66-70	71-74	75-81	82+
36-45	50-56	57-62	63-66	67-70	71-75	76-82	83+
46-55	50-57	58-63	64-67	68-71	72-76	77-83	84+
56-65	51-56	57-61	62-67	68-71	72-75	76-81	82+
65+	50-55	56-61	62-65	66-69	70-73	74-79	80+

Resting heart rate chart for women							
By Age	Heartbeats Per Minute						
	Athlete	Excellent	Good	Above Average	Average	Below Average	Poor
18-25	54-60	61-65	66-69	70-73	74-78	79-84	85+
26-35	54-59	60-64	65-68	69-72	73-76	77-82	83+
36-45	54-59	60-64	65-69	70-73	74-78	79-84	85+
46-55	54-60	61-65	66-69	70-73	74-77	78-83	84+
56-65	54-59	60-64	65-68	69-73	74-77	78-83	84+
65+	54-59	60-64	65-68	69-72	73-76	77-84	84+

Figure 41: Expected heart rate chart values used. Average values were used for comparison. (8)



Blue line = Experimental Green Line = Control X = standard deviation y= change towards normal for age

Figure 42: Standard deviation changes noted in heart rates when looking at change towards age related normal values.

4.2.4. Standard deviation of the inter beat interval

The IBI has been related to affective valence and arousal because of its dual innervation by both the sympathetic and parasympathetic fibres. (7) When the HRV is reduced (indicated by a low standard deviation of the amplitude of the R-R interval (SDARR)) or even absent it may be an indication of pathology. (3) A SDARR of less than 50 milliseconds can lead to a fourfold increase in relative risk of death after myocardial infarction compared to those with a value greater than 100 milliseconds. (3)

Analysis of the time domain of HRV includes evaluating the SDRR calculated by the following formula:

$$SDRR \quad ms \quad \sqrt{\frac{\sum_{i=1}^N (RR_i - mRR)^2}{N-1}}$$

No significant changes were noted in the HRV SDRR of either group. When looking at the values the mean SDRR value for the experimental group was 91,4 and increased to 93.8. There was a minimum value of 36,6 which increased to 41,9 (subject 16), indicating that the participant with the highest risk at least showed improvement. The standard deviation of the group also decreased showing that the outliers in the group moved more towards the average. More variance is still seen in the control group but due to the small sample size it is not necessarily significant to use comparatively. See table 12 and 13 for a summary of the results.

Table 12. Inter beat interval standard deviation of the R-R Interval summary statistics experimental group.

BVP IBI SDRR ms N=20							
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	36,6	304,6	91,4	61,6	79,4	48,6	105,6
Session 10	41,9	234,2	93,8	48,7	84,3	57,2	109,1

p-value: p=0.068 for comparison of session 1 to session 10

Table 13. Inter beat interval standard deviation of the R-R interval summary statistics control group.

BVP IBI							
SDRR		ms		N=9			
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	30,81	137,53	65,22	29,73	58,23	57,67	59,41
Session 10	28,44	411,55	94,08	119,68	58,31	50,96	65,70

p-value: p=0.51 for comparison of session 1 to session 10

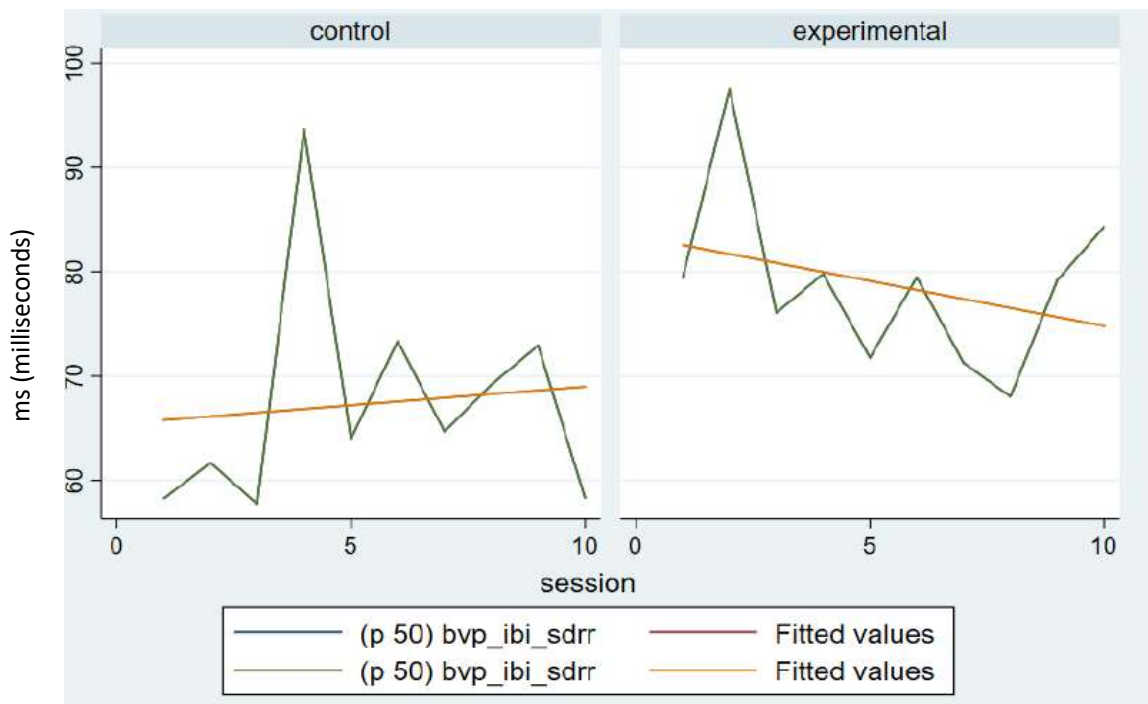


Figure 43: Standard deviation of the inter beat interval (SDRR) with p50 fitted regression line.

There were no significant changes noted in either the experimental or control groups when comparing session 1 to session 10. (Figure 43,44)

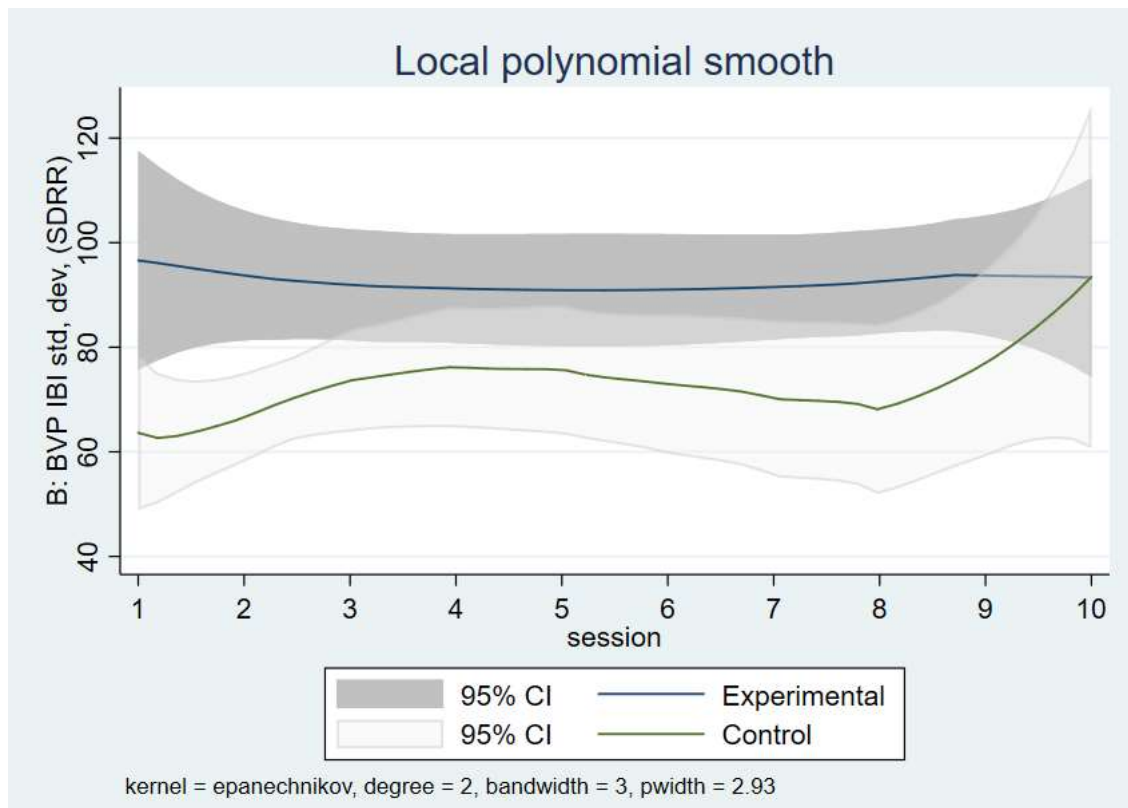


Figure 44: Smoothed curve for HRV SDRR with 95% confidence interval.

4.2.5. Blood Pressure

The normal blood pressure in the brachial artery is approximately 120/70 mmHg in young adult (Figure 45). It is affected by cardiac output and peripheral resistance and emotion has been shown to increase these two factors by up to 20% and can fall up to 20 mmHg during sleep. It is known that BP increases with age, but various aspects can have an influence on this. (8)

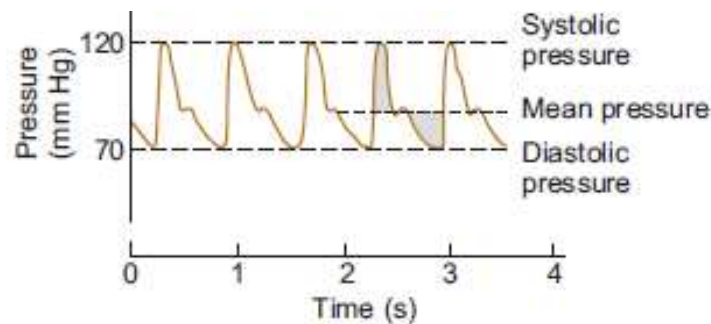


Figure 45: The Brachial artery pressure curve in a normal young adult indicating the relation of systolic and diastolic pressure to mean pressure. The shaded area above the mean is equal to the area below.

Table 14. Pre- and post-systolic and diastolic blood pressure statistics for the experimental group.

Systolic BP							
Pre	mmHg		N=20				
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	94,00	142,00	122,55	12,61	120,00	115,50	133,50
Session 10	104,00	143,00	124,40	10,59	127,00	120,00	130,00
Diastolic BP							
Pre	N=20						
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	62,00	102,00	79,60	8,99	80,00	75,00	84,50
Session 10	64,00	92,00	78,45	6,35	78,00	75,00	83,00
Systolic BP							
Post	N=20						
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	96,00	141,00	115,45	10,10	113,50	108,00	122,50
Session 10	107,00	128,00	119,85	5,72	121,00	116,50	124,50
Diastolic BP							
Post	N=20						
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	60,00	94,00	76,55	9,12	78,00	68,50	82,50
Session 10	68,00	86,00	77,65	4,77	78,50	74,00	80,50

Pre Sys p-value: p=0.22 **Post Sys p-value:** p=0.049

Pre Dia p-value: p=0.72 **Post Dia p-value:** p=0.083

for comparison of session 1 to session 10

Table 15. Pre- and post-systolic and diastolic blood pressure statistics for the control group.

Systolic BP							
Pre	mmHg		N=9				
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	108,00	134,00	122,33	7,11	123,00	121,00	125,00
Session 10	109,00	135,00	118,22	8,11	116,00	114,00	119,00
Diastolic BP							
Pre	N=9						
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	62,00	92,00	81,33	8,34	83,00	80,00	85,00
Session 10	68,00	79,00	74,78	3,15	75,00	74,00	76,00

Systolic BP							
Post N=9							
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	108,00	131,00	121,78	6,76	123,00	119,00	126,00
Session 10	115,00	129,00	123,89	4,08	124,00	123,00	126,00

Diastolic BP Post N=9							
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	68,00	95,00	80,78	7,48	80,00	77,00	83,00
Session 10	57,00	83,00	78,11	8,28	81,00	78,00	83,00

Pre Sys p-value: $p=0.231$ **Post Sys p-value:** $p=0.74$

Pre Dia p-value: $p=0.106$ **Post Dia p-value:** $p=0.79$

for comparison of session 1 to session 10

There was a significant change noted in the post systolic comparison in the experimental group (table14,15). In the diastolic value a p value of 0.083 is noted when comparing session 1 to session 10, which also show a large change. It appears clear that there is an effect on the blood pressure of participants when doing ISF training when compared to the control group where no significant changes were noted.

As with the heart rate analysis there was also a very large change in the standard deviation of the group indicating that we are dealing with a non-linear change. There appears to rather be a homeostatic change towards what is considered as normal (Figure 46).

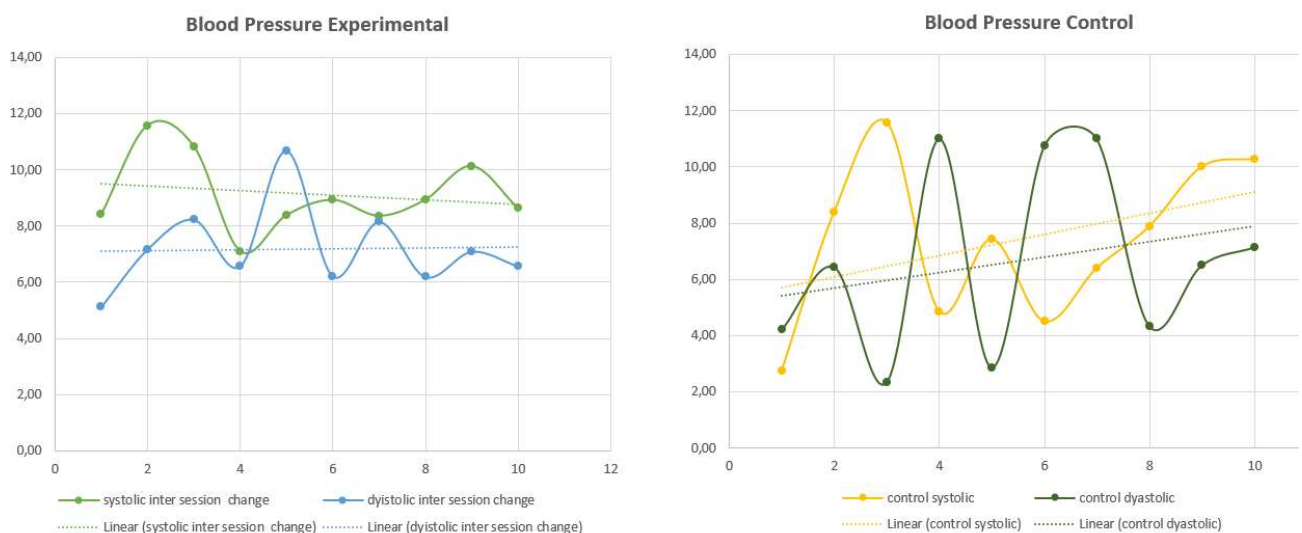


Figure 46: In session change towards normal values for blood pressure.

4.2.6. Electromyogram

Anxiety is often accompanied by muscle over-activity. (9) Typically, the amplitude of action potentials recorder from the next muscles of individuals with high anxiety is higher than healthy controls when a stressor is applied. Typically, higher levels of muscle tension are recorded in individuals with complaints of anxiety and depression. One will expect a decrease in muscle tension with relaxation and parasympathetic activation. (9) In table 16 and 17 the summary results can be seen.

Table 16. Electromyogram summary statistics experimental group.

EMG		μV N=20					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	0,52	29,84	4,82	6,83	2,77	1,07	5,21
Session 10	0,46	9,38	2,14	2,27	1,23	0,97	2,28

p-value: $p=0.01$ for comparison of session 1 to session 10

Table 17. Electromyogram summary statistics control group.

EMG		μV N=9					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	0,52	4,46	2,20	1,56	2,22	0,99	3,28
Session 10	1,10	6,70	2,66	2,07	1,77	1,62	2,11

p-value: $p=0.33$ for comparison of session 1 to session 10

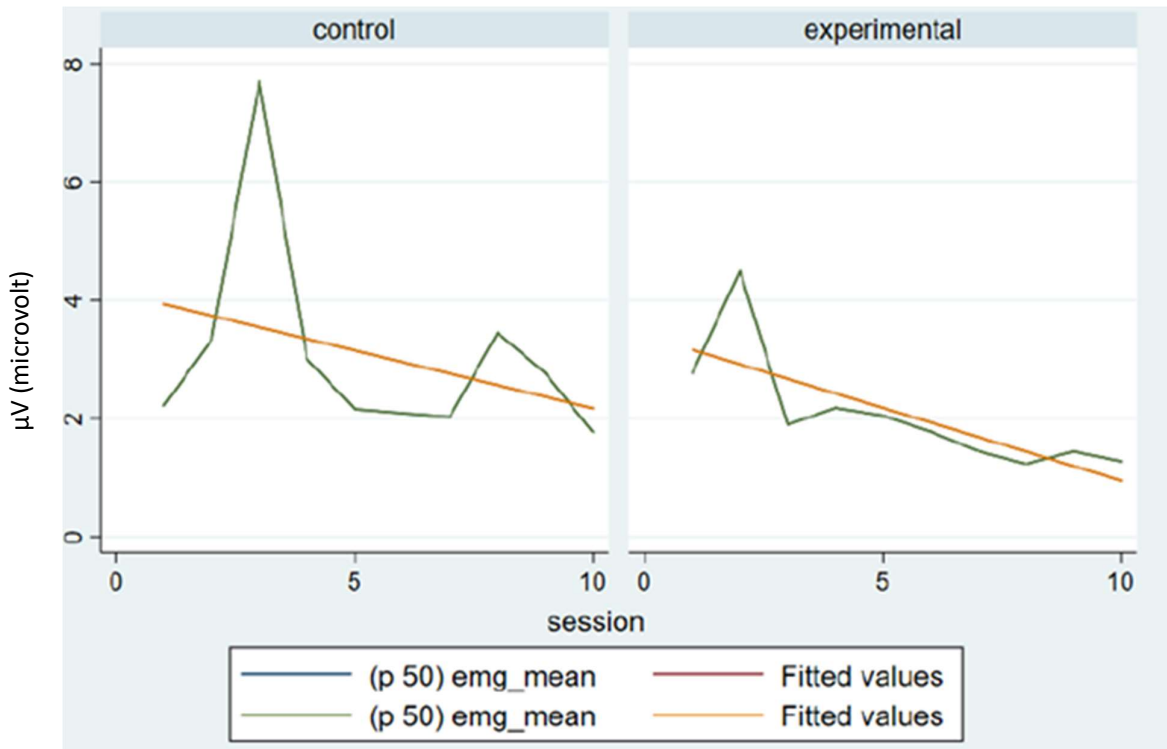


Figure 47: Electromyogram with p50 fitted regression line.

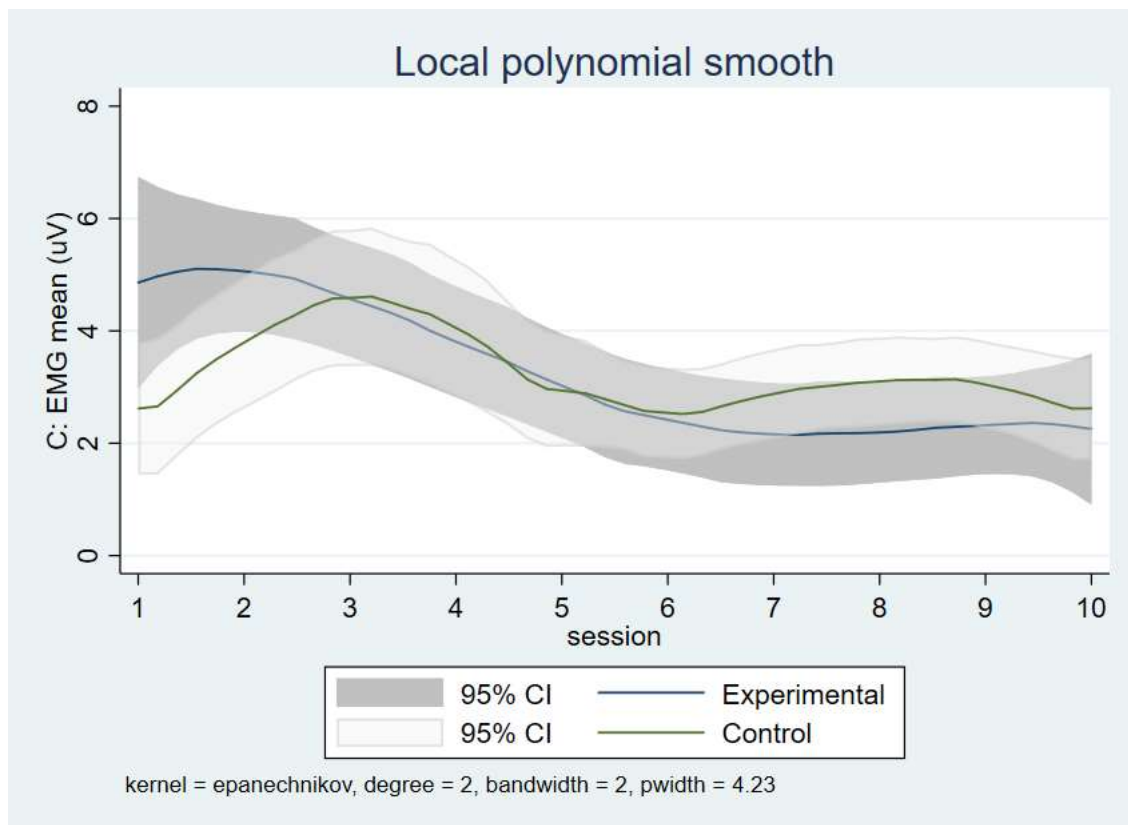


Figure 48: Smoothed curve for electromyogram with 95% confidence interval.

At rest there should be very low muscle activity as no muscle fibres are being recruited. Under chronic or repeated stress certain muscles may not be able to return to a resting state. This is known as “residual” muscle tension and commonly causes back, shoulder or neck pain. This can lead to increased fatigue. (10) A high resting muscle tension also leads to an impedance of blood flow which slows down healing. Adaptive habits such as muscle guarding can also have a negative impact by reducing flexibility and decreasing muscular efficiency. (10,11)

In the control group a change is seen in the positive direction when comparing session 1 to session 10, but it is not significant. (Figure 47,48)

The p-value for EMG in the experimental group is $p=0.01$ when comparing session 1 to session 10, which shows a significant decrease in muscle tension and more specifically the resting muscle tension.

4.2.7. Respiratory Amplitude

Respiratory amplitude is the depth of breathing. It is expected that an individual who is relaxed will breathe deeper and slower. See table 18 and 19 for a summary of the results when comparing session 1 to session 10.

Table 18. Respiratory amplitude summary statistics experimental group.

Respiratory Amplitude	Litre		N=20				
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	0,04	7,10	1,62	1,40	1,39	1,12	1,80
Session 10	0,41	5,55	1,63	1,44	0,99	0,72	2,41

p-value: $p=0.72$ for comparison of session 1 to session 10

Table 19. Respiratory amplitude summary statistics control group.

Respiratory Amplitude	Litre		N=9				
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	1,48	3,87	2,13	0,75	1,91	1,57	2,33
Session 10	0,05	1,89	0,85	0,53	0,87	0,57	1,14

p-value: $p=0.55$ for comparison of session 1 to session 10

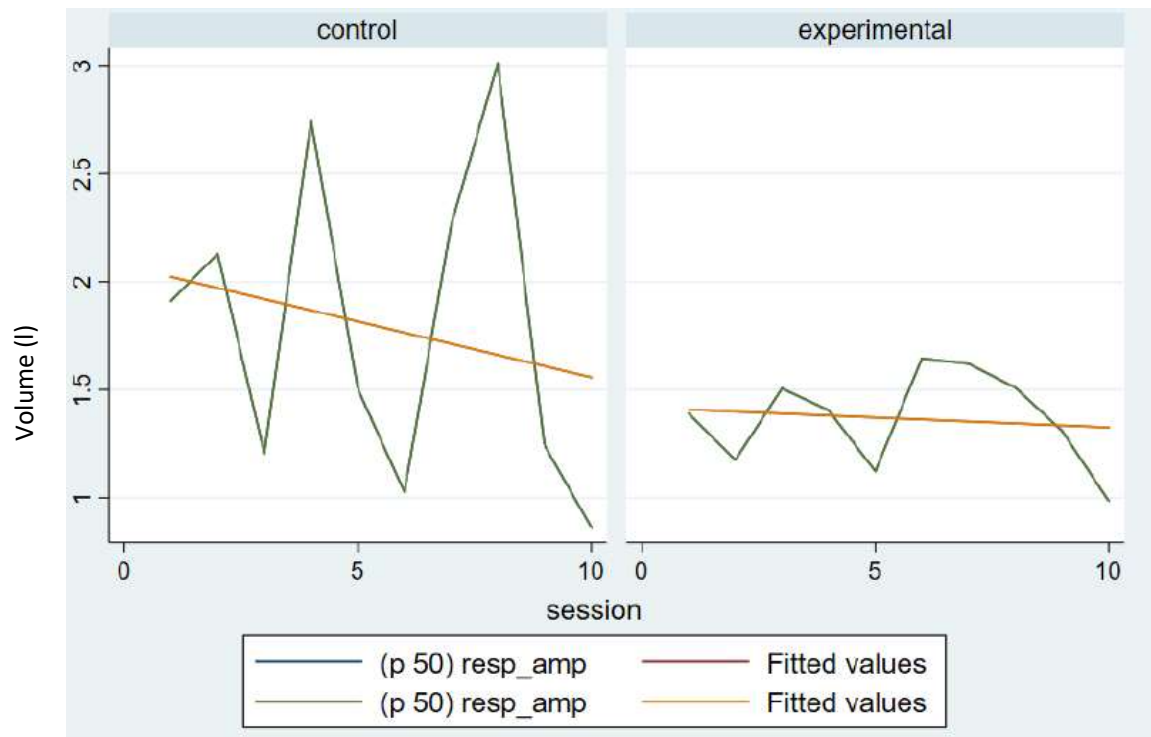


Figure 49: Respiratory amplitude with p50 fitted regression line.

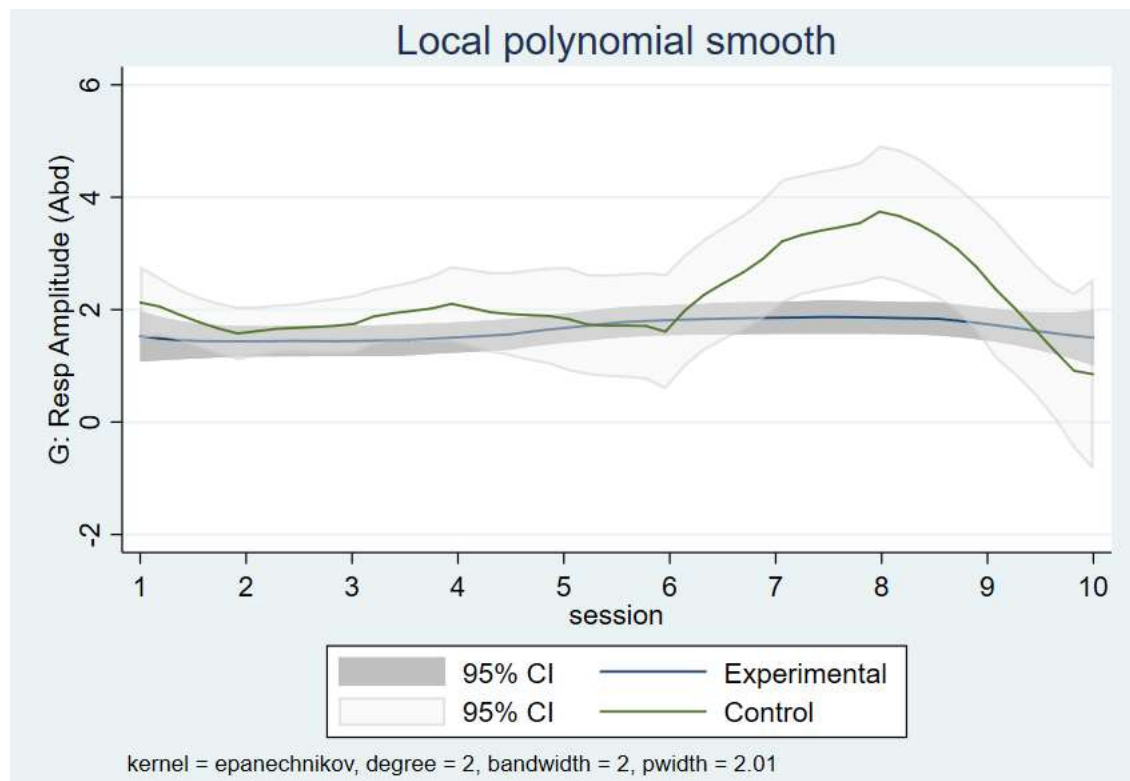


Figure 50: Smoothed curve for respiratory amplitude with 95% confidence interval.

No significant changes were noted in either of the groups with the experimental group having a p-value of $p=0.72$ and the control group a p value of $p=0.55$ when comparing session 1 to session 10). (Figure 49,50)

In many anxiety management programmes slow diaphragmatic breathing exercises are commonly taught. The person must breathe from the abdomen instead of the chest and shoulders. As external influence that can impact the results wanted to be avoided, this technique was not taught to the participants, even though it is commonly noted that highly anxious individuals do not breathe correctly. As the sensor is placed below the ribs to measure chest and abdomen expansion it is possible that there was very little change in this value as the participants were not breathing correctly. (10) The other possibility is that this aspect was just not influenced by the neurofeedback training in any of the groups.

4.2.8. Skin Conductance

Skin conductance is generally accepted as one of the most sensitive indices of emotional arousal. (7) This is one of the reasons why it is generally used to help an individual become aware of unconscious physiological responses to stress. A certain level of arousal is important but if this increases too much it can lead to fatigue and anxiety as can be seen in Figure 51. Table 20 and 21 includes a summary of the results when comparing session 1 to session 10).

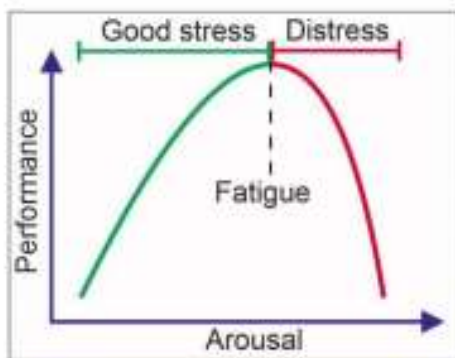


Figure 51: The stress response curve. (10)

Table 20. Skin conductance summary statistics experimental group.

Skin Conductance Mean MicroSiemens N=20							
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	0,40	18,28	4,80	4,55	3,94	1,06	7,40
Session 10	0,25	10,46	2,33	2,38	1,35	0,77	3,22

p-value: $p < 0.0001$ for comparison of session 1 to session 10

Table 21. Skin conductance summary statistics control group.

Skin Conductance Mean μ Siemens N=9							
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	1,27	6,10	3,31	2,04	2,38	1,99	5,84
Session 10	0,57	6,35	2,62	2,16	2,55	0,72	3,50

p-value: $p=0.39$ for comparison of session 1 to session 10

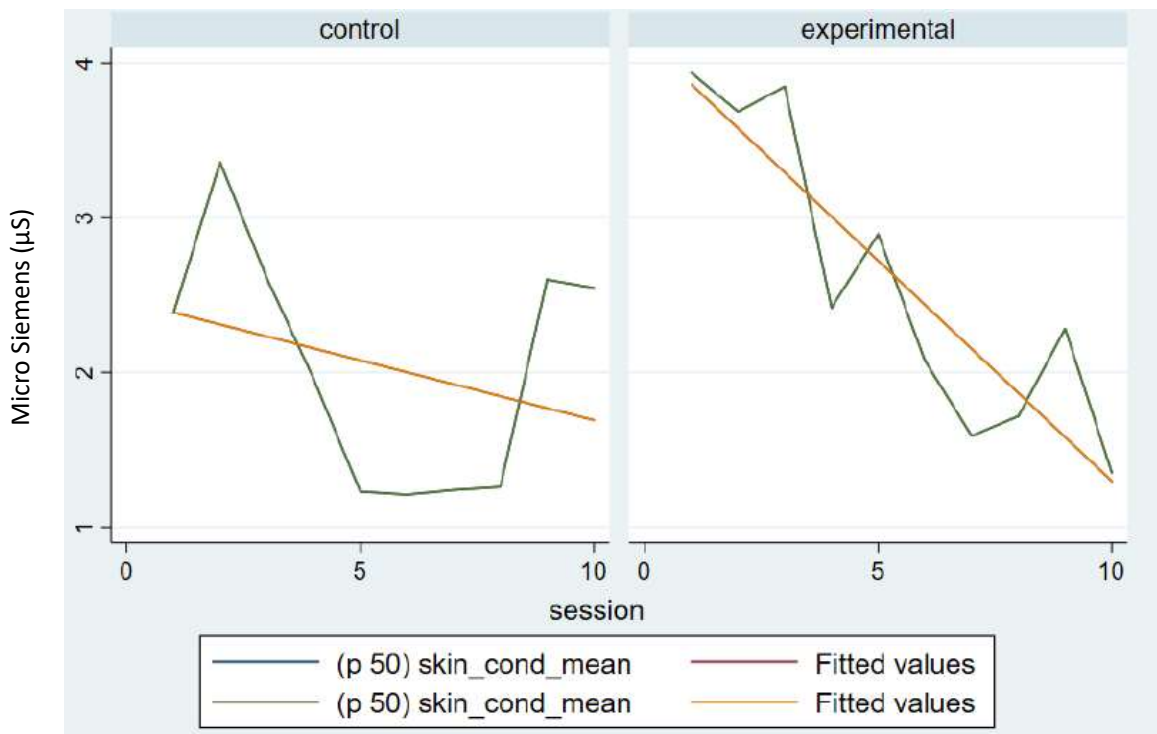


Figure 52: Skin conductance with p50 fitted regression line.

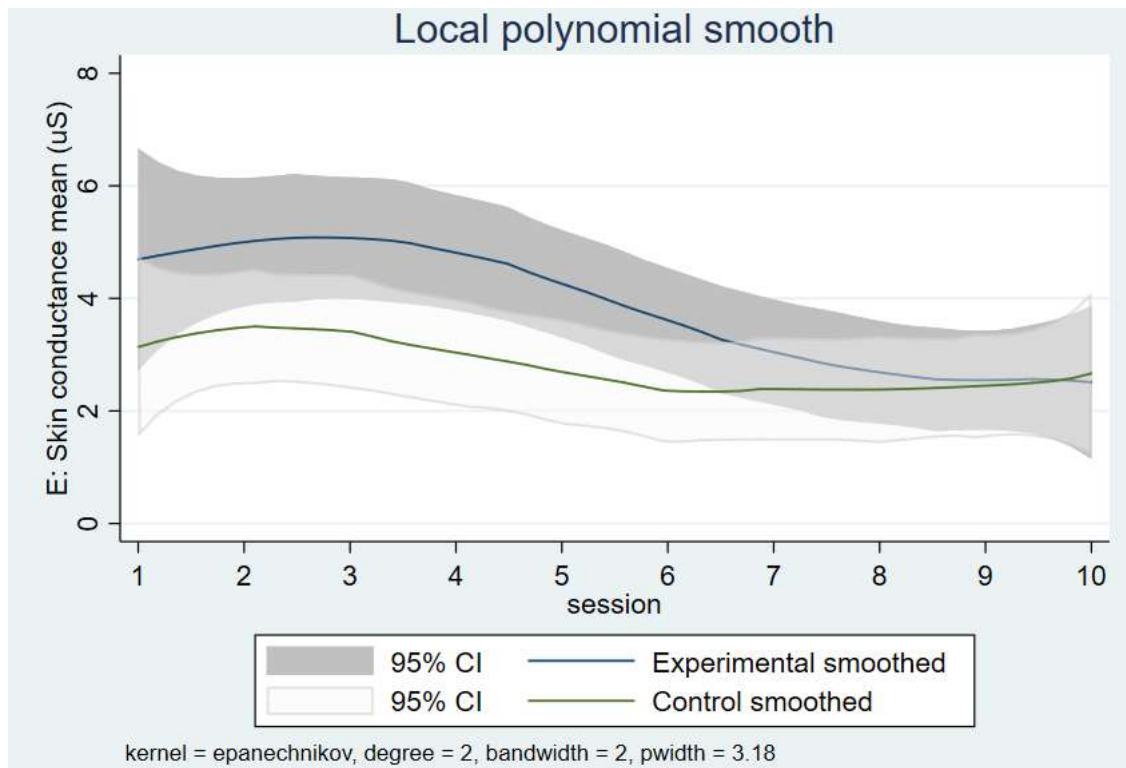


Figure 53: Smoothed curve for skin conductance with 95% confidence interval.

The p-value for skin conductance is $p < 0.0001$ which indicates a significant decrease in the experimental group when comparing session 1 to session 10. This is indicative of lower arousal levels which is a positive change in a high anxiety population group where very high arousal levels are typically noted. There is also a decrease noted in the standard deviation of the group as well as a decrease of the median (Figure 52,53). This can be an indication of decreased anxiety as an increase in electrodermal activity is commonly reported in high anxiety individuals. (2)

In the control group a decrease is also seen with a p-value of $p = 0.39$ when comparing session 1 to session 10. This is however not as significant as what is seen in the experimental group. This can however be influenced by the small sample size.

4.2.9. Temperature

Greater relaxation is associated with an increase in peripheral finger temperature. This is due to a decrease in vasoconstriction where blood pressure and heart rate also decreases. This has been associated with lower anxiety and a lowering in pain. (11,12)

Table 22. Temperature summary statistics experimental group.

Temperature	Celsius		N=20				
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	19,76	34,21	27,49	4,84	27,77	23,26	32,46
Session 10	19,48	35,11	27,05	5,43	26,06	22,79	31,76

p-value: p=0.084 for comparison of session 1 to session 10

Table 23. Temperature summary statistics control group.

Temperature	Celsius		N=9				
Training Session No	min	max	mean	SD	p50	p25	p75
Session 1	22,51	33,97	29,58	3,44	30,40	28,69	31,16
Session 10	21,96	33,25	30,48	3,51	31,81	30,38	32,37

p-value: p=0.53 for comparison of session 1 to session 10

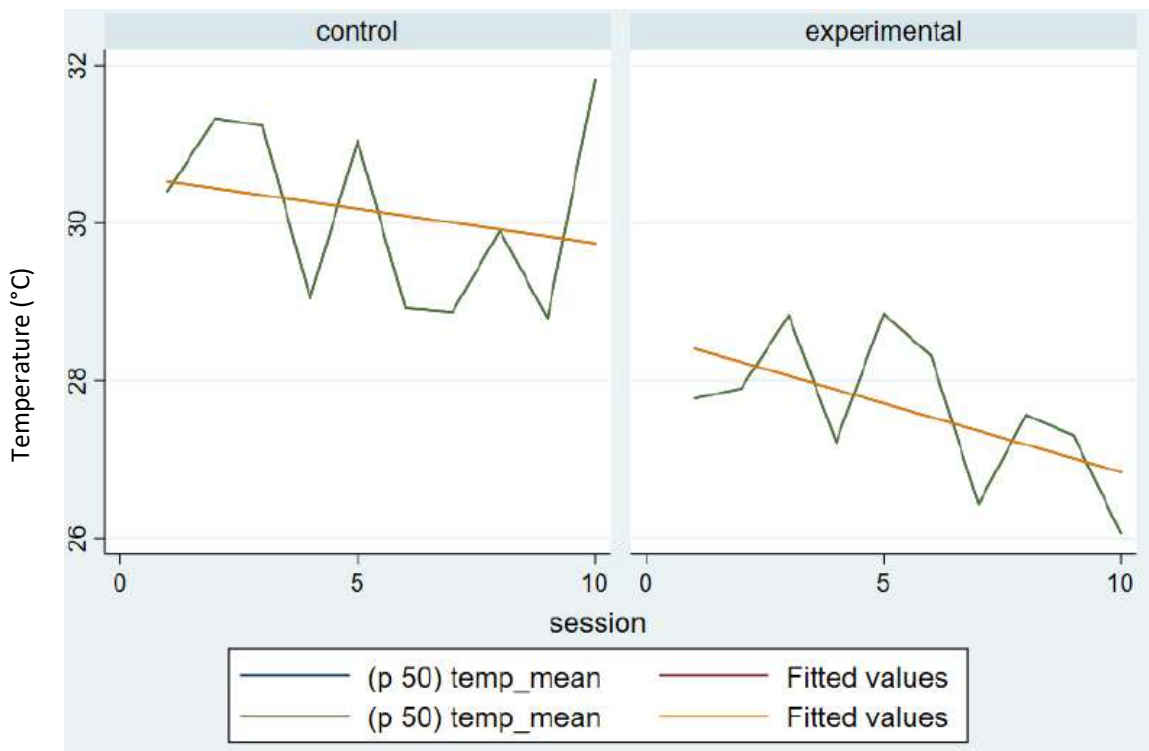


Figure 54: Temperature with p50 fitted regression line.

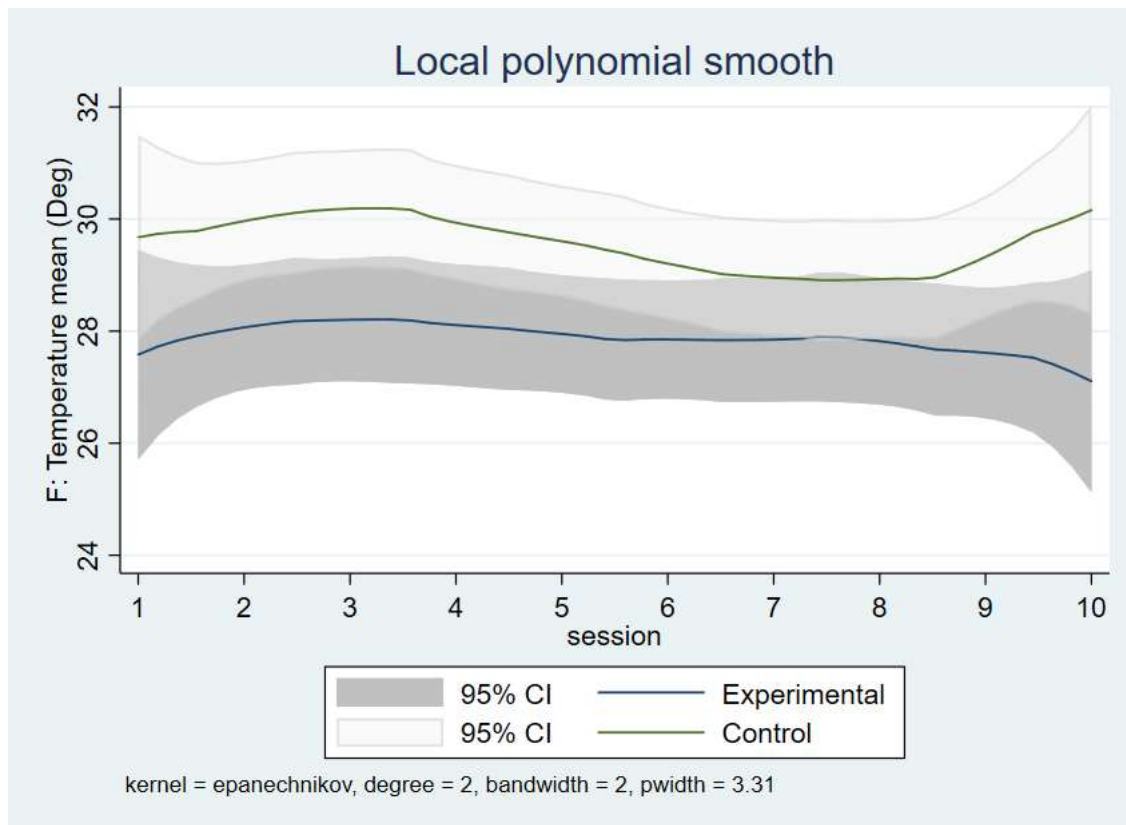


Figure 55: Smoothed curve for temperature with 95% confidence interval.

A summary of the results can be seen in table 22 and 23. The p-value for temperature change is $p=0.084$ which does not show a significant change when comparing session 1 to session 10) (Figure 54,55). The change that did occur also happened in the opposite direction of what was expected. It is suspected that the environment had a large impact on our temperature measurements. For future research it is recommended that all session be done in a climate-controlled environment with a set temperature. It will also be advisable that the participant first sits in this environment for 15 -30 minutes to get acclimatised to the environment. This should make temperature readings more accurate and more valid and one will then better be able to determine if there is any significant change with ISF training.

4.2.10. In session changes

In a separate analysis of autonomic function recording it was tried to determine which changes that happen within a session of training are the most relevant or show a large enough change that it can determine if the participant is having a positive or negative

effect. Until recently any clinician doing ISF clinical training was taught to measure the peripheral temperature to evaluate if their patient is relaxing and whether they might be close to the optimum frequency of that patient. This method has however been shown to be influenced by many factors which make it inaccurate, for example:

- The temperature of the environment.
- The placement of the hand.
- Kids tend to play or fiddle with it which influences readings.

The in-session changes were evaluated by comparing the first 2 minutes of the data to the last two minutes of the recording. The variables we compared include skin conductance, electromyogram, temperature and heart rate.

4.2.10.1. In session changes of skin conductance

From deduction when looking at the curves a change is noted from around session 5, which is typically when most participants were at their optimum frequency as was noted during training sessions. In session changes in skin conductance always show an increase in the electoral dermal activity. This can be indicative of a more aroused state in session, but from around session 5 there is a definite shift from a state of distress to a state of normal stress or arousal level when looking at the results (Figure 56).

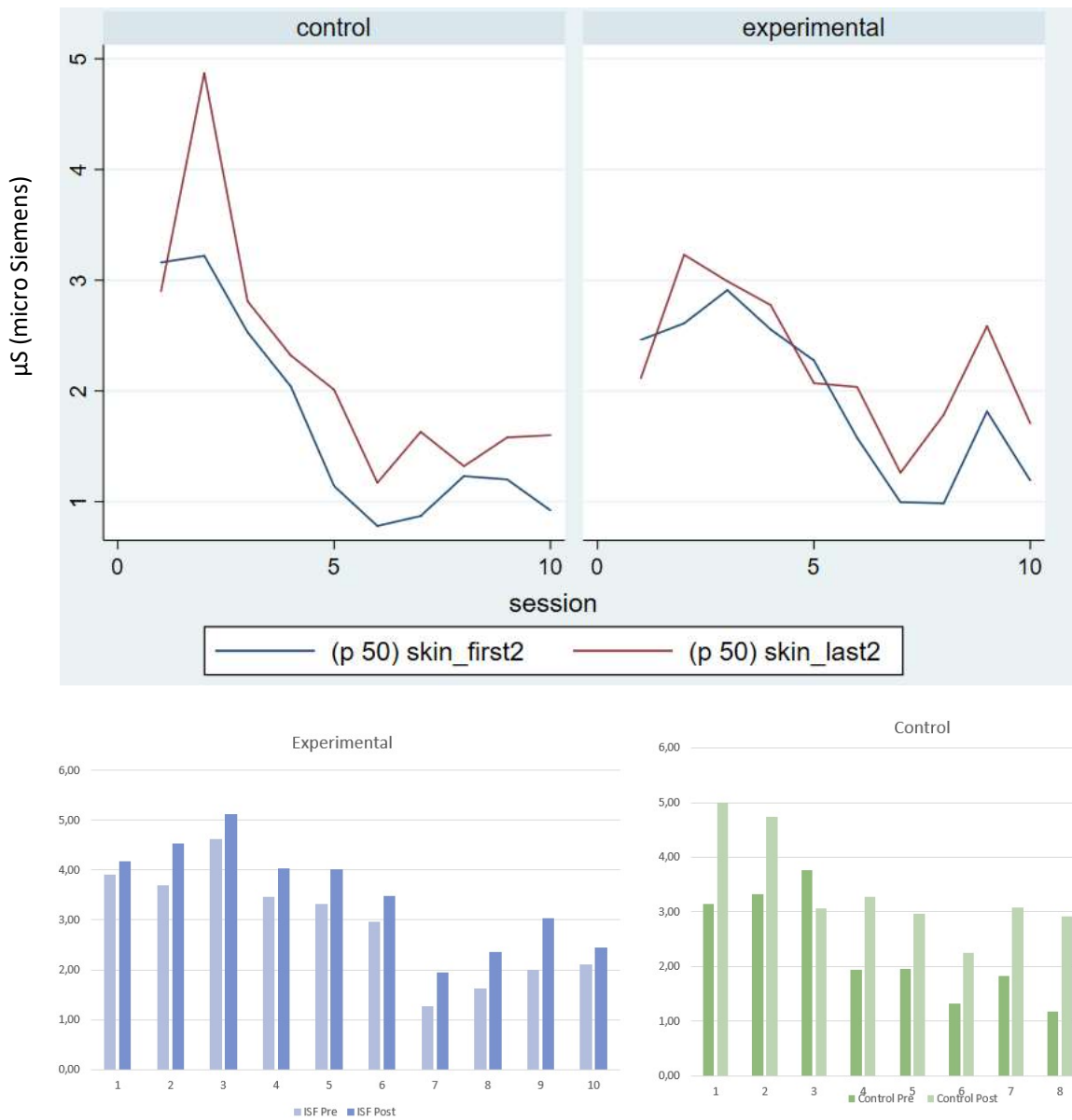


Figure 56: Pre- and post-session comparison for skin conductance.

This show that clinicians can used skin conductance for an indicator of optimization for their clients, but they will have to track the value over sessions and not just look at in session change as the temporary increase seen in session can be misleading and seen as a stress response instead of heightened arousal.

4.2.10.2. In session changes of electromyogram

In the resting EMG values large changes could be seen when comparing the first and last two minutes of the session (Figure 57). EMG typically shows a decrease in a training session and it appears to be the best indicator of in session relaxation.

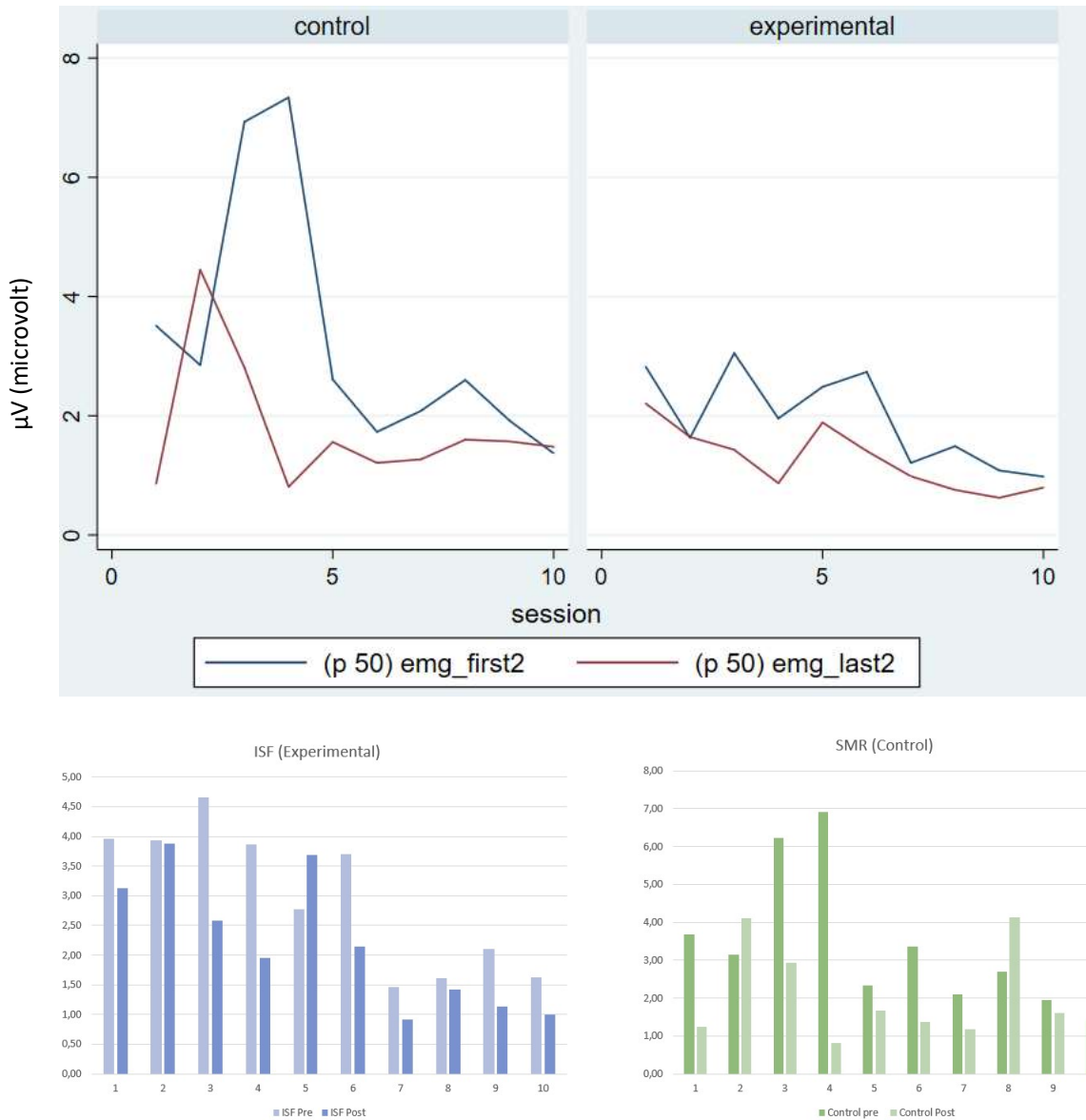


Figure 57: Pre- and post-session comparison for electromyogram.

4.2.10.3. In session changes of temperature

When looking at the in-session changes in peripheral temperature there was an increase noted in most sessions in both the control and the experimental group (Figure 58). This shows that it can be a good indicator for parasympathetic activation and relaxation but as discussed in the global changes it can also purely be the impact of the environment.

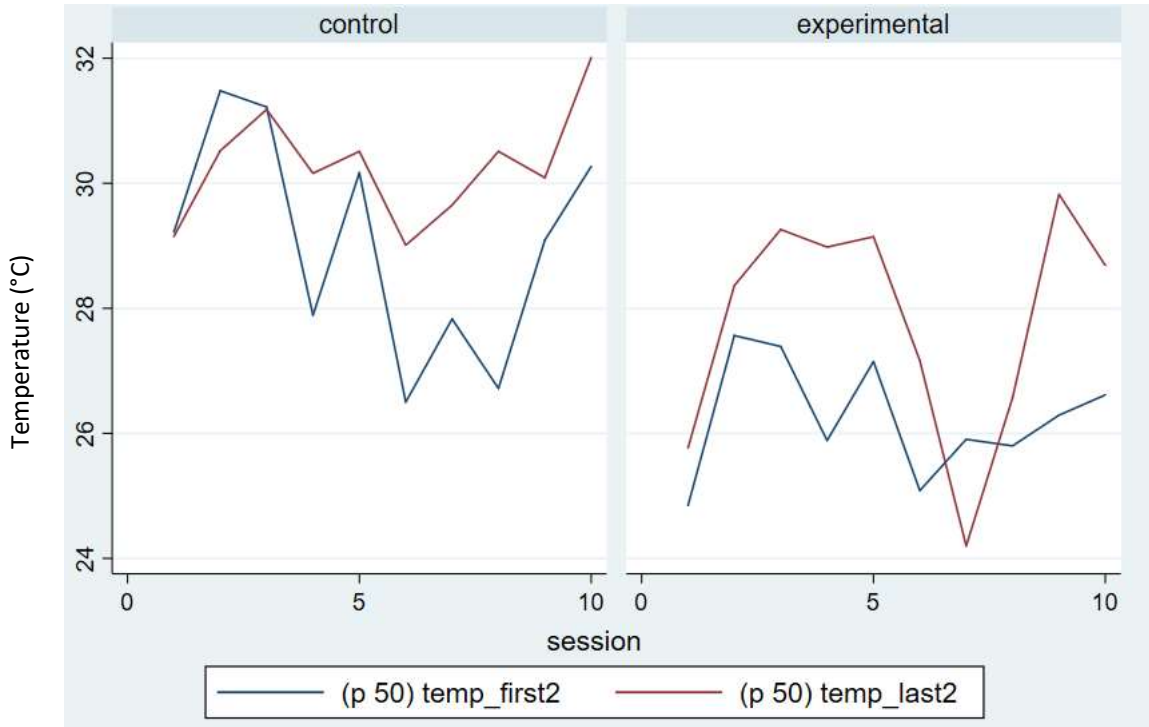


Figure 58: Pre- and post-session comparison for temperature.

4.2. Results of the Quantitative electroencephalogram analysis

To determine the global changes that occurred we made use of the QEEGProTM comparison report. This includes a comparative analysis of QEEG based on two different datasets. It includes the deviances as a percentage of deviant Z scores. The percentages are calculated based on the Z scored amplitudes of all the available electrode sites and across all the frequency bands. The Z- scored FFT Absolute Power and the Z scored Phase Coherence were analysed. The phase coherence is calculated by the following formula:

$$PH_{xy}(f) = \frac{|P_{xy}(f)|^2}{P_{xx}(f)P_{yy}(f)}$$

Where PH is the phase coherence, x and y are the EEG signals from two electrodes. F is the frequency and P is the cross power spectral density.

The normative database was constructed from resting-state EEG and questionnaire data of clients at the Neurofeedback Institute of Netherlands (NIN). All data is anonymous but may be used for research purposes. The questionnaire used was the CNC1020 and consisted of 292 questions directly based on the criteria of 46 DM psychopathologies and the recording were done on a 19 Channel Deymed™ Truscan Amplifier. The electrode locations were according to the 10/20 system. Recording session consisted of both an eyes closed and eyes open recording. It consists of the EEGs of 1482 eyes closed and 1231 eyes open recordings ranging in age from 4 to 82 years. The age distribution can be seen in Figure 59.

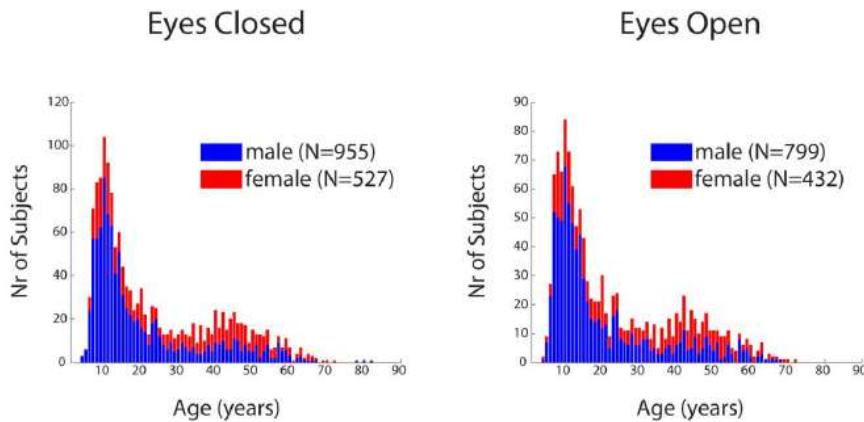


Figure 59: The distribution of EEG recordings according to age and gender.

The data was artifacted by making use of S.A.R.A. A total of 150 subgroups were created by selecting subjects that had a minimum age difference with the age bin of interest. For all log-transformed metrics a regression analysis was performed by making use of the data from the 47 psychopathology categories in the completed questionnaire. The residual of the regression model represents which cannot be

explained and these were then used to calculate the means and standard deviations for all metrics.

A paired t-test was used to determine if significant changes occurred. However as with many of the analysis performed it was noted that looking at a global change does not indicate any significant changes. It is once again a non-linear change which is noted where the population showed larger changes in the standard deviation changes. With the QEEG analysis there was the added complexity of the different frequency bands. It seems to be clear that ISF training has a larger effect on some frequency bands than others and one of the newest hypotheses from this which is now being studied at Ontario University in New Zealand is that there appears to be a cross-coupling co-modulating effect between specifically the infra slow frequency and the Beta bands.

Even though, when looking at the global difference, no significant change was measured, there were a change noted when looking at the individual band frequencies. It is also important to note that clinically all the participants reported improvement of various functions. The clinical discussion as was reported via clinical interview at each session is discussed in section 4.4. Changes noted in the different frequency bands:

4.3.1. Delta band

Delta brain waves (0.5–3.5 Hz) are very slow, high-amplitude brainwaves. Delta brain waves are what we experience in deep, restorative sleep. In general, different levels of awareness are associated with dominant brainwave states and Delta brainwaves can occur, for instance, when areas of the brain go “off line”. If someone is becoming drowsy, there are more Delta and slower Theta brainwaves creeping in. This can lead to inattention and wandering of the mind and is commonly associated with learning difficulties.

In Attention Deficit Disorder (ADD) there tends to be the presence of high amplitude Delta slow waves, excessive Theta or a locked in Alpha state. Excessive Alpha and Beta is the brain’s most reliable signature for depression which may present with high Alpha or Beta, excessive coherence problems or poor inter-hemisphere communication.

Delta is generated from the brain stem and cerebellum. These are less than 4 Hz and occur in deep sleep and in some abnormal processes also during experiences of 'empathy'. It reflects the unconscious mind. Delta is normally the dominant rhythm in infants up to one year of age and it is present in stages 3 and 4 of sleep. It tends to be the highest in amplitude and the slowest waves. Increase Delta waves will decrease our awareness of the physical world.

Peak performers' decrease Delta waves when high focus and peak performance is required whereas individuals diagnosed with ADD, naturally increase rather than decrease Delta activity when trying to focus. The inappropriate Delta response often severely restricts the ability to focus and maintain attention. (14)

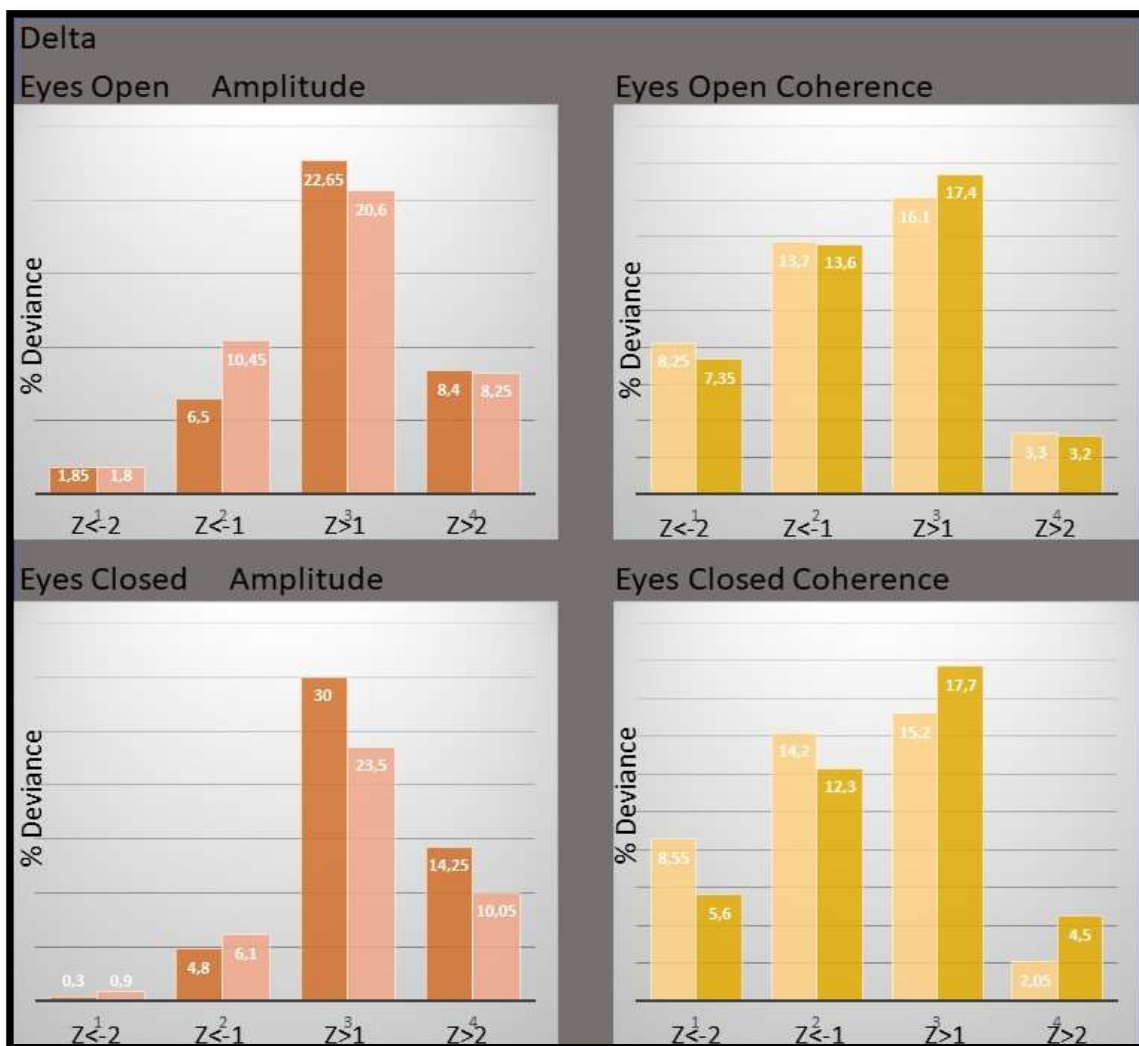


Figure 60: Percent deviance change noted in the Delta band for amplitude and coherence in the experimental group.

Eyes open amplitude: In the Delta band it was noted that there was an increase in the deficits of power and a decrease in the excessive Delta activity. This indicates that the brain became more alert, as there was less slow activity present. (Figure 60)

Eyes open coherence: There is a decrease in the hypocoherence values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 60)

Eyes closed amplitude: The amplitude of Delta decreased with a minimal increase in low amplitudes. Less Delta activity indicates higher functionality, less drowsiness and better focus. (Figure 60)

Eyes closed coherence: There is a decrease in the hypocoherence values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 60)

4.3.2. Theta band

Theta (4–8 Hz) activity generally represents a daydream like, fantasy prone state of mind and is associated with mental inefficiency. At very slow levels, Theta brainwave activity is a very relaxed state, representing the twilight zone between waking and sleep. Generally, an increase in Theta is seen with additional increases in Delta and Alpha (all slower waves), which is like driving with the breaks on.

In ADD/ADHD, head injuries, stroke, epilepsy, developmental disabilities, and often chronic fatigue syndrome and fibromyalgia individuals tend to have excessive slow waves (usually Theta and sometimes excess Alpha) present. When this excess of slow waves is present in the executive (frontal) parts of the brain, it becomes difficult to control attention, behaviour, and/or emotions. This can lead to problems with cognitive processing, concentration, memory, controlling impulses and moods, or hyperactivity. They typically have problems focusing and exhibit diminished intellectual efficiency.

Theta is generated through the thalamo-cortical path and reflects resources used in the body. Diet, exercise and other health issues can have an impact on the amount of Theta activity in the brain. Elevated Theta in the posterior of the brain tends to be associated with feelings of calm and well-being.

It is abnormal to have Theta in awake adults but is perfectly normal in children up to 13 years old. It is also present during sleep and believed to reflect activity from the limbic system and hippocampal regions. (14)

Theta is observed in anxiety, behavioural activation and behavioural inhibition. When the Theta rhythm appears to function normally it mediates and promotes adaptive, complex behaviours such as learning and memory. Under unusual emotional circumstances, such as stress or disease states, there may be an imbalance of three major transmitter systems, which results in aberrant behaviour. Excessive Theta and Delta have a slowing effect and the brain which makes it underactive. Lack of blood flow to the brain also increases Theta and Delta waves. (14)

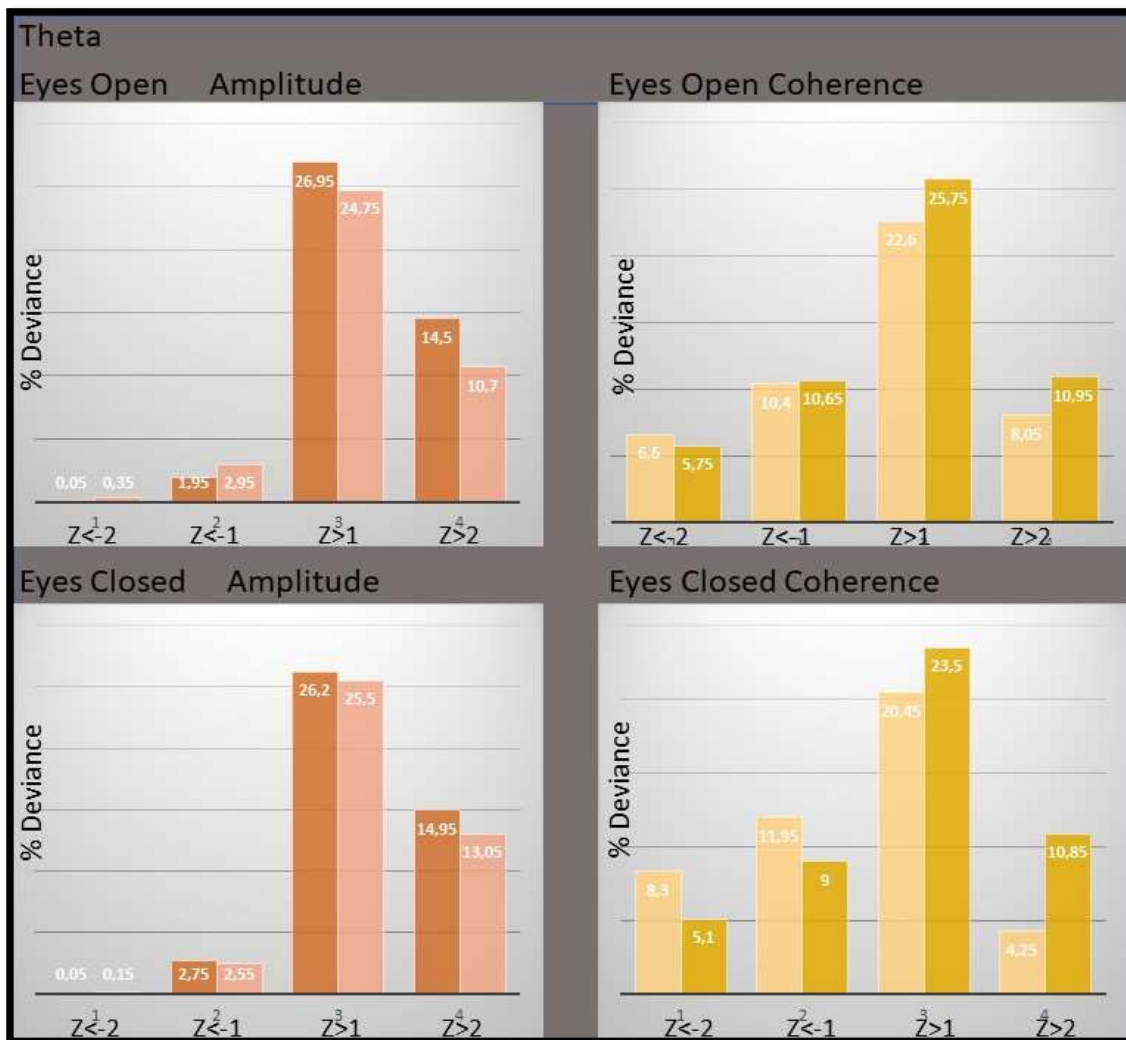


Figure 61: Percent deviance change noted in the Theta band for amplitude and coherence in the experimental group.

Eyes open amplitude: A decrease in excessive Theta activity is noted which should indicate a higher level of alertness and better functionality. (Figure 61)

Eyes open coherence: There is a decrease in the hypocoherece values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 61)

Eyes closed amplitude: A decrease in excessive Theta activity is noted which should indicate a higher level of alertness and better functionality. (Figure 61)

Eyes closed coherence: There is a decrease in the hypocoherece values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 61)

4.3.3. Alpha band

Alpha is generated from resonance between the thalamus and the cortex. They are generally associated with a state of relaxation, peacefulness and alertness. Activity in the lower half of this range typically represents the brain shifting into an idling state, relaxed and a bit disengaged, waiting to respond when needed. An increase in Alpha should be noted if an individual merely closes their eyes and begin picturing something peaceful. These brainwaves are especially large in the back third of the head.

Alpha waves will peak around 10 Hz from age 13 and promotes mental resourcefulness, aids in the ability to coordinate mentally and enhances the overall sense of relaxation and fatigue. When Alpha predominates most people feel at ease and calm and is the major rhythm seen in normal relaxed adults.

Alpha rhythms are reported to be derived from the white matter of the brain which can be considered as the part of the brain that connects all parts with each other.

It is a preferred state for the brain and occurs whenever a person is alert but not actively processing information. The Alpha frequency is strongest over the occipital cortex. (14)

Typically, the traumatized brain idles too fast (in the Beta direction), or too slowly (in the Theta direction). If excessive Alpha coherence is present, the brain may be locked up in Alpha and be hard to speed up or slow down. Low Alpha activity can be indicative of anxiety, PTSD, or short-term memory impairment. Low Alpha also increases cortisol

in the brain, which affects the hippocampus and thus short-term memory.

Alpha allows us to shift easily from one task to another. Too much Alpha in the right frontal cortex may be associated with defiance in children while a similar amplitude in the left frontal cortex may be associated with a depressed mood state. (14)

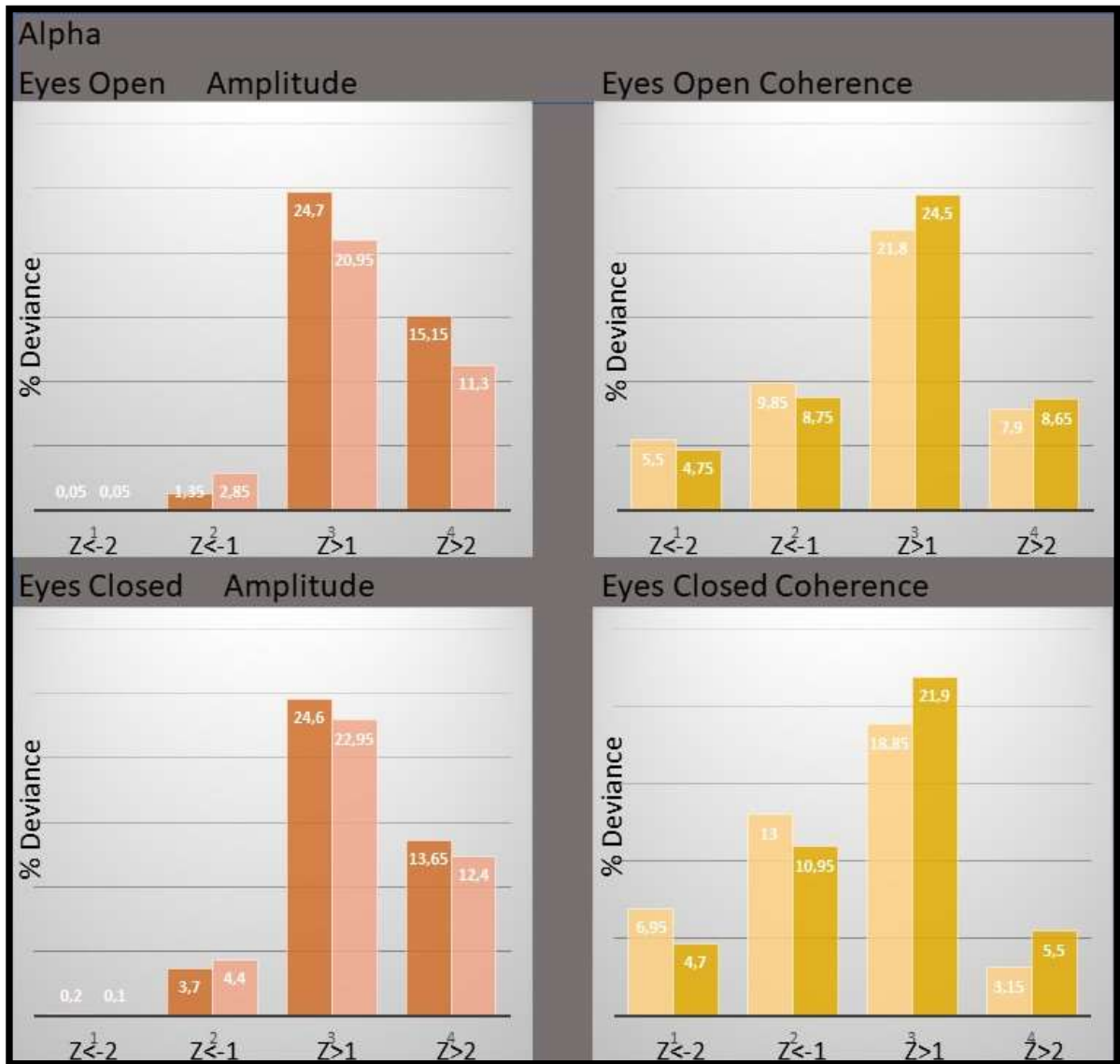


Figure 62: Percent deviance change noted in the Alpha band for amplitude and coherence in the experimental group.

Eyes open amplitude: A decrease is seen in the excessive Alpha activity. (Figure 62)

Eyes open coherence: There is a decrease in the hypocoherence values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 62)

Eyes closed amplitude: A decrease is seen in the excessive Alpha activity. (Figure 62)

Eyes closed coherence: There is a decrease in the hypocoherence values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 62)

4.3.4. The various Beta bands

Beta brainwaves are small, relatively fast brainwaves (above 13–30 Hz) and are associated with a state of thinking, mental and intellectual activity and outwardly focused sustained concentration. Activity in the lower end of this frequency band (e.g., the sensorimotor rhythm, or SMR at Cz) is associated with a relaxed attentiveness. In an individual who is exceptionally anxious and tense, an excessively high frequency of Beta brainwaves may be present in different parts of the brain. In other cases, this may be associated with an excess of inefficient Alpha activity in frontal areas that are associated with emotional control. If Beta is deficient, either all over or in small areas, the brain may have insufficient energy to perform tasks at peer group standards.

It typically reflects desynchronized active brain tissue and is usually seen on both sides in symmetrical distribution most evident frontally. Increased Beta asymmetry in the right hemisphere is indicative of anxiety and Beta hyper-coherence may indicate anxiety, panic attacks, and test anxiety. It may be absent or reduced in areas of cortical damage.

The Beta rhythm is generally regarded as a normal rhythm. It is the dominant rhythm in those who are alert or anxious or who have their eyes open. Fast Beta above 15Hz is the state that most of brain is in when we have our eyes open and are listening and thinking during analytical problem solving, judgment, decision making and processing of information about our environment.

Dominant frequency Beta may indicate that there is excess norepinephrine. Increased Beta alone is often indicative of withdrawal from social interaction (when Theta and Alpha are lower). Increased Beta at Fp2 and F3 simultaneously can be indicative of the patient hiding all feelings and emotions and a flat affect may be seen. Increased

Beta and decreased Alpha in frontal areas is indicative of agitation, being controlled by anxiety, feeling overwhelmed, and impulsivity with explosiveness. (14)

The Beta band has a relatively large range, and has been divided into Lobeta, Beta and High Beta.

Beta hypercoherence is seen in stress and when there is a feeling of being overwhelmed. The individual can't process activated networks. In Contrast Beta hypocoherence is seen as immobilization of networks.

4.3.4.1. Lobeta band

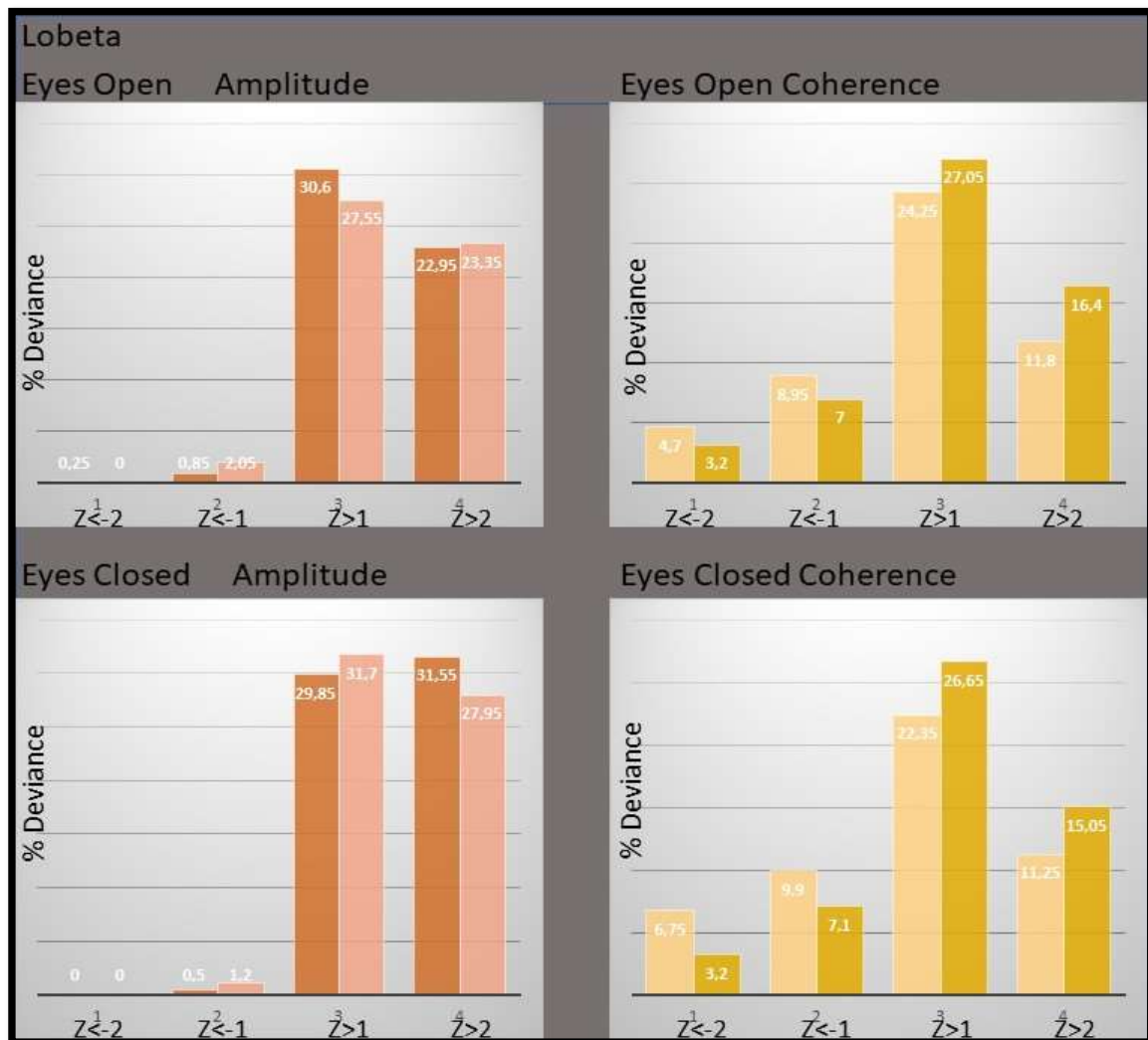


Figure 63: Percent deviance change noted in the Lobeta band for amplitude and coherence in the experimental group.

Eyes open amplitude: A decrease is noted in the percent deviant activity above 1 Z scores and an increase is noted in the percent deviant activity above 2 Z scores. (Figure 63)

Eyes open coherence: There is a decrease in the hypocoherence values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 63)

Eyes closed amplitude: An increase is noted in the percent deviant activity above 1 Z scores and a decrease is noted in the percent deviant activity above 2 Z scores. (Figure 63)

Eyes closed coherence: There is a decrease in the hypocoherence values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 63)

4.3.4.2. Beta band

Midrange Beta (15-18) Hz: Subjective feeling states: thinking, aware of self & surroundings; associated tasks and behaviours: mental activity; physiological correlates: alert, active, but not agitated. Localized activity where work is being done, asynchronous. (14)

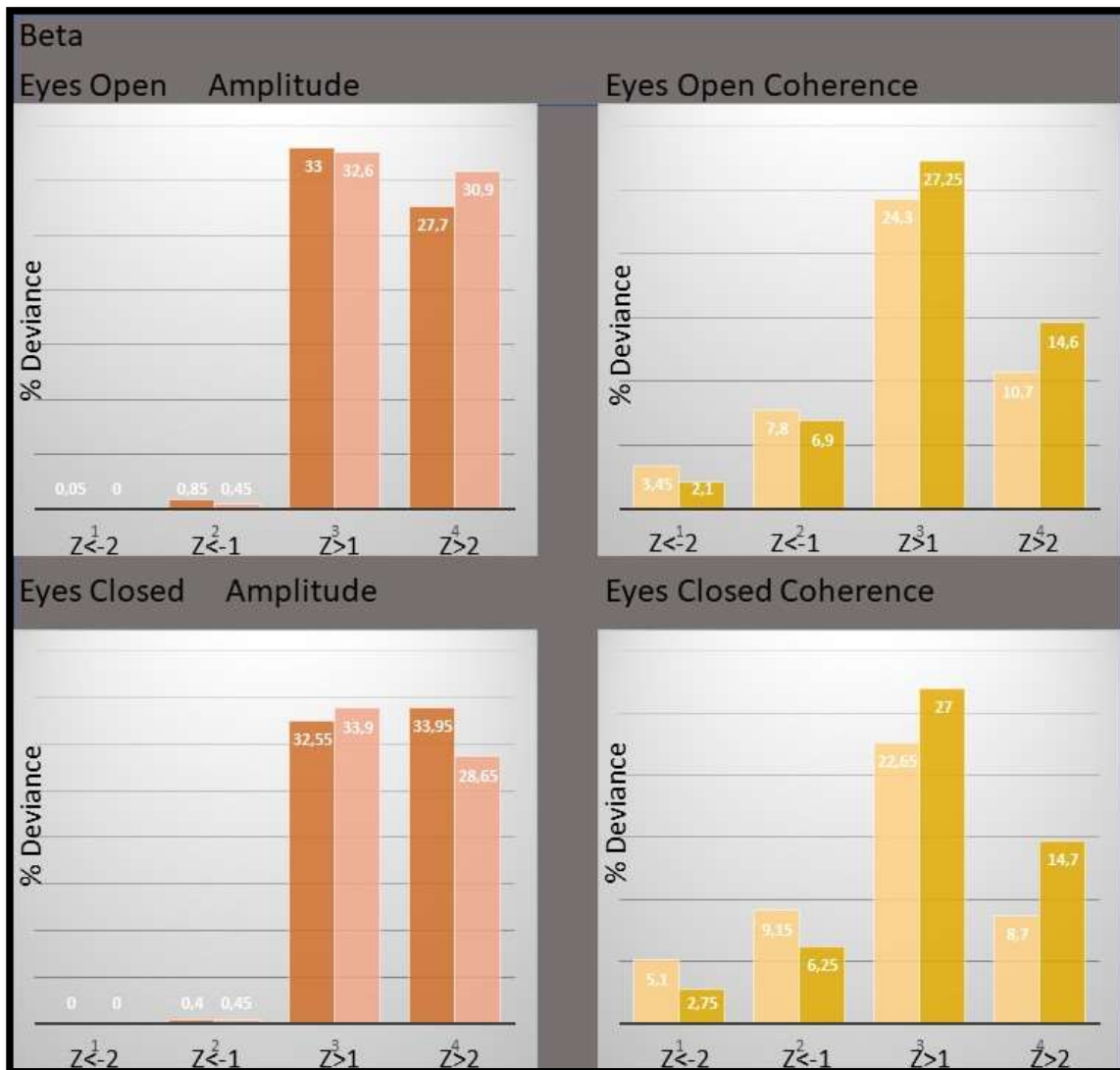


Figure 64: Percent deviance change noted in the Beta band for amplitude and coherence in the experimental group.

Eyes open amplitude: A decrease is noted in the percent deviant activity above 1 Z scores and an increase is noted in the percent deviant activity above 2 Z scores. (Figure 64)

Eyes open coherence: There is a decrease in the hypocoherece values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 64)

Eyes closed amplitude: An increase is noted in the percent deviant activity above 1 Z scores and a decrease is noted in the percent deviant activity above 2 Z scores. (Figure 64)

Eyes closed coherence: There is a decrease in the hypocoherece values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 64)

4.3.4.3. High Beta band

Subjective feeling states: alertness, agitation, problem solving, anxiety, worrying, rumination, mental effort. Associated tasks and behaviours include mental activity, e.g. math, planning, etc. Physiological correlates include general activation of mind & body functions. (14)

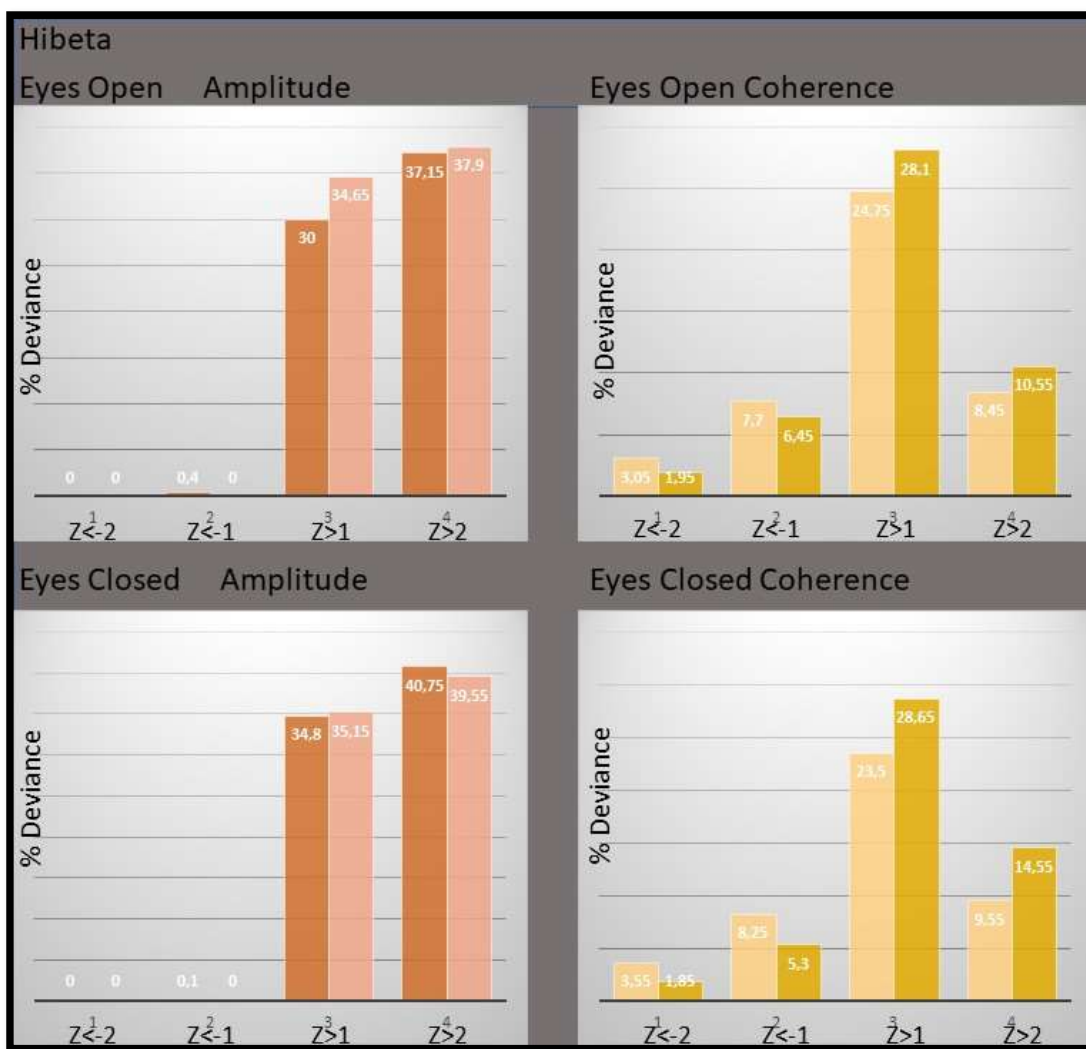


Figure 65: Percent deviance change noted in the High Beta band for amplitude and coherence in the experimental group.

Eyes open amplitude: An increase is noted in the percentage of deviant activity for $Z > 1$ and $Z > 2$. (Figure 65)

Eyes open coherence: There is a decrease in the hypocoherece values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 65)

Eyes closed amplitude: An increase is noted in the percentage of deviant activity for $Z > 1$ and $Z > 2$. (Figure 65)

Eyes closed coherence: There is a decrease in the hypocoherece values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 65)

4.3.5. Gamma band

Gamma brainwaves activity is very fast asynchronous EEG activity above 30 Hz, some of which is associated with intensely focused attention and in assisting the brain to process and bind together information from different areas of the brain (network integration). It is measured between 36 – 44 Hz and is the only frequency group found in every part of the brain. When the brain needs to process simultaneous information from different areas, it is hypothesized that the 40 Hz activity consolidates the required areas for simultaneous processing. A good memory is also associated with well-regulated and efficient 40 Hz activity. Deficiencies in 40 Hz activity is seen in learning disabilities. When deficits in Gamma is trained it is associated with improved memory, language and effortlessness in learning. (14,15)

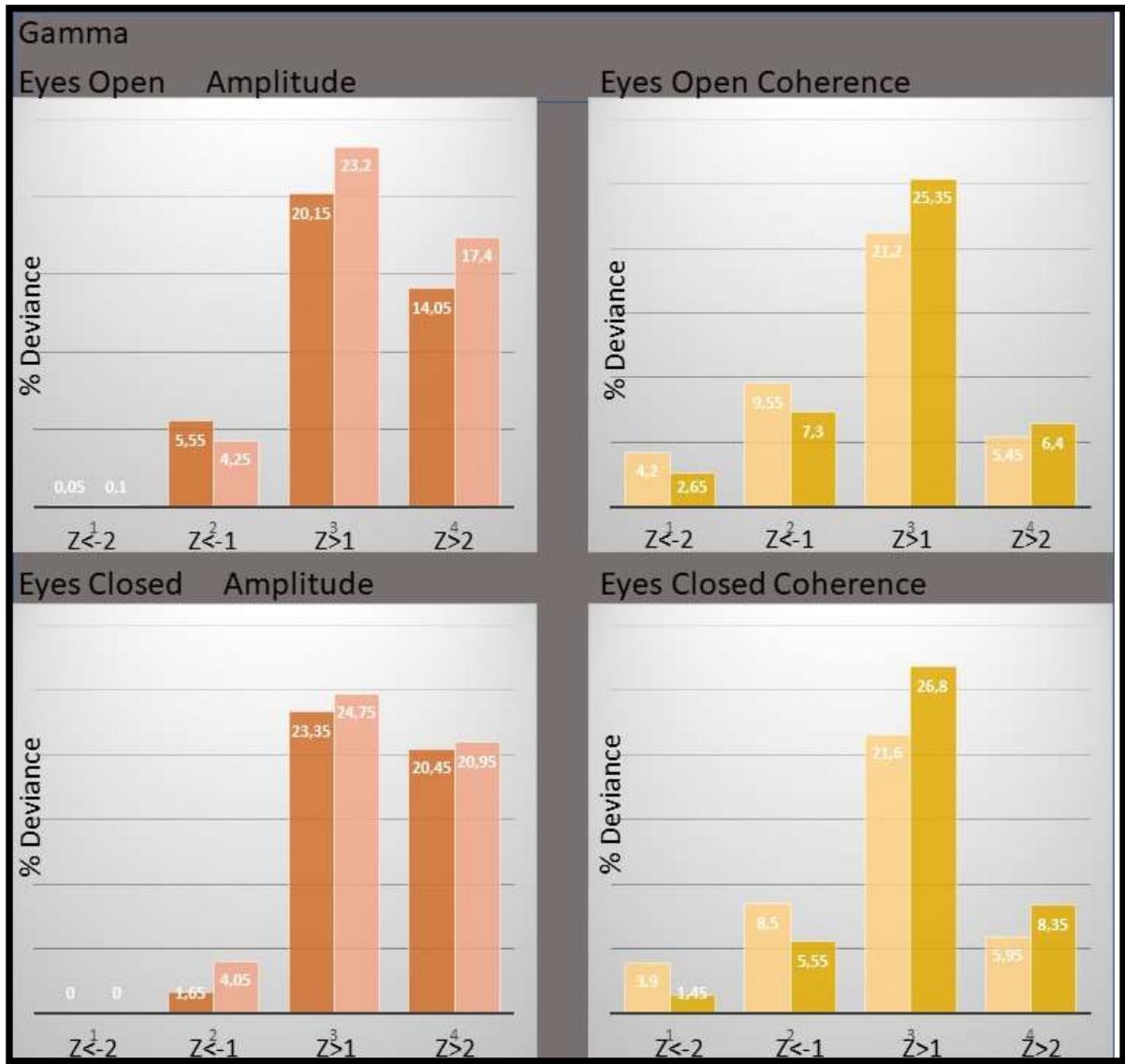


Figure 66: Percent deviance change noted in the Gamma band for amplitude and coherence in the experimental group.

Eyes open amplitude: An increase is noted in the percentage of deviant activity for $Z > 1$ and $Z > 2$. (Figure 66)

Eyes open coherence: There is a decrease in the hypocoherece values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 66)

Eyes closed amplitude: An increase is noted in the percentage of deviant activity for $Z > 1$ and $Z > 2$. (Figure 66)

Eyes closed coherence: There is a decrease in the hypocoherece values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 66)

4.3.6. Alpha 1 band

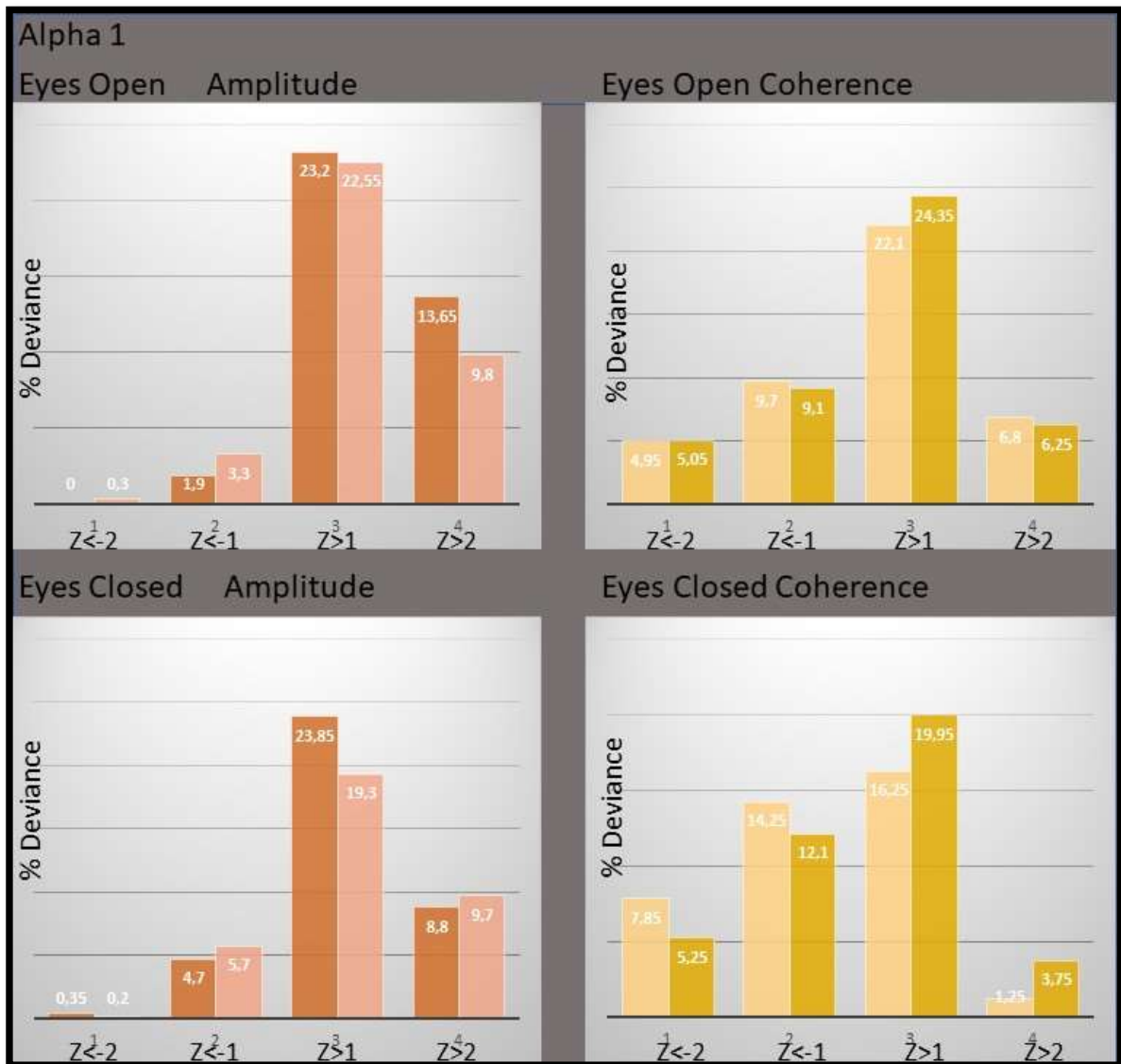


Figure 67: Percent deviance change noted in the Alpha 1 band for amplitude and coherence in the experimental group.

Eyes open amplitude: A decrease is noted in the percentage of deviant activity for both $Z > 1$ and $Z > 2$. (Figure 67)

Eyes open coherence: There is a decrease in the hypocoherence values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 67)

Eyes closed amplitude: A decrease is noted in the percentage of deviant activity for $Z > 1$. (Figure 67)

Eyes closed coherence: There is a decrease in the hypocoherence values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 67)

4.3.7. Alpha 2 band

Sub band high Alpha: (10-12) Hz: If Alpha is blunted or absent, clients cite poor retention of information and/or poor short-term memory. When Alpha response is non-existent or negative one should suspect the possibility of traumatic stress or emotional trauma, especially if there is a negative response at both Cz and O1. (14)

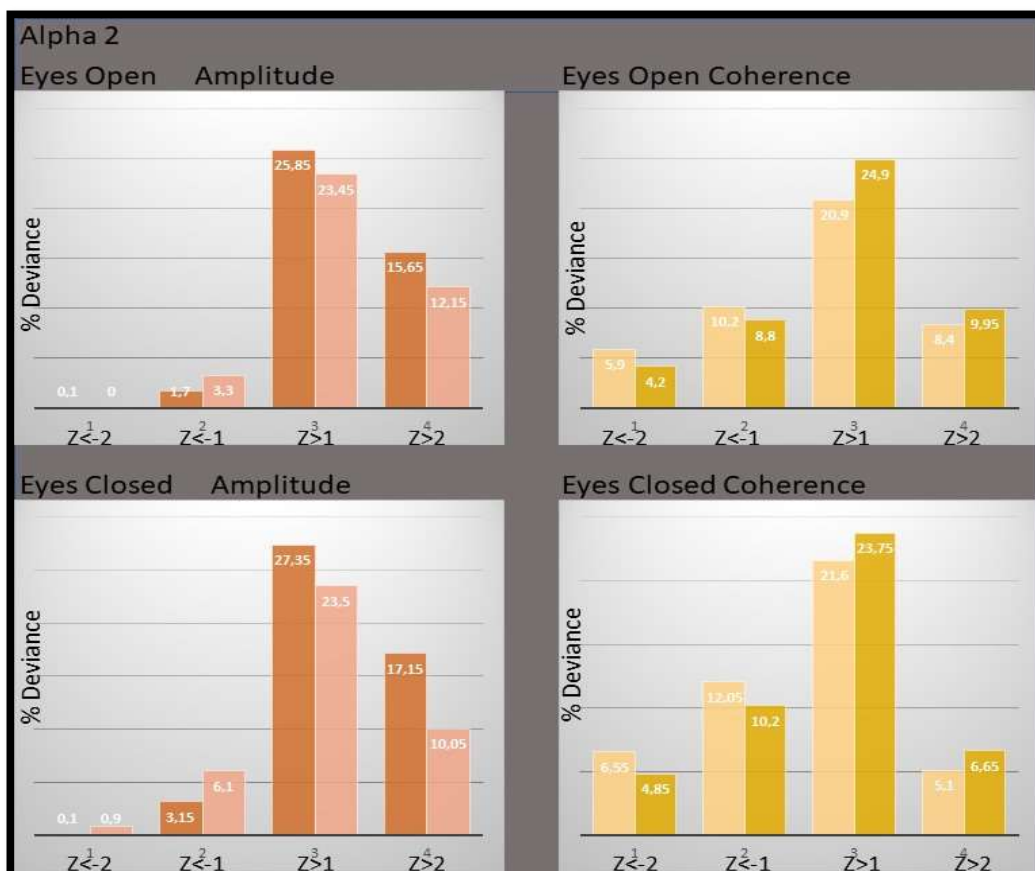


Figure 68: Percent deviance change noted in the Alpha 2 band for amplitude and coherence in the experimental group

Eyes open amplitude: A decrease is seen in the percent deviant activity for $Z > 1$ and $Z > 2$. (Figure 68)

Eyes open coherence: There is a decrease in the hypocoherence values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 68)

Eyes closed amplitude: A decrease is seen in the percent deviant activity for $Z > 1$ and $Z > 2$. (Figure 68)

Eyes closed coherence: There is a decrease in the hypocoherence values and an increase in the hypercoherence values. This can be interpreted as less disconnection and more connectiveness in the brain. (Figure 68)

In summary:

- A decrease was seen in the percentage of deviant activity for $Z > 1$ in the Delta, Theta and Alpha bands (more specifically Alpha 2).
- An Increase was noted in High Beta and Gamma activity for $Z > 1$.
- In the Beta band both increases and decreases are noted in the percentage of deviant activity $Z > 1$.
- Across all bands a decrease is noted in hypocoherences percent deviance and an increase is noted in hypercoherences.

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Chapter 5: Conclusion

The body has a natural and sophisticated mechanism which ensures that there is as much physiological stability as possible while we navigate through life. The control centre for this homeostatic mechanism is the autonomic nervous system which unconsciously controls and manages heart rate, breathing, blood pressure and various other functions. It consists of the sympathetic and parasympathetic nervous systems which complement each other and so regulate physiological processes in response to external or internal stimuli. When there is a stress reaction the SNS will respond and shift the body from its normal state of equilibrium. Once the threat is over the PNS will shift it back towards its point of equilibrium. However, if this process becomes less responsive and an individual stay in a state of increased or decreased arousal it can lead to disease. See Figure 69. (1)

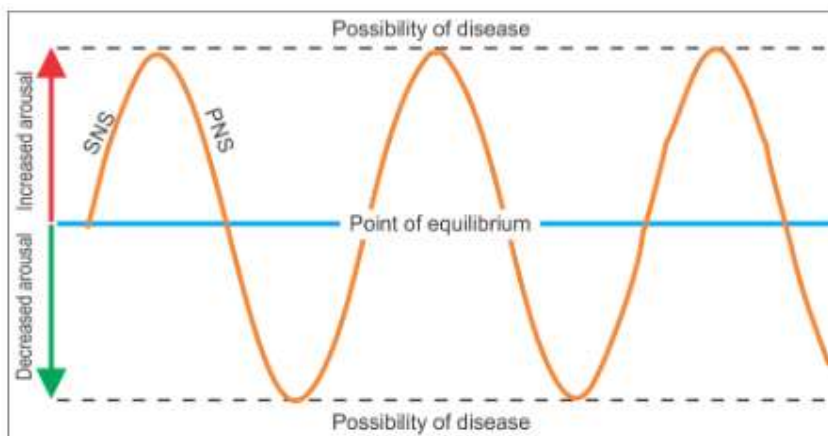


Figure 69: Equilibrium of the Autonomic nervous system. (1)

Table 24 summarizes the most significant p-values that were measured during the study.

Table 24. Comparison summary between the ISF (experimental) and SMR (amplitude) training paired t-test results after 10 sessions of training

Variable	P-Value ISF	P-Value Amplitude (SMR)
HRV VLF Power	0,05	0,30
HRV LF Power	0,004	0,98
EMG Mean	0,01	0,33
Skin Conductance Mean	<0,0001	0,39
Blood Pressure (Systolic)	0,049	0,74
Blood Pressure (Diastolic)	0,083	0,79
Respiratory Amplitude	0,21	0,55
BVP Amplitude	0,25	0,91
IBI SDRR	0,06	0,51

The following hypotheses were formulated for this study:

1. The QEEG will show significant change when comparing the pre-and post-percentages deviance.
2. The autonomic functions measured in the ISF training participants will show significant changes when comparing the 10th to the first session.
3. The autonomic functions measured in the participants who did amplitude training will show less significant changes.
4. There will be no significant difference in QEEG pre-and post-percentages deviance.
5. There will be no significant difference in any of the autonomic functions measured during ISF training or amplitude training.

The null hypothesis can be rejected as there were significant changes in the ISF training group compared to no significant changes in the control group. It is thus clear that ISF neurofeedback training does have an influence on the autonomic nervous system. There were also measurable differences in the EEG percent deviances when looking at the different bands indicating that it does influence the EEG of an individual. It did however not show any significant global change in amplitude or coherence.

A very important aspect in the discussion and interpretation of results is the clinical data obtained via interview per session, as it is important to remember that we are working with an individual and not just the components of their nervous system. As was identified in Chapter 3, the main complaints of participants were:

- Anxiety/panic attacks
- Either falling staying asleep
- Irritation/anger problems
- Executive function problems (Concentration/Focus/Memory complaints)
- Constipation and or irritable bowels

From the ISF training group clinical interview data after 10 sessions the following can be summarized:

- 19 participants reported that they felt calmer and less anxious in general.
- 2 participants who were experiencing daily panic attacks reported cessation of these attacks by session 7 and 9 respectively.
- 15 participants reported that they were better able to manage their emotions and anger outbursts by average session 4-7.
- 5 reported that they were able to sleep without taking any medication to fall asleep by average session 5-8.
- 12 reported that they were sleeping better, not waking up at night and feeling rested and alert when waking in the morning from average session 4-8.
- 16 reported that they were focusing better at work and completing tasks faster and more efficiently.
- 8 participants reported being less constipated and 4 having less intestinal cramping.

- Additionally, 4 of the female participants reported that they had almost no negative premenstrual stress (PMS) symptoms where it would usually be very severe.

From the amplitude training group clinical interview data, the following can be summarized:

- 2 participants reported they were feeling more relaxed.
- 1 participant reported that his mood was more stable.
- 4 participants reported feeling they can focus better.
- 5 participants reported that they did not really notice any change.

5.1. Summary

In the evaluation of the changes in autonomic function changes significant changes were noted in the experimental group or skin conductance, electromyogram and in the analysis of the frequency domain of HRV for % power VLF and % power LF. Heart rate data showed significant decrease was not noted but when looking at the change towards normal a definite trend is seen where the standard deviation of the group decreased and their heart rates either increased or decreased towards what is known as an age and sex related norm. The same was noted in the Blood Pressure readings where the standard deviation of the group decreased, and more participants BP values increased or decreased towards more normal values. In other words, closer to the normal range of 120/70.

5.2. Future work

Forty different statistics were measures in order to identify those variables that may have been significantly impacted by the ISF training. Eleven were identified which appeared to show relevant results. In hindsight however, one might have to look at all the data differently as it became more and more apparent that the change in the system was not necessarily linear. Thus, it will not indicate a significant p-value even though there might have been significant changes. If one can explore how one can measure a change to autonomic balance rather than just a directional change it might be possible to show more significant changes that had taken place.

Another study with a larger group of both experimental and control participants as well as a control group where no training is done (double blind study) can also be

considered. That will give an even clearer indication of what variables are purely influenced by the ISF training.

References:

1. Beauchamp P. The Peak Performance Suite Manual. Thought Technology.

ANNEXURES

Annexure A: Ethics approval

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 03/14/2020.



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences Research Ethics Committee

16/08/2018

Approval Certificate New Application

Ethics Reference No: 216/2018

Title: The effect of infra slow frequency neurofeedback on quantitative electroencephalogram and autonomic nervous system function in adults with anxiety and related diseases

Dear Karlien Balt

The **New Application** as supported by documents specified in your cover letter dated 12/07/2018 for your research received on the 12/07/2018, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 15/08/2018.

Please note the following about your ethics approval:

- Ethics Approval is valid for 1 year
- Please remember to use your protocol number (216/2018) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, or monitor the conduct of your research.

Ethics approval is subject to the following:

- The ethics approval is conditional on the receipt of **6 monthly written Progress Reports**, and
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely



Dr R Sommers; MBChB; MMed (Int); MPharMed, PhD

Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health).

☎ 012 356 3084

✉ deepeka.behari@up.ac.za / fnsethics@up.ac.za

🌐 <http://www.up.ac.za/healthethics>

✉ Private Bag X323, Arcadia, 0007 - Tswelopele Building, Level 4, Room 60 / 61, 31 Bophelo Road, Gezina, Pretoria

Annexure B: Stats support letter



BIostatISTICS UNIT

1 November 2017

LETTER OF STATISTICAL SUPPORT

This letter confirms that **K. Balt** from the **Department of Human Physiology, Faculty of Health Sciences of the University of Pretoria** discussed her project: **"The effect of Infra Slow Frequency Neurofeedback on Quantitative Electroencephalogram, Heart Rate Variability, Temperature, Electromyography, respiration and skin conductance."** with me. I confirm that I will assist with the statistical analysis of the study data.

Data analysis

The descriptive statistics mean, median, standard deviation and inter-quartile range will be used to describe the ISF and QEEG parameters. Frequencies and proportions will be used to describe the categorical variables. The paired t-test, or non-parametric alternative will be used to test for differences in the pre and post QEEG values. A linear mixed model will be used to determine if there are trends in the ISF parameters over the 10 sessions of each patient that will be monitored, using random intercept and slope effects for the patient, as well as if there are differences between pre and post session values. Tests will be evaluated at 5% level of significance. All analysis will be done using STATA 14.

Sample size

The researcher is encouraged to recruit 30 – 40 patients as a rule of thumb for the pre-post test, and since no covariates are important to control for.

Name: C Janse van Rensburg
Biostatistics Unit
MRC Pretoria
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MEDICAL RESEARCH COUNCIL
Biostatistics Unit
Private Bag X385
Pretoria
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Tel: 012 339 8523 / Fax: 012 339 8582



Annexure C: Informed consent and Questionnaire

PATIENT OR PARTICIPANT'S INFORMATION & INFORMED CONSENT DOCUMENT

(Investigator/Student to complete all sections in red text)

Karlien Balt

Student Number 21077194

Department of Physiology

University of Pretoria

Dear Participant

The effect of infra slow frequency neurofeedback on quantitative electroencephalogram and autonomic nervous system function in adults with anxiety and related diseases

I am a Postgraduate MSc student/s in Human Physiology in the Department of Health Sciences University of Pretoria. You are invited to volunteer to participate in our research project on the effect of infra slow frequency neurofeedback on quantitative electroencephalogram and autonomic nervous system function in adults with anxiety and related diseases.

This letter gives information to help you to decide if you want to take part in this study. Before you agree you should fully understand what is involved. If you do not understand the information or have any other questions, do not hesitate to ask us. You should not agree to take part unless you are completely happy about what we expect of you.

The purpose of the study is to determine whether we can measure any physiological changes during neurofeedback training.

We would like you to complete a questionnaire. This may take about 15 minutes. I will collect the questionnaire from you before you leave the office. It will be kept in a safe place to ensure confidentiality. Please do not write your name on the questionnaire. This will ensure confidentiality. I will be available to help you with the questionnaire or to fill it in on your behalf. Be aware that some questions may be of a sensitive nature. This includes questions on drug use, medication use, alcohol use and questions regarding the urogenital system.

The Research Ethics Committee of the University of Pretoria, Faculty of Health Sciences, telephone numbers 012 356 3084 / 012 356 3085 granted written approval for this study.

Your participation in this study is voluntary. You can refuse to participate or stop at any time without giving any reason. Once you have given the questionnaire back to us, you can still recall your consent. You will not be identified as a participant in any publication that comes from this study.

In the event of questions asked, which will cause emotional distress, then the researcher is able to refer you to a competent counselling.

Note: The implication of completing the questionnaire is that informed consent has been obtained from you. Thus, any information derived from your form (which will be totally anonymous) may be used for e.g. publication, by the researchers.

We sincerely appreciate your help.

Yours truly,

Karlien Balt

COMPREHENSIVE ADULT QUESTIONNAIRE

SUBJECT CODE: _____

Please tick and rate the conditions that apply to you by placing a 0, 1, 2 or 3 to indicate the level of severity: 0=not a problem, 1=mild, 2=medium, 3=severe. Please include any additional information about the disorders such as age of onset, length of duration, interventions undertaken, that you consider important.

GENERAL HEALTH:

☐ Sleep				
Difficulty falling asleep or staying asleep	0	1	2	3
Difficulty waking	0	1	2	3
Restless sleep	0	1	2	3
Sleepwalking or night terrors	0	1	2	3
Nightmares	0	1	2	3
Other sleep problems	0	1	2	3
Bruxism	0	1	2	3
☐ Allergies	0	1	2	3
☐ Asthma	0	1	2	3
☐ Frequent Illness	0	1	2	3
☐ Fatigue	0	1	2	3
☐ Appetite awareness				
I am aware of my appetite increasing.	0	1	2	3
I often find myself suddenly aware that				
I am starving or shaky due to lack of food.	0	1	2	3

	I am always hungry	0	1	2	3
☐	Sense of taste	0	1	2	3
☐	Thirst awareness	0	1	2	3
☐	Heat or cold sensitivity	0	1	2	3
☐	Thyroid disorder	0	1	2	3
☐	Sense of smell	0	1	2	3
☐	Skin problems	0	1	2	3
☐	Low pain threshold	0	1	2	3
☐	High pain tolerance	0	1	2	3
☐	Earaches	0	1	2	3
☐	Bruxism (Teeth Grinding)	0	1	2	3

VISUAL ACUITY:

☐	Double vision	0	1	2	3
☐	Blurred vision	0	1	2	3
☐	Blind spots	0	1	2	3
☐	Eye pain	0	1	2	3
☐	Visual sensitivity to light	0	1	2	3
☐	Poor night vision	0	1	2	3

HEARING:

☐	Hearing loss	0	1	2	3
☐	Ringing in ears	0	1	2	3
☐	Sensitivity to sound	0	1	2	3

CARDIOVASCULAR / PULMONARY:

☐	Breathing problems	0	1	2	3
☐	Heart problems	0	1	2	3
☐	Hypertension	0	1	2	3
☐	Palpitations or tachycardia	0	1	2	3

GASTROINTESTINAL:

☐	Nausea or vomiting	0	1	2	3
☐	Stomach pain	0	1	2	3
☐	Intestinal pain	0	1	2	3
☐	Chronic constipation	0	1	2	3
☐	Irritable bowel	0	1	2	3
☐	Crohn's Disease	0	1	2	3

PAIN:

☐	Chronic pain or stiffness	0	1	2	3
☐	Headaches	0	1	2	3
☐	Chronic aching pain	0	1	2	3
☐	Chronic nerve pain (burning or stabbing)	0	1	2	3
☐	Muscle cramps	0	1	2	3

NEUROLOGICAL:

☐	Migraines	0	1	2	3
☐	Fainting	0	1	2	3
☐	Seizures	0	1	2	3
☐	Speech problems	0	1	2	3
☐	Tremor or spasticity	0	1	2	3
☐	Weakness	0	1	2	3
☐	Balance	0	1	2	3

☐	Coordination	0	1	2	3
☐	Accident prone	0	1	2	3
☐	Motor or vocal tics	0	1	2	3

ATTENTION AND COGNITIVE:

☐	Academic strengths and weaknesses				
	Reading	0	1	2	3
	Math	0	1	2	3
	Art	0	1	2	3
☐	Sense of direction	0	1	2	3
☐	Concentration	0	1	2	3
☐	Memory	0	1	2	3
☐	Distractibility	0	1	2	3
☐	Impulsivity	0	1	2	3
☐	Hyperactivity	0	1	2	3

UROGENITAL SYSTEM:

☐	Incontinence	0	1	2	3
☐	PMS symptoms	0	1	2	3
☐	Menopausal symptoms	0	1	2	3
☐	Erectile Dysfunction	0	1	2	3
☐	Sexual interest	0	1	2	3

HABITS:

Coffee use (# of cups per day) _____

Alcohol use (type and # of drinks per day) _____

Tobacco use (type and # per day) _____

Diet---anything unusual, recent changes, restrictions _____

Other drug use _____

BEHAVIOR / EMOTIONS:

☐	Mood swings	0	1	2	3
☐	Depression	0	1	2	3
☐	Anxiety	0	1	2	3
☐	Anger or aggression	0	1	2	3
☐	Risk-taking behavior	0	1	2	3

Have you ever been diagnosed with, taken medication for, or think you may have:

Manic-depression _____

Panic attacks _____

Phobias _____

Obsessive-compulsive behaviors _____

Eating disorders _____

Addictions _____

Schizophrenia _____

PERSONAL HISTORY

Please tick next to relevant data that apply to you. Please include any additional information about the disorder or historical circumstance such as age of onset, length of duration, interventions undertaken, that you consider important.

EARLY CHILDHOOD DEVELOPMENT:

Prenatal stress or injury _____

Prenatal drug exposure _____

Difficult labor _____

Difficult birth _____

Premature or late birth _____

Medical problems after birth _____

Adopted at age: _____

Colic _____
Sleep problems _____
Eating problems _____
Activity level _____
Attachment difficulties _____
Emotional development _____
Motor development _____
Language development _____
Chronic ear infections _____
Allergies _____
Asthma _____

PHYSICAL TRAUMAS:

Head injury _____
Concussions _____
Accidents _____
High fever _____
Serious illness _____
CNS infection _____
Drug overdose _____
Poisoning _____
Anoxia _____
Stroke _____

SPORTS

Football _____
Soccer _____
Boxing _____
Martial Arts _____
Dance _____
Baseball _____
Track/Long Distance Running _____
Weight Lifting _____
Other (please specify) _____

History of Trauma & Stress:

Abuse or neglect _____
Family stress _____
School or job stress _____
Recent death in family _____
Illness _____

TREATMENT HISTORY

MEDICATIONS:

Medication	For Condition	Dose	Dates

MEDICAL TREATMENT:

Procedure	For Condition	Description	Dates

PSYCHOLOGICAL THERAPY:

Therapy	For Condition	Therapist	Dates

OTHER THERAPY:

Therapy	For Condition	Therapist	Dates

FAMILY HISTORY

Symptom	Yes	No	Relationship
Alcoholism or Drug Abuse			
Asthma			
Autoimmune Disorders: Diabetes, Rheumatoid Arthritis, Lupus, MS, Scleroderma, etc.			
Thyroid disorder			
Migraine			
Sleep Problems			
Depression			
Manic-depression			
Anxiety			
Phobias			
Panic Attacks			
Motor or Vocal Tics			
Seizures			
Eating Disorders or Obesity			
Addictions			
Obsessive Compulsive Symptoms			
Speech Problems			
Attention Problems			
Hyperactivity			
Learning Problems			
Conduct Problems or Criminal Behavior			
Autism spectrum			
Schizophrenia			
Diabetes			

PATIENT OR PARTICIPANT'S INFORMATION & INFORMED CONSENT DOCUMENT

STUDY TITLE: The effect of infra slow frequency neurofeedback on quantitative electroencephalogram and autonomic nervous system function in adults with anxiety and related diseases

Principal Investigators: Karlien Balt

Institution: University of Pretoria

DAYTIME AND AFTER-HOURS TELEPHONE NUMBER(S):

Daytime numbers: 082 332 0633

Afterhours: 082 332 0633

DATE AND TIME OF FIRST INFORMED CONSENT DISCUSSION:

			:
dd	mmm	year	Time

Dear Participant

Dear Mr. / Mrs. date of consent procedure/...../.....

1) INTRODUCTION

You are invited to volunteer for a research study. This information leaflet is to help you to decide if you would like to participate. Before you agree to take part in this study you should fully understand what is involved. If you have any questions, which are not fully explained in this leaflet, do not hesitate to ask the investigator. You should not agree to take part unless you are completely happy about all the procedures involved. In the best interests of your health, it is strongly recommended that you discuss with or inform your personal doctor of your possible participation in this study, wherever possible.

2) THE NATURE AND PURPOSE OF THIS STUDY

You are invited to take part in a research study. The aim of this study is to evaluate the effect of infra slow frequency neurofeedback on quantitative electroencephalogram and autonomic nervous system function in adults with anxiety and related diseases. By doing so we wish to learn more about the effect of neurofeedback on the autonomic nervous system.

3) EXPLANATION OF PROCEDURES TO BE FOLLOWED

This study involves firstly answering some questions with regard to your wellbeing. Secondly it involves the placement of surface electrodes on your scalp to measure brain activity. The purpose is to record the electrical activity of the brain and then use this signal to provide video displays and audio signals as a form of training. In the same way that one wears a heart rate monitor to track your exercise activity to know how you are doing this just reflects your brain activity back to you in order to know how you are performing. Based on this awareness you can learn to adapt or change your behaviour. We will place additional sensors on the fingertips, shoulder and around the abdomen which will just measure the changes in your body while we do the neurofeedback training. This will include measurement of your heart rate, temperature, moisture on the skin, shoulder tension and breathing rate and depth. I will also measure your blood pressure before and after the session making use of a wrist blood pressure monitor. Each session will last for 1 hour and a total of 12 hours of your time is needed spread over approximately 6 weeks. No remuneration will be received for participation.

4) RISK AND DISCOMFORT INVOLVED.

The only possible risk and discomfort involved is possible emotional discomfort that might occur in the first 2 sessions. The risk of this is very low and if it does happen it should resolve within 12-24 hours as there are no permanent changes made in the brain. The brain will revert back to its original functioning relatively fast as the goal of neurofeedback is to train the flexibility of the brain over time. It is more likely that you will benefit from the study in terms of feeling calmer and experiencing increased focus. The University of Pretoria has limited insurance for research related injuries.

5) POSSIBLE BENEFITS OF THIS STUDY.

The results of this study will help researchers, neurofeedback trainers and neurofeedback clinicians understand the effect of Neurofeedback training not just on the brain but the on the wellbeing of their clients and patients.

6) I understand that if I do not want to participate in this study, I will still receive standard neurofeedback training to help improve my performance.

7) I may at any time withdraw from this study.

8) HAS THE STUDY RECEIVED ETHICAL APPROVAL?

This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, telephone numbers 012 356 3084 / 012 356 3085 and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving human/subjects. A copy of the Declaration may be obtained from the investigator should you wish to review it.

9) INFORMATION

If I have any questions concerning this study, I should contact: Prof. PJ Du Toit at tel : 012 420 2536 or cell: 083 254 4293

10) CONFIDENTIALITY

All records obtained whilst in this study will be regarded as confidential. Results will be published or presented in such a fashion that participants remain unidentifiable.

11) CONSENT TO PARTICIPATE IN THIS STUDY.

I have read or had read to me in a language that I understand the above information before signing this consent form. The content and meaning of this information have been explained to me. I have been given opportunity to ask questions and am satisfied that they have been answered satisfactorily. I understand that if I do not participate it will not alter my management in any way. I hereby volunteer to take part in this study.

I have received a signed copy of this informed consent agreement.

.....

Participant name

.....

Date

.....

Participant signature

.....

Date

.....

Investigator's name

.....

Date

.....
Investigator's signature Date

.....
Witness name and signature Date

VERBAL PATIENT INFORMED CONSENT (applicable when participant cannot read or write)

I, the undersigned, ..., have read and have explained fully to the participant, named and/or his/her relative, the participant information leaflet, which has indicated the nature and purpose of the study in which I have asked the participant to participate. The explanation I have given has mentioned both the possible risks and benefits of the study. The participant indicated that he/she understands that he/she will be free to withdraw from the study at any time for any reason and without jeopardizing his/her training.

I hereby certify that the participant has agreed to participate in this study.

Participant's Name _____
(Please print)

Participant's Signature _____ Date _____

Investigator's Name _____
(Please print)

Investigator's Signature _____ Date _____

Witness's Name _____ Witness's Signature _____ Date _____
(Please print)

(Witness - sign that he/she has witnessed the process of informed consent)

Annexure D: Descriptive Statistics

Experimental Group Statistics for changes recorded from session 1 to 10

BVP Amplitude N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	0,62	7,95	3,51	2,01	3,10	1,99	4,91
Session 2	0,49	12,90	4,37	3,54	3,50	1,43	6,41
Session 3	0,65	10,75	4,45	2,85	4,26	2,27	5,52
Session 4	0,44	16,59	4,27	4,60	2,34	1,03	5,77
Session 5	0,62	14,52	5,23	3,38	4,82	2,48	6,93
Session 6	0,63	17,32	4,80	4,58	3,29	1,81	5,77
Session 7	0,48	15,85	5,45	4,37	4,10	1,69	8,00
Session 8	0,37	22,46	6,44	6,10	4,61	1,97	9,22
Session 9	0,58	10,99	3,72	2,83	2,81	2,07	4,79
Session 10	0,39	13,67	3,90	3,61	2,03	1,29	5,90

BVP HR from IBI N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	47,21	145,77	76,97	23,72	73,10	61,71	87,03
Session 2	52,87	130,58	75,34	18,49	77,28	59,89	79,69
Session 3	47,52	130,17	72,29	18,44	70,96	59,71	79,36
Session 4	32,42	112,73	73,02	16,98	71,92	63,74	81,19
Session 5	44,88	118,61	70,82	17,60	71,06	59,18	80,46
Session 6	49,27	92,81	72,03	11,31	74,51	63,22	79,70
Session 7	9,38	97,06	68,87	19,69	70,16	58,85	83,51
Session 8	47,55	88,47	69,99	12,64	70,20	58,66	80,91
Session 9	47,55	88,47	69,99	12,64	70,20	58,66	80,91
Session 10	53,61	86,72	72,00	10,55	73,29	62,88	80,13

BVP VLF Power N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	4,28	62,52	25,94	19,88	21,58	8,84	36,63
Session 2	4,28	56,23	23,08	17,61	16,69	9,21	35,67
Session 3	2,31	47,62	23,79	11,67	24,31	15,92	30,57
Session 4	1,30	77,29	26,62	17,86	25,13	18,52	33,23
Session 5	3,37	56,32	21,71	17,18	16,37	7,84	29,91
Session 6	3,37	56,32	21,71	17,18	16,37	7,84	29,91
Session 7	2,01	40,79	17,90	10,69	16,50	10,82	23,02
Session 8	5,29	47,77	21,12	11,36	18,67	15,90	25,77
Session 9	1,24	62,16	22,11	15,73	17,54	12,04	29,65
Session 10	1,04	45,52	16,17	14,23	10,22	5,73	23,08

BVP LF Power		N=20					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	15,12	85,93	37,19	16,54	34,78	27,07	43,60
Session 2	15,23	78,95	37,31	16,47	35,93	22,45	48,92
Session 3	4,60	57,45	35,59	16,26	39,22	26,61	48,60
Session 4	11,07	79,13	34,95	19,51	31,44	19,52	50,59
Session 5	13,86	76,13	42,31	16,51	40,30	31,63	53,74
Session 6	12,07	66,50	39,51	15,02	38,48	31,16	47,13
Session 7	15,13	74,43	41,17	16,42	42,46	26,63	54,32
Session 8	6,82	78,74	41,30	17,27	42,34	30,00	52,38
Session 9	12,36	65,91	45,94	16,37	50,68	34,30	57,21
Session 10	11,07	61,20	43,36	13,54	45,72	38,77	51,34

BVP HF Power		N=20					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	8,02	72,74	34,04	19,78	30,68	17,20	44,43
Session 2	11,92	53,93	34,02	12,86	36,88	24,45	44,02
Session 3	7,64	65,40	35,60	12,69	34,52	29,50	43,62
Session 4	9,22	60,55	32,78	15,89	36,63	16,99	42,09
Session 5	5,97	74,32	32,05	16,87	29,89	20,03	37,93
Session 6	13,27	58,61	33,22	11,96	36,32	25,27	39,99
Session 7	10,70	72,55	35,84	16,67	32,79	25,39	41,80
Session 8	6,71	60,38	33,44	17,41	32,65	14,65	48,49
Session 9	7,40	52,44	28,12	14,04	25,70	19,52	37,60
Session 10	6,97	57,75	35,76	13,60	35,85	31,51	46,74

Respiratory Amplitude		N=20					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	0,04	7,10	1,62	1,40	1,39	1,12	1,80
Session 2	0,05	2,22	1,16	0,61	1,18	0,69	1,55
Session 3	0,07	2,97	1,48	0,63	1,51	1,07	1,82
Session 4	0,19	6,92	1,75	1,42	1,41	0,98	1,97
Session 5	0,37	6,94	1,47	1,41	1,12	0,80	1,62
Session 6	0,61	2,88	1,64	0,64	1,65	1,19	2,04
Session 7	0,59	6,83	2,11	1,42	1,62	1,24	2,78
Session 8	0,54	4,90	2,05	1,28	1,51	1,36	2,53
Session 9	0,48	3,16	1,36	0,66	1,31	0,88	1,69
Session 10	0,41	5,55	1,63	1,44	0,99	0,72	2,41

BVP IBI SDRR		N=20					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	36,6	304,6	91,4	61,6	79,4	48,6	105,6

Session 2	34,9	290,6	106,6	64,2	97,5	60,6	134,3
Session 3	51,1	181,9	80,8	30,3	76,1	55,7	95,6
Session 4	34,0	329,9	98,3	65,9	79,8	62,5	111,4
Session 5	31,6	181,8	82,5	36,0	71,8	61,2	105,2
Session 6	37,0	184,8	91,6	42,1	79,5	60,3	116,3
Session 7	30,9	267,2	97,3	57,8	71,3	61,7	120,2
Session 8	38,4	267,7	93,3	56,4	68,0	54,4	126,6
Session 9	31,1	193,7	92,1	42,2	79,2	57,7	121,2
Session 10	41,9	234,2	93,8	48,7	84,3	57,2	109,1

EMG		N=20					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	0,52	29,84	4,82	6,83	2,77	1,07	5,21
Session 2	0,28	17,08	5,23	4,86	4,50	1,26	6,70
Session 3	0,51	26,97	5,10	6,56	1,90	1,04	7,16
Session 4	0,38	15,26	3,60	3,93	2,18	1,05	3,74
Session 5	0,90	14,35	2,95	3,13	2,02	1,16	2,98
Session 6	0,36	6,21	2,21	1,40	1,78	1,39	2,99
Session 7	0,93	8,53	2,11	1,97	1,43	1,15	1,86
Session 8	0,40	9,01	2,25	2,22	1,15	0,92	2,70
Session 9	0,46	9,38	2,73	2,57	1,39	1,25	3,23
Session 10	0,46	9,38	2,14	2,27	1,23	0,97	2,28

Skin Conductance Mean		N=20					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	0,40	18,28	4,80	4,55	3,94	1,06	7,40
Session 2	0,32	14,39	4,63	4,23	3,69	1,20	6,22
Session 3	0,28	24,07	5,43	5,85	3,85	1,38	7,89
Session 4	0,46	19,19	4,71	5,14	2,42	1,14	6,84
Session 5	0,36	16,41	4,51	4,70	2,89	1,08	7,38
Session 6	0,31	19,93	3,55	4,57	2,08	0,61	4,75
Session 7	0,39	10,49	2,77	3,00	1,59	0,72	3,62
Session 8	0,40	7,33	2,46	2,16	1,72	0,70	3,69
Session 9	0,73	8,04	3,10	2,34	2,28	0,93	5,07
Session 10	0,25	10,46	2,33	2,38	1,35	0,77	3,22

Temperature		N=20					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	19,76	34,21	27,49	4,84	27,77	23,26	32,46
Session 2	20,34	35,02	28,19	4,15	27,90	25,20	30,96
Session 3	20,99	34,10	28,91	3,56	28,83	27,06	31,76
Session 4	18,67	34,43	27,03	5,20	27,22	22,04	31,49

Session 5	22,01	34,65	28,77	4,41	28,85	24,57	32,61
Session 6	20,30	34,27	27,49	4,64	28,32	22,66	31,72
Session 7	20,07	35,60	27,59	4,96	26,43	23,56	32,53
Session 8	20,10	34,38	28,07	4,21	27,56	24,84	31,74
Session 9	19,48	35,31	27,91	4,80	27,31	24,72	31,98
Session 10	19,48	35,11	27,05	5,43	26,06	22,79	31,76
Systolic BP Pre N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	94,00	142,00	122,55	12,61	120,00	115,50	133,50
Session 2	90,00	147,00	120,60	15,02	123,00	113,00	127,50
Session 3	102,00	153,00	123,45	14,23	124,00	110,00	131,50
Session 4	97,00	146,00	121,55	15,54	117,50	109,50	136,50
Session 5	93,00	165,00	120,30	16,03	123,50	107,50	129,00
Session 6	103,00	149,00	123,45	11,91	124,00	116,50	130,00
Session 7	106,00	142,00	122,80	8,67	125,00	117,00	128,00
Session 8	99,00	151,00	124,15	11,91	122,00	118,50	129,50
Session 9	99,00	143,00	118,95	11,00	121,00	111,00	127,00
Session 10	104,00	143,00	124,40	10,59	127,00	120,00	130,00
Diastolic BP Pre N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	62,00	102,00	79,60	8,99	80,00	75,00	84,50
Session 2	62,00	102,00	80,05	9,83	80,00	72,50	86,00
Session 3	63,00	100,00	80,55	12,48	77,00	69,00	91,00
Session 4	60,00	94,00	77,60	11,07	75,50	69,00	89,00
Session 5	54,00	101,00	76,45	10,59	76,50	69,50	82,50
Session 6	58,00	95,00	75,70	10,13	75,00	68,00	81,50
Session 7	62,00	97,00	80,90	9,60	80,50	74,50	89,00
Session 8	64,00	118,00	79,70	11,69	78,00	74,00	82,50
Session 9	66,00	89,00	77,60	5,75	78,00	73,50	81,50
Session 10	64,00	92,00	78,45	6,35	78,00	75,00	83,00
Systolic BP Post N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	96,00	141,00	115,45	10,10	113,50	108,00	122,50
Session 2	96,00	134,00	119,35	10,89	117,50	112,50	129,00
Session 3	92,00	152,00	118,60	15,67	116,50	109,00	128,00
Session 4	79,00	152,00	121,25	18,26	121,00	108,50	133,00
Session 5	73,00	158,00	116,85	20,38	117,50	111,00	126,50
Session 6	107,00	136,00	120,40	8,67	118,50	113,50	126,50
Session 7	106,00	136,00	118,30	7,71	118,00	112,00	122,50
Session 8	94,00	142,00	117,80	10,55	117,50	114,50	122,00

Session 9	94,00	130,00	118,90	7,64	119,00	116,50	123,50
Session 10	107,00	128,00	119,85	5,72	121,00	116,50	124,50
Diastolic BP Post N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	60,00	94,00	76,55	9,12	78,00	68,50	82,50
Session 2	68,00	94,00	78,95	8,56	77,50	71,00	85,50
Session 3	57,00	98,00	76,45	11,14	77,00	67,00	83,50
Session 4	63,00	89,00	77,35	7,80	77,50	73,00	82,50
Session 5	59,00	96,00	75,48	8,63	77,50	71,25	79,50
Session 6	61,00	101,00	77,30	9,31	76,50	70,50	82,00
Session 7	67,00	95,00	80,30	6,88	79,50	76,50	86,00
Session 8	62,00	94,00	78,00	6,78	79,50	76,00	81,50
Session 9	62,00	96,00	79,55	7,42	79,00	75,50	84,00
Session 10	68,00	86,00	77,65	4,77	78,50	74,00	80,50

Control Group Statistics

BVP Amplitude N=9							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	2,01	14,24	7,25	4,25	6,54	3,72	9,87
Session 2	1,67	9,43	4,63	2,36	4,73	3,43	5,61
Session 3	1,26	8,74	5,05	2,11	5,07	3,81	6,37
Session 4	0,92	9,65	5,78	3,27	5,64	3,90	9,03
Session 5	0,79	4,41	2,81	1,17	3,07	2,01	3,63
Session 6	1,59	8,37	5,27	2,35	5,25	4,52	6,68
Session 7	1,37	9,63	5,58	2,40	5,69	5,26	6,22
Session 8	1,17	12,19	5,83	3,72	5,97	2,87	7,53
Session 9	1,27	8,03	5,06	2,57	5,98	2,60	7,11
Session 10	0,68	9,63	4,73	2,69	4,58	3,22	5,46
BVP HR from IBI N=9							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	57,61	82,19	76,63	7,49	79,23	78,52	79,84
Session 2	59,48	97,37	76,66	11,97	75,21	70,95	82,18
Session 3	66,06	80,00	72,60	4,10	73,30	71,73	74,01
Session 4	65,89	86,90	75,52	6,70	76,04	71,51	79,23
Session 5	51,59	78,87	74,53	8,90	78,41	76,04	78,72
Session 6	58,13	72,24	69,30	4,51	71,15	68,15	72,24
Session 7	64,10	86,78	76,66	7,95	79,01	71,24	81,76
Session 8	60,56	147,34	82,19	27,65	75,89	64,10	82,96

Session 9	60,56	147,34	82,19	27,65	75,89	64,10	82,96
Session 10	61,26	89,96	72,89	9,28	75,71	64,10	76,46
BVP VLF Power N=9							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	6,96	45,42	28,51	11,67	27,48	22,46	36,07
Session 2	8,59	52,51	32,92	14,06	31,32	28,45	40,22
Session 3	2,85	59,52	25,80	17,19	31,19	11,51	31,69
Session 4	6,51	21,21	11,51	5,22	11,62	7,15	14,14
Session 5	12,35	39,59	23,58	8,04	23,28	20,61	25,94
Session 6	12,35	39,59	23,58	8,04	23,28	20,61	25,94
Session 7	10,57	64,99	25,34	16,64	19,34	15,21	30,80
Session 8	2,75	64,99	30,92	16,35	29,61	28,12	36,10
Session 9	5,71	79,62	41,54	21,04	42,65	42,62	45,96
Session 10	6,73	65,28	37,34	18,60	37,30	31,99	45,13
BVP LF Power N=9							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	27,22	65,72	51,11	10,99	52,16	46,63	56,93
Session 2	22,99	44,67	30,20	7,26	28,81	23,70	32,83
Session 3	32,33	70,27	46,20	10,64	44,71	41,25	48,73
Session 4	32,13	79,49	58,55	16,38	60,53	48,52	71,61
Session 5	25,40	73,31	57,78	18,70	68,03	59,00	68,49
Session 6	20,05	75,67	37,89	17,62	38,74	21,19	43,66
Session 7	7,97	71,67	51,19	19,32	56,75	44,03	63,26
Session 8	7,97	58,49	41,39	13,86	41,86	41,80	47,38
Session 9	17,66	52,06	38,23	10,39	37,40	35,71	42,47
Session 10	7,74	85,62	49,03	22,01	52,06	38,62	58,77
BVP HF Power N=9							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	6,64	49,51	19,50	13,15	15,80	11,06	25,57
Session 2	18,29	48,69	31,13	9,10	31,17	26,55	35,89
Session 3	2,48	50,78	26,40	15,11	22,99	18,96	31,58
Session 4	13,18	41,89	25,28	8,82	22,74	21,42	30,94
Session 5	5,04	34,18	14,21	9,50	11,00	8,02	14,00
Session 6	6,67	27,30	15,98	5,91	16,01	14,07	18,84
Session 7	6,20	31,81	19,93	8,02	21,25	15,13	24,06
Session 8	9,68	49,13	24,74	10,96	21,90	20,42	26,29
Session 9	2,63	42,61	17,53	12,67	16,15	8,18	22,62
Session 10	4,04	44,88	12,01	14,12	5,38	5,12	6,97

Respiratory Amplitude							
N=9							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	1,48	3,87	2,13	0,75	1,91	1,57	2,33
Session 2	0,19	5,26	1,85	1,58	2,13	0,47	2,28
Session 3	0,82	1,88	1,25	0,34	1,20	1,01	1,41
Session 4	1,50	3,54	2,59	0,62	2,75	2,24	2,79
Session 5	1,23	3,90	1,99	1,00	1,51	1,37	1,97
Session 6	0,10	2,26	1,08	0,59	1,03	0,97	1,21
Session 7	0,05	9,26	3,02	2,93	2,26	0,68	4,04
Session 8	0,05	15,28	4,75	4,79	3,01	1,08	6,37
Session 9	0,57	3,26	1,44	0,77	1,24	1,08	1,58
Session 10	0,05	1,89	0,85	0,53	0,87	0,57	1,14

BVP IBI SDRR							
N=9							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	30,81	137,53	65,22	29,73	58,23	57,67	59,41
Session 2	38,99	85,24	62,43	16,80	61,70	50,86	73,06
Session 3	41,28	81,61	59,05	12,30	57,72	50,96	65,12
Session 4	65,78	133,20	92,54	22,26	93,70	73,96	106,69
Session 5	47,47	182,18	78,88	41,22	63,96	59,48	79,00
Session 6	47,98	90,35	70,60	11,56	73,36	67,86	74,80
Session 7	50,78	73,36	63,79	6,60	64,67	61,17	67,27
Session 8	61,17	88,34	69,63	8,45	69,17	63,52	71,06
Session 9	28,44	112,59	74,56	23,78	72,92	62,60	88,53
Session 10	28,44	411,55	94,08	119,68	58,31	50,96	65,70

EMG							
N=9							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	0,52	4,46	2,20	1,56	2,22	0,99	3,28
Session 2	0,89	6,37	3,23	1,79	3,34	1,97	4,37
Session 3	0,49	12,65	6,22	4,63	7,70	1,66	9,63
Session 4	0,96	8,94	3,54	2,96	3,01	1,35	3,64
Session 5	0,54	5,58	2,65	1,87	2,16	1,39	4,07
Session 6	0,66	6,51	2,76	2,24	2,09	1,20	2,93
Session 7	0,58	3,41	2,11	0,99	2,03	1,81	2,70
Session 8	0,58	9,66	4,14	2,80	3,45	2,94	5,35
Session 9	0,66	3,96	2,56	1,00	2,77	2,11	2,99
Session 10	1,10	6,70	2,66	2,07	1,77	1,62	2,11

Skin Conductance Mean							
N=9							
Training Session No	min	max	mean	sd	p50	p25	p75

Session 1	1,27	6,10	3,31	2,04	2,38	1,99	5,84
Session 2	0,60	4,75	2,94	1,53	3,36	2,19	4,22
Session 3	0,49	12,73	4,22	3,71	2,61	1,98	5,56
Session 4	0,60	8,11	2,66	2,36	1,96	0,97	3,45
Session 5	0,64	8,10	2,63	2,46	1,23	0,86	3,29
Session 6	0,32	7,06	2,22	2,23	1,21	0,47	2,91
Session 7	0,18	9,26	2,75	2,99	1,24	0,53	3,66
Session 8	0,33	6,72	2,12	2,12	1,26	0,53	2,77
Session 9	0,66	6,35	2,49	1,84	2,60	1,01	3,27
Session 10	0,57	6,35	2,62	2,16	2,55	0,72	3,50

Temperature N=9							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	22,51	33,97	29,58	3,44	30,40	28,69	31,16
Session 2	21,48	32,14	29,97	3,41	31,33	30,51	31,67
Session 3	22,76	34,00	30,56	3,26	31,24	29,86	32,37
Session 4	26,27	31,44	28,94	1,58	29,04	28,18	29,38
Session 5	29,99	33,12	31,19	0,93	31,05	30,75	31,23
Session 6	22,42	31,48	28,34	2,64	28,93	27,66	29,44
Session 7	21,12	33,42	28,35	4,16	28,87	27,92	30,77
Session 8	27,76	32,60	30,01	1,69	29,91	28,65	30,60
Session 9	23,86	33,25	28,50	2,97	28,79	27,28	30,26
Session 10	21,96	33,25	30,48	3,51	31,81	30,38	32,37

Systolic BP Pre N=20							
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	108,00	134,00	122,33	7,11	123,00	121,00	125,00
Session 2	107,00	146,00	125,56	12,51	126,00	118,00	131,00
Session 3	103,00	142,00	122,33	11,45	123,00	116,00	128,00
Session 4	109,00	142,00	125,67	9,82	127,00	120,00	127,00
Session 5	112,00	135,00	125,11	7,74	127,00	123,00	131,00
Session 6	119,00	132,00	124,44	4,50	124,00	121,00	126,00
Session 7	117,00	133,00	125,67	4,44	126,00	124,00	128,00
Session 8	109,00	129,00	123,44	6,02	125,00	123,00	126,00
Session 9	109,00	138,00	123,00	8,05	124,00	118,00	126,00
Session 10	109,00	135,00	118,22	8,11	116,00	114,00	119,00

Diastolic BP Pre N=20							
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Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	62,00	92,00	81,33	8,34	83,00	80,00	85,00
Session 2	107,00	146,00	125,56	12,51	126,00	118,00	131,00
Session 3	68,00	85,00	77,89	5,46	78,00	75,00	83,00
Session 4	79,00	95,00	86,89	4,83	86,00	85,00	90,00
Session 5	54,00	96,00	75,56	11,81	76,00	74,00	78,00
Session 6	76,00	101,00	83,44	7,91	82,00	80,00	82,00
Session 7	65,00	117,00	82,56	14,84	79,00	77,00	82,00
Session 8	65,00	82,00	75,67	5,02	77,00	74,00	78,00
Session 9	66,00	93,00	76,00	7,91	74,00	71,00	78,00
Session 10	68,00	79,00	74,78	3,15	75,00	74,00	76,00

Systolic BP Post		N=20					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	108,00	131,00	121,78	6,76	123,00	119,00	126,00
Session 2	107,00	142,00	121,89	10,89	121,00	116,00	125,00
Session 3	111,00	127,00	117,56	4,25	117,00	116,00	118,00
Session 4	112,00	133,00	124,33	5,72	125,00	122,00	127,00
Session 5	102,00	134,00	117,44	9,18	119,00	115,00	120,00
Session 6	115,00	133,00	122,33	5,43	122,00	119,00	125,00
Session 7	116,00	130,00	123,89	4,99	124,00	122,00	128,00
Session 8	99,00	126,00	115,78	9,32	118,00	113,00	122,00
Session 9	99,00	128,00	115,56	8,44	116,00	113,00	119,00
Session 10	115,00	129,00	123,89	4,08	124,00	123,00	126,00

Diastolic BP Post		N=20					
Training Session No	min	max	mean	sd	p50	p25	p75
Session 1	68,00	95,00	80,78	7,48	80,00	77,00	83,00
Session 2	65,00	93,00	79,33	10,02	79,00	74,00	87,00
Session 3	68,00	85,00	77,33	6,00	77,00	74,00	83,00
Session 4	66,00	94,00	77,44	8,25	79,00	73,00	80,00
Session 5	60,00	94,00	76,44	9,38	76,00	73,00	79,00
Session 6	72,00	93,00	78,67	6,78	78,00	72,00	81,00
Session 7	68,00	94,00	82,11	7,06	82,00	81,00	84,00
Session 8	68,00	88,00	78,78	6,28	81,00	75,00	82,00
Session 9	66,00	80,00	74,33	4,39	75,00	71,00	78,00
Session 10	57,00	83,00	78,11	8,28	81,00	78,00	83,00

Experimental Group Statistics for pre- post- session changes recorded from session 1 to 10

Group		Experimental							
Session	Variable	N	min	max	mean	sd	p50	p25	p75
1	emg_first2	20	0,5	17,7	4,0	4,1	2,8	1,0	5,4
	temp_first2	20	20,0	33,8	27,0	4,5	24,8	23,7	31,8
	skin_first2	20	0,3	17,3	3,9	4,2	2,5	1,4	4,8
	bvp_hr_fir~2	20	9,7	125,9	73,2	21,3	76,6	64,3	82,4
	emg_last2	20	0,3	17,3	3,1	3,8	2,2	0,7	4,0
	temp_last2	20	19,2	34,2	27,4	5,2	25,8	23,3	32,6
	skin_last2	20	0,4	16,8	4,2	4,5	2,1	0,7	7,2
	bvp_hr_last2	20	52,6	121,5	75,3	15,4	74,2	69,1	79,6
Session	Variable	N	min	max	mean	sd	p50	p25	p75
2	emg_first2	20	0,4	17,1	3,9	4,8	1,6	0,9	5,3
	temp_first2	20	22,2	34,9	28,3	3,7	27,6	26,1	30,8
	skin_first2	20	0,3	14,2	3,7	3,5	2,6	0,9	5,5
	bvp_hr_fir~2	20	54,4	100,4	71,4	12,1	70,1	61,3	78,9
	emg_last2	20	0,2	19,8	3,9	5,4	1,6	0,6	4,4
	temp_last2	20	19,5	35,0	28,2	4,3	28,4	24,5	31,1
	skin_last2	20	0,3	15,4	4,5	4,5	3,2	1,4	6,1
	bvp_hr_last2	20	55,5	96,8	71,9	11,3	74,1	61,7	79,8
Session	Variable	N	min	max	mean	sd	p50	p25	p75
3	emg_first2	19	0,8	19,6	4,8	4,9	3,1	1,0	8,0
	temp_first2	19	21,5	34,2	28,2	3,6	27,4	25,7	32,3
	skin_first2	19	0,2	19,5	4,8	5,1	2,9	1,4	5,6
	bvp_hr_fir~2	19	51,5	98,4	73,1	13,8	73,5	63,7	81,8
	emg_last2	19	0,3	12,9	2,7	3,3	1,4	0,4	3,7
	temp_last2	19	21,2	34,4	28,5	4,1	29,3	25,0	32,0
	skin_last2	19	0,3	25,4	5,4	6,3	3,0	1,1	6,6
	bvp_hr_last2	19	52,2	100,5	71,2	13,7	72,1	59,0	81,8
Session	Variable	N	min	max	mean	sd	p50	p25	p75
4	emg_first2	20	0,5	13,9	3,9	3,8	2,0	1,1	6,2
	temp_first2	20	20,7	34,2	26,9	4,0	25,9	24,4	29,3
	skin_first2	20	0,3	14,1	3,5	3,5	2,6	1,1	4,6
	bvp_hr_fir~2	20	48,8	109,6	76,3	15,8	76,7	64,7	86,3
	emg_last2	20	0,3	10,9	2,0	2,5	0,9	0,5	2,6
	temp_last2	20	22,0	35,4	29,0	3,9	29,0	26,6	32,0
	skin_last2	20	0,4	16,6	4,0	4,3	2,8	0,7	5,3
	bvp_hr_last2	20	56,4	113,7	76,3	14,8	77,2	66,2	82,7
Session	Variable	N	min	max	mean	sd	p50	p25	p75
5	emg_first2	20	0,3	9,4	2,8	2,2	2,5	1,2	3,7
	temp first2	20	13,4	34,6	26,9	5,3	27,2	23,6	31,1

	skin_first2	20	0,2	13,3	3,3	3,3	2,3	0,9	5,1
	bvp_hr_fir~2	20	46,5	115,9	74,4	15,7	73,9	64,8	83,5
	emg_last2	20	0,3	16,9	3,7	4,6	1,9	0,9	3,7
	temp_last2	20	21,9	34,6	29,0	4,3	29,1	25,8	32,9
	skin_last2	20	0,4	17,4	4,0	4,5	2,1	0,8	6,4
	bvp_hr_last2	20	49,1	118,0	76,2	15,0	77,6	68,1	83,6
Session	Variable	N	min	max	mean	sd	p50	p25	p75
6	emg_first2	20	0,4	16,8	3,7	3,9	2,7	1,2	4,6
	temp_first2	20	0,2	34,0	25,3	7,6	25,1	21,9	31,1
	skin_first2	20	0,2	18,2	3,0	4,1	1,6	0,7	3,6
	bvp_hr_fir~2	20	13,8	94,5	69,5	16,7	69,7	63,2	80,4
	emg_last2	20	0,4	8,0	2,1	2,2	1,4	0,9	2,2
	temp_last2	20	20,8	34,3	28,0	4,1	27,2	25,4	32,4
	skin_last2	20	0,4	18,0	3,5	4,2	2,0	0,6	4,8
	bvp_hr_last2	20	57,4	93,4	72,2	11,4	68,8	63,2	80,8
Session	Variable	N	min	max	mean	sd	p50	p25	p75
7	emg_first2	20	0,3	4,4	1,5	1,1	1,2	0,6	1,8
	temp_first2	20	20,1	35,6	26,5	5,3	25,9	20,9	31,2
	skin_first2	20	0,5	5,7	1,3	1,1	1,0	0,8	1,3
	bvp_hr_fir~2	20	55,9	98,1	73,8	11,1	73,7	64,8	78,6
	emg_last2	20	0,3	1,5	0,9	0,4	1,0	0,7	1,1
	temp_last2	20	19,5	35,4	26,0	5,3	24,2	21,8	32,0
	skin_last2	20	0,4	9,7	2,0	2,1	1,3	0,8	2,2
	bvp_hr_last2	20	17,5	94,1	71,6	16,5	73,9	65,5	81,8
Session	Variable	N	min	max	mean	sd	p50	p25	p75
8	emg_first2	20	0,4	3,1	1,6	0,8	1,5	1,0	2,1
	temp_first2	20	19,8	34,2	26,6	4,5	25,8	23,1	30,9
	skin_first2	20	0,4	6,5	1,6	1,6	1,0	0,8	1,8
	bvp_hr_fir~2	20	51,2	87,6	70,1	9,5	69,2	65,4	77,5
	emg_last2	20	0,3	6,5	1,4	1,5	0,8	0,5	1,7
	temp_last2	20	20,6	34,9	27,6	5,0	26,6	23,0	32,1
	skin_last2	20	0,4	8,1	2,4	2,1	1,8	1,0	2,9
	bvp_hr_last2	20	19,5	82,0	64,8	13,2	65,8	60,0	71,7
Session	Variable	N	min	max	mean	sd	p50	p25	p75
9	emg_first2	20	0,3	15,6	2,1	3,3	1,1	0,9	1,8
	temp_first2	20	18,9	57,5	28,3	8,1	26,3	23,6	29,5
	skin_first2	20	0,3	5,0	2,0	1,5	1,8	0,8	2,7
	bvp_hr_fir~2	20	37,9	86,2	70,6	12,7	75,7	60,6	79,6
	emg_last2	20	0,4	5,5	1,1	1,3	0,6	0,5	1,1
	temp_last2	20	19,6	35,6	29,3	4,2	29,8	26,0	32,5
	skin_last2	20	0,6	10,9	3,0	2,7	2,6	0,9	4,2
	bvp_hr_last2	20	55,5	93,3	72,7	10,5	75,5	64,7	80,5
Session	Variable	N	min	max	mean	sd	p50	p25	p75
10	emg_first2	20	0,4	5,1	1,6	1,3	1,0	0,7	2,6
	temp_first2	20	16,8	35,0	26,7	5,7	26,6	22,8	31,2

	skin_first2	20	0,2	10,5	2,1	2,4	1,2	0,6	3,0
	bvp_hr_fir~2	20	50,8	89,7	68,2	12,7	67,5	55,3	79,3
	emg_last2	20	0,3	3,2	1,0	0,7	0,8	0,5	1,4
	temp_last2	20	16,9	35,1	27,9	5,9	28,7	22,7	33,1
	skin_last2	20	0,3	11,0	2,4	2,5	1,7	0,8	3,2
	bvp_hr_last2	20	52,4	88,0	67,3	11,6	68,4	55,0	75,5
Session	Variable	N	min	max	mean	sd	p50	p25	p75
Total	emg_first2	199	0,3	19,6	3,0	3,5	1,7	0,9	3,6
	temp_first2	199	0,2	57,5	27,1	5,4	26,5	23,4	31,1
	skin_first2	199	0,2	19,5	2,9	3,4	1,8	0,8	3,6
	bvp_hr_fir~2	199	9,7	125,9	72,1	14,4	73,3	63,3	80,4
	emg_last2	199	0,2	19,8	2,2	3,1	1,0	0,6	2,5
	temp_last2	199	16,9	35,6	28,1	4,7	28,6	24,1	32,3
	skin_last2	199	0,3	25,4	3,5	4,0	2,1	0,9	4,3
	bvp_hr_last2	199	17,5	121,5	72,0	13,6	73,5	62,0	80,3

Group		Experimental				
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
1	emg_first2	20	4,0	0,9	2,0	5,9
	temp_first2	20	27,0	1,0	24,8	29,1
	skin_first2	20	3,9	0,9	1,9	5,9
	bvp_hr_fir~2	20	73,2	4,8	63,3	83,2
	emg_last2	20	3,1	0,9	1,3	4,9
	temp_last2	20	27,4	1,2	25,0	29,8
	skin_last2	20	4,2	1,0	2,1	6,3
	bvp_hr_last2	20	75,3	3,4	68,1	82,5
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
2	emg_first2	20	3,9	1,1	1,7	6,2
	temp_first2	20	28,3	0,8	26,6	30,1
	skin_first2	20	3,7	0,8	2,1	5,3
	bvp_hr_fir~2	20	71,4	2,7	65,7	77,1
	emg_last2	20	3,9	1,2	1,4	6,4
	temp_last2	20	28,2	1,0	26,2	30,2
	skin_last2	20	4,5	1,0	2,4	6,6
	bvp_hr_last2	20	71,9	2,5	66,6	77,2
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
3	emg_first2	19	4,8	1,1	2,4	7,2
	temp_first2	19	28,2	0,8	26,4	29,9
	skin_first2	19	4,8	1,2	2,4	7,2
	bvp_hr_fir~2	19	73,1	3,2	66,4	79,7

	emg_last2	19	2,7	0,8	1,1	4,3
	temp_last2	19	28,5	0,9	26,5	30,5
	skin_last2	19	5,4	1,4	2,3	8,4
	bvp_hr_last2	19	71,2	3,1	64,6	77,8
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
4	emg_first2	20	3,9	0,9	2,1	5,7
	temp_first2	20	26,9	0,9	25,1	28,8
	skin_first2	20	3,5	0,8	1,8	5,1
	bvp_hr_fir~2	20	76,3	3,5	68,9	83,7
	emg_last2	20	2,0	0,6	0,8	3,1
	temp_last2	20	29,0	0,9	27,2	30,9
	skin_last2	20	4,0	1,0	2,0	6,1
	bvp_hr_last2	20	76,3	3,3	69,4	83,3
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
5	emg_first2	20	2,8	0,5	1,7	3,8
	temp_first2	20	26,9	1,2	24,4	29,4
	skin_first2	20	3,3	0,7	1,8	4,8
	bvp_hr_fir~2	20	74,4	3,5	67,0	81,7
	emg_last2	20	3,7	1,0	1,5	5,8
	temp_last2	20	29,0	1,0	27,0	31,0
	skin_last2	20	4,0	1,0	1,9	6,1
	bvp_hr_last2	20	76,2	3,3	69,2	83,2
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
6	emg_first2	20	3,7	0,9	1,9	5,5
	temp_first2	20	25,3	1,7	21,7	28,9
	skin_first2	20	3,0	0,9	1,0	4,9
	bvp_hr_fir~2	20	69,5	3,7	61,7	77,4
	emg_last2	20	2,1	0,5	1,1	3,2
	temp_last2	20	28,0	0,9	26,1	29,9
	skin_last2	20	3,5	0,9	1,5	5,5
	bvp_hr_last2	20	72,2	2,6	66,9	77,6
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
7	emg_first2	20	1,5	0,2	1,0	2,0
	temp_first2	20	26,5	1,2	24,0	29,0
	skin_first2	20	1,3	0,3	0,7	1,8
	bvp_hr_fir~2	20	73,8	2,5	68,6	79,0
	emg_last2	20	0,9	0,1	0,7	1,1

	temp_last2	20	26,0	1,2	23,5	28,5
	skin_last2	20	2,0	0,5	1,0	2,9
	bvp_hr_last2	20	71,6	3,7	63,9	79,4
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
8	emg_first2	20	1,6	0,2	1,2	2,0
	temp_first2	20	26,6	1,0	24,6	28,7
	skin_first2	20	1,6	0,3	0,9	2,4
	bvp_hr_fir~2	20	70,1	2,1	65,7	74,6
	emg_last2	20	1,4	0,3	0,7	2,1
	temp_last2	20	27,6	1,1	25,3	30,0
	skin_last2	20	2,4	0,5	1,4	3,4
	bvp_hr_last2	20	64,8	3,0	58,6	71,0
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
9	emg_first2	20	2,1	0,7	0,5	3,7
	temp_first2	20	28,3	1,8	24,5	32,0
	skin_first2	20	2,0	0,3	1,3	2,7
	bvp_hr_fir~2	20	70,6	2,8	64,7	76,5
	emg_last2	20	1,1	0,3	0,5	1,7
	temp_last2	20	29,3	0,9	27,3	31,3
	skin_last2	20	3,0	0,6	1,8	4,3
	bvp_hr_last2	20	72,7	2,3	67,8	77,6
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
10	emg_first2	20	1,6	0,3	1,0	2,2
	temp_first2	20	26,7	1,3	24,0	29,4
	skin_first2	20	2,1	0,5	1,0	3,2
	bvp_hr_fir~2	20	68,2	2,9	62,2	74,2
	emg_last2	20	1,0	0,2	0,7	1,3
	temp_last2	20	27,9	1,3	25,1	30,6
	skin_last2	20	2,4	0,6	1,3	3,6
	bvp_hr_last2	20	67,3	2,6	61,9	72,8

Control Group Statistics for pre- post- session changes recorded from session 1 to 10

Group		Control							
Session	Variable	N	min	max	mean	sd	p50	p25	p75
1	emg_first2	9	0,5	9,8	3,7	3,0	3,5	1,1	4,7
	temp_first2	9	22,4	33,0	28,5	3,3	29,2	26,5	29,4
	skin_first2	9	1,2	6,6	3,1	1,8	3,2	1,7	4,4

	bvp_hr_fir~2	9	61,8	82,5	75,4	6,0	77,8	72,5	78,3
	emg_last2	9	0,3	4,7	1,2	1,3	0,9	0,6	1,0
	temp_last2	9	21,2	32,6	27,8	3,7	29,2	26,4	30,0
	skin_last2	9	0,7	14,3	5,0	4,3	2,9	2,2	6,2
	bvp_hr_last2	9	60,6	79,5	73,9	6,3	77,3	72,4	77,7
Session	Variable	N	min	max	mean	sd	p50	p25	p75
2	emg_first2	9	0,8	8,4	3,2	2,2	2,9	2,2	3,4
	temp_first2	9	20,5	32,3	30,3	3,7	31,5	31,3	31,5
	skin_first2	9	1,7	5,8	3,3	1,2	3,2	2,5	3,7
	bvp_hr_fir~2	9	61,3	86,3	70,2	7,7	70,0	65,6	72,5
	emg_last2	9	0,6	8,6	4,1	2,6	4,5	2,5	4,7
	temp_last2	9	22,9	31,3	29,7	2,6	30,5	30,4	30,8
	skin_last2	9	2,4	8,8	4,7	2,0	4,9	3,5	5,4
	bvp_hr_last2	9	61,9	81,5	71,5	5,9	71,9	68,8	75,2
Session	Variable	N	min	max	mean	sd	p50	p25	p75
3	emg_first2	9	0,6	12,5	6,2	3,8	6,9	4,1	8,4
	temp_first2	9	20,5	33,6	29,9	3,8	31,2	29,9	31,7
	skin_first2	9	0,5	10,6	3,8	3,2	2,5	1,7	4,8
	bvp_hr_fir~2	9	67,1	80,3	72,7	4,2	72,7	69,1	75,4
	emg_last2	9	0,5	6,6	2,9	1,8	2,8	2,4	3,7
	temp_last2	9	22,9	33,2	30,3	2,9	31,2	30,6	31,5
	skin_last2	9	0,5	5,8	3,1	1,5	2,8	2,6	3,7
	bvp_hr_last2	9	67,9	86,3	75,7	5,4	76,0	71,9	77,9
Session	Variable	N	min	max	mean	sd	p50	p25	p75
4	emg_first2	9	0,7	11,5	6,9	3,8	7,3	5,2	9,7
	temp_first2	9	17,6	30,9	26,7	4,3	27,9	26,5	28,7
	skin_first2	9	0,5	4,7	1,9	1,4	2,0	0,6	2,5
	bvp_hr_fir~2	9	39,4	78,2	67,7	11,7	71,1	67,3	74,5
	emg_last2	9	0,4	1,2	0,8	0,2	0,8	0,7	1,0
	temp_last2	9	27,3	31,5	29,9	1,4	30,2	29,7	30,9
	skin_last2	9	0,7	9,5	3,3	2,8	2,3	1,5	4,1
	bvp_hr_last2	9	67,5	81,8	74,3	5,0	74,3	70,2	78,0
Session	Variable	N	min	max	mean	sd	p50	p25	p75
5	emg_first2	9	0,6	6,1	2,3	1,7	2,6	1,0	2,9
	temp_first2	9	27,4	32,9	30,3	1,7	30,2	29,9	30,9
	skin_first2	9	0,5	5,9	2,0	1,8	1,1	0,5	2,5
	bvp_hr_fir~2	9	60,7	92,3	75,8	8,8	74,1	72,2	80,0
	emg_last2	9	0,6	3,5	1,7	1,0	1,6	1,0	2,0
	temp_last2	9	29,2	32,4	30,6	1,0	30,5	30,1	30,8
	skin_last2	9	0,6	8,6	3,0	2,6	2,0	1,1	3,8
	bvp_hr_last2	9	67,6	99,5	79,7	11,4	75,2	73,9	81,7
Session	Variable	N	min	max	mean	sd	p50	p25	p75
6	emg_first2	9	0,8	11,0	3,4	3,4	1,7	1,0	4,2
	temp_first2	9	20,4	31,4	26,7	3,7	26,5	26,4	28,7
	skin_first2	9	0,3	4,0	1,3	1,2	0,8	0,7	1,9

	bvp_hr_fir~2	9	68,0	83,8	77,8	6,1	79,0	72,4	82,9
	emg_last2	9	0,3	2,8	1,4	0,7	1,2	1,1	1,6
	temp_last2	9	22,8	32,7	28,6	3,0	29,0	27,1	31,0
	skin_last2	9	0,4	7,3	2,2	2,3	1,2	0,5	2,9
	bvp_hr_last2	9	65,0	74,7	72,0	2,8	72,8	72,3	73,1
Session	Variable	N	min	max	mean	sd	p50	p25	p75
7	emg_first2	9	0,6	3,9	2,1	1,0	2,1	1,5	2,4
	temp_first2	9	21,5	33,2	27,3	3,5	27,8	26,8	28,5
	skin_first2	9	0,2	6,0	1,8	1,9	0,9	0,5	2,5
	bvp_hr_fir~2	9	60,2	85,1	74,9	8,8	78,1	71,0	80,2
	emg_last2	9	0,3	2,1	1,2	0,5	1,3	0,9	1,5
	temp_last2	9	21,3	33,4	28,9	3,6	29,7	27,7	30,7
	skin_last2	9	0,2	10,5	3,1	3,4	1,6	0,4	4,2
	bvp_hr_last2	9	59,9	84,7	73,2	7,4	75,4	70,2	77,1
Session	Variable	N	min	max	mean	sd	p50	p25	p75
8	emg_first2	9	1,5	4,6	2,7	1,0	2,6	2,2	3,1
	temp_first2	9	22,3	32,0	26,9	3,3	26,7	25,2	27,6
	skin_first2	9	0,2	2,6	1,2	0,7	1,2	0,7	1,3
	bvp_hr_fir~2	9	58,3	82,5	67,8	7,3	67,2	65,8	69,3
	emg_last2	9	0,4	14,6	4,1	4,8	1,6	0,6	5,5
	temp_last2	9	29,1	33,0	30,9	1,3	30,5	30,3	31,2
	skin_last2	9	0,3	9,8	2,9	3,2	1,3	0,8	3,8
	bvp_hr_last2	9	61,8	86,3	72,7	6,7	71,4	70,4	75,2
Session	Variable	N	min	max	mean	sd	p50	p25	p75
9	emg_first2	9	0,7	3,5	1,9	1,0	1,9	1,4	2,2
	temp_first2	9	21,9	33,2	28,4	4,1	29,1	26,8	31,5
	skin_first2	9	0,3	4,6	1,8	1,3	1,2	1,0	2,2
	bvp_hr_fir~2	9	27,6	90,6	65,6	17,3	70,4	63,2	71,6
	emg_last2	9	0,8	2,6	1,6	0,6	1,6	1,4	1,9
	temp_last2	9	25,3	33,1	29,5	2,6	30,1	27,8	30,5
	skin_last2	9	0,2	4,6	1,9	1,3	1,6	1,2	2,3
	bvp_hr_last2	9	62,8	88,3	75,6	7,2	76,8	71,0	79,3
Session	Variable	N	min	max	mean	sd	p50	p25	p75
10	emg_first2	9	0,5	2,5	1,4	0,7	1,4	0,7	1,8
	temp_first2	9	21,6	33,0	29,5	3,4	30,3	28,7	31,0
	skin_first2	9	0,4	4,8	1,6	1,4	0,9	0,7	2,0
	bvp_hr_fir~2	9	57,2	91,1	73,8	9,4	72,5	70,6	78,1
	emg_last2	9	0,5	2,5	1,5	0,7	1,5	1,0	1,9
	temp_last2	9	22,4	34,1	30,6	3,7	32,0	30,1	32,7
	skin_last2	9	0,6	7,6	2,5	2,3	1,6	0,8	3,2
	bvp_hr_last2	9	67,9	92,0	76,1	7,4	76,6	70,3	77,5
Session	Variable	N	min	max	mean	sd	p50	p25	p75
Total	emg_first2	90	0,5	12,5	3,4	2,9	2,5	1,4	4,2
	temp_first2	90	17,6	33,6	28,4	3,7	29,1	26,7	31,4
	skin_first2	90	0,2	10,6	2,2	1,8	1,8	0,8	3,0

bvp_hr_fir~2	90	27,6	92,3	72,2	9,7	72,4	68,0	78,1
emg_last2	90	0,3	14,6	2,1	2,2	1,4	0,8	2,5
temp_last2	90	21,2	34,1	29,7	2,8	30,4	29,1	31,3
skin_last2	90	0,2	14,3	3,2	2,7	2,7	1,0	4,2
bvp_hr_last2	90	59,9	99,5	74,5	6,9	74,1	70,4	77,6

----- 95 % CI for means -----

Group		Control				
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
1	emg_first2	9	3,7	1,0	1,4	6,0
	temp_first2	9	28,5	1,1	26,0	31,1
	skin_first2	9	3,1	0,6	1,8	4,5
	bvp_hr_fir~2	9	75,4	2,0	70,8	80,1
	emg_last2	9	1,2	0,4	0,2	2,3
	temp_last2	9	27,8	1,2	25,0	30,6
	skin_last2	9	5,0	1,4	1,7	8,3
	bvp_hr_last2	9	73,9	2,1	69,1	78,8
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
2	emg_first2	9	3,2	0,7	1,5	4,8
	temp_first2	9	30,3	1,2	27,5	33,1
	skin_first2	9	3,3	0,4	2,4	4,3
	bvp_hr_fir~2	9	70,2	2,6	64,2	76,1
	emg_last2	9	4,1	0,9	2,1	6,1
	temp_last2	9	29,7	0,9	27,7	31,7
	skin_last2	9	4,7	0,7	3,2	6,3
	bvp_hr_last2	9	71,5	2,0	66,9	76,0
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
3	emg_first2	9	6,2	1,3	3,3	9,2
	temp_first2	9	29,9	1,3	26,9	32,8
	skin_first2	9	3,8	1,1	1,3	6,2
	bvp_hr_fir~2	9	72,7	1,4	69,5	75,9
	emg_last2	9	2,9	0,6	1,5	4,4
	temp_last2	9	30,3	1,0	28,1	32,6
	skin_last2	9	3,1	0,5	1,9	4,2
	bvp_hr_last2	9	75,7	1,8	71,5	79,9
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
4	emg_first2	9	6,9	1,3	4,0	9,9
	temp_first2	9	26,7	1,4	23,4	30,0
	skin_first2	9	1,9	0,5	0,9	3,0

	bvp_hr_fir~2	9	67,7	3,9	58,7	76,7
	emg_last2	9	0,8	0,1	0,6	1,0
	temp_last2	9	29,9	0,5	28,8	31,0
	skin_last2	9	3,3	0,9	1,1	5,5
	bvp_hr_last2	9	74,3	1,7	70,5	78,1
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
5	emg_first2	9	2,3	0,6	1,0	3,6
	temp_first2	9	30,3	0,6	29,0	31,6
	skin_first2	9	2,0	0,6	0,6	3,3
	bvp_hr_fir~2	9	75,8	2,9	69,0	82,5
	emg_last2	9	1,7	0,3	0,9	2,4
	temp_last2	9	30,6	0,3	29,8	31,4
	skin_last2	9	3,0	0,9	1,0	4,9
	bvp_hr_last2	9	79,7	3,8	71,0	88,5
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
6	emg_first2	9	3,4	1,1	0,7	6,0
	temp_first2	9	26,7	1,2	23,9	29,5
	skin_first2	9	1,3	0,4	0,4	2,2
	bvp_hr_fir~2	9	77,8	2,0	73,1	82,5
	emg_last2	9	1,4	0,2	0,8	1,9
	temp_last2	9	28,6	1,0	26,3	30,9
	skin_last2	9	2,2	0,8	0,5	4,0
	bvp_hr_last2	9	72,0	0,9	69,8	74,2
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
7	emg_first2	9	2,1	0,3	1,3	2,9
	temp_first2	9	27,3	1,2	24,6	30,0
	skin_first2	9	1,8	0,6	0,4	3,3
	bvp_hr_fir~2	9	74,9	2,9	68,1	81,6
	emg_last2	9	1,2	0,2	0,8	1,6
	temp_last2	9	28,9	1,2	26,1	31,6
	skin_last2	9	3,1	1,1	0,5	5,7
	bvp_hr_last2	9	73,2	2,5	67,6	78,9
Session	Variable	Obs	Mean	Std,	Err,	[95% Conf Interval]
8	emg_first2	9	2,7	0,3	2,0	3,4
	temp_first2	9	26,9	1,1	24,3	29,4
	skin_first2	9	1,2	0,2	0,6	1,7
	bvp_hr_fir~2	9	67,8	2,4	62,2	73,4

	emg_last2	9	4,1	1,6	0,5	7,8
	temp_last2	9	30,9	0,4	29,8	31,9
	skin_last2	9	2,9	1,1	0,5	5,4
	bvp_hr_last2	9	72,7	2,2	67,6	77,8
	[95% Conf Interval]					
9	emg_first2	9	1,9	0,3	1,2	2,7
	temp_first2	9	28,4	1,4	25,2	31,5
	skin_first2	9	1,8	0,4	0,8	2,8
	bvp_hr_fir~2	9	65,6	5,8	52,3	78,9
	emg_last2	9	1,6	0,2	1,2	2,0
	temp_last2	9	29,5	0,9	27,5	31,5
	skin_last2	9	1,9	0,4	0,9	2,9
	bvp_hr_last2	9	75,6	2,4	70,1	81,2
	[95% Conf Interval]					
10	emg_first2	9	1,4	0,2	0,9	1,9
	temp_first2	9	29,5	1,1	26,9	32,1
	skin_first2	9	1,6	0,5	0,5	2,7
	bvp_hr_fir~2	9	73,8	3,1	66,5	81,0
	emg_last2	9	1,5	0,2	1,0	2,0
	temp_last2	9	30,6	1,2	27,8	33,4
	skin_last2	9	2,5	0,8	0,7	4,3
	bvp_hr_last2	9	76,1	2,5	70,3	81,8

Annexure E: Declaration of originality

DECLARATION OF ORIGINALITY

UNIVERSITY OF PRETORIA

The Department of Human Physiology places great emphasis upon integrity and ethical conduct in the preparation of all written work submitted for academic evaluation.

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The declaration which follows must accompany all written work submitted while you are a student of the Department of Human Physiology. No written work will be accepted unless the declaration has been completed and attached.

Full names of student: KARLIGEN BALT

Student number: 21077194

Topic of work: THE EFFECT OF INTER SLOW NEUROFEEDBACK ON QUANTITATIVE ELECTROENCEPHALOGRAPH AND AUTONOMIC NERVOUS SYSTEM FUNCTION IN ADULTS WITH ANXIETY AND RELATED DISEASES

Declaration

1. I understand what plagiarism is and am aware of the University's policy in this regard.
2. I declare that this DISSERTATION (eg essay, report, project, assignment, dissertation, thesis, etc) is my own original work. Where other people's work has been used (either from a printed source, Internet or any other source), this has been properly acknowledged and referenced in accordance with departmental requirements.
3. I have not used work previously produced by another student or any other person to hand in as my own.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.

SIGNATURE

K. Balt