AN INVESTIGATION INTO THE OPTIMUM TRAINING PARADIGM FOR ALPHA ELECTROENCEPHALOGRAPHIC BIOFEEDBACK

by

Tammy Dempster

Canterbury Christ Church University

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I hereby declare that this thesis has not been submitted, either in the same or different form, to this or any other University for a degree.

Signature:

Abstract

Alpha neurofeedback training has been put forward for use in the optimal performance field as a way to enhance cognitive abilities and musical performance amongst others. The literature to date, however, has been characterised by methodological limitations and disagreement on procedural and analytic matters which makes drawing conclusions and comparing results problematic. To provide clarity to the field, and to enable effective investigation of the usefulness of alpha neurofeedback training in the realm of optimal performance, it would be useful if a standardised way of conducting alpha neurofeedback was established. It is unclear, for instance, what influence the current variations have on participants' ability to train their alpha and to the outcome (e.g. on cognition) of their performance. This thesis therefore sets out to investigate whether there is an optimum methodology for alpha neurofeedback training. The first experiment was designed to establish an index of learning to use in the successive experiments; that is, to establish how alpha should be measured and how participants' performance should be analysed. Fifty-two participants were given 10 sessions of once weekly alpha (8-12Hz) enhancement and alpha suppression training at Pz. From the results of this first experiment it was decided that amplitude and per cent time would be the measures used to investigate participants' performance and that analyses of participants' performance both within and across sessions would be examined. Further, it was decided that baseline measures needed to be incorporated in to the analyses in order to establish a clearer picture of participants' ability to learn. Experiment 2 involved training 33 participants to both enhance and suppress their alpha (8-12Hz) at Pz. Over the course of 10 once weekly sessions, 17 participants trained with their eyes open and 16 were trained with their eyes closed. The results suggested that eyes open alpha neurofeedback training is a more optimal

training paradigm than eyes closed. The third experiment therefore set out to examine whether the *type* of eyes open training has an influence on participants' performance. Specifically, 15 participants were given audio feedback, 15 were given audio-visual feedback, and 17 were given visual feedback over the course of 10 once weekly alpha (8-12Hz) enhancement and alpha suppression sessions. The results showed that of the 3 types of feedback, audio feedback produced the more optimal results. Although there are further aspects of methodology and analysis to be investigated, the results from this thesis suggest that these fundamental design decisions do make a difference to the participants' ability to exert a conscious control over their own EEG alpha activity suggesting that there is, in fact, an optimum methodology for alpha (8-12Hz) neurofeedback training.

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Chapter One: Literature Review

Part 1 – The EEG

There are several methods for gaining insight into the brain's activity, including positron emission tomography (PET), magnetoencephalography (MEG), magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), and electroencephalography (EEG), all varying in terms of temporal and spatial characteristics. For instance, PET scans are a way of obtaining images that provide information on the structure and function of the brain and have the advantage of good spatial resolution but the disadvantages of poor temporal resolution and high expense (Gevins, Le, Brickett, Reutter, & Desmond, 1991). In contrast, the MRI only provides information on the brain's structure. This has the advantage of providing good spatial resolution but the disadvantage of poor temporal resolution (Dale & Sereno, 1993). While an MEG provides information on the structure of the brain, and is considered to have a good temporal resolution, it sometimes misses patterns of deeper cranial activity that can be more easily detected by an EEG (Dale & Sereno, 1993). Although Gevins et al. (1991) have argued that the EEG is only limited by the number of scalp locations recorded from and the subsequent analysis which is then utilised, the EEG is generally considered to have the advantage of providing 'real time' information about the activity of the brain but the disadvantage of being less accurate when it comes to the provision of spatial information. In contrast, the fMRI is considered to have the advantage of high spatial resolution but the disadvantage of having lower temporal resolution (Dale & Sereno, 1993).

If one wishes to gain a rich understanding of brain activity, then the solution might be to combine the above techniques rather than rely on one (e.g. Bablioni et al., 2004). To date, however, only the EEG and fMRI have been used in neurofeedback (aka EEG/fMRI biofeedback), with the latter being used only recently after improvements in the temporal resolution (Rota et al., 2009) and the discovery that the time lag between brain activity and the information from the fMRI is not as much of a hindrance to participants when learning to control the activity of their brain as was originally thought (Johnstone, Boehm, Healy, Goebel & Linden, 2010). With fMRI neurofeedback still in its infancy, however, the EEG is still the most commonly utilised of the two, and carries with it the advantages of being relatively inexpensive (and therefore more accessible), comfortable for the participants (Gevins et al., 1991), and allows us to build upon decades of EEG-related neurofeedback research. It is EEG neurofeedback that will therefore be the focus of this thesis.

1.1. The 10-20 International Electrode Placement System

Electrodes placed on the scalp enable the detection and recording of the cortical activity of the areas of the brain underneath the corresponding electrodes. The 10-20 International Electrode Placement System (Jasper, 1958) was developed as a way of standardising the locations on the scalp and thus enabling comparability of data. Electrodes are placed at distances of 10-20% away from each other (hence the name '10-20') and their locations named using a letter and a number, with letters referring to the lobe of the brain they are positioned over and the numbers relating to the hemisphere and location of that part of the hemisphere (see Figure 1, below). So the letters F, P, T, O and C mean that the scalp locations are over the frontal, parietal, temporal, occipital and central regions of the brain respectively. Odd numbers (1, 3, 5 . . .) refer to scalp locations on the left side of the brain and even numbers (2, 4, 6 . . .) refer to scalp locations on the right hand side of the brain. Where the letter ‘z’ replaces a number (i.e., Fz, Cz, Pz, Oz) this indicates that the scalp location falls along the central line running between the nasion (bridge of the nose) and the inion (base of the occipital bone which protrudes from the back of the skull). Additional scalp locations Fp1 and Fp2 (see Figure 1) stand for the left and right frontal poles, respectively, and additional non-scalp locations A1 and A2 stand for the left and right auricular, respectively, and denote two of the common places on the body used for the placement of ground and reference electrodes (see section 3.2.1. below).

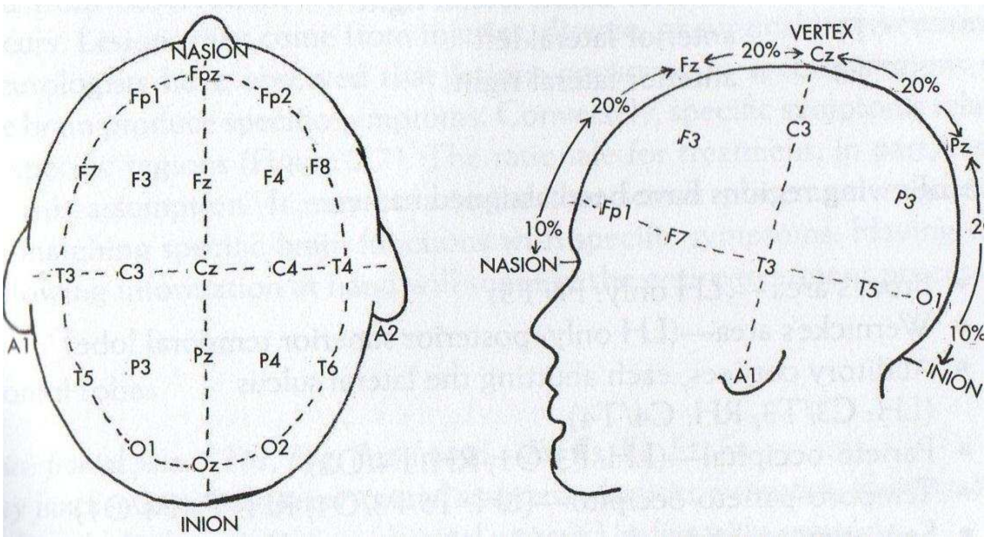

Figure 1. The 10-20 electrode placement system (taken from Demos, 2005, p37).

The number of electrodes which are used at any one time depend on the type of research being done and the employment of full cap electrodes means that there are distances measured which fall outside of the 10/20 range (at distances of 5% for example) although for the purposes of neurofeedback (see section 2, below) it is most common to see the use of only one or two active electrodes in use at any one time in order to train specific aspects of the brain's electrical activity (Vernon & Dempster, in press).

1.2. The Different Frequency Components (Brain Waves)

The firing of neurons (brain cells) is the way the brain transfers information and every time the neurons fire they produce electrical activity. By placing electrodes on the scalp this electrical activity can be detected and recorded and the resulting output is known as the electroencephalogram (EEG). More specifically, the EEG results from the synchronous firing of a specific type of neuron, known as pyramidal, and reflects the electrical output from (mainly) the areas of the cortex (Heinrich, Gevensleben, & Strehl, 2007) underneath the parts of the scalp where the electrodes have been placed.

The EEG takes the form of oscillatory waves which in its purest form is known as the raw trace. The raw trace is an amalgamation of all of the electrical activity being picked up by the electrodes and can be broken down further in to the different patterns of electrical activity (i.e. synchronous firing) being detected by a fast Fourier transform (see Figure 2, over page).

Vernon (2008) compares the process to the way light shines through a prism. The original light appears as one colour – white – but when it hits a prism the light is revealed to be made up of a number of component colours – yellow, red, green, blue, etc. – which can all then be viewed separately. A fast Fourier transform, Vernon (2008) explains, can be considered to be doing the same thing.

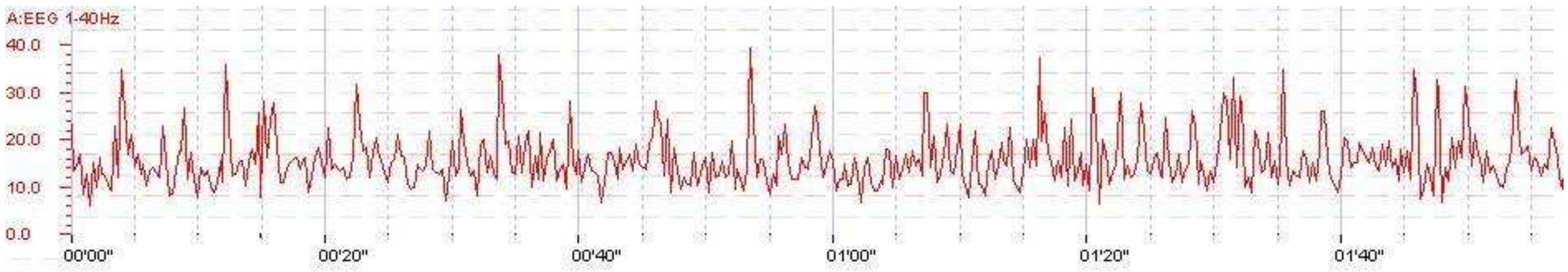

Figure 2. Example of a raw EEG trace taken from one of the participants from the sample utilised in Experiment 1 (see Chapter 3 for details of Experiment 1).

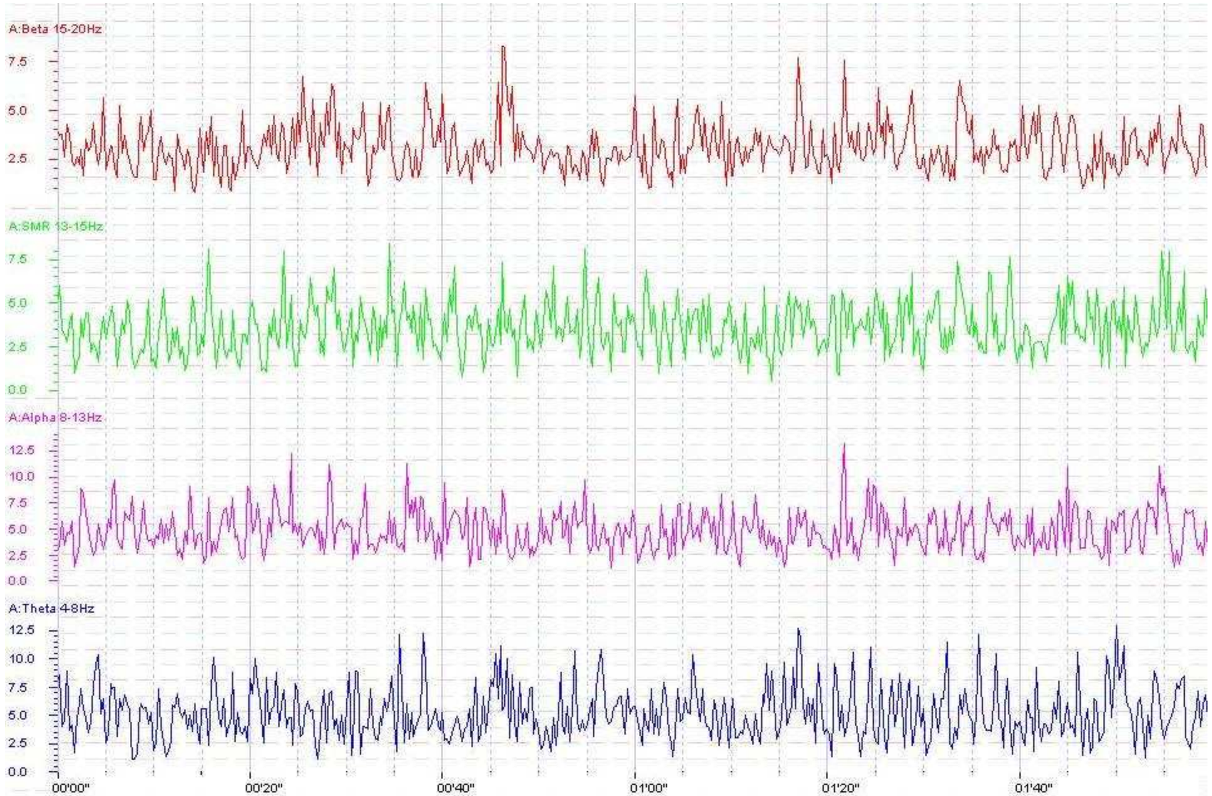

Figure 3. Example of how a raw EEG trace can be broken down in to its component parts. In this case, the same raw EEG shown in Figure 2, above, has been broken down in to theta (4-8Hz), alpha (8-13Hz), SMR (the sensorimotor rhythm) (13-15Hz), and low beta (15-20Hz).

It breaks the raw EEG trace up in to the discrete patterns of electrical activity oscillating within it. These different patterns of electrical activity, known as brain waves, are distinguished by their frequency and amplitude (see Figure 3). Where frequency represents how fast the waves oscillate, as measured by number of waves per second (Hertz (Hz)) and amplitude represents the power of those waves, i.e. how large the waves are (measured in microvolts, µv). So, to illustrate, a 20 µv brain wave of 8Hz represents synchronous neuronal firings at a rate of 8 oscillations per second and with an amplitude of 20 µv.

The different frequency bands the raw trace has traditionally been divided into are: delta (<4Hz), theta (4-8Hz), alpha (8-13Hz), beta (13-30Hz), and gamma (30-100Hz). As will be discussed later in this chapter, however, the designation of the range of Hz covered by these frequency bands is somewhat arbitrary and not always consistent in the literature (see section 3.1.1, below) and there are certain parts of the brain which are often considered to exhibit additional frequency bands. For instance, the mu rhythm is a specific type of alpha wave (8-13Hz) found at central cortical areas and related to motor/sensorimotor activities (Hughes & Crunelli, 2005) and SMR (12-15Hz) (the sensorimotor rhythm) is a frequency band which is found over the sensorimotor cortex (Demos, 2005).

It is important to note that all of the traditional frequency bands are present at all times across the scalp but it depends on the task being undertaken by the individual and the scalp location in question as to which is the most prevalent (Norris & Currieri, 1999). However, whilst it is inappropriate to think of each frequency band as reflecting a single function (Başar, Başar-Eroğlu, Karakaş, & Schürmann, 2000), as a general overarching rule the faster the oscillation of the most prevalent frequency band the more alert the individual is thought to be. So delta waves tend to dominate the EEG when the individual is asleep, theta when the individual is drowsy, alpha when the individual is relaxed but alert, beta when the individual is alert and concentrating, and gamma when the individual is trying to solve problems (Demos, 2005). Whilst these are convenient rules of thumb, each frequency is multi-functional (Başar et al., 2000) and each may reflect a number of different states and types of communication resulting from different sources during different tasks (Gruzelier & Egner, 2005).

1.3. The Alpha Frequency Band

Although the EEG comprises a range of frequency bands, for the purposes of this thesis the focus will be on the alpha frequency band (see section 2, below, for further discussion of this point). Alpha waves are sinusoidal waves that are particularly dominant when the eyes are closed (Kaiser, 2002) and the frequency of which varies as a result of age, increasing from childhood to adulthood and then decreasing again as the individual approaches old age (Klimesch, 1999). The alpha frequency is often thought of as being generated from communication between thalamo-cortical and cortico-cortical structures (Lopes da Silva, Vos, Mooibroek, & Van Rotterdam, 1980) but the exact mechanism or mechanisms responsible for their generation are still unknown (Bollimunta, Mo, Schroeder, & Ding, 2011). Research focusing on the debate regarding the source of the alpha frequency tends to point towards either the thalamus (Feige et al., 2005; Hughes & Crunelli, 2005) or the pyramidal neurons (Bollimunta et al., 2011) as the main generators of the alpha frequency with current evidence leaning towards a more complex explanation relating to their generation being due to the involvement and interaction of both (Bollimunta et al., 2011).

The precise role of the alpha rhythm is also still under debate with the arguments polarising from alpha as cortical idling (e.g., Pfurtscheller, Stancák, & Neuper, 1996) or alpha as functionally significant (e.g., Başar et al., 2000), such as for the inhibition of irrelevant information during a task (e.g., Cooper, Croft, Dominey, Burgess, & Gruzelier, 2003).

Cortical idling suggests that the alpha frequency is dominant at a particular scalp location when that area of the scalp is not processing any information. It is a hypothesis resulting from research demonstrating a decrease in alpha power, or desynchronisation, at the onset of a task (e.g. Moore, Gale, Morris, & Forrester, 2008). For instance Pfurtsheller et al. (1996) carried out a study whereby they examined the behaviour of the alpha mu rhythm over the area of the brain that controls hand movement. During finger movement the mu rhythm desynchronises in the hand area of the brain. During visual processing and foot movement, however, neither of which requires the involvement of the hand movement area of the brain, the hand movement area of the brain showed a synchronisation of alpha. Because alpha desynchronizes during relevant tasks, i.e., when that area of the scalp is processing information, and synchronises during irrelevant tasks, Pfurtsheller et al. (1996) suggest that when alpha is present that area of the brain is not task relevant and therefore not processing information. Thus they took the dominance of alpha at particular scalp locations as being indicative of that part of the brain doing nothing, i.e., of cortical idling.

Research demonstrating event-related alpha oscillations, however, directly contradicts this theory (Schűrmann & Başar, 1999) and Cooper et al. (2003) therefore put forward an alternative explanation. In their study, Cooper et al. (2003) found that alpha was greater with tasks requiring internally directed, in comparison to externally directed, attention and that the greater the demands of the task the greater the increase in alpha. Participants were given visual, auditory and haptic stimuli and in the external attention tasks they were asked to pay attention to the stimuli, answer a simple question relating to the stimuli, and answer a hard question relating to the stimuli. For the internal attention tasks the participants had to imagine each of the three types of stimuli, imagine the stimuli and answer a simple question, and imagine the stimuli whilst answering a hard question. Imagining the stimuli increased alpha amplitude whereas paying attention to the actual external stimuli itself resulted in a decrease in alpha amplitude. This is perhaps not surprising given that visualisation has been linked to alpha (Cremades, 2002; Cremades & Pease, 2007) but Cooper et al. (2003) argue that because alpha amplitude increases during internal attention and during tasks requiring increased cortical load then the cortical idling hypothesis does not make sense. They therefore suggest that alpha is in actual fact part of an active process of inhibiting internal information during tasks.

The presentation of research demonstrating event-related alpha synchronisation – i.e., an increase in alpha (Aftanas & Golocheikine, 2001) – means that functional significance is now the more favoured explanation for the role of alpha in the EEG. For instance, Fink et al. (2009) demonstrated that there was an increase in alpha synchronisation in areas shown by an fMRI to be active during an ideational fluency task which led them to suggest that alpha is related to creativity. Evidence for a link between alpha and creativity has also been found by Bazanova and Aftanas (2008a, 2008b) and Martindale and Armstrong (1974). It is not just creativity which alpha has been linked to, however. Other research has provided evidence to suggest alpha as having a role in areas such as memory (e.g. Angelakis et al., 2007; Klimesch, 1999; Klimesch, Schimke, Ladurner, & Pfurtscheller, 1990; Krenn et al., in review), musical ability (e.g., Bazanova &

Mernaya, 2008; Markovska-Simoska, Pop Jordanova, & Georgiev, 2008), intelligence (e.g., Doppelmayr, Klimesch, Hödlmoser, Sauseng, & Gruber, 2005; Jaušovec, Jaušovec, & Gerlič,. 2001), visual imagery (e.g., Cremades, 2002; Cremades & Pease, 2007), mental rotation ability (e.g., Hanslmayr, Sauseng, Doppelmayr, Schabus, & Klimesch, 2005; Zoefel, Huster, & Herrman, 2011), attention (Aftanas & Golocheikine, 2001; Schauerhofer et al., 2011), and speed of information processing (e.g., Angelakis et al., 2007; Kilmesch, 1996; Klimesch, 1999).

In each of these instances, good performance is related to large desynchronisation (i.e., suppression of activity) during the task but a large synchronisation (i.e. increase of activity) when at rest (Hanslmayr et al., 2005). Klimesch (1999) describes this as a double dissociation and explains that the larger the desynchronization during mental activity and the larger the synchronisation during mental inactivity, the better the individual's performance during the relevant task would be expected to be. So using research on intelligence as an example, Doppelmayr et al. (2005) demonstrated that the more intelligent the individual the larger the amount of desynchronisation seen in their alpha during a verbal semantic task.

Similarly, in the case of memory performance, Klimesch (1999) discusses research showing that individuals who perform better on tests of memory have higher resting (i.e. when not undertaking the task) alpha power – i.e. higher alpha synchronisation, than those classified as 'bad memory performers'. During the semantic memory tasks themselves, however, alpha showed a larger desynchronisation for those considered to demonstrate good, compared to those considered to demonstrate bad, performances on the semantic memory tasks.

These findings can be linked to the neural efficiency hypothesis whereby those with more intelligence/task-related skill are considered to be more neurally efficient (Doppelmayr, Klimesch, Stadler, Pőllhuber, & Heine, 2002) such that the more effective the individual is at blocking extraneous information, the larger the level of event related alpha desynchronisation, and the better they will perform during the task (Vernon et al., 2009).

Given the links between alpha and cognitive ability/behaviour it follows that if there was a way of altering the relevant aspects of alpha it could thus result in an improvement in ability and this is where neurofeedback comes in.

Part 2 – Neurofeedback

2.1. Neurofeedback – General Overview

Neurofeedback is not a new concept and has been the topic of research for decades (e.g. Albert, Simmons, & Walker, 1974; Beatty, 1971; Cott, Pavloski, & Goldman, 1981; Kamiya, 1968). It has been purported to be of use to both clinical and healthy populations and is a method for individuals to learn to exert a conscious control over some aspect of their brainwaves. Often described as a form of operant conditioning, it involves presenting the individual with information regarding the specific aspects of their brain activity with the intention of seeing if they can work out how it ‘feels’ when the feedback alters.

For instance, it has been suggested that enhancing the amplitude of the alpha (8-12Hz) frequency band at position Pz on the scalp can improve the individual’s ability to focus and increase both the speed and accuracy of their responses to cognitive tasks (Norris & Currieri, 1999). In order to improve the speed/accuracy of their response on those tasks the individual would thus be given feedback telling them about the amplitude of their alpha at Pz. The form of feedback varies (see section 3.5., below) but as an example the feedback may be in the form of a moving bar on the screen which increases in height in proportion to increases in the individual's amplitude at (in this example) Pz and decreases in height in proportion to decreases in the individual's amplitude at Pz. Because the feedback is paired with – in this instance - the amplitude of their alpha waves, by learning to recognise whatever it is they are thinking/feeling/doing when the height of the bar increases/decreases they can learn to exert a conscious control over the amplitude of their alpha waves at Pz. The assumption being that learning to increase them will then result in improvement in the associated cognitive abilities; so in this case the hypothesised improvement in focus, speed and accuracy of reaction times.

There are several different forms of neurofeedback, varying in process and purpose. For instance, fMRI neurofeedback, as already mentioned earlier, trains the individual to consciously alter blood oxygen levels in the target areas of their brain (e.g. Rota et al., 2009). Slow cortical potential neurofeedback, on the other hand, uses neurofeedback to train event-related changes in the individual's cortical activity in their sensorimotor cortex (Drechsler, Straub, Doehnert, Heinrich, Steinhausen, & Brandeis, 2007). An electrode is placed at Cz and the positive polarization (i.e. inhibition of electrical potentials) and negative polarization (i.e. the excitation of electrical potentials) in the 0.3Hz-1.5Hz frequency range is trained (Hammond, 2011), usually as a treatment for ADHD (e.g. Drechsler et al., 2007) and epilepsy (e.g. Kotchoubey et al., 2001). Another form of neurofeedback is frontal asymmetry training which trains brain activity in the frontal lobes with the aim being to increase activity in the desired brain frequency more on the right side of the brain compared to the left or more on the left side of the brain compared to the right (Harmon-Jones, Gable, & Peterson, 2010). More passive forms of neurofeedback training are those such as LORETA (Low Resolution Electromagnetic Tomography) and LENS (Low Energy Neurofeedback System). LORETA uses a 19 electrode cap to emit low resolution electromagnetic pulses into the 19 corresponding regions of the brain (Hammond, 2011) and has been purported as being useful for the treatment of traumatic brain injury and in the control of aggression and anger (Hammond, 2010). Similarly, LENS emits an electrical pulse (one four hundredths of that emitted by a mobile phone being held to the ear) every second in to the brain with the feedback being altered multiple times per second to ensure that it is oscillating faster than that of the most dominant brain frequency in that particular area of the brain (Hammond, 2011).

Whilst these are all examples of recent and emerging forms of neurofeedback training, the most common is still EEG neurofeedback using either a single or multiple electrodes to alter the amplitude or power of a particular brain frequency in a particular area or areas of the brain and so it is this form of neurofeedback which this thesis will concentrate on.

With regards to why neurofeedback training is used, the use of neurofeedback in clinical populations varies in the potential applications which have been proposed but is based on the idea that if there is an abnormality in a particular brain frequency which has been associated with a particular disorder (for instance an excess of theta and a lack of beta in the EEG of some patients suffering with ADHD) then using neurofeedback to alter the EEG to what would be expected in a healthy individual could improve the patient’s condition. In clinical populations, neurofeedback has been put forward as a method for treating attention deficit hyperactivity disorder (ADHD) (see Arns, De Ridder, Strehl, Breteler, & Coenen, 2009, for a meta-analysis of its use in this area), epilepsy (see Sterman & Egner, 2006, for an overview), autistic spectrum disorders (see Coben, Linden, & Myers, 2010, for a review), anxiety disorders (see Moore, 2000, for a review), and depression (e.g. Baehr, Rosenfeld, & Baehr, 2001) to name a few. For the purposes of this thesis it is optimal performance which is of interest and so it is its use on healthy populations which will be the focus.

When it comes to the use of neurofeedback in healthy populations, the goal is to optimise performance. The main areas where neurofeedback has been purported to be of use in the realm of optimal performance are for sport (e.g. Radlo, Steinberg, Singer, Barba, & Melinkov, 2002), musical (e.g. Markovska-Simoska et al., 2008) and artistic performance (e.g., Raymond, Sajid, Parkinson, & Gruzelier, 2005), and cognitive performance (e.g. Zoefel et al., 2011).

In addition to being used as a treatment for clinical populations and a way of optimising performance in healthy patients, a third use for neurofeedback has also been put forward which is what Vernon and Dempster (in press) call functional validation. This is the use of neurofeedback to increase or decrease activity at a particular site to see what effect it has on behaviour (see Keizer, Verment, & Hommel, 2010, for an example). Thus testing to see if the hypothesised function for specific frequency bands in specific areas of the brain can be supported with the manipulation of the relevant aspects (e.g. amplitude) of those specific frequency bands in those specific areas of the brain.

According to Doppelmayr and Weber (2011), the frequency bandwidths most often focused on in the neurofeedback literature are SMR (12-15Hz) and the ratio of beta to theta. Alpha/theta neurofeedback , however, is also increasing in popularity (e.g., Vernon & Gruzelier, 2008). Examples of gamma (e.g. Keizer et al., 2009) and delta (e.g. Todder et al., 2010) do exist in the literature but are far rarer and whilst alpha neurofeedback was being utilised as far back as the 60s (e.g. Kamiya, 1968) interest drastically decreased during the 1980s and 1990s and it is only recently, with the emergence of the concept of individual alpha (e.g., Bazanova & Aftanas, 2006b) (see section 3.1.2., below) , that research using alpha neurofeedback (not to be confused with alpha/theta neurofeedback) has started to reappear.

Given that, SMR, beta/theta, and alpha/theta neurofeedback, have already accumulated their own body of more recent (i.e. 2000 onwards) literature and that up-to-date alpha neurofeedback studies are still sparse in comparison, it would be useful to include alpha neurofeedback in the growing body of up-to-date research looking at the use of neurofeedback for optimal performance. The fixed alpha frequency band versus individual alpha frequency band (see section 3.1.2., below) debate and the increasing amount of research now implicating alpha as having a role in cognitive ability (e.g., Klimesch, 1999) (see section 1.3., above) provides a further rationale for the need to make room for alpha neurofeedback in the continuing investigations in to the role and efficacy of using neurofeedback to optimise performance in healthy populations. It is for these reasons, then, that this thesis will focus on the alpha frequency band.

2.2. Neurofeedback of the Alpha Frequency Band

As already mentioned above (see section 1.3), the alpha frequency band has been linked to a whole range of cognitive abilities. It is perhaps not surprising then that the number of areas which alpha neurofeedback has been purported to be of use for in the optimal performance arena are multiple.

A glance at Table 1, below, certainly seems to be suggestive of the multiple benefits of utilising alpha neurofeedback to enhance particular areas of

Table 1

List of empirical studies providing evidence for the use of alpha neurofeedback in optimal performance and the areas they found alpha neurofeedback improved.

Area influenced by alpha neurofeedback	Researchers
Musical Performance	Bazanova and Mernaya (2008)
	Markovska-Simoska et al. (2008)
Mental Rotation	Hanslmayr et al., (2005)
	Zoefel et al. (2011)
	Vernon and Withycombe (2006)
Attention	Schauerhofer et al. (2011)
Speed of Processing	Angelakis et al. (2007)
	Woodruff (1975)
Memory Performance	Angelakis et al. (2007)
Recall	Krenn et al. (in review)
Mood	Schmeidler and Lewis (1971)
Perception of Time	Wacker (1996)

performance. However, many of the studies have limitations or are disputed by the contradictory results of other studies.

For instance, Bazanova and Mernaya (2008) showed an improvement in musical performance after alpha neurofeedback training but alpha enhancement training was done in conjunction with electromyogram (EMG) training so it is difficult to know whether the improvement in 'quality of sound' seen in the alpha neurofeedback group but not in the preceeding no feedback session was due to the alpha neurofeedback training or the EMG training or a combination of both. Given that the neurofeedback sessions took place after the no feedback session the results may also have been as a result of practice effects and/or to the self-report measure used to judge the 'quality of sound'. Specifically, because this measure was in the form of self-reports this may plausibly indicate that the participants simply felt better about their performances due to an increase in mood rather than because the quality of their musical performance actually improved.

The earlier study by Wacker (1996) also demonstrates the problem of failing to include an appropriate control. In her study she gave participants either 10 sessions of alpha (8-13Hz) or 10 sessions of beta (14Hz+) enhancement training and found that the alpha neurofeedback had a far less accurate perception of the passing of time with the beta group showing greater accuracy when asked to judge the passing of specific time intervals and the alpha group tending to underestimate how much time had actually passed. A potential problem with this, however, is that, as the author herself points out, it could be that the beta enhancement training resulted in improved time perception as opposed to the alpha training resulting in poorer time perception. Further, it is unclear if the participants were actually successful in enhancing their required frequency bands because no evidence of them doing so was discussed or presented in the paper, which makes relating the results of differences in time perception to the training of specific frequencies even more problematic.

As well as failing to show evidence of participants actually learning to control their brainwaves via neurofeedback, there can also be the problem of vagueness with regards to the methodology itself. For instance, Schmeidler and Lewis (1971) talk about a relationship between alpha and positive mood states but they are not clear on how it is they are defining alpha (i.e. the specific frequency range used or the amplitude threshold (see section 3.1. below) used). Additionally, there was no correlation between mood score and alpha, which makes their claims of mood change after alpha neurofeedback training questionable.

Another problem with some of the studies is the size and generalizability of the samples used. For instance, Angelakis et al. (2007) used only a sample of 6 participants, all of whom were aged 70 and above, and Vernon and Withycombe (2006) used a sample of 9, 4 of which comprised the no-feedback control group. Vernon and Withycombe's (2006) results also, as the authors themselves point out, suffer from the fact that whilst an improvement in mental rotation ability was shown in the alpha neurofeedback group the performance in the mental rotation task was poorer for the neurofeedback group during the pre-training task. In addition, the post-training mental rotation performance does not actually exceed the performance of the control group which somewhat limits the conclusions which can be drawn from their study.

As well as methodological limitations undermining the confidence that can be had in the results, methodological differences between studies with contradicting results also make it hard to pull apart the key factors which make the difference as to whether an effect of training is found. For example, Krenn et al.'s (in review) study showing a relationship between alpha and recall is in contradiction with the earlier study by Bauer (1976) which found no relationship between alpha and recall. However, Krenn et al. (in review) used individual alpha frequency training (see section 3.1.2.), divided alpha in to subbands (see section 3.1.3.) and gave participants 5 twice daily 18 minute sessions of neurofeedback training using visual feedback. Bauer (1976), on the other hand, used the same fixed alpha frequency band (8.5-12.5Hz) for each participant, did not divide alpha in to sub-bands, and gave participants 4 daily one hour sessions of neurofeedback training using audio feedback. The differences in their results could therefore be due to differences in the number of sessions given, the length of the sessions given, the way alpha was defined for each participant, differences in the type of feedback given, or a combination of any or all those variations.

Methodological limitations and conflicting results are not just a potential problem for studies which have found a relationship between alpha and optimal performance. The area of alpha neurofeedback in general suffers from a number of methodological issues which need to be addressed. In other words, whilst there is support for the use of neurofeedback in performance enhancement it is important to address the current methodological limitations in the field in order for clear comparisons and conclusions to be made regarding the use of alpha neurofeedback for optimal performance.

Part 3 – Methodological Issues

What constitutes an optimal training methodology for neurofeedback has yet to be established (Heinrich et al., 2007). In the first step to addressing this, this section is an overview of the methodological limitations that currently exist and that need to be addressed in order for an optimal training methodology to be established. The year 1968 was chosen as the cut-off point because it was then that Kamiya's (1968) work kick-started the original interest in alpha neurofeedback training. The earlier the work was published the larger the likelihood that the neurofeedback training equipment being used was very different from the more advanced equipment used today, which could potentially limit the results of any experiments conducted. The year 1968 was therefore taken as the cut-off point and all the empirical research literature found and therefore referred to throughout this section is listed in Appendix A.

The reason this approach was taken as opposed to using an overall meta-analysis of all the relevant literature in the field is because the majority of the literature does not provide enough information to conduct a meta-analysis. As can be seen from Tables 2-18, details regarding the definition of alpha, the training process, and the measurement of alpha, and the definition of success, are either unclear of not specified at all. A lack of clarity and/or lack of information prohibits the ability to perform a successful meta-analysis. Instead, then, the methodological limitations which currently exist in the area of alpha neurofeedback training will be addressed one by one.

There are three main areas relating to limitations in the current alpha neurofeedback literature: how to define alpha, how to train alpha, and how to measure alpha and thus to define training success. These can be seen as a hierarchy whereby if alpha is being trained an idea of the purpose, i.e. what is meant by 'success', should be defined meaning a way of measuring alpha is needed, and in order to measure alpha it first needs to be established what the criteria are for defining alpha. Likewise, when deciding what is meant by alpha and how it is that alpha will be trained these issues themselves can be seen as having their own hierarchies of questions need to be answered (see Figure 4).

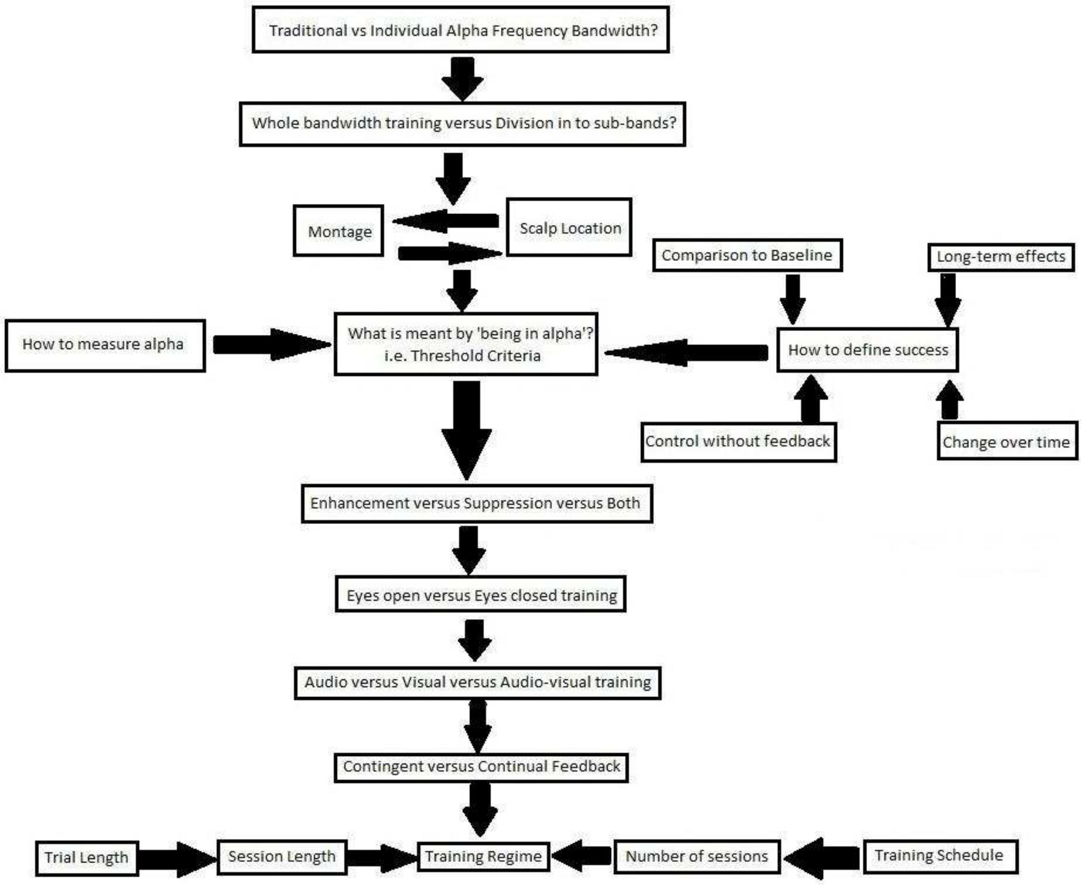

Figure 4. Hierarchy of issues to be addressed when setting up alpha neurofeedback training. Before answering the questions at the bottom of the hierarchy, it makes more sense to first decide on the answers to the preceding questions in the hierarchy.

The remainder of this chapter will focus on each of these and these and other methodological limitations highlighted by the literature shall now be addressed in detail.

3.1. Defining Alpha

One of the most immediate problems present in the alpha neurofeedback literature is that it is not always clear what it is the researchers mean by 'alpha'. Some do not state the frequency bandwidth they are using (e.g., Gertz & Lavie, 1983) (n = 25 studies, see Table 2, below) and some do not state what the cut-off threshold is they are using when they are talking about participants being 'in' and 'out' of alpha (e.g. Pressner & Savitsky, 1977). Even amongst those who are clear on their definition of alpha, what it is researchers mean when they talk about 'alpha' varies widely between the studies. The use of a single standard frequency band for all participants versus an individual frequency band for each participant, the range of the frequency band used, the use of multiple alpha sub-bands versus one single alpha band, and the threshold criteria used, have all resulted in wide variation amongst the literature. Each of these, and the related problems with their discrepancies, will now be discussed in turn:

3.1.1. Traditional Alpha Frequency Bandwidth

Traditionally the alpha band frequency is usually defined as 8-12 Hz (e.g. Cho et al., 2008) or 8-13Hz (e.g. Angelakis et al., 2007), although both Klimesch (1999) and Krenn et al. (in review) state that the traditional alpha frequency band is 7.5-12.5Hz. Classification of the frequency bands, however, is arbitrary (Bazanova & Aftanas, 2006b) and perhaps because of this considerable variation exists in the alpha neurofeedback literature, as can be seen in Table 2 (below).

Table 2

The frequency ranges used to define the alpha frequency bandwidth in the alpha neurofeedback studies reviewed (see Appendix A).

Frequency Range	Width of Frequency Band	Number of Studies
7-13Hz	6Hz	1
7-15Hz	8Hz	1
7.5-12.5Hz	5Hz	1
7.5-13Hz	5.5Hz	1
8-12Hz	4Hz	18
8-13Hz	5Hz	37
8-14Hz	6Hz	2
8.5-12.5Hz	4Hz	1
8.5-13.5Hz	5Hz	2
9-10.5Hz	1.5Hz	1
9-11Hz	2Hz	1
Individual Alpha Frequency	Varied	7
Not Specified	Not Specified	25

The most common frequency bandwidth used is 8-13Hz (n = 37 studies) followed by 8-12Hz (n = 18 studies). Of the rest, 4 studies use frequency bandwidths where the upper limit of the frequency range exceeds 13Hz and 4 studies use frequency bandwidths where the lower end of the frequency range is below 8Hz. The reason this is relevant is because, as noted in section 1.2. above, SMR is classified as 12-15Hz (Doppelmayr & Weber, 2011), beta as 13-30Hz and theta as 4-8Hz (Heinrich et al., 2007). This means that what some studies are calling the alpha band may actually, as Ancoli and Kamiya (1978) have previously pointed out, incorporate frequencies which others would classify as being part of other distinctly separate bands leaving a question mark as to whether it is true alpha being trained in some of the alpha neurofeedback studies. This is important because adjacent frequency bands do not necessarily behave in the same way and may, in fact, show opposing patterns (see for example, Klimesch, 1999) so employing a protocol that reinforces participants for increasing alpha and for increasing their upper theta for example may be counterproductive as it may be reinforcing two different patterns of brain activity, each of which potentially having a countering effect on the other. In fact Knox (1980) explicitly stated that the reason she chose 8-12Hz as the frequency bandwidth was because she wanted to decrease the likelihood of training beta as well as alpha. Justification as to why a particular bandwidth outside of the traditional alpha frequency band has been chosen, however, is rare.

On a related point, it is not just the specific upper and lower limits of the frequency band used which varies between studies. It is also the width of that range. Excluding studies which divide alpha into a number of sub-bands (see section 3.1.3., below) for training, the width of the frequency range (i.e. the number of Hz between the upper and lower limits defining the frequency bandwidth) used to define alpha vary from 1.5Hz (Bridgwater, Sherry, & Marczynski, 1975) to 8Hz (Brown, 1970) although the most commonly used widths comprise 5Hz (n = 40 studies) and 4 Hz (n = 19 studies). Again, the decision as to why a particular width, as with the precise frequency range itself, has been chosen is not something commonly reported in the literature. The choice is usually arbitrary (Kaiser, 2002) but again is important because it may mean what participants are learning to train via neurofeedback in one study is not the same as what is being trained in another. For example, Vernon and Withycombe's

(2006) study looked at the effect enhancing alpha had on participants' mental rotation ability. During the neurofeedback session participants were asked to enhance alpha whilst suppressing their surrounding beta and theta waves. They defined alpha as 8-12Hz, theta as 4-7Hz, and beta as 13-20Hz. In contrast, Brown (1970) had her participants train to enhance their alpha using an alpha frequency bandwidth of 7-15Hz. This means that although both of these studies were purporting to be enhancing alpha, Brown (1970) was actually training her participants to enhance frequencies which Vernon and Withycombe (2006) were getting their participants to suppress. Again, this is problematic in trying to establish whether any differences in the results of studies (either in ability to learn to consciously alter their alpha via neurofeedback or on the effects on cognition, behaviour, etc.) are due to training alpha or due to training other frequencies (Knox, 1980). It also makes it difficult to establish whether or not discrepancies found between the results of the studies in the area are due to the differences in what it is the researchers mean by 'alpha', differences in some other aspect of the methodology, or to a combination of both.

3.1.2. Individual Alpha Frequency Band

Although the majority of the alpha neurofeedback literature uses the same frequency band for each participant, there is a growing number of researchers who have started using alpha frequency bands which are individually tailored to each participant. This is in both the literature looking at training alpha via neurofeedback specifically (e.g. Zoefel et al., 2011) and in the literature regarding alpha waves themselves (e.g. Klimesch, 1999). Klimesch (1999) states that the alpha frequency varies amongst individuals depending on their age, memory abilities, and other tonic (i.e., long-term aspects of neurology as opposed to phasic aspects which alter in relation to the task) aspects of the brain so therefore when doing research the frequency bands should be tailored accordingly to each individual. Bazanova and Aftanas (2008c) suggest that using traditional bandwidths which do not take into account individual differences in those bandwidths may not be as effective. Additionally, Klimesch (1996) suggests that using fixed frequency bands may mean that cognitions which are linked to alpha may not be able to be detected due to, he says, nearly a third of individuals having an alpha frequency bandwidth which differs by 2Hz or more from the traditional alpha frequency bandwidth. To illustrate this point, Kaiser (2002) conducted a study on 124 adults in order to examine the distribution of their dominant eyes-closed peak-alpha frequency (the single frequency in the alpha range which has the highest amplitude [Angelakis et al., 2007]) distribution. He found that although more than 95% had a peak alpha frequency which fell somewhere between 8 and 12 Hz this still meant that 5 % did not and so it follows that any alpha neurofeedback training they received would actually involve training something which was not alpha if traditional fixed frequency bands were used. Hanslmayr et al. (2005) support this viewpoint, hypothesising that the effects found by studies looking at the effect of neurofeedback training of the SMR frequency band (e.g., Vernon et al., 2003) may actually have done so because of the influence of the alpha waves rather than because of their SMR. In other words, the participants may have had higher individual alpha than the traditional fixed frequency bandwidth meaning that the bandwidth they were actually training was alpha rather than SMR.

There has yet to be any research in the optimal performance field directly comparing the effectiveness of alpha neurofeedback when using fixed frequency bands versus when using individual alpha frequency bands, although Bazanova and Aftanas (2006b) did report clinical evidence that suggested that individual alpha frequency neurofeedback was more effective. They used both traditional and individual alpha frequency (IAF) on two patients, one with Attention Deficit Disorder (ADD) and one with what they described as 'functional pain contraction'. Although they do not give specific details they report that IAF neurofeedback showed an improvement in symptoms whereas traditional alpha frequency band neurofeedback training did not and did, they state, worsen the patients' symptoms. However, it is unclear what the rationale for using alpha neurofeedback to treat these patients was. Further, given that the aim of the training was to enhance alpha as well as decreasing theta and beta the results could plausibly have been the effect of suppressing the surrounding individual frequencies rather than due to increasing their individual alpha. Although raising some interesting hypotheses for testing, this study also does not necessarily say anything about the use of neurofeedback on non-clinical populations. It is interesting to note, however, that 7 of the 11 studies listed in Table 1 which have presented results suggestive of alpha neurofeedback having an effect on cognition, have been ones which have used individual alpha as the training frequency. Given that they also happen to be, for the most part, the most up to date studies in the list, however, it could be argued that a general improvement in technology and/or evolution in the refinement of methodology in the last 25-30+ years could be responsible for this disproportionate weighting towards the IAF studies rather than training of the IAF over the traditional frequency band per se.

As with traditional bandwidth training, however, care still needs to be taken when comparing results from studies utilising individual alpha frequency bands as to how those individual bandwidths are defined. Klimesch (1999) defines the IAF as between 3.5-4Hz below and 1-1.5Hz above each person's own peak alpha frequency whereas Klimesch, Schimke, and Pfurtscheller (1993) and Hanslmayr et al. (2005) define it as a bandwidth of between 2Hz above and 2Hz below each individual's peak alpha frequency. Contrastingly, Woodruff (1975) individualised her participants' alpha frequencies by getting them to train between 1Hz above and 1Hz below their own modal alpha frequencies (the alpha frequency which they spent the most time at during a four minute baseline recording). The reason these differences in how the IAF is measured may be problematic are the same as the reasons for why the differences between fixed frequency alpha band training studies may be problematic. Namely, if different frequencies are being used we cannot be sure that 'alpha' training is a meaningful term.

In addition, Kaiser (2002) has argued that even if alpha is individualised to each person the range of the bandwidth itself is still artificial and states that that should also be individualised too. Some individuals, he explains, may have an individual alpha bandwidth of 5Hz but others may only have one of 3Hz. His solution is to look at the difference in strength between participants' alpha when they have their eyes closed to when they have their eyes open and use a frequency range which falls within 2-3 standard deviations of that. The reason he suggests using the difference between eyes open and eyes closed is because alpha is distinctive by the fact that it increases in amplitude when participants go from an eyes open to an eyes closed state. This is supported by Bazanova and Aftanas' (2006a) method for calculating individual alpha, whereby they compare the spectral power of their EEG during eyes open conditions to the spectral power of their EEG during eyes closed conditions.

The individual alpha neurofeedback training undertaken by Angelakis et al. (2007) gets round this problem of how wide to set the bandwidth by getting participants to train their individual peak alpha frequencies rather than an individual band but Klimesch (1996) argues that use of a single discrete frequency rather than a frequency range is a less representative way of capturing alpha.

In summary, whilst it has been suggested that individualising the alpha frequency band for each person may be a more useful way of conducting neurofeedback training than using fixed frequency band training there is currently a lack of empirical research in the area to support this. In the meantime, however, the use of IAF neurofeedback training still holds the potential for having the same problems when trying to compare the results of studies unless a standardised way of calculating the individual alpha frequency range and the width of the alpha frequency band is used.

3.1.3. Sub-bands of Alpha

Alpha had originally always been thought of as a single fixed frequency band, but there is an emerging trend to think of alpha as comprising a number of functionally different sub-bands (e.g. Zoefel et al., 2011). Moore et al. (2008) talk of two sub-bands, low alpha which resonates at 8-10Hz, and high alpha, which resonates at 10-12Hz. Cremades and Pease (2007) also talk of lower and upper alpha, but put lower alpha at 8-10Hz and upper alpha at 11-13Hz. In the alpha neurofeedback literature specifically, Krenn et al (in review) also treat alpha as two separate sub-bands but base them on the IAF, such that upper alpha frequency range for each participant was located between IAF and IAF + 2Hz and lower alpha was classified as being between IAF and IAF – 4Hz. The justification that they give for this is that they are following Klimesch's (1999) definition although as it happens Klimesch (1999) reports the alpha frequency band as being between IAF and IAF + 1/1.5Hz (upper alpha) and IAF and IAF – 4Hz (incorporating two further sub-bands, lower alpha 1 and lower alpha 2). Zoefel et al. (2011) also based their division of alpha in to sub-bands on each individual's own EEG but although they used the same classification for upper alpha as Krenn et al. (in review), they classified lower alpha as being from IAF – 1Hz to IAF – 3Hz although what their rationale for doing this is not stated.

Even in studies which agree on the division of alpha into sub-bands rather than treating it as one single band, however, there is disagreement as to how many sub-bands to divide it in to. The above mentioned studies used 2 but those such as Aftanas and Golocheikine (2001), Doppelmayr et al. (2002) and Klimesch (1999) talk of alpha as comprising of 3.

The division of alpha in to sub-bands at all is based on research suggesting that upper and lower alpha behave in a different manner and represent functionally distinct things (Cremades & Pease, 2007). With regards to the alpha bands behaving in a different manner, Zoefel et al. (2011) argue that it may be the case that both upper and lower alpha do the same thing but that they need to be trained differently because they do so in different ways. They hypothesise that the optimisation of cognitive performance can be obtained by the enhancement of upper alpha and the suppression of lower alpha.

In terms of the effects of training upper and lower alpha separately using neurofeedback, not many studies have compared using neurofeedback to train both. Usually, they pick one or the other. For instance Hanslmayr et al. (2005) showed an improvement in the mental rotation abilities of participants who trained their upper alpha (IAF to IAF + 2Hz); the amount of improvement on the mental rotation task correlated with the ability to increase their upper alpha via neurofeedback. In other words, the better the participants were at enhancing their alpha via neurofeedback, the larger the improvement on their mental rotation task. No training was given on lower alpha or whole band alpha training, however, so it is unclear whether the same effects would have been seen for people enhancing lower alpha or the alpha band as a whole.

Similarly, a study by Schauerhofer et al. (2011) also focused on the training of just the upper alpha band via neurofeedback although their results suggested a link to attention. It was not stated, however, what the criteria were for defining 'upper alpha' so it is unclear whether they were using the same criteria as Hanslmayr et al. (2005). It is also not stated which location(s) of the brain the training took place so says nothing about whether upper alpha relates to both mental rotation and attention regardless of scalp location or if upper alpha in some parts of the brain correlate with mental rotation and upper alpha at other scalp locations relate to attention.

One alpha neurofeedback study which did incorporate both upper and lower alpha in to their training was Krenn et al. (in review). They found that lower alpha was linked to recall in semantic memory whereas upper alpha was not, suggesting a functional distinction between the two. This is interesting, particularly when paired with the above mentioned findings by Schauerhofer et al. (2011) showing a link between upper alpha and attention because, as discussed earlier, research discussed in Klimesch (1999) contrastingly suggested that it is upper alpha which is linked to semantic memory and lower alpha which is linked to attention.

In sum, whilst there is evidence that it is possible to separate alpha in to separate bands and that training the bands separately may have an effect on some aspects of cognitive performance, the precise number of sub-bands, how they are defined, and the effects they may have when trained via neurofeedback have not yet been clearly established. Direct comparisons between lower alpha, upper alpha, and whole band alpha would also seem to be advisable in order to see if dividing the alpha band up in to separate components produces anything extra that keeping them as one single band does not. It would also help address the hypothesis that upper and lower alpha are functionally distinct because whilst there is some evidence to suggest that they are, differences amongst the results and the methodologies of existing studies mean that that is as yet still inconclusive.

3.1.4. Threshold Criteria

The aim of alpha neurofeedback is for the individual to learn to be able to exert a conscious control over some aspect of their alpha brain waves. In order to do this their aim is to increase (in the case of enhancement training) some aspect of their alpha (usually the amplitude and/or percentage of time spent over the required threshold of alpha, see section 3.7, below). In order to do this the individual is usually given the goal of trying to increase/decrease their alpha over/under a particular threshold. Learning how to achieve this thus enables them to learn to consciously influence their alpha. It is the crossing of this threshold in the desired direction (see section 3.3) that the studies talking about being 'in' or 'out' of alpha are referring to (e.g. Strayer, Scott, & Bakan, 1973). For instance, if the goal of training is for the individual to increase the amplitude of their alpha to over 10µv then if the study talks about the amount of time spent 'in' alpha then they mean the amount of time that the individual spends over that 10µv threshold.

However, as can be seen from Table 3, below, what the threshold is actually set at varies greatly amongst the alpha neurofeedback studies and therefore what one study means when it refers to a participant being 'in' alpha is rarely what is meant when another does so. For instance, Markovska-Simoska et al. (2008) set their feedback tone so that it would be elicited 60% of the time meaning that it varied for each individual and was adjusted throughout the course of each individual's training sessions. In contrast, Cho et al. (2008) set the feedback tone for their participants' eyes closed enhancement training to 70% of their mean eyes closed baseline and Holmes, Burish and Frost (1980) set their participants' thresholds to 10µv for each participant irrespective of their baselines or performance during training.

Even amongst the studies using similar methods to set their thresholds (i.e., an arbitrary amplitude versus participants' performance during training versus participants' own individual baselines) there still exists a wide variation. For instance, of the studies adjusting thresholds throughout the course of training, Allen, Harmon-Jones, and Cavender (2001) set the thresholds so that they would occur 20% of the time whereas London and Schwartz (1984) set the threshold so that feedback would occur 50% of the time and Markovska-Simoska et al. (2008) set the threshold so that the feedback would occur 60% of the time. With regards to studies basing the thresholds during training on participants' own baselines, some use a particular percentage of the participants' mean baseline amplitude (e.g., Cho et al., 2008) whereas others set the threshold at the level at which participants spent at a particular amount of time at during their baselines (e.g., Cram, Kohlenberg & Singer, 1977). Those studies who set their threshold at the same specific amplitude for all the participants range from using thresholds of 10 µv (e.g., Valle & Levine, 1975) to 40 µv (Ancoli & Green, 1977) with the most common being 10 µv (n = 11 studies), 15 µv (n = 10 studies) , and 20 µv (n= 9 studies).

Table 3

The threshold criteria used in the alpha neurofeedback literature for which participants were asked to increase/decrease their alpha over/under.

Threshold Used	**Number of Studies**
10 µv	11
15 µv	10
20 µv	9
29 µv	1
40 µv	1
20% baseline amplitude	1
25% eyes closed baseline	6
50% mean baseline amplitude	4
70% of mean eyes closed amplitude	1
80% baseline amplitude	1
Mean of baseline	4
10% maximum eyes closed baseline	1
1/3 maximum eyes closed baseline amplitude	1
2/3 maximum eyes closed baseline amplitude	1
1/3 mean peak amplitude	1
Level at which they were at 20% of the time during their baseline	1
Level at which they were at 25-35% of the time during their baseline	1
Level at which they were at 40% of the time during their baseline	2

Level at which they were at 50% of the time during their eyes open baseline	3
5 consecutive cycles of mean baseline amplitude	1
3 'consecutive cycles of alpha'	1
Set so the feedback tone was on 20% of the time	1
Set so the feedback tone was on 50% of the time	1
Set so the feedback tone was on 60% of the time	1
Unspecified/Unclear	33

The reason that such differences in threshold settings may be problematic was demonstrated by Knox (1980). She found that during a 10 minute recording of participants' alpha (8-12Hz) waves, 65% of participants spent less than 25% of their time exceeding a threshold of 15 µv. She therefore argues that differences in the way thresholds are set means that there is a potential for losing data because data included in some studies are excluded from others. It is for this reason that Travis, Kondo and Knott (1975) argue that comparison of studies utilising different thresholds is therefore unwise. For instance, using two groups of participants whose pre-training alpha amplitude each average at around 10 µv as an example: If one group participated in a study where the goal is to increase the amount of time they spend over a threshold of 10 µv and the other took part In a study where the goal is to increase the time spend over a threshold of 40 µv then even if both groups increase their average alpha three fold (i.e. to 30 µv instead of their usual 10 µv), their success may be rated differently depending on the study they took part in. The first group would be considered to be successful at enhancing their alpha but if the second group did not actually spend more time exceeding 40 µv then even though they had actually increased their alpha by three times more than before they started training, there is a danger that the second group would be considered to be unsuccessful (see section 3.7, below).

On a related point, it is difficult for an individual to learn if they are getting constant feedback or, contrastingly, if they receive very little (Hord & Barber, 1971) so it is important that the threshold at which participants receive feedback is set at a level which means they are receiving enough to work out what it is which is causing the feedback (Knox, 1980; Vernon et al., 2009). Knox (1980) recommends that thresholds are therefore set based on empirical/theoretical evidence although Vernon et al. (2009) point out that, as yet, very little of this type of evidence actually exists in relation to optimum feedback thresholds.

In sum, the threshold criteria used as the goal at which participants are to enhance their alpha over and/or suppress their alpha under shows great variation amongst the alpha neurofeedback literature. This again makes comparison of the studies' results difficult because it is unclear the extent to which the success of the training (i.e. participants' ability to learn to exert a conscious control over their alpha waves, see section 3.8 and 3.9) is dependent on the thresholds the participants are given. As yet there is no empirical evidence as to what would be the most optimal thresholds to use (Knox, 1980; Vernon et al., 2009). It seems beneficial, however, for a standardised way of setting thresholds to be attained in order to enable adequate comparisons between all future studies to be made.

3.2. Electrode Placement

As well as deciding how it is alpha is going to be defined, another important decision for neurofeedback training is how many electrodes to use (i.e., the training montage) and where those electrodes will be placed, i.e. which area or areas of the brain the training will take place at (i.e., scalp location). Issues relating to each of these will therefore now be discussed below.

3.2.1. Montage

Although the use of full cap neurofeedback training (i.e. neurofeedback training at multiple sites across the scalp) is plausible (Vernon & Dempster, in press) and there is now the potential for neurofeedback training utilising fMRI (e.g. Yoo, Lee, O'Leary, Panych, & Jolesz, 2008), the majority of neurofeedback training is undertaken using either a monopolar (aka referential) or bipolar (aka sequential) montage (Vernon & Dempster, in press).

A monopolar montage is where one 'active' electrode is placed on the scalp and the recordings from it are compared to a second 'reference' electrode (Fehmi & Collura, 2007) which is placed elsewhere, often the earlobe (Demos, 2005). The recording from the reference electrode is necessary in order to ensure any activity being picked up from the 'active' electrode which is not a result from the neurons firing underneath is not included. So the activity at the active electrode minus the activity at the reference electrode is thought to be a reflection of the brain activity at the active site (Fehmi & Collura, 2007) and it is that which is used to provide the feedback for neurofeedback training.

A bipolar montage, on the other hand, uses two active electrodes placed on separate sites on the scalp. The difference between the recordings taken from those two scalp electrodes is what the feedback provided is based upon (Fehmi & Collura, 2007).

Table 4

Type of montage use in the alpha neurofeedback studies reviewed.

Montage	**Number of Studies**
Monopolar	47
Bipolar	12
Multiple Monopolar	6
Multiple Bipolar	4
Symmetry/Assymmetry training	2
Unspecified/Unclear	11

As can be seen from Table 4, above, the most commonly used montage for alpha neurofeedback training is monopolar (n = 53 monopolar studies; n = 16 bipolar studies) although it is worth noting that whilst the majority of studies utilise just one monopolar montage (n = 47) for neurofeedback training or one set of bipolar electrodes (n = 12), there are some who ask their participants to simultaneously alter the activity of their alpha at multiple monopolar/bipolar electrode sites (n = 10). For instance, Hanslmayr et al. (2005) gave participants visual feedback for upper alpha (IAF) power at several separate scalp locations - F_3, Fz, F_4, P_3, Pz, and P_4 - and their task was to increase the alpha power at all of these sites. In other words the participants undertook monopolar training at 6 sites simultaneously.

Multiple bipolar training is also possible (n = 4 studies). For example, Markovska-Simoska et al. (2008) had participants enhance the alpha power of their upper IAF over sites F_3-O_1 (bipolar montage 1) and F_4-O_2 (bipolar montage 2) in order to examine the effects of alpha neurofeedback on musical performance.

Whilst both monopolar and bipolar training have been shown to be effective methods for conducting neurofeedback, Putnam (2001) states that the effect on the brain is different depending on which montage is used. Monopolar training is thought to train the synchronisation and desynchronisation of alpha activity directly under the active scalp electrode whereas Putnam (2001) points out that bipolar training is a reflection of what is happening between the two active sites once any similarities have been removed and points out that therefore the more in synchrony two sites are the closer the data is to zero. It can therefore be argued that the focus of bipolar training is more to do with desynchronisation than synchronisation. So whilst changes in alpha seen during monopolar training are a reflection of changes at the active scalp electrode, the changes in alpha seen during bipolar training could be due to a number of possibilities. They could be a result of changes in active electrode 1, active electrode 2, a change in both at the same time, or a change between them, and Lubar (2001) therefore hypothesizes that bipolar training offers more potential for learning due to the larger number of possibilities for producing a change in alpha.

On the other hand, Rosenfeld (2000) argues that this potential range of reasons for a change in alpha during bipolar training is actually disadvantageous because it makes it then unclear where the changes are occurring (i.e. at one scalp location, at both, or somewhere on the path between the two). Lubar (2001) points out, however, that this problem can be remedied by setting the equipment up so that it is possible for the researcher to see what is happening at each site and under an electrode placed in-between.

An additional disadvantage to bipolar training has been purported by Fehmi and Collura (2007) who argue that because bipolar training is more likely to train out-of-phase activity (i.e. non-synchronous) it is therefore less likely to produce the kind of training effects that are the goal of optimal performance training (e.g. an improvement in some aspect of cognitive ability) than training in phase activity. They add that multiple site monopolar training would be a better alternative to bipolar training in order to remove the possibility of ambiguity.

There does not appear to be any empirical research directly comparing the effectiveness of the two types of montage although Plotkin (1978) did show that there was a positive correlation between the amplitude of alpha when using bipolar training at 0_2-F_4 to the amplitude of alpha produced at Oz. Whilst this could be taken to suggest that it does not matter which montage is used as they produced similar results it would arguably have been more appropriate to compare the bipolar training at 0_2-F_4 with monopolar training at 0_2 and monopolar training at F_4 for a more direct comparison. As it happens those training at Oz showed greater increase in their alpha within sessions (see section 3.8.2. below) than those who received the 0_2-F_4 training but Plotkin (1978) attributes this to the participants being less successful at alpha enhancement in session 1 and more successful in session 10 than the 0_2-F_4 participants rather than because of any consistent differences.

Either way it is still unclear whether monopolar or bipolar training are comparable forms of neurofeedback training or whether one is more optimal for neurofeedback training (Vernon, Frick, & Gruzelier, 2004). It also remains a possibility that the most effective montage may depend on the site(s) being trained (Vernon, 2008). Until these questions have been answered, comparisons of the results of studies utilising one montage with those utilising another are arguably inadvisable because they may not actually be comparing the same thing.

3.2.2. Scalp Location

As can be seen from Tables 5 and 6, the most common scalp locations used in the alpha neurofeedback studies are O_1- P_3 (n = 9) and O_2- P_4 (n = 8) for the studies using a bipolar montage for training and position Oz (n = 22 studies) for those using a monopolar montage. Occipital scalp locations are in fact the most commonly used in both the monopolar studies (n = 44) and the bipolar studies (n = 36) with parietal locations being the second most commonly used (n = 18 for the monopolar studies; n = 17 for the bipolar). Justification for a particular scalp location(s) is rarely given, although alpha is known to be particularly dominant in parietal (Hanslmayr et al., 2005) and parietal-occipital (Danko, 2006) sites, so that may be a contributing factor. Also, Krenn et al (in review) have pointed out that parietal electrodes are less likely to pick up artefacts (such as muscle movement, muscle tension and eye blinks, all of which interfere with EEG readings) so that may be another reason why these sites are the most common choice.

Plotkin (1976a, 1978), Hardt and Kamiya (1978) and Ancoli and Kamiya (1978) have all pointed out that training at one scalp location may not be the same as training at another, either in terms of ability to train or effect on cognition/behaviour. Therefore, trying to compare the results of studies using alpha neurofeedback at one scalp location may not be comparable to those using others. As an example, Cremades and Pease (2007) found that there was a positive correlation between lower alpha and visual imagery at parietal sites and that there was a negative correlation between lower alpha and visual imagery at occipital sites. It would thus follow that attempts to use neurofeedback training to try and enhance a person's visual imagery abilities would require them to train to increase their lower alpha if they were training at parietal sites but to decrease their alpha if the electrodes were placed over occipital sites.

Table 5

Scalp location used for monopolar alpha neurofeedback training in the literature reviewed (see Appendix A)

Scalp Location	**N^{o} of Studies**	**Scalp Location**	**N^{o} of Studies**
C_3	2	Non-specific left occipital	2
C_4	2	Non-specific right occipital	1
Cz	1	Non-specific occipital	2
F_3	2	POz	2
F_4	1	P_3	2
Fz	2	P_4	6
O_1	3	Pz	7
O_2	10		
Oz	22		

On a related point, Klimesch (1999) advocates the use of defining alpha individually for each scalp location as well as for each person due, he says, to alpha frequencies behaving differently depending on scalp location. For instance, the alpha frequency being higher at the back of the head than it is at the front (Klimesch, 1999).

Table 6

Scalp location used for bipolar alpha neurofeedback training in the literature reviewed (see Appendix A)

Scalp Location	**N^o of Studies**	**Scalp Location**	**N^o of Studies**
C_3- Cz	1	O_1- O_2	1
C_3-Oz	1	O_1- O_3	1
Non-specific occipital central	1	O_1- P_3	9
Non-specific occipital frontal	1	O_2- P_4	8
F_3- O_1	1	O_2- T_6	1
F_4- O_2	1	O_1- T_3	3
F_4- Oz	3	O_2- T_4	1
Unspecific occipital	2	T_3-T_4	1
Unspecific parietal occipital	1		

A study by Nowlis and Kamiya (1970) did suggest that the ability to train alpha itself, as opposed to the effect on cognition/behaviour due to the training, may not be a function of scalp location. When they conducted both enhancement and suppression bipolar training at right occipital parietal versus frontal-occipital sites they found no significant differences in participants' ability to train their alpha at either. However, they based their results on one 2 minute enhancement trial and one 2 minute suppression trial and the amount of training each participant received totalled 15 minutes or less. Whether this is an adequate amount of time to learn in in order to be drawing conclusions about training ability, then, is questionable and it would be interesting see if a study where participants were given a larger number of sessions and a greater amount of time to learn in would produce different results (an issue which is discussed in section 3.6, below).

In sum then, whilst occipital and parietal scalp locations are by far the most commonly used sites for alpha neurofeedback training regardless of montage, there is nonetheless a wide variety of locations utilised with rarely any rationale why studies chose the ones they did. Given the suggestions that training at one scalp location may produce a differential effect on both training ability and outcome of training, caution is therefore needed in attempting to examine the results of studies which have differed in their choice of scalp locations at which they trained alpha.

3.3. Enhancement versus Suppression versus Both

When using neurofeedback it is possible to learn to consciously enhance alpha (e.g., Hanslmayr et al., 2005) and to learn to consciously suppress alpha (e.g., Jackson & Eberly, 1982). Very few of the alpha neurofeedback studies focus solely on suppression training, however (n = 2 studies), with the majority instead asking their participants to enhance alpha alone (n = 54 studies) (see Table 7, below). Only just over one third of the alpha neurofeedback studies reviewed incorporated both (n = 39 studies).

This is interesting given that Glaros (1977) stated that for neurofeedback training to be a success, individuals need to learn to suppress their alpha as well as to enhance it. This has been shown not to be the case, with many examples of participants learning to enhance their alpha without undertaking training to suppress it (e.g., Cho et al., 2008; Zoefel et al., 2011). However, Plotkin, Mazer and Loewy (1976) suggested that alternating between alpha enhancement and alpha suppression enables participants to get an understanding of what each direction feels like which therefore allows them to learn to exert a conscious control over their alpha more quickly.

Table 7

Number of studies training participants to either enhance, suppress, or both enhance and suppress some aspect of their alpha waves via neurofeedback training

Type of Training	**Number of Studies**
Enhancement Only	54
Suppression Only	2
Both	39
Unspecified	1

Although their study was on blood pressure biofeedback rather than neurofeedback specifically, Shannon, Goldman, & Lee (1978) make a pertinent comment in relation to this point. Specifically, that control arguably involves being able to make the desired response both appear and disappear. They argue that being asked to enhance then stop enhancing and suppress then stop suppressing demonstrates a conscious influence and also controls for the possibility that confounding variables, such as habituation (see section 3.7.3., below), are responsible for any changes seen rather than actual conscious control.

Of course, the appropriateness of enhancement versus suppression training depends on the reason the individual is undertaking neurofeedback training. For example, Cremades and Pease (2007) found that in the parietal lobe upper alpha is positively correlated with visual imagery and lower alpha is negatively correlated with kinaesthetic imagery. If an individual wanted to enhance their visual imagery abilities this suggests that they would need to train to enhance their upper alpha at parietal sites whereas it they wanted to enhance their kinaesthetic imagery abilities they would need to suppress their lower alpha at parietal sites.

Whether or not each type of training (i.e. enhancement versus suppression) is equally as achievable, or is a result of the same underlying mechanism(s), however, is another matter. Those such as Prewett and Adams (1976), Peper (1970), and Peper and Mullholland (1970) have suggested that alpha suppression may actually be easier than alpha enhancement. Indeed, there is some evidence to support this. Schwartz, Davidson and Pugash (1976) gave 20 participants 12 minutes of eyes closed training to keep alpha 'on' at P_3 and 'off' at P_4 and 12 minutes of eyes closed training to keep alpha 'off' at P_3 and 'on' at P_4. They discovered that in order to achieve this participants did so by suppressing alpha at the 'off' site rather enhancing it at the 'on' site. At first glance this could be taken to suggest that suppression may be easier to achieve than enhance. However, before they did their asymmetry training, participants underwent 12 minutes of symmetry training involving suppressing their alpha at these same two sites simultaneously. The use of suppression rather than enhancement to alter ratios of alpha in the asymmetry training may therefore merely reflect the fact that suppression was the method they needed to use to influence their alpha waves during the previous symmetry training. It would be interesting to see what would happen if the study was repeated but this time with participants training to keep P_3 and P_4 on in the symmetry part of the session rather than off.

DeGood, Elkin, Lessin and Valle (1977) also suggested that alpha suppression training may be easier to learn than enhance. Again, though, there are potential confounds related to the methodology which means caution needs to be used when interpreting their data. Firstly, the alpha threshold was set at 15 µv but there is no information on the mean amplitude participants produced during their baselines. If their average amplitude during baseline was lower than this and/or they spent most of their time below this threshold during their baseline then this would have resulted in them being given more feedback during their suppression trials than during their enhancement ones and therefore, arguably, more information for them to work from when suppressing their alpha. It is also interesting to note that in the enhancement condition participants had to keep the tone on whereas in the suppression condition participants had to keep the tone off. The results may well be a function of the feedback (i.e. perhaps turning a tone off is more conducive to training than turning it on) rather than the training direction itself (see section 3.5.2., below).

There are also those such as Plotkin (1980) who question whether alpha enhancement is even possible at all, although the debates in this matter come down to how it is successful enhancement is defined and what is considered to be an appropriate baseline against which to measure successful enhancement (see section 3.7.3.).

In contrast to the above, there are others who have presented evidence indicating that alpha enhancement may actually be more attainable than alpha suppression (e.g., Cram et al., 1977; Hord & Barber, 1971). For instance, Kondo, Travis, Knott and Bean (1979) found that although participants' integrated alpha (8-13Hz) was lower than baseline levels in the suppression group, alpha was not seen to decrease across the session whereas the enhancement group did show an increase in alpha and participants' self-reports revealed that they thought suppression was difficult. However, participants were only given one 40 minute session of either suppress or enhance training which may not be sufficient and, further, the suppression group did not actually realise that they were being given feedback for suppressing their alpha. They thought that the increase in the pitch of the tone indicated enhancing alpha and it was that which they had been asked to do. If they knew they were being trained to suppress alpha potentially they may have used different strategies and been more successful.

Hord and Barber (1971) likewise found evidence to suggest that enhancement may be easier than suppression with the percentage of alpha during enhance trails being significantly greater in both their training sessions than during baseline, whereas per cent time in alpha was only significantly less than baseline in the final session's suppression trials, not the first's. That said, participants received twice as much training in enhancement (a total of 32 minutes with feedback) than suppression (a total of 16 minutes with feedback which amounts to just 8 minutes in each session). The results are further complicated because participants did not all have the same thresholds. The aim was to adjust the thresholds individually for each participant to the level which occurred 20% of the time during baseline but the authors state that they had trouble getting this right for some participants. This resulted in some of the participants ending up with different thresholds to others (see section 3.1.4. for discussion of why this might be a problem) and they found those who ended up with more feedback did better at controlling their alpha.

Whether training in one direction is easier to learn than training in another, the discrepancies between the results of the studies which have attempted to investigate this thus far means that it is a question which still remains to be answered. Why these discrepancies even exist may be due to the methodological limitations discussed in the preceding paragraphs or to methodological differences between the studies. For instance, as already mentioned, Hord and Barber (1971) found evidence that enhancement training may be easier than suppression training whereas Peper and Mullholland (1970) found evidence to suggest the opposite. Hord and Barber's (1971) participants undertook eyes open monopolar training at position Oz whereas Peper and Mullholland's (1970) participants undertook eyes closed bipolar training at O_2- P_4. Based on these two studies it is plausible that eyes open training and/or a monopolar montage and/or training at Oz may be more conducive for enhancement training. Likewise it is plausible that eyes closed training and/or a bipolar montage and/or training at O_2- P_4 may be more conducive to suppression training. Once more, the methodological differences make comparisons difficult.

Individual differences may also be another source of variability in the findings thus far. It may be that some participants are more apt at suppression training and others at enhancement. This is a view put forward by several researchers such as Lynch and Paskewitz (1971) and Kuhlman and Klieger (1975) and has been shown to have some empirical support. For example, Kuhlman and Klieger (1975) found that participants with very high (close to 100% of time spent over the 20 µv threshold) or very low (although unclear what precisely they meant by 'very low', it was somewhere less than 24% of their time spent over the 20 µv threshold) baseline alpha (8-12Hz) did not manage to enhance their alpha but those with moderate (24%-55% of time spent over the 20 µv threshold) baseline alpha did. They suggest that this is because the high alpha baseline groups were receiving too much feedback to learn from and the low alpha groups too little.

Relatedly, regardless of the level the feedback is set at, Lynch and Paskewitz (1971) hypothesize that those with higher alpha may have a harder time suppressing alpha and those with low alpha may have a harder time enhancing it because their brains clearly, based on the higher or lower baselines, have a preference for being at a certain level. Regestein, Pegram, Cook and Bradley's (1973) study offers some support for this suggestion as the more time participants spent enhancing their alpha the harder they found it to stop.

The argument could, however, be made for the opposite. That is, participants who have particularly high alpha baselines may find alpha enhancement harder and those with particularly low alpha baselines may find alpha suppression harder due to what Vernon et al. (2009) describe as 'the notion of natural limits' (p221) and Valle and DeGood (1977) call 'the law of initial values' (p5). In other words, Vernon et al. (2009) elaborate, it may not be that alpha can be enhanced without limit, there is likely to be a maximum limit (and likewise a limit for how low alpha can be suppressed given that it would be impossible to suppress alpha to below 0µv). So the nearer participants already are naturally to that point when they start the harder they therefore may find it to reach it. Valle and DeGood (1977) therefore posit that those with high baselines would find suppression easier and those with low baselines would find enhancement easier as they have more 'room' to manoeuvre in. This is, however, as Vernon et al. (2009) point out, only speculative and more research would be needed to establish if there is a limit on the extent to which alpha can be enhanced/suppressed and whether that limit is similar for everyone or dependent on the individual's baseline.

There has also been the suggestion that individual differences amongst the participants may also interact with which type of training (i.e. suppression versus enhancement) is easier. Martin and Armstrong (1974) found that participants scoring high in tests of creativity were both better at suppression in comparison to the low creativity scorers and better at suppression than enhancement. However, it should be pointed out that participants were only classified as high and low scorers in comparison to each other not to the general population, in which context the 'high creatives' creativity scores would be classified as average or below average on one of the tasks. Also, participants only received one session with less than 10 minutes of enhancement training and less than 3 minutes of suppression. This raises the question of whether they received a sufficient amount to make judgements on (see section 3.6. for further discussion of this point).

Another variable which has been suggested to play a part in participants' ability to suppress their alpha is how anxious they are feeling at the start of training. Valle and DeGood (1977) found that those with low levels of pre-training anxiety were significantly better at suppressing alpha than those with high levels, although, as there was no significant enhancement seen, it is difficult to tell if any relationship between anxiety levels and training ability is exclusive to suppression or applies to training ability in general. In addition Valle and DeGood (1977) point out that, consistent with the findings from Martindale and Armstrong (1974), low and high scores are a function of their participants' scores in comparison to each other rather than in comparison to the general population. That is to say, 'high' and 'low' anxiety groups were actually high and low normal groups rather than high anxiety and low anxiety in general.

More recently, Konareva (2006) suggested that personality may account for differences in participants' ability to both suppress and to enhance alpha. He found that those who suppressed alpha had lower levels of self-control and were more likely to be irresponsible, disorganised and anxious and do less well in social situations. He theorised that those who were better at enhancement would therefore be the opposite - although did not actually test to see if this hypothesis were true. Additionally, participants only received one 3 minute session of neurofeedback training and whether these correlations between measures of personality and training ability would remain if participants undertook a more substantial amount of training would need to be investigated as such a short amount of training is not generally considered to be enough to draw conclusions from (e.g., Ancoli & Kamiya, 1978; Hardt & Kamiya, 1978. See section 3.6., below).

Even if it is not the case that one type of training (i.e. enhancement or suppression) is better than another there is still doubt as to whether participants' ability to train their alpha in one direction is correlated with their ability to train it in the other. Paskewitz and Orne (1973) state that it is unusual to find individuals who demonstrate the same ability to do both. Indeed, Regestein, Buckland and Pegram (1973) gave 5 participants 12 consecutive hours of alpha (8-13Hz) enhancement training and then a week later 12 continuous hours of alpha (8-13Hz) suppression training. What they found was that participants' ability to enhance their alpha in the first session did not predict their ability to suppress their alpha in the second. Whilst this would seem to support the idea that being able to control alpha in one direction does not mean a person can control it in the other, it should be noted that no significance tests seem to have been performed on the data to indicate whether participants were actually successful at alpha enhancement and/or suppression or whether the percentage of time spent in 'alpha' or 'non-alpha' was merely a reflection of their natural alpha levels. It is also unclear what Regestein, Buckland and Pegram's (1973) thresholds for being ‘in’ and ‘out’ of alpha were so it is unclear what exactly they mean by ‘alpha’ and ‘non-alpha’.

On the other hand, rather than there being no relationship between the two types of training in terms of each individual’s ability to train their alpha, Lynch Paskewitz, and Orne (1974) found that there was in-fact a negative correlation between the two. Participants who found enhancement easier reported finding suppression harder although participants received more enhancement training than they did suppression training so whether they would have said the same had they received an equivalent amount of training in both is unknown.

In summary, alpha neurofeedback can consist of training to either enhance, suppress, or both enhance and suppress the individual’s alpha waves. It has been suggested that incorporating both into the training is more beneficial for learning overall control (e.g., Plotkin, Mazer, & Loewy, 1976). Although it has been suggested that training alpha in one direction may be easier than training alpha in another, if true it is still unclear which is which because whilst there is research which indicates that enhancement may be the easier of the two (e.g., Hord & Barber, 1971), there is also opposing research indicating that suppression may be (e.g., DeGood, Elkin, Lessin, & Valle, 1977). It has been suggested that an individual’s ability to train their alpha in one direction is not necessarily indicative of their ability to train it in the other (e.g. Regestein, Buckland, & Pegram, 1973) and individual differences may mean that it depends on the person as to which they are more apt at (e.g., Konareva et al., 2006).

3.4. Eyes Open versus Eyes Closed Training

Once it has been established what is meant by alpha and whether the aim of the training is to enhance it, suppress it, or both the next logical step is to establish how it is the training is going to be conducted. One of the cardinal ways of distinguishing between the type of training which is possible is whether or not the training is conducted with eyes open or eyes closed. As can be seen from Table 8, the most common way to conduct alpha neurofeedback training is with eyes open (n = 45 studies) although there is nonetheless a fairly even split in the literature with 35 studies carrying out eyes closed training.

Table 8

Number of studies utilising eyes open versus eyes closed alpha neurofeedback

Type of Training	**Number of Studies**
Open	45
Closed	35
Both	6
Unclear/Unspecified	10

A more in-depth discussion of this can be found in Chapter 4 but to summarise, there is an assumption in some areas of the alpha neurofeedback literature (e.g. Prewett & Adams, 1976) that eyes closed training is the most optimal of the two for alpha enhancement due to the natural increase in alpha which occurs when eyes go from an open to closed position (Kaiser, 2002). Or perhaps more specifically due to the reduction in amplitude seen when eyes are opened. This has left some to refer to eyes open conditions as being an alpha blocking state (e.g. Hardt & Kamiya, 1976b). This same reasoning has, however, been used to suggest that, in fact, eyes open conditions may be advantageous to alpha enhancement (and by the same logic therefore, presumably, eyes closed conditions to alpha suppression) due to ‘the law of infinite values’ (Valle & DeGood, 1977, p5) and the subsequent larger amount of potential for enhancement between the initial starting point (i.e. the participants’ natural levels of alpha) and the maximum potential abundance (Travis, Kondo, & Knott, 1974a, 1974b, 1974c).

Whilst arguments have been put forward for each as the more optimal method of training there is no definitive evidence either way. It is also unclear whether the ability to train with eyes closed is, as Chisholm et al. (1977) indicate, correlated to an individual’s ability to train with eyes open or, as put forward by Travis, Kondo and Knott (1974b), they are not.

Until these questions have been answered the advice not to compare studies undertaken in one condition to studies undertaken in another (e.g. Ancoli & Kamiya, 1978, 1979) seems wise. Otherwise it is hard to know if discrepancies between the results of each are due to training with eyes open versus training with eyes closed or due to something else entirely.

3.5. Feedback

Once alpha has been defined and the type of training has been established (i.e. enhancement versus suppression versus both; eyes open versus eyes closed) it follows that the next stage is to decide how the training is going to be conducted. One element of this is choosing the type of feedback the individuals will receive.

As explained previously, neurofeedback allows the participants to receive feedback, in real time, of their alpha activity. The aim of this feedback is to make the participant aware of when the desired aspect of their alpha activity (e.g.

amplitude) increases/decreases thus in turn enabling them to attempt ways at influencing this themselves so they can learn to alter their alpha in the desired direction at will. The decision regarding the form this feedback takes, then, is arguably an important one.

When discussing the type of feedback used for neurofeedback training there are two broad categories. Firstly, the sense modality that the feedback is aimed at (i.e., eyes or ears) with 3 types used: audio, visual, and audio-visual. Secondly, whether the feedback is set to occur only when the desired threshold of alpha is attained or whether it is given continually but varying in time with the activity of the individual's alpha. Each of these two broader categories will therefore be discussed in turn.

3.5.1. Audio versus Visual versus Audio-Visual Training

Neurofeedback training can be conducted using visual (e.g. Schauerhoffer et al., 2011), audio (e.g. Cho et al., 2008), or audio-visual (e.g. Angelakis et al., 2007) feedback. As can be seen from Table 9, below, audio feedback is by far the most common type of feedback used in the alpha neurofeedback literature studies reviewed (n = 68). Visual is the second most common (n = 17), and audio-visual is the least (n = 9).

A more in-depth discussion of this topic can be found in Chapter 5 but to summarise, whilst there is evidence from the general biofeedback literature that visual feedback is the more useful type of feedback (e.g. Lal, et al., 1998), O' Connell, Frerker, & Russ (1979) showed that it depends on the type of biofeedback conducted (i.e. EMG versus blood pressure versus heart rate biofeedback . . .) as to which type of feedback is more effective. This is particularly pertinent given the argument by some that visual feedback has a suppressing effect on alpha brainwaves (e.g. Mullholland, Goodman, & Boudrot 1983) (which one would presume, would be something which is irrelevant to biofeedback of other physiological responses such as blood pressure or heart rate).

Table 9

Type of feedback modality used in the alpha neurofeedback literature

Type of Feedback	**Number of Studies**
Audio	68
Visual	17
Audio-Visual	9
Unspecified	3

To date, very few studies have researched whether there is an optimal difference between one type of feedback modality over another and there appears to be no research comparing the three directly with regards to alpha neurofeedback training. Of the studies which compare two, Breteler, Manolova, de Wilde, Caris, & Fowler (2008) failed to find any difference between amplitudes produced during visual compared to audio-visual SMR neurofeedback training. Also Lynch et al. (1974) compared audio to visual alpha (8-12Hz) neurofeedback training but failed to find evidence of learning meaning conclusions regarding the efficacy of one versus the other could not be drawn.

In sum, to echo the advice of those such as Vernon (2005), whilst there is a suggestion that whether audio, visual, or audio-visual feedback is utilised has been hypothesized as making a difference to the efficacy of training (e.g. Travis et al., 1974a), research is needed providing a direct comparison between the three types of feedback in order to establish whether or not this is the case.

3.5.2. Contingent versus Continual Feedback

Whether the feedback from participants learning to control their alpha with neurofeedback is auditory, visual, or audio-visual, there are two main ways in which the feedback can be presented to the participants. It can either be presented continuously, varying as the participants' alpha varies (known as continual or continuous proportional feedback), or the feedback can be set so that it only occurs when the participants' alpha is at a desired threshold (contingent, binary or discrete feedback). For example, Mullholland, Boudrot and Davidson (1979) used coloured slides which only appeared on the screen when participants' alpha reached a desired threshold. Similarly, Cho et al. (2008) set their participants' feedback so that a tone was emitted from the computer every time the participants' alpha exceeded threshold. These are examples of contingent visual and contingent audio feedback respectively. Examples of continuous feedback include varying the size of a bar on the screen as a function of alpha amplitude (e.g. Potolicchio, Jr, Zukerman, & Chernigovskaya, 1979) or the computer emitting a continual tone which varies in volume (e.g. Plotkin & Rice, 1981) or pitch (e.g. Fell et al., 2002) as alpha increases and decreases. It is possible to provide both types of feedback simultaneously, however. For instance, both Vernon and Withycombe (2006) and Dempster and Vernon (2008) provided their participants with continual visual feedback and contingent proportional audio feedback. In both studies, participants were presented with a moving bar on the computer screen which increased or decreased in height according to alpha amplitude. When the amplitude of alpha exceeded threshold, the bar changed from red to green. The contingent audio feedback was a tone which occurred only when the amplitude of participants' alpha exceeded threshold, with the pitch of the tone increasing the further over threshold their alpha went.

As can be seen from Table 10, below, contingent feedback is the most commonly used in the alpha neurofeedback literature (n = 57 studies) although that still means that approximately a third of the alpha neurofeedback studies use continuous feedback (n = 35).

Training success has been reported using each but there are those such as Tyson (1982) who postulate that the type of feedback used may affect the success of training. Both Kamiya (1979) and Ancoli and Kamiya (1978, 1979) have stated that continuous proportional feedback is better than contingent although their evidence is anecdotal rather than empirically supported. Plotkin (1976a), too, has also stated that proportional feedback is the most preferable due to the distractive nature of contingent feedback. He explains that a tone which occurs discretely is more distracting than one which is continuously present, and adds that the appearance of the feedback may itself have a suppressing effect on participants' alpha. Mullholland et al. (1983) suggest that this is particularly pertinent in relation to visual feedback, due, they say, to the suppressing effect visual stimuli has on alpha meaning that the sudden appearance of visual feedback will therefore cause a suppression in alpha.

Table 10

The type of feedback used in the alpha neurofeedback studies reviewed

Type of Feedback	**Number of Studies**
Contingent	49
Contingent Proportional	8
Continual	35
Intermittent Score Included	7
Unspecified/Unclear	11

There is some evidence to support the idea of contingent feedback being more of a distraction than a help during neurofeedback training. Kuhlman and Klieger (1975) demonstrated that although a tone which indicates the presence of alpha (with alpha being defined as a threshold of 20μv and above) showed an increase in alpha over the session, alpha did not actually exceed baseline (baseline being the amount of alpha participants produced when at rest). When the feedback was reversed so that the absence of the feedback tone instead meant the presence of alpha, participants exceeded baseline levels. They did not, however, show any further increase over trials and given that the results are only based on one session (see section 3.6.3.) and that the baseline was taken a week earlier than the training (see section 3.8.2.), any conclusions from this study would be limited. Their results also contradict that of Hord and Barber (1971) who found no significant differences between conditions where the feedback tone indicated the presence of alpha to those where the feedback tone indicated its absence. However, the absence of a bandwidth definition and threshold information makes it difficult to know what it is they mean by the presence, or not, of alpha. Further, the measure Hord and Barber (1971) used for the analysis of the difference between feedback conditions was per cent time in the enhancement condition minus per cent time in the suppression condition as an indicator of the level of alpha control between feedback conditions. Although using per cent time as the measure and treating enhance and suppression conditions separately produced significant results, that is, suggested significant evidence of learning, combining both to make one score showed no reliable evidence of learning when compared to no-feedback conditions. Given that using the combined score indicated no significant evidence of learning, using it to compare the two feedback conditions is perhaps unwise, because while the non-significant result here could mean there is no difference between using a tone to indicate alpha and using it to indicate no alpha, it could also be because no significant evidence of learning was found, in which case reliable conclusions cannot be drawn.

The idea that continuous feedback may be more effective for neurofeedback training than contingent has some support in the general biofeedback literature. Shannon et al. (1978) found contingent feedback to be more effective when trying to exert a conscious influence on blood pressure than did continuous feedback. However, the way Shannon et al. (1978) set their feedback up meant that there was a time lag between participants' physiological responses and the feedback they got about those responses. This time lag was the shortest for the group getting the contingent feedback so it may have been this which made the difference rather than the way the feedback was presented.

Travis, Kondo and Knott (1974b) hypothesise that the reason continuous feedback may provide an advantage over contingent feedback is because it provides more information. Rather than waiting until the participant reaches a desired threshold before occurring, and thus giving no indication of what the participants' alpha has been doing in the meantime, continual proportional feedback means that the participant knows whether their alpha is decreasing or increasing regardless of whether they have crossed the required threshold or not. Interestingly, Travis et al. (1974b) have also hypothesized that it may actually depend on the type of training being given as to which is the most effective type of feedback. Specifically, they suggest that continual feedback may be better for eyes closed training and that contingent feedback may be better for eyes open. Research would be needed, however, to establish if this is a hypothesis which can be empirically supported.

Regardless of whether feedback is continuous or contingent, it has been suggested that including a scoring system in addition to the feedback would help improve participants' performance. Hardt and Kamiya (1976a) explain that using a scoring system helps to motivate participants and helps to keep them on task and alert. They add that it is not always easy for participants to judge their own performance from one minute to the next but a score gives them something to measure their performance against. As Table 10 (above) shows, 7 of the alpha neurofeedback studies have incorporated a scoring system as part of their feedback but as yet there does not appear to be any research directly comparing the effectiveness of neurofeedback training with a scoring system to neurofeedback training without.

In sum, alpha neurofeedback varies as to whether the feedback used for training is continual or contingent and although the majority of the studies use contingent it has been suggested that continual is the more effective method and, further, that a scoring system should be employed as an additional part of the training. As yet, however, evidence to support these claims is limited and more research is needed before the benefits, or not, of including a scoring system can be confirmed and a decision regarding the relative merits of continual versus contingent feedback can be made.

3.6. Training Regime

When undertaking neurofeedback, important questions to be answered are what to train, how, how often, and how long for. This incorporates issues relating to how long each session should last, how many breaks individuals should have during their sessions (trial length), how many sessions are needed, and how often those sessions should occur. Each of these will be addressed separately.

3.6.1. Trial Length

Although some studies (e.g. Albert, Simmons, & Walker, 1974; Cho et al., 2008) do not split their training sessions into separate trials (n = 20 studies), the majority do (n = 64) (see Table 11, below).

A trial constitutes the length of training within a session before a break occurs. Whilst Ancoli and Kamiya (1979) recommend trials of 10 minutes in the first few sessions which then increase to 15-20 minutes in later sessions, trial lengths are rarely as long that. As can be seeing in Figure 5, below, trial length varies from 1 minute (London & Schwartz, 1984) to 12 minutes (Chisholm et al., 1977) with the most common being 5 minutes (n = 18 studies) and 2 minutes (n = 17) and the majority of studies utilising trials of less than 10 minutes (n = 58).

Table 11

A comparison between the number of alpha neurofeedback studies which break each session in to trials and the number which do not

How Each Session is Broken Up	Number of Studies
Trials	64
No Trials	20
Unknown	13

The optimum length of trials has not yet been established empirically. However, Plotkin (1976a) warned that trials should not be too long because there is a risk of tiring the participants. Although he does not specifically state what he means by ‘too long’, he utilises trials of 3 minutes. Hardt and Kamiya (1976b), however, are critical of 3-minute trials, hypothesising that 3 minutes is not enough time for participants to settle into the process before having to stop and start all over again and that stopping after such a short space of time may be too jarring. Although Plotkin (1976a) dismisses this argument, stating that there is no empirical evidence to support such an assertion, Travis, Kondo and Knott (1974a) also argue that trials lasting 2-4 minutes may not allow enough time for participants to reach their potential. They found that during alpha enhancement participants usually did not manage to increase their alpha over threshold for the first 2 to 3 minutes after their rest breaks, which was what led the authors to suggest that trials need to be at least 4 minutes in length.

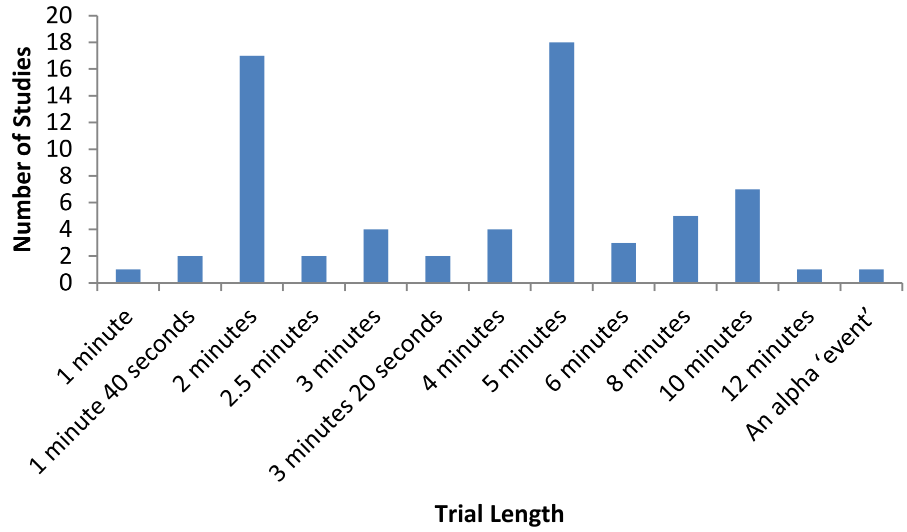

Figure 5. Trial length in each of the alpha neurofeedback studies reviewed

The idea that 4 minute trials may be too short received only limited support when tested by Plotkin (1978). He compared 52 minutes of continuous eyes closed training to 52 minutes of training which incorporated 20 second breaks after every 4 minutes. For the first session the participants who trained for 52 minutes without a break showed a better ability to enhance their alpha than those whose training was split into 4 minute trials, but this effect did not carry over to the remaining 9 sessions, suggesting that such short trials may only be a problem in the earlier stages of training. If this is the case, the issue of trial length is more pertinent for those conducting single sessions of alpha neurofeedback or, potentially, less than 52 minutes of training. As is revealed in the following two sections below, however, this nonetheless constitutes a large proportion of the alpha neurofeedback studies to date.

3.6.2. Session Length

There is yet to be any clear evidence or recommendations as to how long a single session of neurofeedback should last. As can be seen from Figure 6, the length of sessions given ranges from 3 minutes (Konareva, 2005, 2006) to 12 hours (Regestein, Buckland & Pegram, 1973; Regestein, Pegram, Cook, & Bradley, 1973). Such extremes are rare, however, and the most commonly utilised session lengths are between 31 and 40 minutes (n = 18 studies), between 16 and 20 minutes (n = 15 studies), between 21-25 minutes (n = 12 studies) and between 45 and 50 minutes (n = 11 studies).

How long each session should last is closely tied up to the issue of how much training is required, overall, and how many sessions are therefore needed.

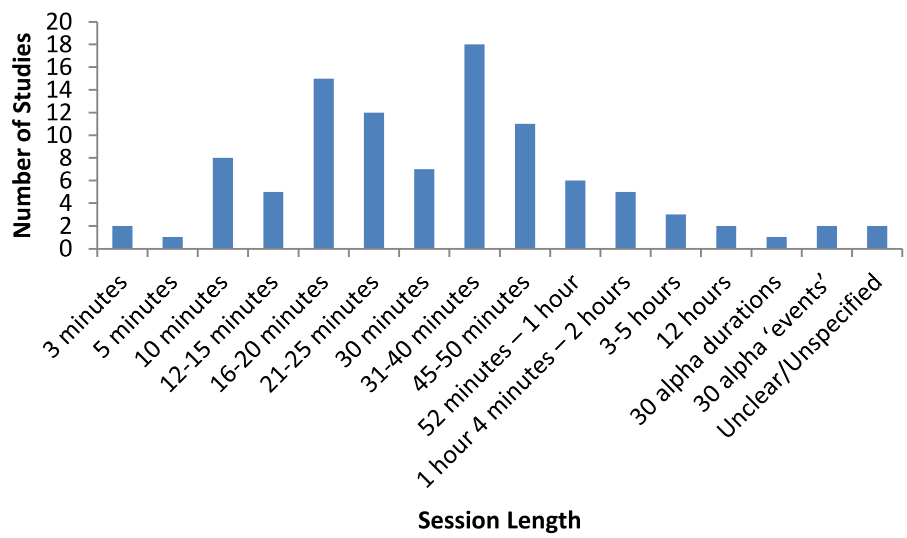

Figure 6. Length of alpha neurofeedback training sessions undertaken

3.6.3. Number of Training Sessions Needed

There are, arguably, two questions in relation to how many sessions are necessary for alpha neurofeedback training. Specifically, (1) how many sessions are needed before participants can learn to exert a conscious control over their own alpha waves? And (2) how many sessions are needed before such training has the desired effect on optimal performance? With no empirical evidence specifically addressing this question we cannot know a priori whether the answers to these questions will be the same.

As can be seen from Table 12, below, it is most common for studies to run just a single session (n = 49 studies). There is little consensus, however, as to whether one session is enough. Knox (1980) argues that basing results on a single session is problematic due to the anxiety which participants are likely to experience in their first session. Hardt and Kamiya (1976b) concur, stating that the first 2 hours of training are more to do with acclimatising to the feedback and the novelty of the situation. Only after that, they argue, are any changes seen in alpha a reflection of actual learning rather than of habituation. This is particularly noteworthy given that approximately two thirds of the studies reviewed (n = 62) give their participants 2 hours or fewer of training (see Table 13, below) with the most common training total being between just 11 and 30 minutes (n = 23).

There are, however, instances where learning has been demonstrated in just one session. For example, Hanslmayr et al. (2005) had 18 participants train to enhance their upper IAF at multiple monopolar scalp locations for 20 minutes using visual feedback. Not only did they find evidence of learning to enhance alpha in that time, they also found that participants who managed to enhance their alpha also showed improvements on a mental rotation task with the extent of improvement correlating with the extent to which they enhanced their alpha.

However, some of their participants failed to show evidence of learning to enhance their alpha and therefore failed to show improvement on the mental rotation task. It would therefore have been interesting to see if those participants would have showed evidence of learning too had more sessions been conducted. It is also unclear whether a single session such as this, even if deemed successful, would be enough to show the long-term effects that are, presumably, the goal of optimal performance (see section 3.8.4.).

Table 12

Number of sessions given to participants in the alpha neurofeedback studies to date

Number of Sessions	**Number of Studies**	**Number of Sessions**	**Number of Studies**
1	49	6	2
“1-24”	1	7	3
2	9	10	4
3	5	11	1
4	10	12	1
5	8	14	1
“5-7”	1	20	1
“5-10”	1	31-36	1
“5-52”	1	Unclear/Unspecified	2

Table 13

Total time participants spent undertaking alpha neurofeedback training

Total Training Time	Number of Studies
10 minute or less	6
11-30 minutes	23
31-59 minutes	20
1 hour	3
1 hour 12 minutes – 2 hours	10
2 hours 5 minutes – 5 hours	21
5 hours 38 minutes – 10 hours	5
10 ½ hours +	5
Unclear/Unspecified	6

Despite the success of Hanslmayr et al. (2005) in just a single session there are nonetheless other studies which fail to find evidence of learning in a single session (e.g. Gertz & Lavie, 1983; Marshall & Bentler, 1976) and many researchers (e.g. Ancoli & Kamiya, 1978) argue that more than one is needed. Precisely how many, however, has yet to be resolved. For clinical populations 30 to 40 sessions or more are often recommended (e.g. Gunkelman & Johnstone, 2005) but for the purposes of optimal performance training, the recommendations are mixed. Rasey, Lubar, McIntyre, Zoffuto, and Abbott (1996) suggest that some may need 20 sessions before evidence of learning is demonstrated and recommend at least 30 sessions. These figures are, however, based on giving their own participants a mean of 20 sessions to enhance beta (16-22Hz) and simultaneously suppress high theta and low alpha (6-10Hz) and discovering that not all of their participants (n = 2 out of the 4 participants in their sample) could be classified as 'learners'.

With regards to alpha neurofeedback specifically, Vernon, Egner, et al. (2004) gave their participants 8 twice-weekly sessions of alpha (8-12Hz) neurofeedback training but failed to show evidence of learning. Whereas Zoefel et al. (2011) showed alpha enhancement after 5 daily sessions of upper alpha (IAF) training and a subsequent improvement on mental rotation tasks. Again, however, the reasons for these differences (i.e. successful learning in one study versus no evidence of learning in the other) are difficult to unpick because while both talk of training alpha, the way in which they did so was very different. It could be the use of IAF rather than the traditional frequency bandwidth which made the difference, or it could be that training upper alpha rather than the carrying out whole-band training resulted in successful enhancement, or that Zoefel et al. (2011) gave daily sessions rather than Vernon et al.'s (2004) twice weekly sessions, or some other methodological difference.

It is perhaps surprising that Vernon, Egner, et al.'s (2004) 10 sessions of alpha neurofeedback training did not show evidence of learning when Zoefel et al.'s (2011) 5 sessions of alpha training did because, on one level, one might imagine that performance would increase with more sessions. For instance, Nowlis and Wortz (1973) gave their participants between 5 and 52 sessions of twice-weekly alpha neurofeedback training and found that the more sessions participants had the better their degree of control over their alpha. This would seem intuitive, but Potolicchio, Jr. et al. (1979) gave their participants between 5 and 10 sessions of alpha (8-13Hz) enhancement training and found no improvement in performance after the first session. However, it is unclear what frequency bandwidth Nowlis and Wortz (1973) used to define alpha. Additionally, whereas they conducted eyes closed audio enhancement training using per cent time as their measure, Potolicchio, Jr. et al. (1979) conducted eyes open audio-visual enhancement and suppression training using the difference in alpha 'intensity' between enhancement and suppression trials as their measure. Both of which make it difficult to hypothesise why the discrepancy between the findings may have occurred.

Even if it is the case that the more sessions a person has the more they will improve, Cho et al. (2008) point out that there is likely to be a limit on how many sessions can be undertaken before there is no more improvement to be made and the learning curve flattens out. What this limit might be, however, is unclear. On a related point, it is also unclear if 10 one hour sessions would produce the same effect on training ability and/or effects of training on optimal performance as 20 30-minute sessions or 15 40-minute sessions. In other words, we cannot be sure whether it is the total amount of training which makes the difference or if three studies conducting the same total amount of training would produce differing results if they each varied the number and length of the training sessions in order to reach that total time.

None of these questions have been conclusively answered in the neurofeedback literature to date (Gruzelier & Egner, 2005) and, further, it is also as yet unclear whether how often participants train (i.e. their training schedule) interacts with the length and number of training sessions in trying to establish if there is such a thing as an optimum training regime.

3.6.4. Training Schedule

Of the alpha neurofeedback studies which provide their participants with more than one training session it is uncommon to provide information about how often participants train (n = 22 out of 49 studies). Of the ones which do report such information, the schedule ranges from 90 seconds between each training session (Albert et al., 1974) to a week between each training session (e.g., Cho et al., 2008). The most commonly used training schedules, however, are once a week (n = 10 studies) and once a day (n = 8 studies), as can be seen from Table 14, below. Vernon, Frick and Gruzelier (2004) state that while it is possible that there may be a correlation between how often participants train and how much or how fast they improve, it is a currently a relationship that lacks adequate empirical support.

In their discussion of how far apart training should be scheduled for for biofeedback training in general, Olton and Noonberg (1980) state that sessions which are spaced further apart (termed 'spaced practice') are better than sessions which are scheduled very close together (termed 'massed practice'). They argue that this is because massed training is more likely to result in fatigue, which may in turn hinder performance. Whether or not this is true, it still leaves the question of how far apart is too far?

Two studies which have tried to address the question of massed versus spaced training are Yamaguchi (1980) and Albert et al. (1974). Yamaguchi (1980) gave each of their participants 4 sessions of eyes closed audio alpha (8-12Hz) enhancement training at Oz. Each training session was 15 minutes long with those in the massed training group having 3 sessions in one day with only 7 minutes training break between each session followed by a 4th, final session, the next day. The participants in the spaced group carried out their sessions at a rate of once a day, every day. Yamaguchi (1980) discovered that those in the massed training group showed an increase over baseline levels of the amount of time participants spent over their 20µv threshold whereas the spaced group did not. The authors suggest that scheduling the training sessions so closely together may enable some participants to gain a quicker insight into how to consciously alter their alpha in a way that spacing training sessions further apart does not, perhaps due to the training being fresher in their memory when it is massed closer together.

Table 14

How often training sessions are scheduled in the alpha neurofeedback studies utilising more than 1 training session

Frequency	**Number of Studies**
90 seconds apart	1
Every 7 minutes	1
Twice a day	3
Daily	8
3-5 times a week	2
Twice a week	2
Once a week	10
Unclear/Unspecified	22

In contrast, the earlier study by Albert et al. (1974) found the opposite. In this comparison of massed versus spaced training, they gave their participants 5 sessions of eyes closed audio alpha (8-12Hz) enhancement training. Participants in the massed group received each of their first 20 minute sessions all in the same day with a 90 second break between sessions and their fifth, final session, the next day. Participants in the spaced group received each of their five 20 minute training sessions once a day for 5 consecutive days. Albert et al. (1974) concluded that spaced training was more effective than massed, although it is worth noting that their participants showed a change over time but not in comparison to baseline which some, such as Plotkin (1978), would argue is not evidence of learning at all (see section 3.8.2.).

It should be said that in both Yamaguchi's (1980) and Albert et al.'s (1974) studies daily training was defined as spaced training. Given that it is just as common for studies to set their participants' inter-session training intervals further apart than that (n = 14 studies less than once a day compared to n = 13 studies at least once a day), so it would be informative to compare daily training to once-weekly training. A study by Dempster and Vernon (2008) attempted to do just that, providing a comparison between participants who trained to enhance their alpha (8-12Hz) once a day, participants who trained to enhance their alpha twice a week, and participants who trained to enhance their alpha once a week. No significant effects of learning were found, however, and they recommended further investigation with a larger number of participants than their sample of 6 in order to establish if training schedules have an effect.

Additionally, Allen et al. (2001) conducted 5 daily sessions of alpha (8-13Hz) training with the participants' aim being to increase the frontal alpha power in one hemisphere over another. They found that their participants' performance dropped on the fifth day of training and concluded that daily training may not give participants enough of a rest between sessions resulting in an eventual deterioration in performance.

In sum, there is wide variation in the alpha neurofeedback literature as to how often, how long, and how many sessions participants are trained. While there is some evidence that these are factors which make a difference to individuals' ability to learn to exert a conscious control over their alpha, and therefore potentially on any outcomes in optimal performance, the studies lack consensus. Further investigation is therefore recommended before an optimum training schedule can be established.

3.7. How Alpha is Measured

Even once the decision has been made as to what is meant by 'alpha', where on the scalp to train, and how to train it, there are still further questions to be asked in order to establish whether or not participants are successfully altering their alpha but firstly a way of measuring their performance is needed. As can be seen from Table 15, time spent in alpha, either as a percentage of time spent over/under threshold or as the number of seconds spent over/under threshold, is the most common way of measuring alpha (n = 53 studies). Integrated alpha, which is a measure combining both information about amplitude and information about time spent over/under threshold, is the second most commonly occurring measurement (n = 14 studies) and the amplitude or power of the participants' alpha is the third (n = 15).

An in-depth discussion of this topic can be found in Chapter 3 but to summarise, although the most common way of measuring alpha in the studies reviewed is to measure the amount of time participants spend over/under a

Table 15

Criteria used to measure participants' ability to control their alpha.

Measuring Criteria	**N° of Studies**
% time in alpha	31
N° of seconds in alpha	22
Alpha power	3
Difference between enhance and suppress trials	5
Number of alpha events	2
Ratio of alpha events to non-events	1
Mean Frequency	1
Integrated alpha	14
N° of alpha waves	1
Mean Amplitude	7
Probability of alpha occurring	2
Mean spectral power (μv^2/Hz)	2
Unspecified/unclear	10

particular threshold, the use of per cent time as a measure has come under criticism. For example, Hardt and Kamiya (1976a) have argued that it is unusual to find significant findings when per cent time is used as the measure for looking for evidence of learning during alpha neurofeedback training. They point out that if participants change how much alpha they produce but not how much time they spend producing it that this change would be missed by per cent time measures. In contrast to this, however, when Brown (1970) and Cram et al. (1977) looked for evidence of learning using per cent time as a measure and using amplitude (the third most common way of measuring alpha in the studies reviewed, as already mentioned above) as a measure both found evidence of learning when analysing the per cent time data but not when analysing the amplitude data.

Direct comparisons between the two, however, are rare and there has yet to be any strong empirical evidence establishing one as being preferable over the other (Norris & Currieri, 1999). It has also been argued that using one single measure to reflect the brain's activity is inadequate, resulting in a loss of important information (Tyson & Audette, 1979) with suggestions that a measure combining them both would be a better alternative (e.g. Hardt & Kamiya, 1976a; Travis, Kondo, & Knott, 1974b). Integrated alpha, the second most common method utilised in the literature reviewed (as mentioned above), is an example of this although the lack of information provided by some studies on how to calculate this makes it unclear if they all use the same method even if they are calling it the same thing. Whichever measure or measures are used, Ancoli and Kamiya (1978) warn that the results of studies using one should not be compared to results of studies using another. Presumably because it is as yet unknown if one measure is affected in the same way as another by neurofeedback training (Fell et al., 2002). As has been pointed out more than once in the past (e.g. Travis, Kondo & Knott, 1974b, 1975) it would be better if a standardised way of measuring alpha was established in order to enable comparisons of the findings across studies.

3.8. What Qualifies as Successful Training

Closely tied in with the issue of what measurement to use to assess training ability is the issue of what qualifies as 'successful' training. The aim of alpha neurofeedback training is to learn to either enhance and/or suppress alpha but the method used to determine whether enhancement/suppression has occurred differs depending on the study. Some look for a change over time in the participants' alpha whilst they are training, some compare participants' alpha when they are trying to consciously alter it to when they are not (i.e. comparison to a baseline), and some do both. There are also those who test their participants to see if they can learn to alter their alpha without feedback (e.g. Nowlis & Wortz, 1973) and some who argue that neurofeedback is only worth doing if long term effects can be achieved. Each of these will now therefore be discussed in turn.

3.8.1. Change over Time

Whilst there are alternative methods of measuring extent of learning during alpha neurofeedback training (see section 3.8.3. below) the most common is to look for evidence of a change over time. Usually this is either done by looking for a change in alpha from the start of the session to the end (i.e. within sessions analyses) or from one session to another (i.e. across sessions analyses). A more in-depth discussion of these can be found in Chapter 3 but to summarise, although at first glance (see Appendix A) it would appear that within sessions analysis is by far the most common method of analysis this is mainly attributable to the fact that such a large number of studies only perform a single session of training (see Table 12) and therefore comparing performance from one session to another (i.e. across sessions analyses) is not possible. When only studies

Table 16

Number of studies which found evidence of learning either across and/or within sessions amongst the studies which utilised both and conducted more than one training session

Finding	**Number of Studies**
Across Sessions Learning Only	2
Within Sessions Learning Only	4
Both	3
Neither	4

Table 17

Number of studies which found evidence of learning either across or within sessions amongst the studies which only utilised one or the other but conducted more than one training session

Finding	**Number of Studies**
Across Sessions Learning	4
Within Sessions Learning	2

incorporating 2 sessions or more are looked at the numbers are equal with 6 studies showing evidence of learning across sessions, 6 within, 3 showing evidence of learning both within and across and 4 showing no evidence of learning regardless of which type of analysis was performed (see Tables 16 and

17). A further 27 studies either did not make it clear whether their results were across or within sessions or performed a different method of analysis entirely.As can be seen from Tables 16 and 17, evidence of learning has been found utilising both within and across sessions analyses but the same data does not always agree on whether learning has occurred when the results of the two types of analyses are compared. Thus how learning 'success' is defined is an important issue because it can affect the conclusions drawn. For instance, the results of Cho et al. (2008) suggested that learning was successful when the results were analysed across sessions but not when they were analysed within whereas Potolicchio, Jr. et al.'s (1979) results found evidence for learning when within sessions analysis was used as the way of measuring success but not when across sessions analyses were used. This is important because it means that studies which only analyse the data using one method (i.e. the majority of the studies reviewed) and find no evidence of learning where others did may do so because their participants did not learn or may do so because they used a different method of analysis to those studies which did find evidence of learning.

Potential reasons for this discrepancy are discussed in Chapter 3 but ultimately it seems sensible to establish if one is a more accurate method than the other and for future studies to standardise the way they are defining learning success in order for direct comparisons to be made between different studies' results.

3.8.2. Comparison to Baseline

It has been argued by those such as Ancoli and Kamiya (1978, 1979) that when participants' level of 'success' at alpha neurofeedback is being assessed, a baseline measure should be incorporated. In other words, a comparison between their alpha during training and when they are therefore consciously trying to alter their alpha should be made with their alpha at a time when they are not consciously trying to alter it. The argument being that only when participants increase (in the case of enhancement training) or decrease (in the case of suppression training) their alpha past that which they produce naturally should it be counted as evidence of learning. A more in-depth discussion of this can be found in Chapter 3 but to summarise, although evidence of learning has been reported with and without the inclusion of a baseline (see Table 18) the inclusion-of-baseline supporters posit that unless a comparison of baseline is made then any changes in alpha seen during training, even in the desired direction, may simply be due to natural unconscious changes rather than conscious ones (e.g. Plotkin, 1978).

Tied in with the inclusion-or-not of baselines debate is the problem of what is an appropriate baseline to use. For instance, Plotkin (1976a) argues that a comparison should be made to multiple baselines taken throughout each session in order to allow for participants' natural alpha levels altering as they acclimatise themselves with the training situation. Hardt and Kamiya (1976b) disagree due to the potential possibility of participants' natural alpha levels altering as a function of the training (see section 3.8.4. for a more in-depth discussion of this point). One alternative is to just compare alpha to a single baseline taken before any training has started (e.g. Zoefel et al., 2011). The problem with this, however, is that if multiple training sessions are conducted then that baseline may not be an accurate depiction of participants' alpha at the time of training due to alpha fluctuating naturally as a function of things like time of day (Gertz & Lavie, 1983). Another alternative is to take a baseline at the start of each session (e.g. Cho et al., 2008). Although the argument then is that if training does have any carryover effects on participants' alpha then across sessions improvements may be hidden due to having to improve further and further each session in proportion to the increasing baselines.

Table 18

The number of studies, of those reviewed, which found changes in alpha, or not, when compared to baseline measures.

Finding	Number of Studies
A Change in Comparison to Baseline	30
No change in comparison to baseline	16
Unknown/Unclear with regards to comparisons to baseline	50

On top of this, there is also a debate regarding whether baselines should be taken with eyes open or with eyes closed. Plotkin (1976a, 1976b, 1978, 1980) posits that baselines should be taken with eyes closed because it is under this condition with alpha is likely to reach the highest natural levels and, he argues, alpha neurofeedback training is not a success unless participants can get their alpha to go beyond what is possible naturally. There is scepticism, however, that it is even possible to go beyond eyes closed baseline levels – in the case of enhancement training at least – including by Plotkin himself (Plotkin, 1976a, 1976b, 1978, 1980) although there are others (e.g. Tyson, 1982, 1987) who think that it is. Either way, the appropriateness of eyes closed baselines when the training the baseline is being compared to is undertaken with eyes open has been questioned (e.g. Ancoli & Kamiya, 1978, 1979) due to the natural differences in alpha amplitude when eyes are open compared to when eyes are closed (see section 3.4., above).

At present there does not appear to be any empirical evidence to definitively answer the questions as to whether or not baselines should be included and, if so, what is the most appropriate baseline to use. Again, however, given the suggested differences in the results that the answers to these questions have been argued to make it seems pertinent to make this an area for future investigation.

3.8.3. Ability to Alter Alpha Without Feedback

Neurofeedback utilises feedback to inform the participant of their alpha activity in order for them to learn conscious control over it. This therefore implies that the participant can learn to alter their alpha activity without the presence of feedback. This is a hypothesis supported by Tyson (1987) who argues that controlling alpha means individuals should be able to exert greater conscious influence on their alpha once they have been trained than they could before training. He argues that, to test this, participants should be asked to consciously alter their alpha before they have received any neurofeedback training, that they should then be given training with feedback, and then be asked to consciously alter their alpha. The experimenter should then look for differences in participants' ability after training compared to before, with no feedback in either case. Heinrich et al. (2007) also support this idea, stating that the inclusion of no feedback trials during the training would help enable its use outside of the lab.

Although the use of no feedback trials in the alpha neurofeedback training literature is rare there is some evidence which indicates that it is possible. For instance, Nowlis and Wortz (1973) gave participants two 45 minute sessions of eyes closed alpha neurofeedback training involving, in the first session, increasing alpha at an unspecified frontal site while simultaneously decreasing it at an unspecified parietal site and then, in the second session, decreasing alpha at the same unspecified frontal site while increasing it at the same unspecified parietal site. In the third session participants were asked to do each of these again but without feedback. Nowlis and Wortz (1973) found that 4 of the 6 participants who took part in the without feedback session demonstrated the ability to do so, but the small number of participants meant that the authors did not feel it was appropriate to conduct statistical analysis on the data, and this limits the conclusions which can be drawn from the study. Further, the study utilised a sample of 10 psychiatric outpatients and 6 psychiatric staff, and it is unclear which of these took part in the no feedback session. The sample, therefore, may not be generalizable to healthy individuals.

The rationale for why some think that participants should learn to exert control over their alpha without feedback is tied to the argument that neurofeedback is only worth doing if long-term effects can be see and thus that a carryover effect outside of the training itself should be the goal (e.g. Gruzelier & Egner, 2005; Gruzelier, Egner, & Vernon, 2006).

3.8.4. Long-Term Effects

Neurofeedback has been postulated as a way of eliciting long-term change (Gunkelman & Johnstone, 2005). It is currently unclear whether long-term effects of neurofeedback, either on the EEG or on the outcome of training on cognition/behaviour, is possible (Vernon, Frick, & Gruzelier, 2004). Although Plotkin et al. (1976) express scepticism that training will affect alpha beyond the training environment, work by Kamiya (1969) showed that alpha enhancement training produced an increase in participants' baseline alpha.

Research by Cho et al. (2008) offers support for this. They found that the amplitude of participants' alpha (8-12Hz) at the end of each of their eyes closed training sessions correlated with the amplitude of their eyes open baselines at the start of the next training session. Given that participants undertook their 11 sessions at the rate of once a week this offers some support for the carryover effect Plotkin et al. (1976) are sceptical of.

Further, it is not known how long any long term effects would last for nor whether this would show a correlation with the number of sessions undertaken (Vernon et al., 2009). There is some evidence for the potential of substantial long-term effects from the clinical literature. Tansey (1983) discusses how a 10 year old boy who was given 20 sessions of beta enhancement neurofeedback showed changes in both his EEG and his behaviour. Indeed, the boy was still showing a normalised EEG 10 years later. Although this indicates that long-term effects from neurofeedback are at least feasible this was a single case study on beta, rather than alpha, neurofeedback. Also, Egner, Zech and Gruzelier (2004) point out that training a clinical patient to normalise their EEG may not be comparable to the use of neurofeedback on healthy populations whereby definition the individuals' EEGs are already, presumably, normal.

Given the expense that can be involved in neurofeedback and the impracticality of undertaking neurofeedback long term, Gruzelier and Egner (2005) and Gruzelier et al. (2006) argue that long-term effects need to be established in order to justify undertaking neurofeedback training at all.

3.9. Learners versus Non-Learners

Tied to the issue of how to measure alpha, and how 'successful' learning should be defined, is the classification of learners and non-learners, whether it is necessary to do so, and whether it is possible for all people to benefit from neurofeedback training.

There does not appear to be any research investigating whether or not it is possible for everyone to successfully learn to train their EEG via neurofeedback training (Vernon, Frick & Gruzelier, 2004) and the criteria by which to distinguish learners from non-learners require further development (Vernon & Dempster, in press). Zeier and Kocher (1979) argue that it is important to separate the learners from the non-learners prior to analyses, otherwise the results from each may cancel each other out and hide any evidence of learning or effects of the training. This view is supported by Dempster and Vernon (2008), who interpreted their non-significant results when looking for differences between training schedules as due to half the participants in each group showing no evidence of learning after their alpha neurofeedback training, therefore mitigating evidence of learning shown by the learners in the sample.

Weber, Köberl, Frank, and Doppelmayr (2010) also support the suggestion of dividing participants into learners and non-learners. They argue that it may not be possible for everyone to learn to control their EEG activity via neurofeedback. In their own study, they referred to learners and non-learners as performers and non-performers with 50% of their 28 participants being defined as performers and 50% as non-performers after 25 sessions of neurofeedback training.

While Weber et al.'s (2010) study used SMR neurofeedback training there are also those in the alpha neurofeedback arena who have likewise separated participants in to learners and non-learners before analysing their data. Both

Zoefel et al. (2011) and Hanslmayr et al. (2005) talk of responders and non-responders with Hanslmayr et al. (2005) analysing the two groups separately and Zoefel et al. (2011) excluding the non-responders from all further analyses entirely.

As can be surmised from sections 3.7. and 3.8., above, however, classifications differ between learners/performers/responders and those who show no effect of neurofeedback. Zoefel et al. (2011) defined learners as those who produced a mean of upper alpha (IAF) during their last (fifth) training session which was significantly higher than the mean of the baseline from their first. Weber et al. (2010) categorised learners as those who showed an increase in the amplitude of their EEG by more than 8% over baseline for their last sessions and who also showed an across sessions increase from the first session through to their last, rather than just the final few sessions. Hanslmayr et al. (2005) on the other hand classified their learners, ‘responders’, as those who showed an increase in upper alpha power during their training session in comparison to their eyes open baseline.

While there are recommendations then for those who learn to alter their cortical activity via neurofeedback training to be separated before analyses from those who do not (e.g. Zeier & Kocher, 1979), the few studies which do this differ in how they classify participants as learners. If learners and non-learners are to be delineated, then, it is important that a standardised way of doing so is established if the results of studies are to be compared (Kondo et al., 1979; Vernon et al., 2009).

3.10. Localisation of Effects

Another question which has yet to be sufficiently addressed in the neurofeedback literature is whether or not any changes seen as a result of neurofeedback training are localised to the scalp location(s) being trained or whether more global changes take place. Fehmi and Collura (2007) point out that any given region of the brain is not independent from the rest of the brain

There is evidence, both in the neurofeedback literature in general (e.g. Egner, Zech, & Gruzelier, 2004) as well as in the alpha neurofeedback literature specifically, that training at one particular scalp location influences the activity at other locations on the scalp. For instance, Angelakis et al. (2007) had their participants train to enhance their peak alpha frequency (PAF) at site POz. They found that changes were seen in their participants' PAF in frontal areas rather than at POz. Given that they only had 3 participants who trained their PAF in this way, only 2 of whom were deemed successful, and that those 3 participants were all over the age of 70, caution is needed in generalising from these results but their findings are nonetheless suggestive that neurofeedback can have more than a localised effect. Even if the changes in PAF at the frontal locations were because participants were training frontal sites rather than parietal, the feedback they were getting was from POz, which either means that training at one site also trained alpha at other sites or, as the authors suggest, it is easier for participants to train frontal rather than parietal locations. Unfortunately the authors do not report participants' alpha activity during training, only during their post-training baselines, so it is not possible to determine which of these is most likely.

More clear-cut results can be seen in research by Hanlsmayr et al. (2005). Their training of upper alpha (IAF) at multiple site locations (F_3, F_4, Fz, P_3, P_4, and Pz) showed changes in both the sites trained and elsewhere on the scalp (P6, PO2, O1, Oz and O2). Whether or not training multiple scalp locations simultaneously would be more likely to produce global effects has not yet been investigated, but would be an important area for research.

What Angelakis et al. (2007) and Hanslmayr et al. (2005) have in common is that they both saw changes at scalp locations other than those trained when they got their participants to enhance some aspect of their own individual alpha freuqncy. Angelakis et al. (2007) did, in fact, also train 3 participants to enhance the amplitude of the traditional frequency band (8-13Hz) instead and unlike with their IAF group, the fixed frequency band participants showed no post- training changes in their EEG. However, changes in alpha during the training itself were not reported so without knowing how the participants performed during training - and therefore whether they were actually successful at alpha enhancement - it is very difficult to draw conclusions from this.

There are in fact earlier studies utilising fixed, as opposed to individual, frequency bands which have tried to address this issue, but in each case there are limitations which hamper the drawing of conclusions. Both Bauer (1976) and Plotkin (1978) reported changes in alpha at scalp locations other than those trained. However, while Bauer (1976) talks of a significant number of participants showing changes in alpha (8.5-12.5Hz) he does not talk about significant changes in alpha itself, so it is unclear if his participants' training is as successful as he makes it sound, especially given that they did not show any change in recall ability after training, as predicted. In the case of Plotkin (1978), his participants did not show improvement over their eyes closed baseline, so he did not classify them as having been successful in learning to enhance alpha. This undermines any discussion of changes at other areas of the scalp.

A study in the same year by Hardt and Kamiya (1978) did show changes in integrated alpha (8-13Hz) both at the site of training, Oz, as well as at O_1 and C_3. It is unclear whether these non-localized changes were a result of the enhancement training, the suppression training, or both, but nevertheless it lends support for neurofeedback training having the potential to produce changes in areas of the brain beyond those specifically being trained.

To summarise, when looking at the question of global versus local changes as a function of neurofeedback, research is needed in order to establish how neurofeedback training affects areas of the brain not being specifically trained. There is some evidence that alpha neurofeedback training can influence alpha activity at scalp locations beyond those specifically being trained but this evidence is by no means comprehensive. Those such as Gruzelier and Egner (2005) and Gruzelier et al. (2006) have therefore recommended that full cap assessments of pre- and post-neurofeedback changes are undertaken in order to be able to definitively address the issue.

3.11. The Role of Individual Differences

Methodological aspects aside, another area which has been noted to differ throughout the alpha neurofeedback literature is that of individuals' ability to control their alpha waves (Goesling, May, Lavond, Barnes, & Carreira, 1974). It has been suggested that not everyone can learn to consciously alter their EEG (Konareva, 2005), although Kuhlman and Klieger (1975) argue that studies which fail to demonstrate evidence of learning via alpha neurofeedback may do so due to problems with methodology rather than because participants cannot learn to control their alpha. Whether or not this is the case, it is often noted that there is large variability in the success of neurofeedback training, leading Konareva (2006) to suggest that it depends on the individuals themselves as to the effectiveness of the training. Peper and Mullholland (1970) believe that fluctuations in participants' psychological or physiological state at the beginning of each session should be noted for their potential influence on the training, and DeGood and Valle (1978) suggest that alcohol and nicotine users will produce a different performance pattern to non-users, although their sample comprised male participants, and the smokers had been banned from smoking for the 4 hours prior to taking part.

Factors such as participants' mood have also been suggested as being important with Cott, Pavloski and Goldman (1981) finding that participants in a positive mood were better at both enhancing and suppressing alpha than those in the negative mood group. Problematically though, mood was defined by whether or not participants had been told that training would have a positive effect on their mood (positive mood group) or a negative effect on their mood (negative mood group). In fact, the negative mood group were warned that training alpha could have a depressing or undesirable effect on them so rather than the results being a function of mood per se participants in the negative mood group may simply have been less willing or motivated to try and enhance their alpha than the positive mood group and put less effort in to doing so.

Although the suggestions for contributing variables outside of the training itself which have been theorised to influence neurofeedback ability vary, the two main categories under which potentially confounding participant variables fall are individuals' natural resting levels of alpha (i.e. their baseline alpha) and specific aspects of their personality. These will each, then, be looked at in turn:

3.11.1. Effect of Baseline

Factors such as health, tiredness, age, and demands of the task all have an influence on individuals' natural levels of alpha (Bazanova & Aftanas, 2008b; Klimesch, 1999) and Konareva (2006) states that of all the frequency bands, it is the amplitude of alpha which shows the most difference between individuals. According to Bazanova and Aftanas (2008b), such individual variations are an indicator of an individual's brain 'flexibility' and therefore of their cognitive abilities. This is supported by, for example, Doppelmayr et al. (2002) who found a strong positive association between intelligence and alpha power. More specifically, they found evidence to suggest that alpha power in the upper alpha band positively correlates with semantic processing ability and that alpha power in lower bands positively correlates with the ability to learn new information.

As well as the suggestion that baseline alpha is a reflection of cognitive ability, there is also the suggestion that the natural alpha baselines individuals possess are related to how well they learn to alter their alpha via neurofeedback (e.g. Hare, Timmons, Roberts, & Burman, 1982; Zeier & Kocher, 1979). For example, Lynch and Paskewitz (1971) hypothesize that it depends on the individual's natural alpha levels as to whether they are better at enhancing or suppressing alpha. They argue that those with higher alpha may have a harder time suppressing it than those with low alpha and that the opposite pattern would be expected for enhancement. This suggestion has some support in the literature. For instance, Lynch et al. (1974) showed that participants who spent more time in alpha during their baselines spent more time enhancing alpha during training and Markovska-Simoska et al. (2008) showed that participants with higher baseline peak alpha frequency and individual alpha bandwidth (IABW) had better alpha neurofeedback training ability.

Interestingly, however, there are other studies which have shown the opposite effect. That is, instead of high alpha baseline individuals finding enhancement easier and low baseline alpha finding suppression easier, some studies show that high baseline individuals are better at suppressing and low baseline individuals better at enhancing their alpha. For instance, Strayer, Scott and Bakan (1973) found that participants with low baselines (less than 40% of their time spent in alpha during baseline) successfully enhanced alpha whereas participants with high baselines (more than 40% of time during baseline spent in alpha) did not. However, these results are based on just one session comprising two minute trials, and the authors do not state their alpha criteria. Similarly, Cott, Pavloski and Goldman (1981) found that participants with high baselines, defined as those who spent more than 60% of their time during baseline over two thirds of their maximum eyes closed baseline amplitude, could significantly suppress, but not enhance, their time spent in alpha. In contrast, participants with low baselines, defined as spending less than 40% of their time during baseline under one third of their maximum eyes closed baseline amplitude, were found to be able to significantly enhance but not suppress their time spent in alpha. That said, these results are not representative of the whole sample, with 2 of the 20 low baseline participants managing to decrease their time in alpha below baseline levels and half of the 20 high baseline participants unable to decrease theirs. Although this still produced significant results for the high baseline group it is worth noting that as many high baseline participants did not learn to suppress their alpha as those who did.

One possible explanation for these differences may be due to how alpha is measured. Kondo, Travis and Knott (1973) found that those with large baseline amplitudes showed larger increases in amplitude during their neurofeedback training than those with low baseline alpha amplitudes. The opposite pattern, however, was seen for alpha abundance whereby those who spent more time in alpha during their baselines showed less of an increase in time spent over threshold during training and vice versa for those who spent less time in alpha during their baseline. Note, however, that the relationship they describe between baseline and training using per cent time as the measure is not the pattern Lynch et al. (1974) showed in their study, outlined above.

In fact, Valle and DeGood (1977) failed to find any correlation between participants' baselines and their ability to control alpha. Similarly to Cott, Pavloski and Goldman (1981) though, only the last 2 minutes of each session was used in the analysis and as each of the sessions were 40 minutes in length, this means a lot of data was excluded from the analysis. Beatty (1971) suggests that if baselines are in the normal range they do not have an effect on training ability and it is only those with baselines at the extremes which would show a relationship between alpha during neurofeedback training and alpha during baselines.

In summary, there is some evidence to suggest that participants' baseline alpha is not only a reflection of their cognitive abilities but also a reflection of their ability to train their alpha via neurofeedback. How baselines interact with training ability, however, has not been fully established due to discrepancies in the findings (e.g. Kondo et al., 1973, versus Lynch et al., 1974) and nor is it clear whether any influence which baselines have on training ability can be ameliorated over time if enough sessions are provided.

3.11.2. Personality

Rosenbloom (1972) argues that people who have a strict discipline in some area of their life, e.g. musicianship, are likely to alter their alpha the quickest. While there are many different aspects and dimensions to discussion of personality, it is this notion of self-discipline and the personality dimensions relating to self-control which are most often discussed. For instance, Konareva (2006) hypothesized that individuals with better control of their emotions would be better at enhancing their alpha. However, this hypothesis was based on his findings that individuals with less emotional control and who were less sociable and had more volatile personalities were better at suppressing their alpha. This led him to claim that those with the opposite personality dimensions would be better at enhancement, but he did not present empirical support for this. Also, his findings were based on a single neurofeedback session of just 3 minutes, which is unlikely to be long enough to support any conclusions (see section 3.6., above).

Rather than self-control specifically, however, it is individuals' belief in their own capacity for control which is the aspect of personality most often discussed in relation to alpha neurofeedback training ability. According to Rotter (1966), those with an internal locus of control believe that they have control over their actions and what happens to them, whereas those with an external locus of control believe that what happens to them is determined externally. Because neurofeedback is about putting the individual in control of their brainwaves, those such as Johnson and Meyer (1974) and Goesling et al. (1974) hypothesize that participants with an internal locus of control - that is, those who believe their life is in their own control - will be better at neurofeedback training. And, indeed, both sets of researchers presented evidence to support this. It is worth noting, however, that in Goesling et al.'s (1974) study while both the internal locus of control and the external locus of control participants were classified as being able to enhance their alpha (8-13Hz), the external locus of control participants were not as fast nor as successful. Further, they were given one 40 minute session of neurofeedback training, so it is unclear whether these results would have held out across more sessions, or been applicable to suppression as well as enhancement.

Johnson and Meyer (1974) ran three 40 minute sessions on their participants, but used an all-female sample and did not clearly define alpha, its measurement, or the form of the feedback. This makes it difficult to support any conclusions from the study. Moreover, in place of Rotter's (1966) internal-external locus of control scale, Johnson and Meyer (1974) used Nowicki and Strickland's (1973) alternative scale, for unspecified reasons. Nowicki and Strickland's (1973) scale was designed for use with children, but Johnson and Meyer (1974) do not provide any details on the age of their participants, so it is difficult to know whether use of this scale was appropriate or not.

In contrast, neither Knox (1982) nor Brolund and Schallow (1976) found any correlation between locus of control and alpha neurofeedback training ability. Knox (1982) suggests that the reason for this is because Goesling et al. (1974) used participants on the extreme ends of the internal and external locus of control scale, whereas she herself only had participants who were classified as having an internal locus of control. Similarly, Brolund and Schallow (1976) divided participants up by splitting their locus of control scores at the mean such that they were internal and external in relation to each other but not necessarily in relation to the classifications used by Goesling et al. (1974). Also, Brolund and Schallow (1976) did not show any difference in enhancement ability between their feedback group and their control group, which suggests an absence of learning.

Drawing conclusions, therefore, about differences in learning ability between internal and external locus of control participants may be unwarranted.

It is interesting to note that Yamaguchi (1980) did find a difference between the neurofeedback ability of participants with an internal locus of control compared to those with an external locus of control. In his case, however, he found that after four 15 minute sessions of eyes closed alpha (8-12Hz) neurofeedback training sessions, the external locus of control participants enhanced the percentage of time their alpha over baseline. Yamaguchi (1980) suggests that eyes open training may be better for those with an internal locus of control, and eyes closed training for those with an external locus of control. This is due, he hypothesizes, to internals taking a more active approach than the externals, which better suits eyes open and eyes closed procedures respectively. A closer look at Yamaguchi's (1980) results, however, reveal a complex interaction between training schedule and locus of control, with massed externals significantly increasing alpha over baseline and across trials but, unlike spaced internals, spaced externals did not significantly enhance over baseline. The next best group was actually massed internals, but although they enhanced their alpha above baseline across trials, this was not found to reach significance. This suggests that eyes open or closed may not be the only factor influencing whether participants with an internal or an external locus of control are best suited to the training. It may be that other methodological variables also play a part in which type of participant is more adept at training. If it is the case that particular individuals are more suited to alpha neurofeedback training than others it may be that there are certain aspects of the training which can be altered to suit the needs of each individual.

Aside from internal versus external locus of control, another aspect of personality which has received attention in the alpha neurofeedback literature in relation to training ability is introversion (the tendency towards a more internal focus) versus extraversion (the tendency towards a more external focus). O'Gorman and Lloyd (1987) state that Eysenck's (1967) theories relating to the role of biology in personality lead to the hypothesis that introverts' EEG will show more arousal than extraverts and those such as Mills and Solyom (1974) have suggested that introversion/extraversion scores may be used as a way of predicting neurofeedback training success.

There is some evidence to suggest that participants' baseline alpha, at least, may be related to how introverted/extraverted they are. For instance, Tran, Craig and Melsaac (2001) found that extraverts were three times more likely to have a larger (8-13Hz) amplitude than introverts. Significant differences were seen in frontal and central sites but not posterior which has implications for those studies training at posterior sites. Only two minutes of recording was undertaken per participant though so it may be queried whether they were even natural alpha amplitudes which were found or merely a reaction to the situation (see section 3.8.2.), which in itself could affect introverts and extraverts in different ways. Likewise, Deakin and Exley (1979) also found that extraverts had higher alpha amplitudes than those with low extraversion scores.

Conversely, Kondo, Bean, Travis and Knott (1978) found that individuals scoring high for extraversion actually had less integrated alpha than those scoring low for extraversion, although given their use of a 7-14Hz alpha bandwidth it could be argued that what they were calling alpha may actually have included contamination from surrounding frequencies (i.e. theta and/or beta).

In their own study, O'Gorman and Lloyd (1987) failed to find any link between alpha and extraversion, but they did find a correlation between alpha and impulsiveness. This led them to suggest that the reason extraversion receives mixed results when looking at its relationship to alpha may be because some studies include impulsiveness as a dimension of extraversion and that it is this that correlates with alpha, not the extraversion itself.

With regards to alpha neurofeedback rather than alpha specifically, Knox (1982) did not find any relationship between enhancement ability and extraversion. She argues that Eysenck's (1967) theory does not lead to a prediction about a relationship between neurofeedback and personality dimensions. She explains that this is because the kind of cortical arousal that his theories relate to are influenced by emotions and argues that this is therefore not the type of arousal that neurofeedback training generally operates by.

Both Zirkel, Stewart, & Preston, (1977) and Travis, Kondo and Knott (1974c) also failed to find a correlation between alpha enhancement ability and extraversion although unlike Knox (1982) and Zirkel et al. (1977), Travis et al. (1974c) did find a positive correlation between neuroticism and alpha enhancement. They suggest that neurotics have high levels of anxiety and that as alpha enhancement has been linked to a decrease in anxiety (e.g. Hardt & Kamiya, 1978) those high in anxiety (such as those who score highly for neuroticism) will feel the difference between alpha and non-alpha more acutely than the less anxious (such as the less neurotic) participants.

Taking a different view of the relationship between personality and alpha neurofeedback training, Ancoli and Green (1977) found that after 5 sessions of eyes closed alpha (8-13Hz) training, participants showed a larger difference between alpha enhancement and alpha suppression trials when they scored highly for introspection and low for authoritarianism than those who scored highly for authoritarianism and low for introspection. They suggest that rather than personality per se correlating with neurofeedback ability, it may be that different personality types influence the use of particular feedback strategies.

To summarise, there appears to be wide variation in individuals' ability to train alpha (e.g. Hardt & Kamiya, 1976b), and individual differences relating to personality may contribute to these differences (e.g. Konareva, 2005, 2006). Locus of control and intraversion/extraversion are the individual variables which seem to be the most often cited, although in each instance results are mixed and it has been suggested that other factors such as whether training is carried out with eyes open or eyes closed (Yamaguchi, 1980) and the relationship between personality and training strategy (Ancoli & Green, 1977) may be the reason for the differences in results. The tendency to focus on enhancement but not suppression also makes it unclear whether links between personality variables and alpha suppression training are likely to be the same as for alpha enhancement training.

Those such as Gruzelier and Egner (2005) and Gruzelier et al. (2006) have argued that the investigation of personality traits in relation to neurofeedback training success would be useful for increasing the chances of success in the optimal performance realm, but it is clear that more research in the area is needed before a clear relationship can be shown between personality and neurofeedback ability.

Summary

Alpha brainwaves have been linked to cognitive abilities such as creativity (e.g. Fink et al., 2009), memory (e.g. Klimesch, 1999), intelligence (e.g.

Doppelmayr et al., 2005), visual imagery (e.g. Cremades & Pease, 2007), attention (e.g. Aftanas & Golocheikine, 2001), and speed of information processing (e.g. Kilmesch, 1996). Given this, then it can be argued that a method which allows an individual to alter their alpha brainwaves may also alter their performance on these cognitive tasks. Neurofeedback training has been put forward as a way of enabling them to do just this.

Neurofeedback provides the individual with information about particular aspects of their EEG (for instance, the amplitude of their alpha waves) as a way of enabling the individual to pair their conscious experiences with this information in order to learn to exert a conscious influence over these aspects. It is a method which has been used for each of the different brainwave types, depending on the needs of the individual. In clinical populations, the rationale for its use is the normalisation of EEG; in healthy populations, to enhance performance. It is the latter which is the focus of this thesis.

While alpha neurofeedback training has been shown to be of use for enhancing mental rotation abilities (e.g. Hanslmayr et al., 2005), attention (Schauerhofer et al., 2011) and memory (e.g. Krenn et al., in review), amongst others, methodological limitations and differences between the studies make it hard to draw conclusions and difficult to untangle the key factors in understanding the discrepancies. For instance, there are differences in what authors mean by 'alpha', both in terms of the precise range of the upper and lower limits of the frequency bandwidth used, whether it is divided in to sub-bands or kept as one whole band, as well as what threshold is used when participants are described as being 'in' and 'out' of alpha, and therefore the goal which they are expected to reach during their training (for instance, increasing their alpha over an amplitude of 20μv versus keeping the feedback on for at least

60% of the time). Differences in the studies in the area also exist in relation to where the electrodes are placed on the scalp, how many are used, and whether feedback is given from each scalp location separately or given as a function of the difference between two scalp locations. Likewise, in whether alpha is being suppressed or enhanced or both; whether training is conducted with eyes open or eyes closed; and whether feedback is audio or visual or both and is provided continually or contingently. On top of this some studies only conduct one session, some multiple; some provide multiple breaks during training, some provide none; some only allow participants a few minutes of training in total, some provide them with several hours; some allow their participants to train every day, some several times a day, some once a week. Some assess their participants' level of learning using a measure based on time, some on an aspect of the alpha itself (e.g. amplitude). There are studies which analyse their data by looking at how participants performed within the training sessions themselves, others which look for any differences between participants' performance from one session to the next, some in relation to a baseline, some without. In addition to this, there is as yet no clear answer as to whether neurofeedback has long-term effects on participants' alpha waves, whether any effects found are localised to the areas of the brain trained or are more global and alter other areas of the brain. Likewise, it is also unclear whether everyone can learn to exert a conscious influence over their alpha brainwaves and what role individual differences such as participants' natural alpha levels prior to training and aspects of their own personality play in both the effects on and the effects of training.

It is clear then that in order for the area to progress, some form of standardisation is needed in order to be able to interpret and compare the results of studies and establish whether or not an optimum training methodology actually exists. Not least because, as Fell at al. (2002) argue, there is research which suggests that training the wrong measure or doing so in the wrong way may reduce the effectiveness of the training.

The aim of this thesis, then, is to provide a starting point upon which future studies can build in order to establish a standardised method for training alpha via neurofeedback for the purposes of optimal performance training in healthy participants.

Chapter 2: General Methodology

This chapter will provide a summary of the methodology used in the following experiments (Chapters 3-5). The aim of this chapter is twofold. Firstly to provide a general overview of how the experiments in this thesis were conducted and analysed and secondly to provide a rationale for why. The present chapter will start with an outline of the pilot study and how it informed the general method for experiments 1 -3 (see Chapters 3-5). It will then provide details of who the participants in the experiments were, how they were recruited and the instructions they were give. A general explanation of what the neurofeedback training itself involved and how the sessions were conducted will follow before, finally, a description of how the EEG data was prepared, checked for reliability, and analysed.

The Pilot Study

A pilot study was carried out in order to determine what the neurofeedback thresholds and length of training should be, as well as to identify any potential problems (including those from the perspective of the participants themselves).

1.1. Participants

The volunteers were a convenience sample of one male (aged 26) and one female (aged 24), each with corrected to normal vision. The number of participants was chosen based on how many of those willing to take part in the overall study (outlined in section 2) were willing to receive a smaller fee for completing one session of neurofeedback as opposed to receiving a larger fee for taking part in more. Each of the pilot participants was paid £10 and received two course credits for taking part.

1.2. Neurofeedback Training

Because these sessions were exploratory, each participant undertook one session of audio-visual neurofeedback training. Audio-visual training was chosen for feedback in order to give the participants experience of both feedback modalities. Equipment, montage, electrode attachment procedure, and feedback, were all identical to that of experiments 1-3 (see section 2, below).

1.3. Procedure

Participants undertook 15 minutes of enhancement training followed by 15 minutes of suppression training, with each of those 15 minutes divided in to three 5 minute segments. The pilot session comprised 10 stages (see Figure 7, below). Stage 1 consisted of a 5 minute eyes closed baseline followed by stage 2, a 5 minute eyes open baseline. Baselines were required to identify the amplitude of participants' alpha brainwaves at position Pz (see Figure 1 on page 3) for use in the threshold setting (for justification of why Pz was chosen see section 2.2.3., below). Note that the pilot participants only trained with their eyes open, which makes the eyes closed baseline unnecessary for their training. However, because the experimental participants would need to have both eyes open and eyes closed, baseline recordings of both types of baseline were recorded in order to keep the procedure as close as possible to the experimental participants'.

5 minutes	5 minutes	5 minutes	1 minute	5 minutes	1 minute	5 minutes	1 minute	5 minutes	1 minute	5 minutes	1 minute	5 minutes	5 minutes	5 minutes
Eyes Closed Baseline	Eyes Open Baseline	Enhancement Training	Break	Enhancement Training	Break	Enhancement Training	Break	Suppression Training	Break	Suppression Training	Break	Suppression Training	Eyes Closed Baseline	Eyes Open Baseline
Stage 1	Stage 2	Stage 3		Stage 4		Stage 5		Stage 6		Stage 7		Stage 8	Stage 9	Stage 10

Figure 7. The 10 stages comprising the pilot study

Stages 3, 4, and 5 each consisted of 5 minutes of enhancement training separated by one minute breaks. After another one minute break they then undertook stages 6, 7, and 8, each of which involved 5 minutes of suppression training separated by one minute breaks. Stage 9 was a 5 minute eyes closed baseline followed by a one minute break and then finally finishing with another 5 minute eyes open baseline (stage 10). The post-neurofeedback training baselines (stages 9 and 10) again were included because during the experiments themselves the aim was to see whether training showed an influence on baselines (see Chapter 5, section 4).

The crucial difference between the training in the pilot study and the training during the experiments themselves was the thresholds. Whereas in the experiments participant thresholds were set twice per session, once before the commencement of their enhancement training and once before the commencement of their suppression training, in the pilot study the participants' thresholds were altered every 2.5 minutes during both the enhancement and during the suppression training to try and determine the most optimum threshold for the participants to train to. The 2.5 minute timing was chosen in order to be able to incorporate several variations in threshold.

Before commencement of stage 3, each pilot participants' threshold (i.e. level at which they had to try and increase their alpha amplitude over) was set at 60% of their average amplitude during their eyes open baseline. Every 2.5 minutes the threshold was increased by an additional 20% of their resting eyes open baseline (i.e. from 60%, to 80%, to 100% etc.). This continued until participants reported finding the training to be too hard whereupon the threshold was reduced back to the previous threshold level (e.g. if participants reported finding 120% too hard the next threshold change would go back to 100% as opposed to 140%) and the adjustments continued in the same fashion every 2.5 minutes until the end of stage 5.

The suppression thresholds were explored in a similar fashion with an initial threshold of 100% of their average amplitude during their eyes open baseline being set at the start of stage 6 for them to try and suppress the amplitude of their alpha under. Every 2.5 minutes the threshold was lowered by 20% of the baseline amplitude (i.e. from 100%, to 80%, to 60% etc.) until participants reported the threshold as being too hard, whereupon it was raised back to the previous level they had been training at and adjustment continued back and forth in the direction they requested until the end of stage 8. After stage 10 participants were asked which thresholds they preferred and why and this information was used to inform the design of experiments 1-3 (see Chapters 3 to 5).

1.4. Outcome

There were four outcomes from the pilot study related to: the baselines, the breaks between the segments, the training segments themselves, and the thresholds.

1.4.1. The Baselines

Given the time constraints with regards to both the feasibility of running the number of participants needed for an adequate sized sample and also in relation to the demands on the participants themselves (i.e. not wanting to make the sessions too lengthy and therefore potentially put them off taking part or completing all the sessions), it was decided that each session, including the placement and removal of electrodes, should not exceed an hour per session. To this end, it was decided that baselines should be shortened. Additionally, pilot participants reported finding the baselines too long just for “sitting still not doing anything”. This coupled with the fact that 3 minute baselines still kept in line with prior research in the area (e.g. Angelakis et al., 2007) resulted in the decision to make each baseline a 3 minute recording instead of a 5 minute one.

1.4.2. The Breaks

In the pilot study each stage was separated by a one minute break. The breaks were set at a fixed length in order to keep the training situation as consistent as possible amongst all the participants. This was deemed necessary both for continuity and because factors relating to training schedule (see Chapter 1, section 3.6.4.) has been suggested as having a potential effect on participants’ training ability. Both the pilot participants reported finding one minute breaks between each stage too lengthy and “frustrating” once they had commenced the actual training and so based on this it was decided to halve the length of the breaks to 30 seconds each instead.

1.4.3. The Training Segments

In the pilot, the enhancement training and suppression training were each split in to three 5 minute Segments separated by short breaks in-between. Again, the participants reported finding this frustrating as they felt that they were being stopped just as they were “getting in to it”. They both felt that a break was needed during each type of training (i.e. enhance and suppress) but suggested just having one halfway through each. When questioned about the length of each type of training they both felt that 15 minutes was “about right”. Hence it was decided that the actual training itself would consist of 15 minutes of enhance training with a 30 second break halfway through and 15 minutes of suppression training, again split into two 7.5 minute segments with a 30 second break in-between.

1.4.4. The Thresholds

As discussed in the previous chapter, the thresholds needed to be set at a level which would provide enough feedback for participants to learn from but not set at such an easy level that they would be able to keep their alpha over threshold without trying, therefore rendering the provision of feedback unnecessary and therefore meaningless (Knox, 1980). Based on reported difficulty levels of the various feedback thresholds tried out in the pilot, a threshold of 100% of the average amplitude attained during the relevant baseline (i.e. eyes open or eyes closed depending on whether the participants were training with their eyes open or their eyes closed) was decided on for the enhancement training and 40% of the relevant baseline amplitude for the suppression training.

General Method for all Experiments

The overall method for experiments 1 – 3 (see Chapters 3 – 5) was as follows:

2.1. Participants

The number, age and other details specific to the samples used in experiments 1-3 are outlined in the method section of the individual experiments. All participants were recruited via an email advert sent out to all the undergraduate psychology students at Canterbury Christ Church University. Psychology undergraduates were used as the sample out of convenience as they were the most easily accessible population.

Interested respondents were sent an information sheet (see Appendix B) as well as a consent form (see Appendix D) to fill out and send back if they were still interested in taking part and had not answered 'yes' to any of the questions on the screening form (see Appendix C).

Due to the potential link between alpha and depression (see, for example, Baehr, Rosenfeld, & Baehr, 1997) all patients who reported suffering from or having suffered from depression were excluded from taking part. Likewise, due to potential differences from the assumed normal patterns of brain activity, any participants who had epilepsy or a family history of epilepsy or who had consulted a professional about mental health issues were also excluded from taking part. Finally, respondents who reported being on any medication, either prescribed or otherwise, which could interfere with the activity of the brain (e.g. tranquilizers, stimulants, anti-depressants. . .) were also excluded from taking part.

Participants received all their course credits and £50 for taking part (or proportionally less if they failed to complete all their sessions).

All the participants reported having normal or corrected to normal vision.

Due to the infeasibility of running more than 40 participants in the space of a week the participants were made up from two samples run during separate term times. The first sample was made up of 39 participants (31 female, 8 male), of which 31 (6 male, 25 female, age range 18-44, median and modal age = 21) completed all the required neurofeedback training sessions. The second sample was made up of 29 participants (19 female, 10 male), of which 28 participants (9 male, 19 female, age range 18-42, median age = 20.5, modal age = 19) completed all the required neurofeedback training sessions.

The reason it was deemed necessary to run two samples of participants, as opposed to just one, was because when the analyses were performed on the data from the first sample of participants no significant results were found but power analyses indicated that if the number of participants increased to 15 or more per feedback condition then an effect would likely be found.

In each of the two samples there were participants in eyes closed audio conditions, participants who trained in eyes open audio condition, participants who trained in eyes open visual conditions, and participants who trained in eyes open audio-visual conditions. Once the data from the two samples was gathered the data from all the participants was then combined to form one large sample and for each experiment in the proceeding chapters of this thesis the participants were taken from this one amalgamated sample. So for Chapter 4, for instance, all the eyes open audio participants from the original sample 1 and all the eyes open audio participants from the original sample 2 were combined to form one sample of eyes open participants. Likewise, all the eyes closed audio participants from the original sample 1 and all the eyes closed audio participants from the original sample 2 were combined to form one sample of eyes closed participants.

Participants were allocated to their feedback groups in such a way so as to try and ensure that there were equal numbers of participants in each feedback group. So the first participant was assigned to the audio-visual group, the second to the visual group, the third to the eyes open audio group, the fourth to the eyes closed audio group, the fifth to the audio-visual group, the sixth to the visual group, the seventh to the eyes open audio group, the eighth to the eyes closed audio group, and so on. The only exceptions made to this were if a participant was too uncomfortable to train with their eyes closed (due to feeling anxious about sitting in a small basement lab with their eyes closed for several minutes at a time). If this occurred then they were assigned to one of the other three training groups. Whilst this brings up the criticism of self-selection and some participants being allocated differently to the rest of the participants, it only applied to two participants and allowing them to move to an eyes open group was deemed a better option that the unethical option of leaving them in a group which made them uncomfortable and where there data would have been rendered unusable due to the high levels of anxiety and tension they would display with their eyes closed.

It could be argued that using the same samples of participants for each of the experiments in this thesis says more about the sample of participants themselves than of the training conditions. Given the distinct differences seen between the participants as a function of training condition, however, this seems unlikely, and given the practical problems raised by running such large numbers of participants for such long periods of time this was considered to be the most efficient use of the data collected. However, to ensure that none of the groups differed in their alpha amplitude before they started their alpha neurofeedback training, a one way ANOVA was performed on their alpha amplitudes during the eyes open baselines of each of the four feedback groups before the start of their first neurofeedback training session. This showed that there was no significant difference between the groups in the amplitude of their alpha during their eyes open baselines before they started their alpha neurofeedback training session, F (3, 61) = 1.4, p = .260, MS_E = 7.50. A one way ANOVA was also performed on their alpha amplitudes during their eyes closed baselines before the start of their first training session. This also showed no significant difference between the groups in the amplitude of their alpha before commencing neurofeedback training, F (3, 60) = 1.7, p = .170, MS_E = 39.4. It can therefore be concluded that there were no significant differences between any of the feedback groups in the amplitude of their alpha before they started neurofeedback training.

One final point to note is that because 9 of the 68 participants dropped out of the study before completing all 10 of their sessions this meant that there was a choice between utilising only the participants who completed all of their sessions during the data analyses (known as per protocol analyses) or using the data from all of the participants, including those who dropped out (known as intention to treat analyses). There are two main arguments which could be made here. One is that the drop-outs should not be included because there may be something different about them compared to the rest of the sample which led them to drop out. Another is that they *should* be included because it gives a more representative overview of the original sample and the reason they dropped out may be relevant to the training. For instance, they may have dropped out because they found the training too easy, too hard, too boring, or because they could not do it. In trying to establish the optimum methodology for neurofeedback training it seems pertinent to also take in to account participants such as these (i.e. those who (potentially) find it too hard/easy/boring/etc.). In order to avoid the potential bias characteristic of per protocol analysis (see Newell, 1992, for further discussion of this point), intention to treat analysis was therefore used. However, it should be noted that all missing data was kept as missing and not filled in based on, for example, estimations used based on the performance of the drop-out participants before they dropped out.

In order to check how much of a difference it made using per protocol versus intention to treat analysis all data presented in this thesis was analysed both ways (i.e. first with the inclusion of and then without the inclusion of the data from the drop-outs) and it was discovered that whichever type of analysis was used the overall results were the same. For the purposes of this thesis, then, the dropouts were included in the data analysis although it is worth noting that the overall findings would have been the same even if they had not been included.

2.2. Neurofeedback Training

2.2.1. Training Schedule

In the case of each experiment, participants undertook 10 once-weekly neurofeedback training sessions. The number and schedule of the training sessions was chosen to be consistent with previous research (see Chapter 1, section 3.6.) and also for practicality. The aim was to ensure sessions would be frequent enough to enable learning (see Chapter 1, section 3.6.4., for further discussion of this point) but not so frequent as to encourage a high drop-out rate. One session per week per participant maximised the number of participants that could be run in the given time frame, i.e. during term time when students were present. Given their lack of availability outside of term time, the aim was for each data collection phase to start and end within the same term to try and ensure regularity of training and comparability of participants' data (i.e. the same training schedule for all participants).

2.2.2. Equipment

Training was conducted using a ProComp Infiniti amplifier with Biograph 2.1 monitoring and feedback software (Thought Technology Ltd., Montreal, Quebec). The signal was acquired at 2048Hz, A/D converted and band filtered to extract the alpha (8-12Hz) and electromyographic (EMG) (40Hz+) components. The choice of 8-12Hz for the alpha bandwidth was based on one of the most commonly used alpha bandwidths (see Table 2). Although 18-13Hz is the most commonly utilised, 13Hz is usually classified as being the lower end of the beta bandwidth so, in line with Knox (1980), 8-12Hz was used instead in an attempt to reduce contamination from surrounding bandwidth frequencies.

The way the amplifier works is that the signal from the raw EEG is detected by an encoder using 'common mode rejection' (also known as differential amplification). In other words, the activity from the reference electrode (which picks up all electrical activity not being emitted from that part of the brain specifically) is subtracted from the activity being picked up by the active electrode (which picks up all electrical activity detectable from that part of the scalp) with what is left being taken to be just the brain activity at that scalp location (see Chapter 1, section 3.2.1. for further elaboration of this point). Thought Technology (personal communication, July 2012) explain that the ground electrode, as well as being one of the many safeguards in place if there was a short in the encoder, also serves as a further comparison to the active electrode in order to filter out all environmental, non-brain-originating, signals. Once this subtraction process has occurred the remaining signal is amplified in order to make the signal large enough for changes to be detected. It is at this point that the signal is sent to the computer whereby an IIR (Infinite Impulse Response) filter is used to remove any bandwidths which are not of interest. So in this case it isolated alpha (8-12Hz) and removed theta (4-7Hz), delta (< 4Hz), and beta (13-30Hz). Although the filters may potentially let in signal from the surrounding bandwidths (e.g. high amplitude 7.99Hz activity may be captured by a filter set to remove everything below 8Hz) anything extraneous which they do let through 'is usually insignificantly small' (Thought Technology, personal communication, July 2012). Once all the surrounding bandwidth activity is removed the amplitude of the filtered EEG signal (in this case the alpha (8-12Hz) bandwidth) is calculated using a calculation known as Peak to Peak amplitude in order to provide information on the quantity, or power, of the chosen bandwidth, as measured in microVolts (mV). This information is then used to provide the feedback (see Chapter 2, section 2.2.4., below).

2.2.3. Montage

The equipment used offered a choice of monopolar or bipolar training. A discussion of the relative advantages and disadvantages of each can be found in Chapter 1 (section 3.2.1.). Monopolar training was chosen for the purposes of this research in order to be consistent with the most common method used in the optimal performance alpha neurofeedback literature to date (see Table 4).

Each participant undertook neurofeedback training at position Pz with the reference electrode on the right earlobe and the ground electrode on the left earlobe. Pz was chosen as the active site for three reasons. Firstly, to reduce the likelihood of any interference from muscle movement (Krenn et al., in review). Secondly, alpha is most abundant in parietal and occipital regions (Chisholm, DeGood & Hartz, 1977), and, thirdly, because there has been some suggestion in the literature that Pz may be of particular use for optimal performance training

(Norris & Currieri, 1999) (further discussion of each of these points can be found in Chapter 1, section 3.2.2.).

Earlobes were chosen as the location for the ground and reference electrode placements as they were considered to be the least likely to pick up interference from muscle movement relative to the alternative placements (e.g., nose, chin, and temples) and to be the least physically uncomfortable for the participants.

2.2.4. Feedback

Information relating to participants' alpha amplitude at position Pz was fed back to participants in real time. There were four different feedback groups: eyes open audio, eyes closed audio (Chapter 4 only), visual, and audio-visual. A more in-depth discussion of the differences between eyes open and eyes closed training can be found in Chapter 4 and between audio, visual, and audio-visual feedback in Chapter 5.

Visual feedback was in the form of 2 moving bars on a computer screen, one representing the amplitude of their alpha at position Pz and one representing their EMG (electromyogram, i.e. muscle movement) (see Appendices E-J for examples of the visual feedback used). In the case of the visual feedback, the participants' goal was to try and increase (in the case of alpha enhancement training) or decrease (in the case of alpha suppression training) the height of the alpha bar over (for enhancement training) or under (for suppression training) threshold (see section 2.2.5., below, for an explanation of how the thresholds were set) by as much as possible for as long as possible. The height of the bar represented the amplitude of the participant's alpha and increased and decreased as their alpha amplitude increased and decreased. In addition the colour of the bar changed from red to green every time their amplitude (and therefore the bar) crossed the threshold in the desired direction (i.e. if the bar went above threshold during alpha enhancement training or below threshold during the suppression training) (see Appendices E-H for examples).

Given that muscle movement interferes with the EEG readings the participants' aim was also to keep the EMG bar as low as possible at all times and to prevent it from turning red, which it did every time their EMG exceeded threshold (see Appendices I and J for example screenshots).

The auditory feedback was in the form of a clarinet-style tone which sounded when participants crossed their threshold in the desired direction and from there increased and decreased in both pitch and volume in line with the participant's alpha amplitude. So during enhancement training the greater the participant's alpha amplitude the louder the volume and the higher the pitch of the tone they heard and during suppression training the smaller the participant's alpha amplitude the louder and higher the pitch of the tone. In both types of training, then, the participant's goal was to keep the tone on for as long as possible as often as possible and to make the tone go as high and loud as possible for as long as possible. Crucially though, if the participant's EMG exceeded the pre-set threshold this cut the sound off altogether regardless of how well the participant was doing with their alpha training. This was done to avoid reinforcing the participants for producing EMG readings which would interfere with the clarity of their EEG recordings (see 3.1.1., below). For participants who only had audio and not visual feedback, any time the sound was cut off due to excessive muscle movements the researcher informed them that they were becoming too tense and had therefore cut off the feedback tone. This was done in order to try and stop participants causing excessive artifacts (see 3.1.1. below) in the data recordings due to muscle tension and also to prevent them from discarding a potentially useful training method due to believing it was the method itself which was at fault as opposed to them simply becoming too tense whilst they were trying it.

Participants in the eyes open and eyes closed audio groups only received the audio feedback, the visual feedback being blocked from view by turning the monitor to a 90 degree angle so that the experimenter could still see the feedback but the participants could not. In contrast, participants in the visual group could see the visual feedback but the speakers were turned off to prevent them from receiving any audio feedback. Participants in the audio-visual group received both the audio and the visual feedback.

2.2.5. Thresholds

Thresholds were set individually for each participant at the start of each session. Based on the data for the pilot study, the thresholds for enhancement training were set at 100% of that day's baseline alpha amplitude and at 40% of that day's baseline alpha amplitude for the suppression training. Due to the large increase in the natural levels of their alpha amplitude which were displayed by many of the participants, participants training with their eyes closed had their thresholds set according to the alpha they had produced during their eyes closed baselines. Eyes open baselines were used to set the thresholds for the eyes open participants. If baselines were set according to the eyes open baselines for all participants then there was a danger that this would make the task of enhancement a lot easier, and the task of suppression a lot harder, for the eyes closed group (used in Chapter 4). Likewise, if baselines were set according to the eyes closed baselines for all participants then there was a potential danger that the eyes open participants would find the enhancement training a lot harder, and the suppression task a lot easier, than the eyes closed group. Basing thresholds on the corresponding (i.e. eyes open or eyes closed) baselines was therefore the best way to try and ensure that training conditions started off as equally weighted as possible for each of the feedback groups. It is also in line with the advice of those such as Ancoli and Kamiya (1978, 1979) (see Chapter 1, section 3.8.2. for a more in-depth discussion of this point).

With regards to the EMG threshold, this was set at 100% of the EMG participants produced whilst they were sitting relaxing during whichever baseline their alpha thresholds were based on (i.e. eyes open or eyes closed). During their baselines participants were instructed to sit still and quiet and relax. Using the EMG they produced in such conditions to set the threshold for their EEG therefore seemed like an appropriate way to try and ensure that participants did not become more tense during the course of the session whilst they were concentrating on trying to influence their alpha waves.

2.3. Procedure

2.3.1. Scalp Preparation

In order to maximise the amount of information (i.e. electrical activity of the cells beneath) which could be detected and recorded, all sites where the electrodes were to be placed (i.e. on the scalp at position Pz and on each earlobe) were first wiped with an alcohol wipe to sterilise the area, gently but firmly scrubbed using Nu-Prep abrasive skin prepping gel to remove any dead skin cells etc. which could potentially impair the electrodes from picking up the electrical activity beneath, and then re-wiped with a new alcohol wipe to remove any traces of the prepping gel. The surface of each of the electrodes were then covered with a pea-sized amount of EEG conductive paste before being attached to the skin.

At the end of each training session baby wipes were then used to remove all traces of the paste from the participants' skin and hair before they left the room.

2.3.2. Session 1

At the start of their first session participants were given a brief explanation of the EEG, alpha brainwaves, neurofeedback, the purpose of the study, the feedback, and what the sessions would consist of. They were also shown the electrodes and the EEG paste etc. and were given an explanation as to how each item would be used. The aim throughout was to ensure that the participants were fully informed with regards to the research and to try and help them stay as relaxed as possible, which it was hoped would in turn aid their training. Many of the participants were initially suspicious of the 'real' purpose of the study and worried that the electrodes might hurt etc. so the aim was to ease their fears and be as transparent as possible. They were encouraged to ask questions at any point they wanted. The only question they did not receive an answer to at any point was how to influence their alpha. They were left to work this out for themselves to try and avoid influencing anyone's training success with the information they were given. They were told that their task was to use the feedback to try and guide them in learning how to influence their alpha waves and that they could either do this by waiting for the feedback to occur and trying to work out what they were doing at the time and/or by trying out various strategies to see if they could find one which resulted in the feedback occurring.

If they were happy to continue after all their questions had been answered they were then given a consent form to read and sign (see Appendix D) and then commenced their first session.

2.3.3. Sessions 1 to 10 – Eyes Open Participants

For each neurofeedback training session participants remained seated with their eyes open during all but the first and last of the stages (see Figures 8 and 9). Stage 1 consisted of an eyes closed baseline recording whereby they were asked to sit still and quiet with their eyes closed for 3 minutes. They were then given a 30 second 'blink break' (stage 2) and then stage 3 consisted of sitting still and quiet for a further 3 minutes, this time with their eyes open, whilst their eyes open baseline was recorded. The information from which was then used to set the thresholds for that day's training. Once the thresholds had been set the neurofeedback training (i.e. stages 4-10) commenced. The order of training was counterbalanced such that half the participants in each condition did their enhancement training first and half did their suppression training first. So half the participants did 7.5 minutes of enhancement training (stage 4) followed by a 30 second break (stage 5) and then another 7.5 minutes of enhancement training (stage 6) before being given a 30 second break (stage 7). During this latter stage their thresholds were reset by the researcher ready for the commencement of stage 8, 7.5 minutes of suppression training, followed by a 30 second break (stage 9), and then their final 7.5 minutes of suppression training (stage 10). The other half of the participants did the same but in reverse, i.e. 7.5 minutes of suppression training, 30 second break, 7.5 minutes of suppression, 30 second break, 7.5 minutes of enhancement, 30 second break, 7.5 minutes of enhancement. After stage 10 all participants resumed an identical format with stage 11 being a 30 second break, stage 12 a 3 minute eyes open baseline, stage 13 a final 30 second break, and then finally, stage 14, a 3 minute eyes closed baseline.

2.3.1. Sessions 1 to 10 – Eyes Closed Participants

The procedure was exactly the same as for the eyes open participants except that in their case they were instructed to keep their eyes closed at all times other than during their eyes open baselines and their 30 second breaks.

Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	Stage 9	Stage 10	Stage 11	Stage 12	Stage 13	Stage 14
Eyes Closed Baseline	Break	Eyes Open Baseline	Enhancement Training	Break	Enhancement Training	Break	Suppression Training	Break	Suppression Training	Break	Eyes Open Baseline	Break	Eyes Closed Baseline
3 minutes	30 seconds	3 minutes	7.5 minutes	30 seconds	7.5 minutes	30 seconds	7.5 minutes	30 seconds	7.5 minutes	30 seconds	3 minutes	30 seconds	3 minutes

Figure 8. The stages comprising each neurofeedback session for participants who trained to enhance then suppress their alpha.

3 minutes	30 seconds	3 minutes	7.5 minutes	30 seconds	7.5 minutes	30 seconds	7.5 minutes	30 seconds	7.5 minutes	30 seconds	3 minutes	30 seconds	3 minutes
Eyes Closed Baseline	Break	Eyes Open Baseline	Suppression Training	Break	Suppression Training	Break	Enhancement Training	Break	Enhancement Training	Break	Eyes Open Baseline	Break	Eyes Closed Baseline
Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	Stage 9	Stage 10	Stage 11	Stage 12	Stage 13	Stage 14

Figure 9. The stages comprising each neurofeedback session for participants who trained to suppress then enhance their alpha.

Data Analysis

3.1. Analysis – Data Preparation

3.1.1. Artifact Removal

Once all the EEG data had been collected from the participants the next stage was to remove all artifacts from the data so that it could be analysed. Artifacts are changes in the EEG as a result of something other than brain activity, for example excessive muscle movement, and are often characterised by large fluctuations in the amplitude of the EEG. If they are not removed from the data then the accuracy of the recordings is likely to be impeded. Because the equipment did not come with any form of automatic artifact rejection all the raw EEG data had to be inspected visually and the artifacts manually excluded before analysis.

Figure 10. A sharp spike in a participant's EMG activity (circled here in red). Any such activity is identified during the artefact removal process and then removed before the data is analysed.

Each participant's EEG recordings for each of their training sessions was visually examined for any 'spikes' (i.e. muscle movement and environmental interference) in their EMG (see Figure 10, above). Anywhere where the EMG visibly spiked was removed from the data. That is, for each 1.5 minute period which was analysed, anywhere where there appeared to be abnormal activity (i.e. activity due to something other than brain activity) was highlighted and excluded from the data analysis.

3.1.2. Reliability Analysis

The identification and manual exclusion of artifacts from each participant's data leaves open the possibility of subjectivity when preparing the data. To check for this, the data from 10 participants was randomly selected and a single session from each was randomly chosen to be analysed by the experimenter and another researcher trained in manual artifact rejection. Independently, each visually identified and manually removed artifacts from the same 100 periods (see section 3.1.3., below) (10 periods x 10 sessions) and then made note of the mean amplitude and mean per cent time measures for each. In order to check that their data were in agreement Pearson's correlations were then performed on the per cent time data and Spearman's correlations on the amplitude data (in all instances the distributions of the amplitude data used for this reliability analysis failed to meet the assumption of normal distribution). As Table 19 shows, all results were found to be highly significant at the .001 level with very strong positive correlations for each, thereby indicating that the reliability of, and therefore the confidence in, the artifact removal process was acceptable.

Table 19

Correlations of the data analysed by each of the two researchers during the reliability analysis.

Researcher 1		Researcher 2: Enhancement Training – Amplitude	Researcher 2: Enhancement Training – Per Cent Time	Researcher 2: Suppression Training – Amplitude	Researcher 2: Suppression Training – Per Cent Time
Enhancement Training	Amplitude	r (98) = .989*			
	Per Cent Time		r (98) = .969*		
Suppression Training	Amplitude			r (98) = .995*	
	Per Cent Time				r (98) = .977*

* p < .001

3.1.3. Data Coding

The second stage of the analysis involved calculating the amplitude and percentage of time spent over (in the case of enhancement training) or under (in the case of suppression training) threshold during every 1.5 minutes of data per participant per session.

As mentioned above, each segment of training was 7.5 minutes long and dividing each segment into smaller ‘periods’, for the purposes of analysis, was necessary in order to try and identify changes over time within the segments themselves as well as simply from one segment to another and one session to another. Periods of 1.5 minutes were chosen as the unit of division because this provided five equal length time periods per segment which was judged to be enough to try and identify alterations over time. Shorter periods of, for example, 10 seconds or even 30 seconds seemed unnecessarily laborious.

3.2. Analysis – Data Analysis

The rationale for the measures used are addressed in Chapter 3. All other details relating to measures and details of the design used in each study are listed for each experiment individually.

Chapter 3: Experiment 1 - Identifying Indices of Learning for Alpha Neurofeedback Training

Introduction

As highlighted in Figure 4 (see Chapter 1), in order to establish whether or not participants show evidence of learning to enhance and/or suppress their alpha (8-12Hz) activity during neurofeedback, we first need to decide on how to measure their performance. In other words, an index of learning needs to be established. This index of learning incorporates two elements: one, how alpha is measured; and, two, how success is defined. With regards to measuring alpha there are numerous methods utilised in the alpha neurofeedback literature, as can be seen in Table 15 (see chapter 1). It is clear from this that what one study means by enhancing or suppressing alpha is not what is meant in others. Likewise, the terminology is not always consistent, providing another reason as to why it is important for studies to be clear about how they are defining alpha. Hardt and Kamiya (1976a) provide the example of per cent time also being referred to as alpha density, criterion alpha, alpha index and alpha abundance. In addition, identical terminology is sometimes, confusingly, used to mean completely different things. To take the case of 'integrated alpha', this is usually defined as a combination of both the time spent in alpha and the amplitude of that alpha, usually producing data in the form of mean amplitude per second (μv/second) (Kondo, Travis, Knott & Bean, 1979) but Cram, Kohlenberg and Singer (1977) instead use the term to refer to average amplitude. And of those who do use it to mean a combination of both amplitude and per cent time, it is not always clear if the calculations used to combine the per cent time and amplitude measures to form integrated alpha are done in the same way across the studies. The tendency is to talk about integrated alpha without providing any explanation of how it was derived. There is also a general vagueness in some studies' use of terminology, which leaves the reader unclear as to what the measurement used represents. For instance, both Jackson and Eberly (1982) and Mullholland and Eberlin (1977) refer to 'alpha events' but these are not defined clearly. Similarly, some of the studies refer to alpha abundance but fail to explain which aspect of alpha it is an abundance of. As an example, Kondo, Travis and Knott (1973) talk about alpha abundance but it remains undefined; only when one reads Travis, Kondo and Knott (1974b) is it clear that alpha abundance is the equivalent of what other studies refer to as per cent time.

As can be seen from Table 15, the most commonly used measures are: time the participants spend above/below the required threshold for alpha (n = 53[1]), the mean amplitude of the participants' alpha during training (n = 7), and integrated alpha (n= 14) which is a combination of the two (Kondo, Travis, Knott & Bean, 1979).

Although time spent over/under threshold is by far the most common measure in the literature, there is no compelling empirical evidence as to whether one measure is more useful than the others. It is critical, however, to define what counts as evidence for learning. For example, when Brown (1970) used percentage of time spent above threshold as the measure for assessing the success of alpha neurofeedback training, she found evidence of learning both within and across sessions but when she looked at amplitude no such evidence of learning was found. Thus measuring alpha in one way can produce different results to measuring it in another. This is presumably because different aspects of

[1] calculated by including the number of studies that refer to number of seconds in alpha and the number of studies that refer to per cent time in alpha

alpha are related to different things (Hanslmayr et al., 2005) but as Fell et al. (2002) point out, there is a lack of empirical research in to the different ways of measuring EEG alpha in relation to alpha neurofeedback training, so the reason why one measure would show an effect of learning, when another would not, is unclear. However Fell et al. (2002) argue that it is an important area to research, positing that training the wrong measure of alpha may reduce the effectiveness of the training. This presumably applies both with regards to the neurofeedback training itself and also to the effects (i.e. on cognition and behaviour etc.) of doing the neurofeedback training, with a good example of this demonstrated by Angelakis et al. (2007). When they had their participants increase their peak alpha frequency at POz over the course of 31-36 sessions, an increase in processing speed and executive function was seen. When they had participants increase alpha (8-13Hz) amplitude at POz for 31-36 sessions they showed an increase in memory performance. Perhaps more pertinently, alpha amplitude training seemed to actually have a negative effect on processing speed and central executive function even though the peak alpha frequency training at the same site had shown improvement in these areas. It should be noted, however, that this was a very small sample (3 in the peak alpha frequency training group and 2 in the amplitude group) of elderly patients so caution should be taken in generalising from the results. It does, nonetheless, illustrate Hanslmayr et al.'s (2005) and Fell et al.'s (2002) comments about the differing influences that training can have, and shows that these influences may go beyond simply the detection of whether learning has taken place to the actual outcome of the neurofeedback training too.

Whilst the reasons for the difference are not yet entirely clear, Brown (1970) is by no means the only person to report different results depending on the way alpha is measured. Similar findings have also been reported by Cram, Kohlenberg and Singer (1977). When they gave their participants one 24 minute session of audio alpha (8-12Hz) enhancement and audio alpha suppression training, they found that during the enhancement training their eyes open participants spent significantly more time over threshold than their eyes closed participants. When they used amplitude as the measure of determining enhancement success, however, no significant differences were found between the two. Cram et al. (1977) point out, however, that the participants' individual thresholds were based on the amplitude of their corresponding baselines, so eyes open participants' thresholds were based on their eyes open baselines and eyes closed participants' thresholds were based on their eyes closed baselines, and suggest that this may be why the two measures produce different results. They do not elaborate on this, but we know that eyes closed conditions result in a naturally higher amplitude of alpha in most people than do eyes open conditions (Plotkin, 1976a). The per cent time data suggests that whilst the eyes open group enhanced their alpha over their (lower) thresholds the eyes closed group did not. However, because the eyes closed group would naturally have started off with a higher amplitude threshold than the eyes open then a direct comparison between average amplitude of one group to the other has the potential to mask any effects. To illustrate this, imagine, for example, that the threshold for the eyes open group was 10µv and the threshold for the eyes closed group was 20µv and that during the enhancement training the eyes open group spent most of their time doubling their alpha amplitude to a mean of 20µv whilst the eyes closed group spent most of their time staying at their threshold. A direct comparison between the amplitude produced by the eyes open group during training to the amplitude produced by the eyes closed group during training would show no difference between the two groups because they both produced an average of 20µv. The per cent time measure, however, would show that the eyes closed group spent almost no time over threshold but that the eyes open group spent most of their time over their threshold. This would, however, be solved by looking for change over time with both time and group as factors rather than simply comparing the two groups directly in such a way.

In addition to potential differences between the use of different measures, the use of per cent time as a measure at all has come under criticism for masking evidence of learning. Hardt and Kamiya (1976a) argue that participants who increase the mean amplitude of their alpha but not the amount of time they spend over threshold would wrongly be classified as showing no evidence of change if percentage of time over threshold was used as the measure. They are further critical of the fact that per cent time measures classify individuals who spend the same amount of time increasing their alpha activity as exhibiting the same level of ability even if the amount they increase their alpha by differs. For example, if only time spent over threshold is taken into account, a participant who tripled their mean amplitude and produced a 70% increase in the amount of time they spent over threshold would be classified as showing the same pattern of learning as one who showed a 70% increase in the amount of time spent over threshold but who only produced a mean amplitude of 1 or 2 µv higher than they did before training. Hardt and Kamiya (1976a) state that per cent time measures rarely result in significant findings and argue that the failure of some studies to find evidence of learning may often be attributed to the use of per cent time as the measure.

Despite this, as Norris and Currieri (1999) have pointed out, there has as yet to be any conclusive empirical evidence to determine whether amplitude or per cent time is the most preferable measure to use. Tyson and Audette (1979) argue that looking at brain activity using just one measure is inadequate and will result in a large loss of information and given the arguments about the potential problems with both amplitude and per cent which have been highlighted above, it has been suggested that using a measure which combines the information from both may be a more suitable compromise. Both Travis, Kondo and Knott (1974b) and Hardt and Kamiya (1976a) have suggested that integrated alpha is the preference as it uses information about both the amount of alpha produced (amplitude) and the time spent over threshold (per cent time), meaning that it incorporates more information and is therefore more suitable as an index of learning. Plotkin (1976a) also supports the use of integrated alpha, stating that it is more accurate and more sensitive than per cent time and Knox (1980) adds that it is a better method than simply looking at amplitude alone.

Whichever measure is used, Ancoli and Kamiya (1978) argue that studies using one measure should not be compared to studies using another, presumably because of the likelihood that they are too different and may be measuring different things. Thus differences between studies may be due to differences in participants' performance or they may be a function of the measures used to assess that performance. Whichever measure is used, Travis, Kondo and Knott (1974b, 1975) state that it would be better if all studies in the area used the same DV(s) for comparability.

In addition to this, differences in the measurement of alpha can be compounded with other differences, particularly with regard to whether participants are defined as successful in altering their alpha. What is meant by 'success'? In other words, what is that is taken to be indicative of learning? The answer to these questions also differs among studies. Although there are variations[2], the most frequently used method for looking for alpha neurofeedback training 'success' is to see if there is any change in alpha over time. With the two most common ways of examining this being to look for any evidence of change over time within the sessions themselves (within sessions changes) and/or as sessions progress (across sessions changes). Within sessions changes are usually defined as an increase or decrease in alpha between the start of each session to the end and across sessions changes are usually defined as a significant increase or decrease in alpha when latter sessions are compared to earlier ones.

Whilst both methods are commonly utilised there is evidence to suggest that it can depend on which is chosen as to whether evidence of learning is found. For instance, both Yamuaguchi (1980) and Cho et al. (2008) found that participants enhanced their alpha across sessions but not within whereas Schmeidler and Lewis (1971) and Potolicchio, Jr. et al. (1979) found evidence of participants altering their alpha when they performed a within sessions analysis but not when they performed across sessions analyses. As can be seen from Tables 16 and 17 (see chapter 1), of the studies which conducted more than one session, and were therefore able to perform across sessions analyses as well as within, there were 3 studies which found evidence of learning regardless of which of the two analyses they performed, 4 studies which found no evidence of learning with either method, 2 which found evidence of learning across but not within, and 4 which found evidence of learning within but not across. There were a further 27 studies who did conduct more than one session but whose results made it unclear whether there was evidence of learning either within or across sessions, variously because they did not include any statistical analyses (e.g. Bear,

[2] for instance, comparing the average amount of alpha during enhance trials to average amount of alpha during suppress trials such as in Suter's (1977) study; comparing differences in alpha production between different groups such as in Travis et al.'s (1973b) study

1977), because they used a different method entirely to analyse their results (e.g. Johnson & Meyer, 1974), because the results they discussed were not done so in relation to changes within or across sessions as such (e.g. Krenn et al., in review), or because it was unclear whether they were talking about within sessions or across sessions changes when they were reporting their results (e.g. Orne & Paskewitz, 1974).

A comparison between the two types of method (as opposed to simply utilising them both) is uncommon in the alpha neurofeedback literature, so there seems to be very little discussion as to why differences between the two types of analysis might occur. In the case of enhancement training, however, Cho et al. (2008) have suggested that the degree to which alpha can increase might be limited and that, in the sessions themselves, their participants may have reached their maximum limit for enhancement and then maintained rather than enhanced their alpha throughout the session (hence why they failed to find a within sessions increase). They suggest that with each session, participants were increasing towards that maximum and so were still able to show an across sessions increase. For no within sessions changes to occur, however, participants would have reached this maximum very early on in the session so it is surprising that, if this were the case, enough of a change would occur within each session in order for an across sessions change to be found. It is worth noting, though, that their participants' pre-training eyes open baseline alpha increased with each session. Thus, if there is such a thing as minimums and maximums with regards to alpha, it might be better to interpret these findings in terms of maximum distance of alpha in relation to a participant's baseline. The lack of within sessions increase may in that case suggest that participants learned to enhance their alpha from the start of the session but showed no improvement from that point onwards. They learned to do it but did not learn to improve beyond a certain 'distance', relatively speaking. The increase in alpha seen in their natural baseline levels may be indicative that training has a more cumulative long-term potential (see chapter 1, section 3.8.4 for further discussion of this point) rather than demonstrating a cumulative short-term increase within sessions.

With regards to why the opposite pattern may occur, a within but not across sessions change, it may be that participants are learning to alter their alpha but that they cannot improve it more than they did in the first session (although that seems unlikely given that there are studies which do show across sessions changes) or that they need a larger number of sessions to improve that ability to consciously alter their alpha (the issue of how many sessions are needed for alpha neurofeedback training is discussed in chapter 1, section 3.6.3).

In addition to this, whilst learning can be assessed by looking for evidence of a change over time, there is an argument that this by itself is not enough, and that, however learning is assessed, a baseline measure should be incorporated (e.g. Ancoli & Kamiya, 1978, 1979). That is, the individual's alpha during training should be compared to their alpha when they are not training (and therefore not attempting to exert a conscious influence over it) to see if there is a change. The assumption being that any difference seen between when the individual is trying to exert a conscious influence over alpha compared to when they are not is indicative of learning to exert control over their alpha.

Evidence of learning has been reported both with (e.g. Zoefel et al., 2011) and without (e.g. Pressner & Savitsky, 1977) the inclusion of baseline measures. However, the argument is that unless baseline is taken in to account it could be the case that any changes found over time could be the result of natural changes in alpha rather than the result of a conscious alteration.

As can be seen from Table 18 (see Chapter 1) approximately one third of the studies reviewed (n = 30 studies) reported changes in alpha in comparison to a baseline. Of the rest, 16 did not and 50 variously did not utilise a baseline (e.g. Angelakis et al., 2007), were either unclear as to whether a baseline was incorporated, or unclear as to whether the changes in comparison to baseline were actually significant (e.g. Chisholm et al., 2007). Further, of those 50 studies, 18 studies did not include any indication of having taken baseline readings at all.

The debate regarding the inclusion of baselines is particularly pertinent with the case of enhancement training due to what Plotkin (1976a) identifies as a naturally occurring increase in alpha for the first few minutes of recording. Because the training situation itself can have an initially suppressing effect on alpha (see the further analysis 1 section of this chapter's results section for a more in-depth discussion of this point), Plotkin (1978) argues that increases seen in alpha during training may simply be the result of habituation or disinhibition rather than learning as such, and he and other proponents suggest the incorporation of baselines (e.g. Ancoli & Kamiya, 1978; Ancoli & Kamiya, 1979; Gertz & Lavie, 1983; Prewett & Adams, 1976). It follows that a baseline comparison is needed to ensure that participants' alpha is actually increasing away from baseline levels (in the case of enhancement) rather than back towards baseline after the commonly occurring initial alpha suppression seen at the start of training (see Further Analysis 1, below).

A good example of this is Fell et al. (2002), who conducted one 22.5 minute session of eyes closed alpha (8-12Hz) enhancement training at Cz. As can be seen from Figure 11, below, if only the participants' alpha power during the training itself (i.e. bars T1-T9) are considered it appears that participants showed an increase over time. In other words, this is a within sessions increase. When the baselines (i.e. bars B1-B4) are taken in to account however it is clear that participants' alpha power during training does not exceed the immediately preceding baselines and only three of the nine trials exceed the initial pre-training baseline, which is the baseline which most of the existing studies use to compare performance in training to. In other words, then, the alpha power the participants produced when they were training to consciously increase their alpha rarely appears to exceed the alpha power they produced naturally when they were not, and although Fell et al. (2002) do not talk about significant changes over time, their graph serves as a useful illustration as to why the incorporation of baselines can cast results in a clearer light.

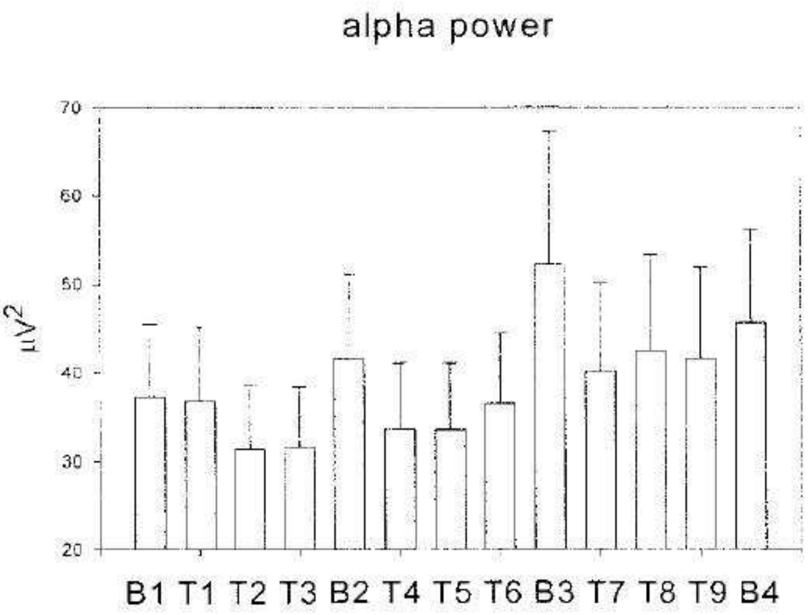

Figure 11. Fell et al.'s (2002, p1052) graph depicting their participants' alpha power during their single session of alpha training with B1-B4 representing participants alpha power during their four 1 minute baselines and T1-T9 depicting their alpha power during each of their nine 2.5 minute trials.

Plotkin (1976a) argues that baselines should be measured at several points during neurofeedback training in order to account for natural changes in alpha and to allow participants to acclimatise to the training situation. The potential issue with taking several baseline measures throughout the course of each individual training session, however, is that training alpha may have a knock-on effect on the participants' natural resting alpha levels (Hardt & Kamiya, 1976b). For instance, Schmeidler and Lewis (1971) took a pre-training and a post-training baseline and found that there was a change from the pre-training baseline during the training but also when the pre training baseline was compared to the post-training baseline taken directly after training, which is suggestive of a potential carry-over effect from the training itself. Likewise, Cho et al. (2008) found that participants' alpha at the end of each session correlated with their baseline at the start of the next session suggesting that those learning to enhance alpha may have been producing a more long-term increase in their alpha. The reason this is relevant is because if baselines are taken throughout a session as a measure of participants' natural alpha levels, then the effects of training may end up being masked if the training itself is causing baseline alpha to rise too. For instance, if a participants' resting alpha temporarily rises due to the enhancement training then comparing training performance to those elevated alpha rest levels would make it seem like training had been less effective than if compared to a baseline at the start of the session. Again, using Figure 11 (above) as an example of this, as participants' alpha power during the training itself increases so too does their alpha power during the 4 baselines (B1-B4 on the graph) taken throughout training. If trials are compared to the baselines immediately preceding them (or even to the average of all 4 of the baselines combined) then participants' alpha power never exceeds their preceding baseline. If their alpha power is only compared to the first baseline then three of the trials do show an increase over baseline levels. The point in the training at which the baseline or baselines are taken then can make a difference to whether evidence of learning is found.

Plotkin (1976a) took multiple baselines throughout training. However, even though, as with Fell et al.'s (2002) study, Plotkin's (1976a) baselines did in fact show a within sessions increase, Plotkin et al. (1976) argue that this is not a problem. However, the focus of their argument is more on dismissing the idea that participants may intentionally try to alter their alpha during baselines as opposed to dealing with the potential problem of rising baselines as a result of an unconscious effect of training which is a different issue entirely.

Whilst it could be argued then, that taking multiple baselines to use as a comparison is unwise in case the alpha neurofeedback training itself is simultaneously altering baseline alpha, using a single pre-training baseline as a measure may be sub-optimal too, especially when more than one session is conducted over a number of different days. This is because alpha changes occur naturally as a function of day and time (Gertz & Lavie, 1983), which means that if multiple separate sessions are run then a change seen in alpha on different days when compared to a single pre-training baseline taken on another day may be due to learning or may simply be due to natural fluctuations present in alpha. Also, taking an initial baseline reading before any neurofeedback training has started to use as a comparison for all the training sessions[3] may be problematic because it is likely that the first baseline reading may be suppressed below natural levels due to initial nervousness or anticipation felt by the participants at the novelty of the situation (Lynch & Paskewitz, 1971).

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[3] such as is the case with Kuhlman & Klieger (1975), who used a baseline taken from a week before the participants' actual training session in order to measure their participants' performance against. Also for Zoefel et al. (2011) who compared participants' performance in their 5 training sessions to the pre-training baseline taken at the start of the very first session

A further addition to the argument of appropriate baselines is whether or not participants' baseline measures should be taken with their eyes open or their eyes closed. There are those such as Plotkin (1976a, 1976b, 1978, 1980) who argue that regardless of whether training is undertaken with eyes open or eyes closed, the baselines themselves should be taken with eyes closed. His argument is that the optimum way of producing alpha, so by his definition the way which is most likely to see the highest amount of alpha produced, is when eyes are closed and that alpha enhancement neurofeedback training can therefore only be deemed successful if it exceeds eyes closed baselines. Interestingly, he himself (Plotkin, 1976a, 1976b, 1978, 1980) is sceptical that it is even possible to learn to enhance alpha over eyes closed baselines, although the opinions in the literature are mixed about this matter. For instance Paskewitz and Orne (1973) have expressed scepticism that above eyes closed baseline levels of enhancement are possible and Orenstein and McWilliams (1976) failed to show an increase in alpha (8-13Hz) above eyes closed baseline levels during their eyes open training. On the other hand, whilst those such as Drennen and Reilly (1986) are more cautious in their assertions and state that it is possible but rare, Tyson (1982, 1987) argue that the sceptics are wrong and that above eyes closed baseline enhancement is possible. In fact, both Plotkin, Mazer and Loewry (1976) and Plotkin and Rice (1981) refer to participants who achieved above eyes closed baseline levels of alpha enhancement.

As it happens, the idea that eyes closed baselines are always the most appropriate baseline to use is not something universally agree on with Ancoli and Kamiya (1978, 1979) advising that eyes open training should not be compared to eyes closed baselines and vice versa due to the difference between eyes open and eyes closed conditions (see Chapter 4 for further discussion of this point).

Whilst there appears to be no empirical evidence as to which of the above is the most useful baseline measure, and there are disadvantages to each, a compromise would seem to be to follow those such as Cho et al. (2008) and take a baseline at the start of each training session as opposed to one pre-training baseline, or multiple-per-session baselines. Given the differences seen in alpha between eyes closed and eyes open conditions (see Chapter 4 for further discussion of this point) it would also seem sensible to keep the baseline representative of the training itself, i.e. eyes open baselines as a comparison for eyes open training, eyes closed baselines as a comparison to eyes closed training.

In sum, there is evidence to suggest that whether or not participants are classified as showing an ability to exert some degree of conscious control over their alpha waves via neurofeedback training depends on the indices of learning used. The same data may produce different results depending on whether alpha is measured using amplitude, per cent time, or integrated alpha, and whether or not success is classified as a change within sessions or across sessions and whether or not baseline is taken into account. Before the question of whether or not there is an optimal method for alpha neurofeedback training is examined, then, a decision needs to be made as to how alpha should be measured and what is meant by 'success' when looking at participants' performance during training.

The aim of this experiment, therefore, is threefold. First, to look for any differences in the three most common measures which exist in the literature: amplitude, percentage of time over/under threshold (per cent time), and integrated alpha. Secondly, to look for any differences (i) within sessions and (ii) across sessions, both with and without comparisons to baseline. By looking for differences between the different measures as well as the distinct methods of comparison the aim is to see whether these variables do indeed make a difference to the results found and to identify an index of learning that will be used for the experiments throughout this thesis.

Method

Participants

The specific details regarding the number and age of the participants used in this experiment can be seen in Figure 12, below.

Of the 52 participants, only 47 completed all 10 sessions of alpha neurofeedback training. Of the 17 audio-visual feedback participants, 15 completed all 10 sessions after one participants dropped out after completing 5 sessions and one dropped out after completing 7 sessions. Of the 18 eyes open audio feedback participants 16 completed all 10 sessions after one dropped out after completing 6 sessions and one dropped out after completing 7. Finally, of the 17 visual feedback participants, 16 completed all 10 sessions after one participant in the group dropped out after completing session 7. When a comparison was run to compare the results of the analyses when these cases were not included to the results of the analyses when they were no differences were found. These cases were therefore left in the analyses.

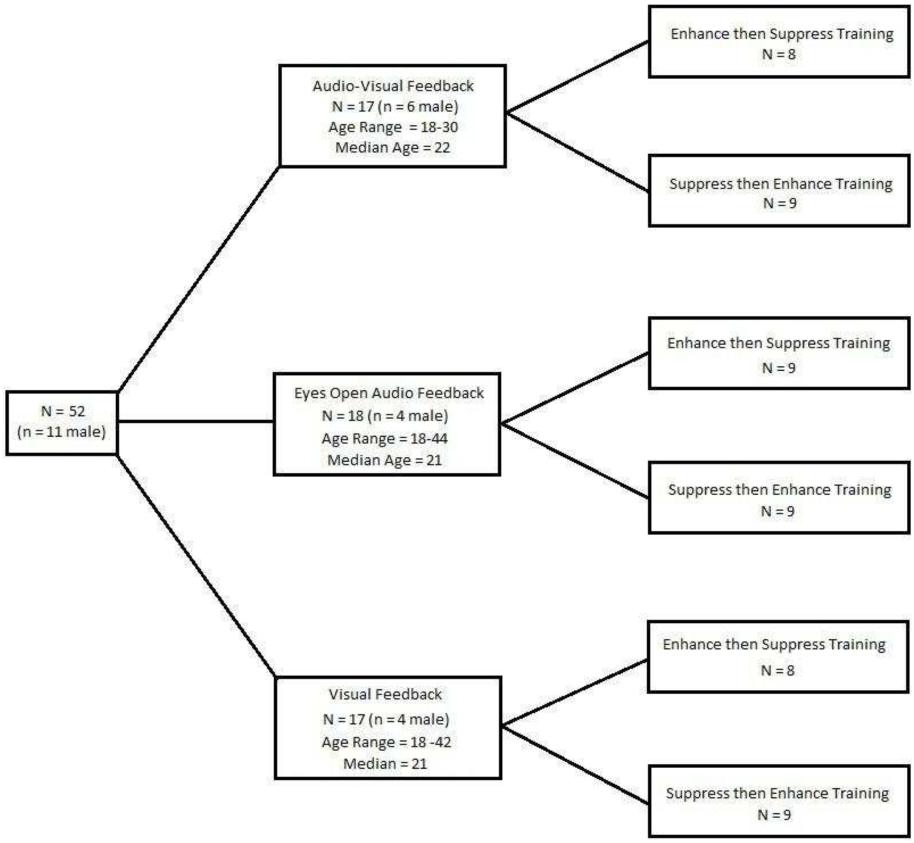

Figure 12. The number and age of participants and how they were dispersed among the groups used (i.e. in relation to feedback type and order of training within each session)

Three types of feedback (i.e. audio-visual, audio and visual) were chosen because it is as yet unclear whether one is more advantageous to training than the other (see Chapter 5 for a more in-depth discussion of this area) so, at this stage, the choice between them would be somewhat arbitrary and therefore just as legitimate to incorporate all. The caveat to this is that because closing the eyes automatically increases alpha levels (Plotkin, 1976a), eyes closed and eyes open training are therefore not considered to be comparable (Ancoli & Kamiya, 1978) (see Chapter 4 for an in-depth discussion of this point) and would cause too much variability for them to be included together with the eyes open participants as one single sample. Eyes open training was therefore chosen instead.

All details relating to recruitment are the same as in Chapter 2 (see section 2.1, page 110). Although the ideal would be to have an equal number of male to female participants the sample from which the participants were recruited from (i.e. psychology students from Canterbury Christ Church University) were predominantly female meaning that the number of male volunteers was considerably smaller than the number of females.

Procedure

All details regarding equipment, scalp preparation, montage, threshold setting, participant instructions and training schedule are the same as previously stated in the general method section.

For an outline of the procedure see Figures 8 and 9 (Chapter 2).

Results

In order to identify any differences in the pattern of learning between the three most commonly used indices of learning (changes in amplitude, per cent time, and integrated alpha), the data were analysed separately for each measure within sessions, within sessions in comparison to baseline, across sessions, and across sessions in comparison to baseline. This was done separately for both the enhancement training (see section 1 below) and then for the suppression training (see section 2, below).

Before starting analyses, normality of distribution checks were performed. With the exception of the per cent time measure used during enhancement training, the data for each measure was found to be non-normally distributed[4]. All data was therefore log transformed before analyses were performed except in the case of the per cent time enhancement data, for which raw scores were analysed (i.e. not log transformed first).

For all resulting analyses a Greenhouse-Geisser correction was used if Mauchley's Test of Sphericity was found to be significant and Cohen's d was used to calculate effect sizes of any of the a priori pairwise comparisons (with Bonferroni corrections) found to be significant.

1. Enhancement Training

The aim of enhancement training is for participants to consciously increase the amount of alpha they produce and to do so for as long as possible. In all cases, the expectation would be to see an increase in amplitude, per cent time (percentage of time spent over threshold), and integrated alpha over time. Although described as a combination of amplitude and per cent time, it is often unclear how integrated alpha is actually calculated in the literature to date (e.g. Travis et al., 1974b). For the purposes of this experiment, then, integrated alpha was calculated by multiplying each value for the amplitude measure by the corresponding per cent time value and then dividing that figure by 100:

i.e. integrated alpha (α_i) = (μv x percentage of time over threshold) / 100.

[4] results of the Shapiro-Wilks statistic (see Razali & Wah, 2011) were all $p < .003$ for amplitude; all $p < .006$ for integrated alpha; and all $p < .004$ for the suppression per cent time data

For example, if the mean amplitude in session 1 was 7.64µv and the mean percentage of time spent over threshold during session 1 was 41.12% then the integrated alpha for session 1 would be 3.14:

$$(7.64 \times 41.12) / 100 = 3.14.$$

Although the paucity of information in the literature referring to integrated alpha means this may not always be the calculation performed for its derivation in other studies, it nonetheless serves the purpose of providing a measurement which reflects both amplitude and per cent time and is less complex than other alternatives (e.g. Hardt & Kamiya, 1976a).

1.1. Within Sessions

In order to look for changes over time within the sessions themselves, each 15 minute enhancement session was divided in to 10 1.5 minute sections (each of which from here-on-in will be referred to as a 'period') with the time spent before prior to the halfway break being divided into 5 periods (from here-on-in referred to, collectively, as 'segment 1' (s1)) and the remaining time spent training between that break and the next also therefore consisting of 5 periods (to be referred to as 'segment 2' (s2)). The mean for each of these periods (1_{s1}-5_{s1} and 1_{s2} - 5_{s2}) was collapsed across sessions so that, for the purposes of analysis, 'period 1_{s1}' was calculated by using the mean of the first period in each of the 10 sessions, 'period 2_{s1}' was calculated by taking the mean of the second period in each of the 10 sessions, etc. Likewise, 'period 1_{s2}' was calculated by using the mean of the first period in each of the 10 sessions' second segments, 'period 2_{s2}' was calculated by taking the mean of the second period in each of the 10 sessions' second segments, etc. The values for these can be seen in Table 20 and Figures 13-15 (below). Changes within sessions were then examined using a 2 (Segment:

Segment 1 vs *Segment 2*) x 5 (Period: *Period 1 – Period 5*) repeated measures analysis of variance (ANOVA) on each of the three measures.

Table 20

Means and standard deviations (SD) for the amplitude, per cent time, and integrated alpha (IA) measures for each period within the 10 enhancement training sessions.

Period	Mean Amplitude	Amplitude SD	Mean Per Cent Time	Per Cent Time SD	Mean IA	IA SD
1_{s1}	7.80	2.84	36.99	8.03	2.94	1.45
2_{s1}	8.45	3.27	42.06	7.85	3.65	1.88
3_{s1}	8.64	3.37	43.47	8.06	3.87	2.03
4_{s1}	8.71	3.38	43.92	7.79	3.94	2.06
5_{s1}	8.55	3.27	42.52	8.22	3.71	1.93
1_{s2}	8.12	3.16	39.04	8.58	3.28	1.86
2_{s2}	8.67	3.57	43.37	8.99	3.92	2.34
3_{s2}	8.73	3.51	43.86	7.60	3.96	2.15
4_{s2}	8.77	3.46	44.39	7.75	4.00	2.12
5_{s2}	8.60	3.16	43.54	7.47	3.81	1.80

1.1.1. Amplitude

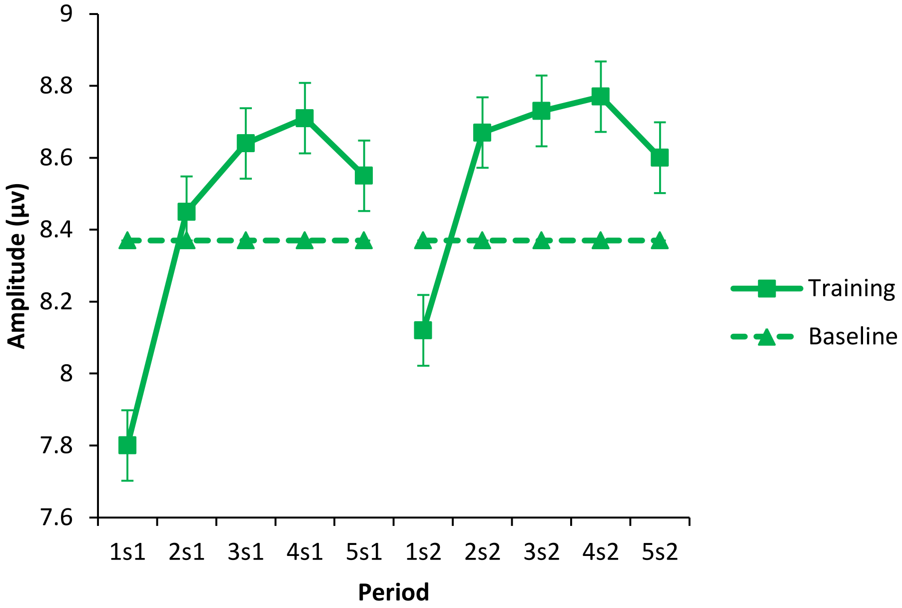

Figure 13. Mean amplitude (with standard error bars) for each *period* within sessions in comparison to baseline during enhancement training

There was a significant main effect of *Segment*, $F(1, 51) = 5.57$, $p = .022$, $MS_E = .029$, *partial* $\mu^2 = .098$ due to participants producing a larger mean amplitude in *Segment 2* ($M = 2.09$, $SE = .049$) than they did in *Segment 1* ($M = 2.07$, $SE = .048$). There was a significant main effect of *Period,* $F(2.22, 113.14) = 61.48$, $p < .001$, $MS_E = .24$, *partial* $\mu^2 = .55$. There was no *Segment* by *Period* interaction effect, $F(2.82, 143.63) = 2.05$, $p = .113$, $MS_E = .003$, *partial* $\mu^2 = .04$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $1_{s1, s2}$ participants produced a significantly smaller amplitude than during *periods* $2_{s1, s2}$ ($p < .001$, $d = .19$), $3_{s1, s2}$ ($p < .001$, $d = .23$), $4_{s1, s2}$ ($p < .001$, $d = .25$), and $5_{s1, s2}$ ($p < .001$, $d = .22$) and a significantly smaller amplitude in *period* $2_{s1, s2}$ than in *period*

3 $_{s1, s2}$ (*p* = .003, *d* =.04) and *period 4* $_{s1, s2}$ (*p* = .001, *d* = .06). No other differences were found to be significant.

1.1.2. Per Cent Time

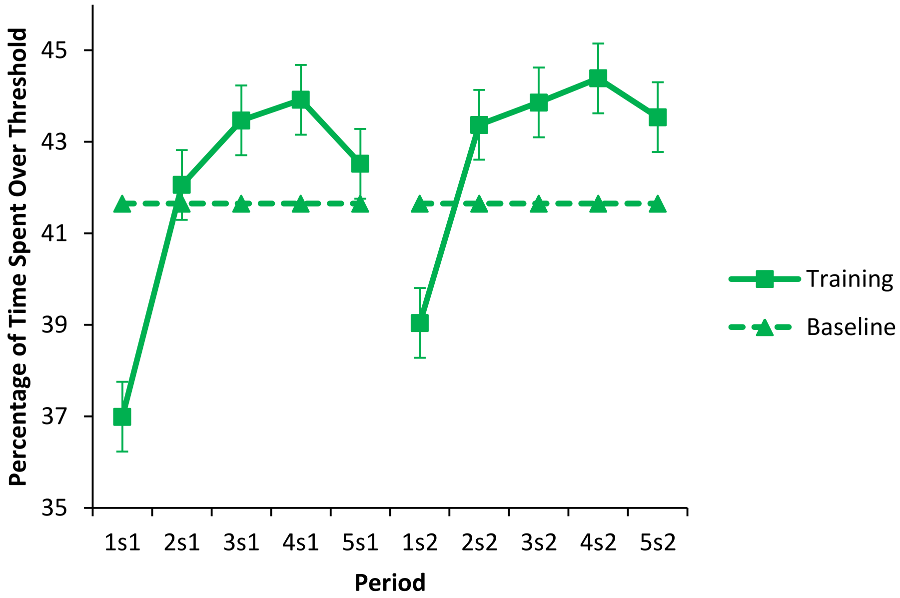

Figure 14. Mean per cent time over threshold (with standard error bars) for each *period* within sessions in comparison to baseline during enhancement training

There was a main effect of *Segment* $F(1, 46) = 5.36$, $p = .025$, $MS_E = 24.16$, partial $\mu^2 = .104$ due to participants spending more time over threshold in *Segment* 2 (*M* = 42.84, *SE* = 1.13) than in *Segment* 1 (*M* = 41.79, *SE* = 1.10). There was a main effect of *Period* $F(2.27, 104.26) = 53.43$, $p < .001$, $MS_E = 18.91$, partial $\mu^2 = .537$. There was no *Segment* by *Period* interaction effect $F(3.06, 140.68) = 2.09$, $p = .103$, $MS_E = 6.82$, partial $\mu^2 = .043$.

Bonferroni's pairwise comparisons were performed in order to investigate the main effect of *Period*. These found that participants spent significantly less time over threshold in *period* 1 $_{s1, s2}$ than they did in *periods* 2 $_{s1, s2}$ ($p < .001$, *d* =

.59), 3 $_{s1, s2}$ (p < .001, d = .73), 4 $_{s1, s2}$ (p < .001, d = .80), and 5 $_{s1, s2}$ (p < .001, d = .65). They also spent significantly less time under threshold in *period* 2 $_{s1, s2}$ than in *period* 4 $_{s1, s2}$ (p = .004, d = .18) and in *period* 5 $_{s1, s2}$ than in *period* 4 $_{s1, s2}$ (p = .014, d = .15). The last of which is in the opposite direction than what would be indicative of enhancement. No other effects were significant.

1.1.3. Integrated Alpha

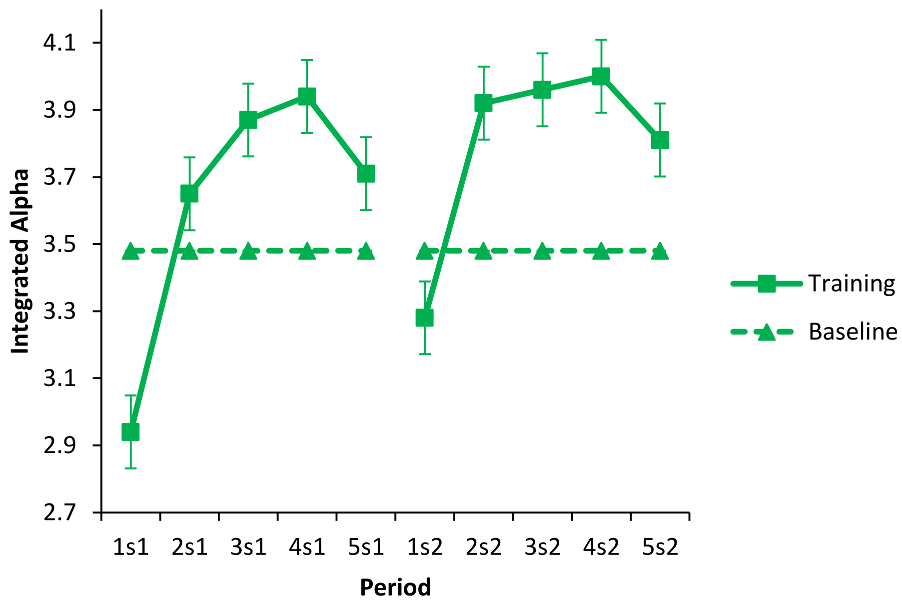

Figure 15. Mean integrated alpha (with standard error bars) for each period within sessions in comparison to baseline during enhancement training

There was a significant main effect of *Segment,* $F(1 ,51) = 7.20$, $p = .010$, $MS_E = .03$, *partial* $\mu^2 = .12$, due to participants producing more integrated alpha in *Segment 2* (M = 1.21, SE = .06) than in *Segment 1* (M = 1.16, SE = .06). There was a significant main effect of *Period,* $F(2.05, 104.64) = 61.17$, $p < .001$, $MS_E = .03$, *partial* μ^2 = .55. There was no *Segment* by *Period* interaction effect, F(2.84, 145.06) = 1.83, p = .15, MS_E = .01, *partial* μ^2 =.04.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $1_{s1, s2}$, participants produced less integrated alpha than they did during *periods* $2_{s1, s2}$ (p < .001, d = .42), $3_{s1, s2}$ (p < .001, d = .52), $4_{s1, s2}$ (p < .001, d = .54), and $5_{s1, s2}$ (p< .001, d = .48). They also produced less integrated alpha in *period* $2_{s1, s2}$ than they did in *periods* $3_{s1, s2}$ (p = .006, d = .10) and $4_{s1, s2}$ (p = .005, d = .05). No other significant effects were found.

1.2 Within Sessions Compared to Baseline

Because the data for the within sessions calculations were achieved by collapsing across sessions, this meant that the within sessions baseline measure (i.e. the overall mean of the pre-training eyes open baseline in session 1, session 2, session 3 . . . and session 10) was a constant with no variability (see Figures 13-15) and therefore could not be added to the analysis as a separate factor. For the within sessions in comparison to baseline analyses each within sessions period was therefore subtracted from baseline in order to provide a comparison to baseline score (see Table 21). For example, to calculate the within sessions in comparison to baseline score for periods 1 to 10 in the amplitude measure the overall mean pre-training eyes open baseline amplitude for sessions 1 to 10 was subtracted from the period data used for the analyses in section 1.1.1. above (i.e. 7.8 µv minus 8.37µv, 8.45µv minus 8.37µv, 8.64 µv minus 8.37µv etc.). This means that any resulting means which are positive in value represent enhancement above baseline and any negative values represent falling below baseline.

Changes within sessions in comparison to baseline could then be examined using a 2 (Segment: *Segment 1* vs *Segment 2*) x 5 (Period: *Period 1* – *Period 5*) repeated measures analysis of variance (ANOVA) on each of the three measures.

Table 21

Means and standard deviations (SD) for each period in comparison to baseline for the amplitude, per cent time, and integrated alpha (IA) measures within the 10 enhancement neurofeedback training sessions. Negative numbers indicate that the measure during training was less than that of the measure during baseline.

Period	Mean Amplitude	Amplitude SD	Mean Per Cent Time	Per Cent Time SD	Mean IA	IA SD
1_{s1}	-0.57	1.12	-4.66	8.34	0.55	1.20
2_{s1}	0.08	1.21	0.41	8.39	-0.16	1.37
3_{s1}	0.27	1.29	1.83	8.71	-0.38	1.50
4_{s1}	0.34	1.28	2.27	8.30	-0.45	1.49
5_{s1}	0.18	1.44	0.87	8.65	-0.23	1.57
1_{s2}	-0.24	1.35	-2.61	9.16	0.21	1.53
2_{s2}	0.30	1.48	1.73	8.53	-0.43	1.78
3_{s2}	0.36	1.28	2.21	8.05	-0.47	1.49
4_{s2}	0.40	1.37	2.74	8.32	-0.52	1.58
5_{s2}	0.23	1.16	1.89	7.98	-0.33	1.37

1.2.1. Amplitude

There was a significant main effect of *Segment,* $F(1, 51) = 6.53$, $p = .014$, $MS_E = .146$, *partial* $\mu^2 = .11$ due to participants producing a larger difference between baseline and training in *Segment 2* ($M = 1.60$, $SE = .04$) than in *Segment 1* ($M = 1.57$, $SE = .04$). There was a significant main effect of *Period,* $F(1.98, 101.03) = 39.55$, $p < .001$, $MS_E = 1.07$, *partial* $\mu^2 = .437$. There was no *Segment* by *Period* interaction effect, $F(2.72, 138.87) = 2.36$, $p = .081$, $MS_E = .02$, *partial* $\mu^2 = .04$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $1_{s1, s2}$ participants produced a significantly smaller difference between baseline and training than in *period* $2_{s1, s2}$ ($p < .001$, $d = .47$), *period* $3_{s1, s2}$ ($p < .001$, $d = .60$), *period* $4_{s1, s2}$ ($p < .001$, $d = .57$), and *period* $5_{s1, s2}$ ($p < .001$, $d = .50$). They also produced a significantly smaller amplitude in *period* $2_{s1, s2}$ than in *periods* $3_{s1, s2}$ ($p = .010$, $d = .13$) and *period* $4_{s1, s2}$ ($p = .033$, $d = .12$). No other significant effects were found.

1.2.2. Per Cent Time

There was a main effect of *Segment* $F(1,46) = 5.36$, $p = .025$, $MS_E = 24.16$, partial $\mu^2 = .104$ due to participants producing a significantly smaller difference between baseline and training in *Segment* 1 ($M = .143$, $SE = 1.17$) than in *Segment* 2 ($M = 1.19$, $SE = 1.21$). There was a main effect of *Period* $F(2.27, 104.26) = 53.43$, $p < .001$, $MS_E = 18.91$, partial $\mu^2 = .537$. There was no *Segment* by *Period* interaction effect $F(3.06, 140.68) = 2.09$, $p = .103$, $MS_E = 6.82$, partial $\mu^2 = .043$.

In order to investigate the significant main effect of *Period*, Bonferroni's pairwise comparisons were performed. These showed that participants produced a significantly larger difference between training and baseline in *period* 1 than in *periods 2* $_{s1, s2}$ (p < .001, d = .55), *3* $_{s1, s2}$ (p < .001, d = .69), *4* $_{s1, s2}$ (p < .001, d = .75), and *5* $_{s1, s2}$ (p < .001, d = .61) and a significantly larger difference between training and baseline in *period 4* $_{s1, s2}$ compared to *periods 2* $_{s1, s2}$ (p = .004, d = .17) and *5* $_{s1, s2}$ (p = .014, d = .04). Participants also produced a marginally larger difference between baseline and training in *period 3* $_{s1, s2}$ than *period 2* $_{s1, s2}$ (p = .060, d = .11). No other effects were significant.

1.2.3. Integrated Alpha

There was a significant main effect of *Segment,* $F(1, 51) = 7.23$, $p = .010$, $MS_E = .03$, *partial* $\mu^2 = .12$, due to participants producing more integrated alpha in *Segment 2* (M = 1.61, SE = .038) than they did in *Segment 1* (M = 1.57, SE = .04). There was a significant main effect of *Period,* $F(2.04, 104.24) = 40.46$, $p < .001$, $MS_E = .03$, *partial* $\mu^2 = .44$. There was no *Segment* by *Period* interaction effect, $F(2.90, 148.10) = 1.98$, $p = .121$, $MS_E = .007$, *partial* $\mu^2 = .04$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that participants produced a significantly smaller difference between baseline and training in *period 1* $_{s1, s2}$ than they did during *periods 2* $_{s1, s2}$ (p < .001, d = .29), *3* $_{s1, s2}$ (p < .001, d = .35), *4* $_{s1, s2}$ (p < .001, d = .35), and *5* $_{s1, s2}$ (p< .001, d = .29). They also produced a significantly smaller difference between baseline and training in *period 2* $_{s1, s2}$ than they did in *periods 3* $_{s1, s2}$ (p = .015, d = .12) and *4* $_{s1, s2}$ (p = .018, d = .13). No other significant effects were found.

Table 22

Summary of the findings for each of the measures within sessions and within sessions in comparison to baseline during the enhancement training. Where an effect was found to be significant the significant pairwise comparisons (with Bonferroni corrections) which were found are listed. Of these, any effects indicative of a pattern opposite to that which would be expected for 'successful' enhancement are highlighted in yellow.

	Amplitude	Enhance Per Cent Time	Integrated Alpha
Within Sessions			
Segment	Yes 1 < 2	Yes 1 < 2	Yes 1 < 2
Period	Yes 1 < 2-5 2 < 3-4	Yes 1 < 2-5 2 < 4 5 < 4	Yes 1 < 2-5 2 < 3-4
Segment by Period	No	No	No
Within Sessions Comparison to Baseline			
Segment	Yes 1 < 2	Yes 1 < 2	Yes 1 < 2
Period	Yes 1 < 2-5 2 < 3-4	Yes 1 < 2-5	Yes 1 < 2-5 2 < 3-4
Segment by Period	No	No	No

1.3. Across Sessions

To look for evidence of change over time across sessions, the mean value for each of the three measures was calculated for each of the 10 sessions (see Tables 23-25 and Figures 16-18) and a one-way repeated measures ANOVA was performed on these 10 sessions' means for each measure.

1.3.1. Amplitude

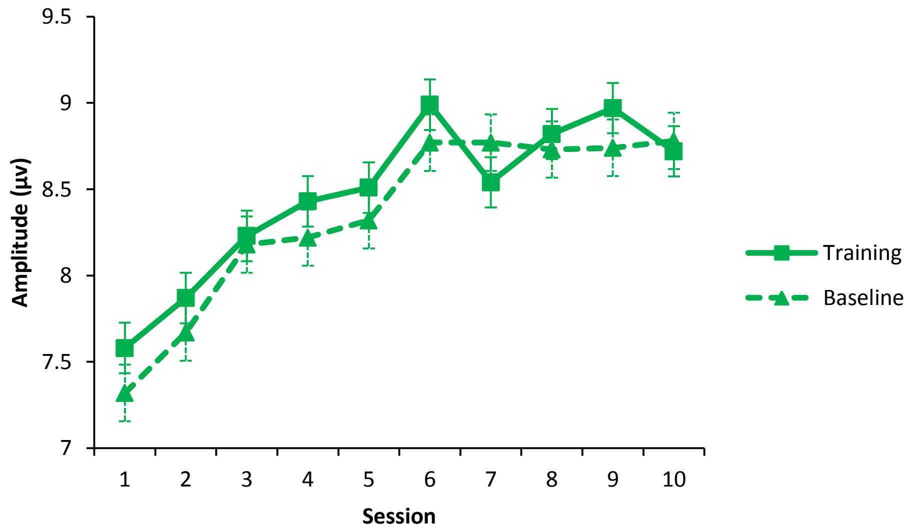

Figure 16. Mean amplitude (with standard error bars) during baseline and during training for each session of enhancement training

There was a significant main effect of *Session,* $F(5.19, 223.10) = 8.89$, $p < .001$, $MS_E = .19$, *partial* $\mu^2 = .17$.

In order to investigate this, pairwise comparisons with Bonferroni corrections were performed. It was found that participants produced a marginally smaller amplitude in *Session 1* than they did in *Session 5* ($p = .055$, $d = .26$) and a significantly smaller amplitude in *Session 1* than they did in *Sessions 6* ($p =.003$, $d = .40$), *7* ($p = .008$, $d = .30$), *8* ($p = .002$, $d = .35$), *9* ($p < .001$, $d = .41$), and *10* ($p <$

.001, *d* = .36). They also produced a significantly smaller amplitude in *Session 2* than they did in *Sessions 6* (*p* = .002, *d* = .33), *7* (*p* = .024, *d* = .23), *8* (*p* = .018, *d* = .28), *9* (*p* = .004, *d* = .33), and *10* (*p* = .021, *d* = .28). No other significant effects were found.

Table 23

Means and standard deviations (SD) for the amplitude measure during training and during baseline in each of the 10 enhancement training sessions

Session	Training	Training SD	Baseline Mean	Baseline SD
1	7.58	2.69	7.32	2.46
2	7.87	3.32	7.67	2.97
3	8.23	3.34	8.18	3.38
4	8.43	3.66	8.22	3.12
5	8.51	3.56	8.32	3.15
6	8.99	3.86	8.77	3.78
7	8.54	3.37	8.77	3.45
8	8.82	3.65	8.73	3.50
9	8.97	3.68	8.74	3.13
10	8.72	3.40	8.78	3.35

1.3.2. Per Cent Time

There was no main effect of *Session* $F(6.16, 265.01) = .446$, $p = .852$, $MS_E = 95.10$, partial $\mu^2 = .01$.

Table 24

Means and standard deviations (SD) for the per cent time measure during training and during baseline in each of the 10 enhancement sessions

Session	Training Mean	Training SD	Baseline Mean	Baseline SD
1	43.43	10.20	40.95	2.44
2	42.72	10.83	41.75	2.41
3	41.59	10.47	41.89	2.56
4	41.66	12.40	42.12	2.83
5	41.96	11.18	42.26	2.66
6	43.39	11.19	41.86	2.29
7	40.96	12.26	40.97	3.62
8	42.22	9.79	41.67	3.65
9	42.53	9.58	41.95	3.19
10	41.59	10.33	41.74	2.27

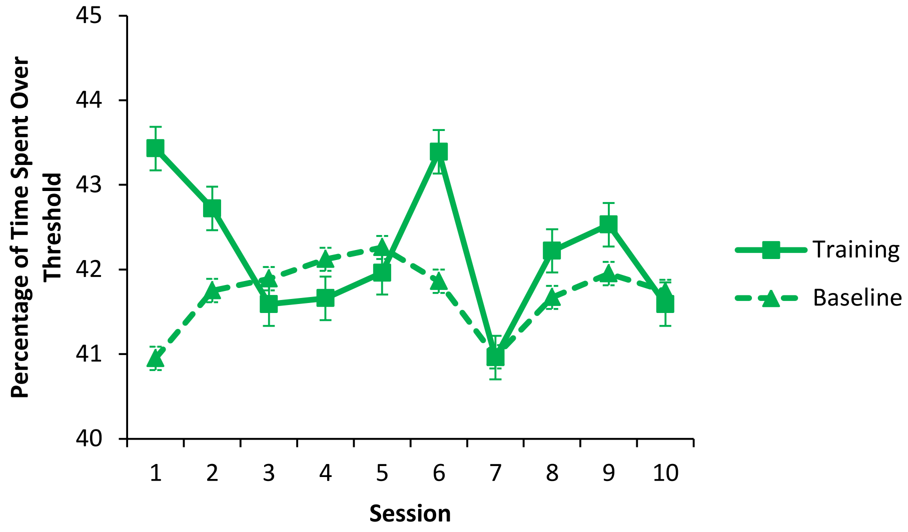

Figure 17. Mean per cent time (with standard error bars) during baseline and during training for each session of enhancement training

1.3.3. Integrated Alpha

There was no main effect of *Session,* $F(5.11, 219.54) = 1.46$, $p = .202$, $MS_E = .15$, *partial* $\mu^2 = .03$.

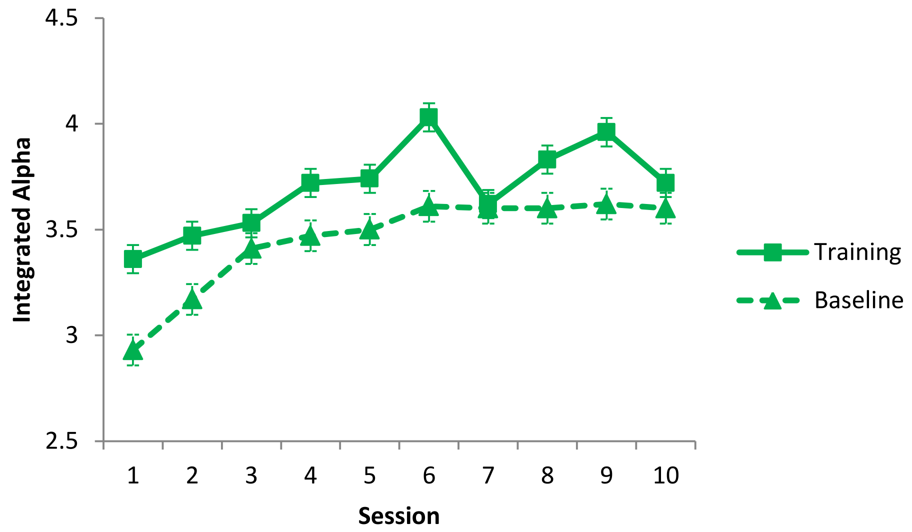

Figure 18. Mean integrated alpha (with standard error bars) during baseline and during training for each session of enhancement training

Table 25

Means and standard deviations (SD) for the integrated alpha (IA) measure during training and during baseline in each of the 10 enhancement sessions

Session	Mean Training IA	SD Training IA	Mean Baseline IA	SD Baseline IA
1	3.36	1.70	2.93	0.95
2	3.47	2.00	3.17	1.32
3	3.53	1.96	3.41	1.56
4	3.72	2.59	3.47	1.48
5	3.74	2.38	3.50	1.45
6	4.03	2.45	3.61	1.60
7	3.62	2.26	3.60	1.58
8	3.83	2.04	3.60	1.55
9	3.96	2.30	3.62	1.37
10	3.72	2.15	3.60	1.39

1.4. Across Sessions Compared to Baseline

To look for evidence of change over time across sessions in comparison to baseline the mean value for each of the three measures was calculated for each of the 10 sessions, both during each sessions' eyes open baseline and during the enhancement training itself (see Tables 23-25 and Figures 16-18). A 2 (Stage:

Baseline vs *Training*) x 10 (Session: *Session 1 – Session 10*) repeated measures ANOVA was then conducted.

1.4.1. Amplitude

There was no main effect of *Stage* $F(1, 43) = .18$, $p = .734$, $MS_E = .01$, *partial* $\mu^2 = .003$. There was a significant main effect of *Session,* $F(6.51, 280.06) = 11.77$, $p < .001$, $MS_E = .35$, *partial* $\mu^2 = .22$. There was no significant *Stage* by *Session* interaction effect $F(6.02, 258.97) = .59$, $p = .742$, $MS_E = .008$, *partial* $\mu^2 = .01$.

In order to investigate the significant main effect of *Session*, pairwise comparisons with Bonferroni corrections were performed. It was found that participants produced a smaller difference in amplitude between baseline and training in *Session 1* than they did in *Sessions 3* ($p = .042$, $d = .24$), *4* ($p = .027$, $d = .27$), *5* ($p = .002$, $d = .30$), *6* ($p < .001$, $d = .42$), *7* ($p < .001$, $d = .39$), *8* ($p < .001$, $d = .40$), *9* ($p < .001$, $d = .45$), and *10* ($p < .001$, $d = .41$). They also produced a smaller mean amplitude in *Session 2* than they did in *Sessions 6* ($p < .001$, $d = .33$), *7* ($p = .001$, $d = .29$), *8* ($p = .001$, $d = .30$), *9* ($p < .001$, $d = .35$), and *10* ($p = .002$, $d = .31$). As well as a smaller amplitude in *Session 3* than they did in *Session 6* ($p = .044$, $d = .19$). No other effects were found to be significant.

1.4.2. Per Cent Time

There was no main effect of *Stage* $F(1, 42) < .001$, $p = .991$, $MS_E = 294.82$, partial $\mu^2 < .001$. There was no main effect of *Session* $F(6.16, 258.88) = .66$, $p =.687$, $MS_E = 51.31$, partial $\mu^2 = .015$. There was no *Stage* by *Session* interaction effect $F(6.13, 257.36) = .82$, $p = .561$, $MS_E = 50.86$, partial $\mu^2 = .019$.

1.4.3. Integrated Alpha

There was no main effect of *Stage,* $F(1, 42) = .57$, $p = .46$, $MS_E = .45$, *partial* $\mu^2 = .01$. There was a significant main effect of *Session,* $F(5.18, 217.52) = 4.84$, $p < .001$, $MS_E = .08$, *partial* $\mu^2 = .10$. There was no significant *Stage* by *Session* interaction effect, $F(6.00, 252.11) = .81$, $p = .564$, $MS_E = .09$, *partial* $\mu^2 = .02$.

In order to investigate this main effect of *Session*, pairwise comparisons with Bonferroni corrections were performed. These showed that participants produced significantly less integrated alpha in *Session 1* than they did in *Session 6* ($p = .027$, $d = .37$), *Session 8* ($p = .049$, $d = .31$), *Session 9* ($p = .007$, $d = .39$), and *Session 10* ($p = .017$, $d = .31$).

Table 26

Summary of the findings for each of the measures across sessions and across sessions in comparison to baseline during the enhancement training. Where an effect was found to be significant the significant pairwise comparisons (with Bonferroni corrections) which were found are listed.

	Amplitude	**Enhancement Per Cent Time**	**Integrated Alpha**
<u>Across Sessions</u>			
Session	Yes 1 < 6-10 2 < 6-10	No	No
<u>Across Sessions Comparison to Baseline</u>			
Stage	No	No	No
Session	Yes 1 < 3-10 2 < 6-10 3 < 6	No	Yes 1 < 6-10
Stage by Session Interaction Effect	No	No	No

1.5. Enhancement Training Summary

Both the within sessions and the within sessions in comparison to baseline analyses showed evidence for participants learning to enhance their alpha (see Table 26 for a summary of the findings found). All three measures (amplitude, per cent time, and integrated alpha) found that participants showed a larger increase in alpha in the second half of their training sessions (segment 2) than in the first half (segment 1) and that they showed an increase as the periods progressed within each segment. The per cent time measure also revealed that participants show a dip in performance at the end of each segment, something which can be seen in Figure 14. It is also worth noting that where the within sessions in comparison to baseline analyses are concerned, although the comparison between periods 2 , 3 and 4 support the suggestion of enhancement, the strongest effects are seen when period 1 is compared to the rest of the periods. This is due to period 1 producing a larger difference between baseline and training than any of the later periods but the negative value for period 1 (see Table 21) and a look at Figures 13-15 show that that difference is actually in the wrong direction to be indicative of enhancement during that period. In other words, participants' ability to produce alpha in the first period of each segment of training is actually below the levels they produced without trying during the baselines (see Further Analysis 1, below, for further discussion of this point).

The across sessions data shows differing results depending on which measure is used (see Table 26 for a summary of the findings found). An effect of *Session* is found with the amplitude measure alone across sessions and, when baseline is taken into account, amplitude and integrated alpha show an effect of *Session* but per cent time does not. The pairwise comparisons also reveal that, where a main effect of *Session* is found, it is coming from a difference between the first 2 sessions (the first three for the amplitude measure when looking at the across sessions in comparison to baseline data) when compared to later sessions. No significant differences were identified with any of the measures from session 4 onwards when compared to any of the proceeding sessions.

2. Suppression Training

The aim of suppression training is for participants to learn to consciously decrease the amount of alpha they produce and to increase the time they can do so. So for the amplitude and integrated alpha measures, suppression is indicated by a decrease over time. For the per cent time measure, however, the aim is still, as with enhancement training, to see an increase over time, although with suppression training this is an increase in the amount of time participants spent under threshold rather than over. One point to note here, however, is that although the per cent time measure for suppression is reversed such that it refers to the percentage of time below threshold rather than above, integrated alpha, which is a combination of both amplitude and per cent time, is calculated in exactly the same way as it was for the enhance data.

i.e. integrated alpha (α_i) = (μv x percentage of time over threshold) / 100.

For example, if the mean amplitude for period 1 was 7.22μv and the mean percentage of time spent under threshold during period 1 was 12.36% then the integrated alpha for period 1 would be 6.33:

$$(7.22 \times (100-12.36))/100 = 6.33$$

This is so that the direction indicative of learning is consistent for the two measures, amplitude and per cent time, so that a direction for change which is indicative of learning can be identified for the integrated alpha data.

All calculations and analyses for the 3 measures (amplitude, percentage of time spent under threshold, and integrated alpha) within sessions, within sessions in comparison to baseline, across sessions, and across sessions in comparison to baseline are the same as in section 1 (above).

2.1 Within Sessions

Table 27

Means and standard deviations (SD) for the amplitude, per cent time, and integrated alpha (IA) measures for each period within the 10 suppression sessions

Period	Mean Amplitude	Amplitude SD	Mean Per Cent Time	Per Cent Time SD	Mean IA	IA SD
1_{s1}	7.15	2.40	11.99	8.38	6.25	2.06
2_{s1}	7.57	2.54	10.16	6.91	6.76	2.17
3_{s1}	7.63	2.51	9.90	6.78	6.84	2.17
4_{s1}	7.62	2.50	10.07	6.76	6.80	2.10
5_{s1}	7.59	2.49	10.25	6.82	6.76	2.08
1_{s2}	7.14	2.10	12.17	8.21	6.22	1.71
2_{s2}	7.57	2.47	10.24	6.81	6.75	2.06
3_{s2}	7.70	2.43	9.79	6.91	6.90	2.04
4_{s2}	7.72	2.36	9.57	6.18	6.92	1.93
5_{s2}	7.65	2.32	10.01	6.83	6.82	1.91

As with the enhancement data, changes within sessions were examined using a 2 (Segment: *Segment 1* vs *Segment 2*) x 5 (Period: *Period 1 – Period 5*) repeated measures analysis of variance (ANOVA) on each of the three measures.

Table 27 (above) shows the means and standard deviations for the within sessions suppression data (see also Figures 19-21).

2.1.1 Amplitude

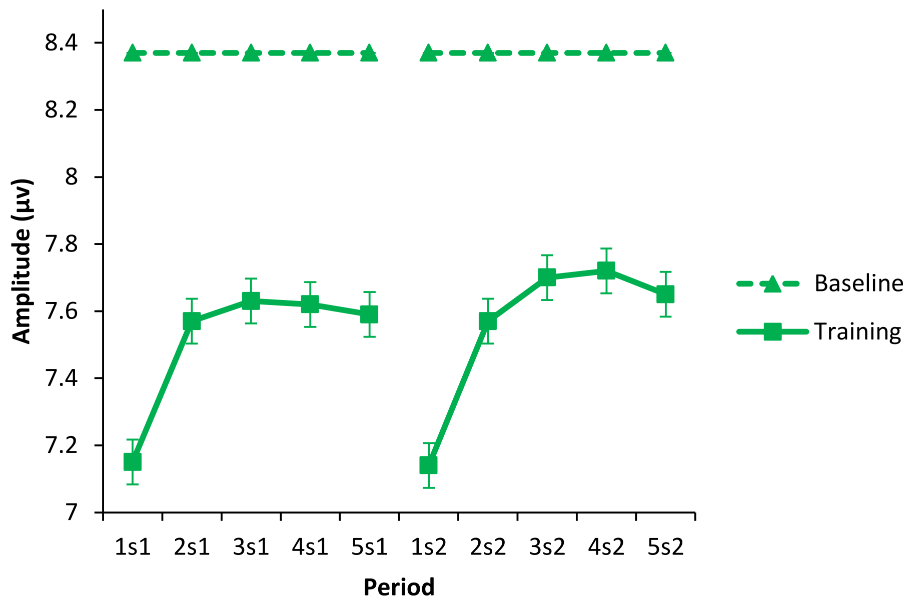

Figure 19. Mean amplitude (with standard error bars) for each period within sessions in comparison to baseline during suppression training

There was a significant main effect of *Segment, F*(1, 51) = 5.06, *p* = .029, MS_E = .02, *partial* μ^2 = .09 due to participants producing a larger average amplitude in *Segment 2* (*M* = 1.99, *SE* = .04) than in *Segment 1* (*M* = 1.98, *SE* = .04). There was a significant main effect of *Period, F*(2.54, 129.42) = 64.45, *p* <

.001, MS_E = .14, *partial* μ^2 = .56. There was no *Segment* by *Period* interaction effect, $F(4, 204) = .90$, $p = .465$, MS_E = .001, *partial* μ^2 = .017.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $1_{s1, s2}$ participants produced a significantly smaller amplitude than during *periods* $2_{s1, s2}$ ($p < .001$, $d = .25$), $3_{s1, s2}$ ($p < .001$, $d = .33$), $4_{s1, s2}$ ($p < .001$, $d = .33$), and $5_{s1, s2}$ ($p < .001$, $d = .31$). They also produced a significantly smaller amplitude in *period* $2_{s1, s2}$ than they did during *period* $4_{s1, s2}$ ($p = .018$, $d = .05$) which is the opposite pattern as to what would be hoped for during suppression training. No other significant effects were found.

2.1.2 Per Cent Time

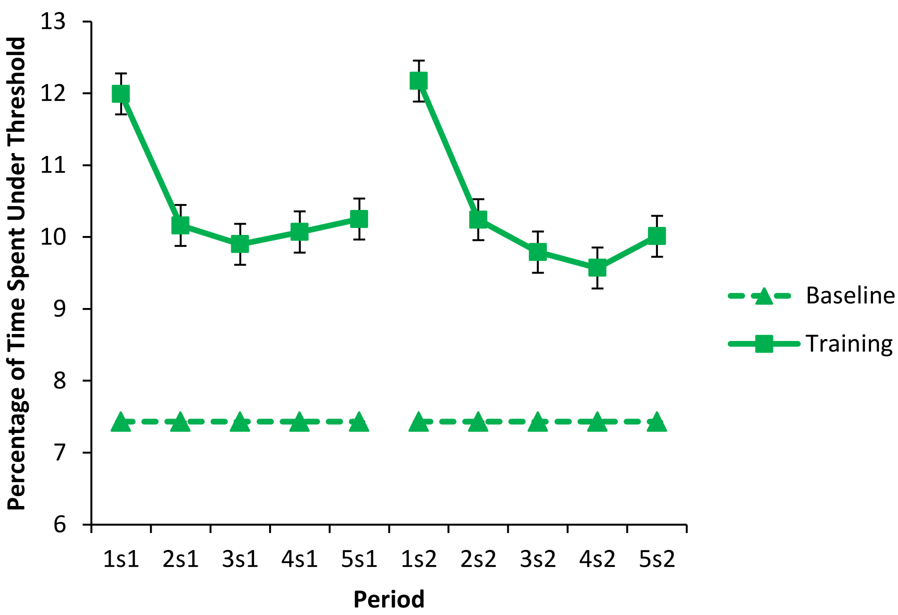

Figure 20. Mean per cent time (with standard error bars) for each period within sessions in comparison to baseline during suppression training

There was no main effect of *Segment,* $F(1, 51) = 1.23$, $p = .273$, $MS_E = .03$, *partial* $\mu^2 = .02$. There was a significant main effect of *Period,* $F(4, 204) = 50.55$, $p < .001$, $MS_E = .01$, *partial* $\mu^2 = .50$. There was a significant *Segment* by *Period* interaction effect, $F(4, 204) = 2.76$, $p = .029$, $MS_E = .01$, *partial* $\mu^2 = .05$.

In order to investigate the *Segment* by *Period* interaction effect, a one way ANOVA split by *Segment* was performed on the *Period* data. This showed that in *Segment 1* there was a significant main effect of *Period*, $F(4, 204) = 22.05$, $p < .001$, $MS_E = .01$, *partial* $\mu^2 = .30$. In *Segment 2* there was also a significant main effect of *Period,* $F(4, 204) = 35.76$, $p < .001$, $MS_E = .01$, *partial* $\mu^2 = .41$.

In order to investigate these main effects of *Period,* pairwise comparisons with Bonferroni corrections were performed. For *Segment 1* it was found that participants spent more time under threshold in *period 1* than they did in *period 2* ($p < .001$, $d = .26$), *period 3* ($p < .001$, $d = .30$), *period 4* ($p < .001$, $d = .27$), and *period 5* ($p < .001$, $d = .26$) which is the opposite pattern one would hope for during suppression training.

For *Segment 2* it was also found that participants spent more time under threshold in *period 1* than they did in *period 2* ($p < .001$, $d = .28$), *period 3* ($p < .001$, $d = .38$), *period 4* ($p < .001$, $d = .43$), and *period 5* ($p < .001$, $d = .36$) and more time under threshold in *period 2* than they did in *period 4* ($p < .006$, $d = .15$). All of which is again the opposite pattern one would hope for during suppression training.

No other effects were found to be significant.

2.1.3 Integrated Alpha

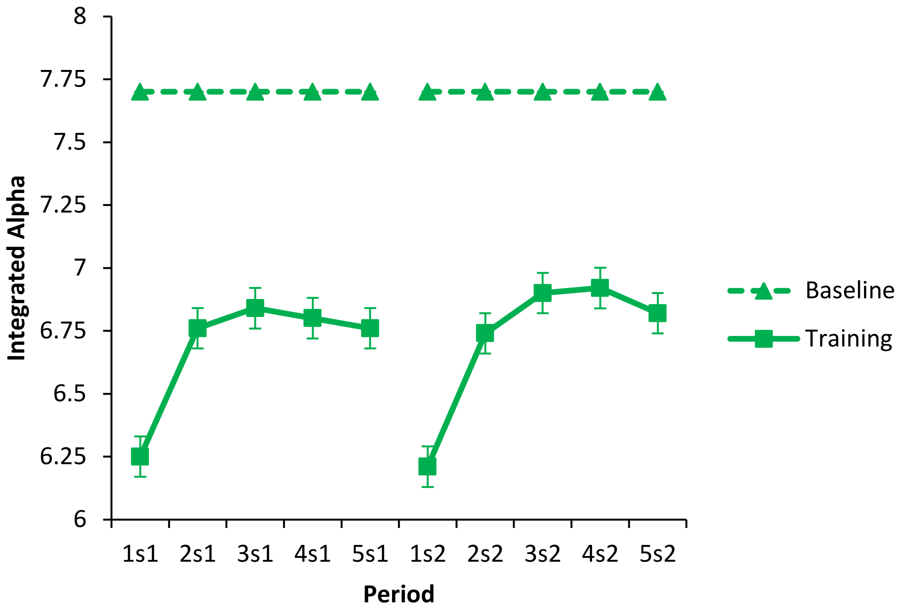

Figure 21. Mean integrated alpha (with standard error bars) for each period within sessions in comparison to baseline during suppression training

There was no main effect of *Segment,* $F(1,51) = 3.92$, $p = .053$, $MS_E = .007$, *partial* $\mu^2 = .071$ due to participants producing more integrated alpha in *Segment 2* ($M = 1.88$, $SE = .04$) than in *Segment 1* ($M = 1.86$, $SE = .04$). There was a significant main effect of *Period,* $F(2.35, 119.70) = 60.60$, $p < .001$, $MS_E = .01$, *partial* $\mu^2 = .54$. There was no *Segment* by *Period* interaction effect*,* $F(4, 204) = 1.34$, $p = .256$, $MS_E = .002$, *partial* $\mu^2 = .03$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that participants produced more integrated alpha during *period* $1_{s1, s2}$ than they did during *period* $2_{s1, s2}$ ($p < .001$, $d = .27$), *period* $3_{s1, s2}$ ($p < .001$, $d = .33$), *period* $4_{s1, s2}$ ($p < .001$, $d = .34$), and *period* $5_{s1, s2}$ ($p < .001$, $d = .31$). They also produced less integrated alpha during *period 2* $_{s1, s2}$ than during *period 4* $_{s1, s2}$ (p = .024, d = .07). No other significant effects were found.

2.2 Within Sessions Compared to Baseline

Table 28

Means and standard deviations (SD) for each period in comparison to baseline for the amplitude, per cent time, and integrated alpha measures within the 10 suppression sessions. Negative numbers are indicative of where the measure during training was less than that of the measure during baseline.

Period	Mean Amplitude	Amplitude SD	Mean Per Cent Time	Per Cent Time SD	Mean IA	IA SD
1_{s1}	-1.22	1.39	4.56	6.87	1.44	1.70
2_{s1}	-0.79	1.23	2.72	5.51	0.93	1.48
3_{s1}	-0.73	1.24	2.46	5.37	0.85	1.48
4_{s1}	-0.74	1.25	2.63	5.30	0.89	1.51
5_{s1}	-0.77	1.23	2.82	5.39	0.93	1.50
1_{s2}	-1.22	1.49	4.74	6.61	1.48	1.83
2_{s2}	-0.79	1.22	2.80	5.34	0.95	1.48
3_{s2}	-0.66	1.24	2.36	5.46	0.80	1.51
4_{s2}	-0.65	1.18	2.14	4.59	0.77	1.43
5_{s2}	-0.72	1.26	2.57	5.27	0.87	1.54

Again, as with the enhancement data, because the baseline was a constant with no variability (see Figures 19-21) it therefore could not be added to the analysis as a separate factor and so for the within sessions in comparison to baseline analyses each within sessions period was therefore subtracted from baseline in order to provide a comparison to baseline score (see Table 28). As with the within sessions data, above, positive values represent above baseline means and negative values indicate means which are below baseline. Once more, changes within sessions in comparison to baseline were then examined using a 2 (Segment: *Segment 1* vs *Segment 2*) x 5 (Period: *Period 1 – Period 5*) repeated measures analysis of variance (ANOVA) on each of the three measures.

2.2.1 Amplitude

There was no significant main effect of *Segment*, $F(1, 51) = 2.34$, $p = .133$, $MS_E = .02$, *partial* $\mu^2 = .04$. There was a significant main effect of *Period*, $F(2.94, 149.70) = 52.07$, $p < .001$, $MS_E = .18$, *partial* $\mu^2 = .51$. There was no *Segment* by *Period* interaction effect, $F(4, 204) = .79$, $p = .534$, $MS_E = .002$, *partial* $\mu^2 = .02$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $1_{s1, s2}$ participants produced a significantly larger difference between baseline and training than they did in *periods* $2_{s1, s2}$ ($p < .001$, $d = .33$), $3_{s1, s2}$ ($p < .001$, $d = .40$), $4_{s1, s2}$ ($p < .001$, $d = .42$), and $5_{s1, s2}$ ($p < .001$, $d = .38$) which as can be seen from Figure 19 is the opposite pattern as to what would be hoped for during suppression training. No other significant effects were found.

2.2.2 Per Cent Time

There was no main effect of *Segment,* $F(1, 51) = 1.70$, $p = .198$, $MS_E = .01$, *partial* $\mu^2 = .03$. There was a significant main effect of *Period,* $F(1.34, 68.25) = 16.64$, $p < .001$, $MS_E = .02$, *partial* $\mu^2 = .25$. There was no *Segment* by *Period* interaction effect, $F(2.62, 133.45) = 1.38$, $p = .254$, $MS_E = .003$, *partial* $\mu^2 = .03$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $1_{s1, s2}$ participants showed a significantly smaller difference between baseline and training than they did during *periods* $2_{s1, s2}$ ($p < .001$, $d = .25$), $3_{s1, s2}$ ($p < .001$, $d = .25$), $4_{s1, s2}$ ($p = .001$, $d = .32$), and $5_{s1, s2}$ ($p = .001$, $d = .27$) but as can be seen from Figure 20 is in the opposite direction to what would be hoped for during suppression training. No other significant effects were found.

2.2.3 Integrated Alpha

There was no significant main effect of *Segment,* $F(1, 51) = 1.30$, $p = .259$, $MS_E = .001$, *partial* $\mu^2 = .03$. There was a significant main effect of *Period,* $F(2.76, 140.56) = 51.49$, $p < .001$, $MS_E = .00$, *partial* $\mu^2 = 50$. There was no *Segment* by *Period* interaction effect, $F(4, 204) = 1.33$, $p = .259$, $MS_E = .00$, *partial* $\mu^2 = .03$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $1_{s1, s2}$ participants produced more integrated alpha than they did during *periods* $2_{s1, s2}$ ($p < .001$, $d = .32$), $3_{s1, s2}$ ($p < .001$, $d = .38$), $4_{s1, s2}$ ($p < .001$, $d = .39$), and $5_{s1, s2}$ ($p < .001$, $d = .34$) but as can be seen from Figure 21 is in the opposite direction to what would be hoped for during suppression training. No other significant effects were found.

Table 29

Summary of the findings for each measure within sessions and within sessions in comparison to baseline during the suppression training. Where an effect was found to be significant the significant pairwise comparisons (with Bonferroni corrections) which were found are listed. Of these, any effects indicative of a pattern opposite to that which would be expected for 'successful' training are highlighted in yellow.

	Amplitude	**Suppression Per Cent Time**	**Integrated Alpha**
Within Sessions			
Segment	Yes 1 < 2	No	Marginal 1 < 2
Period	Yes 1 < 2-5 2 < 4	Yes	Yes 1 < 2-5 2 < 4
Segment by Period	No	Yes In Segment 1: 1 > 2-5 In Segment 2: 1 > 2-5 2 > 4	No
Within Sessions Comparison to Baseline			
Segment	No	No	No
Period	Yes 1 < 2-5	Yes 1 > 2-5	Yes 1 < 2-5
Segment by Period	No	No	No

2.3 Across Sessions

As with the analyses on the enhancement training data, evidence of change over time across sessions during the suppression training involved calculating the mean value for each of the three measures for each of the 10 sessions (see Tables 30-32 and Figures 22-24) and a one-way repeated measures ANOVA was performed on these 10 Sessions' means for each measure.

2.3.1 Amplitude

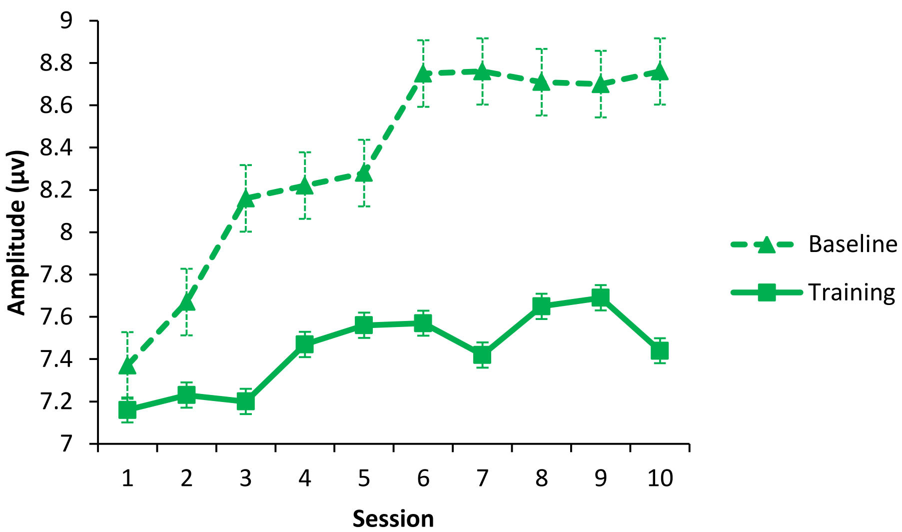

Figure 22. Mean amplitude (with standard error bars) during baseline and during training for each session of suppression training

There was a significant main effect of *Session*, $F(4.96, 213.45) = 3.09$, $p = .010$, $MS_E = .06$, *partial* $\mu^2 = .67$. In order to investigate this, pairwise comparisons with Bonferroni corrections were performed. It was found that participants produced a significantly smaller amplitude in *Session 3* than they did in *Session 9* (*p* =.041 , *d* = .23), which is the opposite pattern to what would be hoped for during suppression training, but no other effects were found to be significant.

Table 30

Means and standard deviations (SD) for the amplitude measure during training and during baseline in each of the 10 suppression sessions

Session	Training Mean	Training SD	Baseline Mean	Baseline SD
1	7.16	2.41	7.37	2.45
2	7.23	2.92	7.67	2.97
3	7.20	2.61	8.16	3.39
4	7.47	2.46	8.22	3.12
5	7.56	2.49	8.28	3.16
6	7.57	2.63	8.75	3.79
7	7.42	2.35	8.76	3.45
8	7.65	2.60	8.71	3.52
9	7.69	2.39	8.70	3.14
10	7.44	2.15	8.76	3.35

2.3.2. Per Cent Time

Table 31

Means and standard deviations (SD) for the per cent time measure during training and during baseline in each of the 10 suppression sessions

Session	Training Mean	Training SD	Baseline Mean	Baseline SD
1	8.54	7.52	6.91	2.50
2	8.85	6.28	6.86	2.33
3	10.99	7.95	7.01	2.50
4	10.63	8.41	7.45	2.97
5	10.16	8.73	7.11	2.85
6	10.95	8.43	7.67	2.80
7	11.24	8.48	7.72	3.02
8	11.22	10.02	7.82	3.28
9	11.08	7.76	7.23	2.64
10	12.29	9.60	7.61	3.10

There was a significant main effect of *Session,* $F(6.21, 267.06) = 3.79$, $p = .001$, $MS_E = .20$, *partial* $\mu^2 = .08$. In order to investigate this main effect of *Session*, pairwise comparisons with Bonferroni corrections were performed. These showed that participants spent significantly less time under threshold in *Session 1* than they did in *Session 10* ($p = .037$, $d = .52$). No other effects were found to be significant.

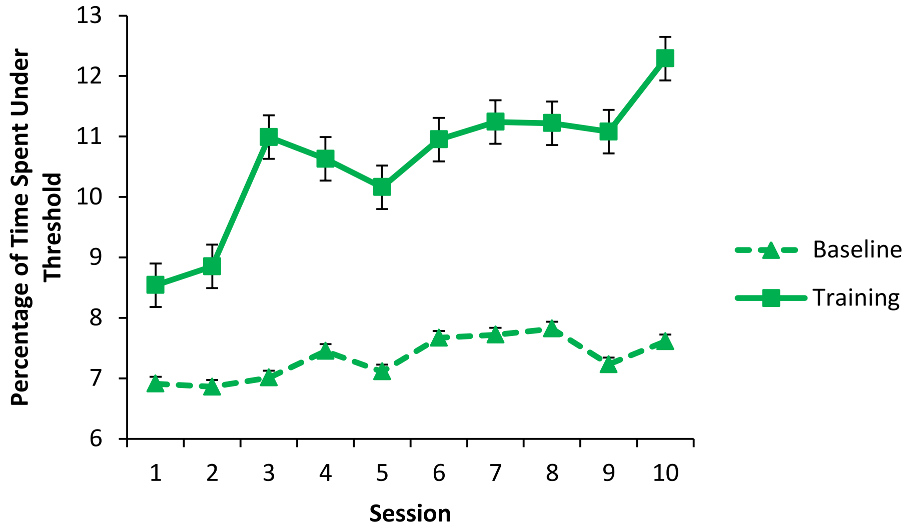

Figure 23. Mean per cent time (with standard error bars) during baseline and during training for each session of suppression training

2.3.3. Integrated Alpha

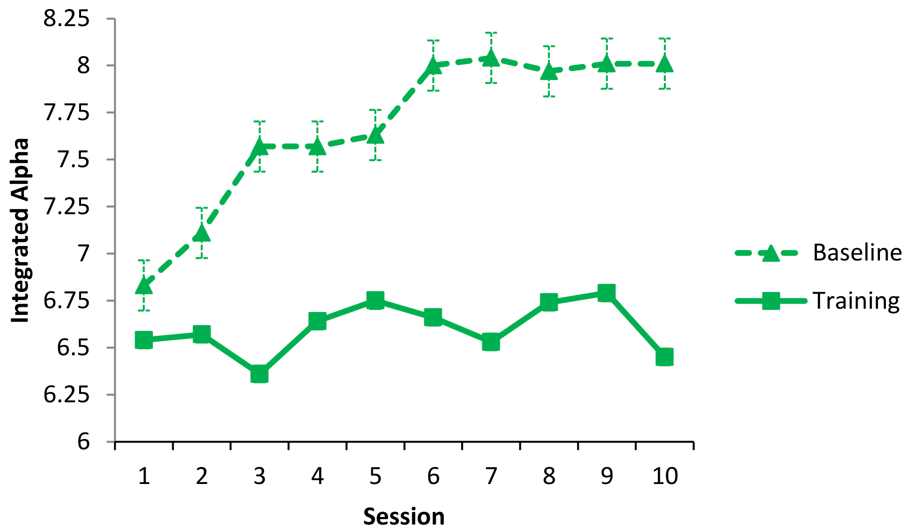

Figure 24. Mean integrated alpha (with standard error bars) during training for each session of suppression training (where error bars cannot be seen this is due to them being large enough to be visible on the graph)

Table 32

Means and standard deviations (SD) for the integrated alpha (IA) measure during training and during baseline in each of the 10 suppression sessions

Session	Training Mean	Training SD	Baseline Mean	Baseline SD
1	6.54	2.22	6.83	2.17
2	6.57	2.61	7.11	2.68
3	6.36	2.20	7.57	3.10
4	6.64	2.08	7.57	2.78
5	6.75	2.13	7.63	2.73
6	6.66	2.15	8.00	3.27
7	6.53	1.97	8.04	3.08
8	6.74	2.25	7.97	3.05
9	6.79	2.04	8.01	2.75
10	6.45	1.81	8.01	2.84

There was no main effect of *Session,* $F(4.81, 206.70) = 1.06$, $p = .385$, $MS_E = .04$, *partial* $\mu^2 = .02$.

2.4 Across Sessions Compared to Baseline

As with the enhancement data analyses, evidence of change over time across sessions in comparison to baseline was performed by calculating the mean value for each of the 10 sessions during each sessions' eyes open baseline and separately during the suppression training itself (see Tables 30-32 and Figures 22-24). A 2 (Stage: *Baseline* vs *Training*) x 10 (Session: *Session 1 – Session 10*) repeated measures ANOVA was then conducted.

2.4.1 Amplitude

There was a significant main effect of *Stage* $F(1, 43) = 22.76$, $p < .001$, $MS_E = 2.05$, *partial* $\mu^2 = .35$ due to participants producing a lower amplitude during *Training* ($M = 1.96$, $SE = .04$) than during *Baseline* ($M = 2.05$, $SE = .05$). There was a significant main effect of *Session,* $F(6.28, 269.80) = 7.06$, $p < .001$, $MS_E = .20$, *partial* $\mu^2 = .14$. There was a significant *Stage* by *Session* interaction effect, $F(5.80, 249.33) = 2.84$, $p = .01$, $MS_E = .04$, *partial* $\mu^2 = .06$.

In order to investigate the *Stage* by *Session* interaction effect a one way repeated measures ANOVA, split by *Stage,* was performed on the *Session* data. This revealed that there was a significant main effect of *Session* for the *Baseline* data, $F(9, 396) = 7.72$, $p < .001$, $MS_E = .14$, *partial* $\mu^2 = .15$, and a significant main effect of *Session* for the *Training* data, $F(4.96, 213.45) = 3.09$, $p = .010$, $MS_E = .06$, *partial* $\mu^2 = .67$.

In order to investigate the main effect of *Session* for the *Baseline* data, pairwise comparisons with Bonferroni corrections were performed. It was found that participants produced a significantly smaller amplitude in *Session 1* than they did in *Sessions 5* ($p = .025$, $d = .33$), *6* ($p = .003$, $d = .43$), *7* ($p = .002$, $d = .47$), *8* ($p = .008$, $d = .43$), *9* ($p < .001$, $d = .48$), and *10* ($p < .001$, $d = .47$). They also produced a significantly smaller difference in amplitude in *Session 2* than they did in *Sessions 6* ($p = .004$, $d = .31$), *7* ($p = .025$, $d = .34$), *8* ($p = .029$, $d = .31$), *9* ($p = 002$, $d = .35$) and *10* ($p = 009$, $d = .34$).

In order to investigate the main effect of *Session* for the *Training* data, pairwise comparisons with Bonferroni corrections were performed. It was found that participants produced a significantly smaller amplitude in *Session 3* than they did in *Session 9* (p =.041 , d = .23) but no other effects were found to be significant.

2.4.2 Per Cent Time

There was a significant main effect of *Stage,* $F(1, 43) = 20.26$, $p < .001$, $MS_E = .50$, *partial* $\mu^2 = .32$ due to participants spending more time under threshold during training ($M = 2.14$, $SE = .08$) than they did during baseline ($M = 1.92$, $SE = .04$. There was a significant main effect of *Session,* $F(6.54, 281.02) = 3.48$, $p = .002$, $MS_E = .18$, *partial* $\mu^2 = .08$. There was a significant *Stage* by *Session* interaction effect, $F(6.17, 265.31) = 2.50$, $p = .022$, $MS_E = .10$, *partial* $\mu^2 = .06$.

In order to investigate the *Stage* by *Session* interaction effect a one way repeated measures ANOVA, split by *Stage*, was performed on the *Session* data. This showed that during *Baseline* there was no main effect of *Session,* $F(6.79, 298.89) = 1.72$, $p = .107$, $MS_E = .08$, *partial* $\mu^2 =.04$. During *Training*, however, there was a significant main effect of *Session,* $F(6.21, 267.06) = 3.79$, $p = .001$, $MS_E = .198$, *partial* $\mu^2 = .08$.

In order to investigate this main effect of *Session*, pairwise comparisons with Bonferroni corrections were performed. These showed that participants spent significantly less time under threshold in *Session 1* than they did in *Session 10* ($p = .037$, $d = .52$). No other effects were found to be significant.

2.4.3 Integrated Alpha

There was a significant main effect of *Stage,* $F(1, 43) = 19.92$, $p < .001$, $MS_E = .21$, *partial* $\mu^2 = .32$, due to participants producing more integrated alpha during *Baseline* (M =1.98 , SE = .05) than during *Training* (M = 1.84, SE = .04). There was a significant main effect of *Session,* $F(5.94, 255.48) = 4.89$, $p < .001$, $MS_E = .03$, *partial* $\mu^2 = .10$. There was a significant *Stage* by *Session* interaction effect, $F(5.41, 232.73) = 2.56$, $p = .025$, $MS_E = .028$, *partial* $\mu^2 = .056$.

In order to investigate this *Stage* by *Session* interaction effect, a one way repeated measures ANOVA, split by *Stage*, was performed on the *Session* data. This revealed that there was a significant main effect of *Session* during *Baseline,* $F(6.86, 301.95) = 7.08$, $p < .001$, $MS_E = .02$, *partial* $\mu^2 = .14$, but during *Training* there was no main effect of *Session,* $F(4.81, 206.70) = 1.06$, $p = .385$, $MS_E = .04$, *partial* $\mu^2 = .02$.

In order to investigate the main effect of *Session* shown during their *Baseline*, pairwise comparisons with Bonferroni corrections were performed. These showed that participants produced significantly less integrated alpha in *Session 1* than they did in *Session 5* ($p = .017$, $d = .34$), *Session 6* ($p = .006$, $d = .42$), *Session 7* ($p = .005$, $d = .45$), *Session 8* ($p = .015$, $d = .40$), *Session 9* ($p < .001$, $d = .49$) and *Session 10* ($p < .001$, $d = .45$). They also produced significantly less integrated alpha in *Session 2* than they did in *Session 6* ($p = .004$, $d = .31$), *Session 9* ($p = .002$, $d = .38$), and *Session 10* ($p = .014$, $d = .34$) and marginally less integrated alpha in *Session 2* than they did in *Session 7* ($p = .054$, $d = .34$) and *Session 8* ($p = .059$, $d = .29$).

Table 33

Summary of the findings for each measure across sessions and across sessions in comparison to baseline during the suppression training. Where an effect was found to be significant the significant pairwise comparisons (with Bonferroni corrections) which were found are listed. Of these, any effects indicative of a pattern opposite to that which would be expected for 'successful' training are highlighted in yellow.

	Amplitude	**Suppression Per Cent Time**	**Integrated Alpha**
Across Sessions			
Session	Yes 3 < 9	Yes 1 < 10	No
Across Sessions Comparison to Baseline			
Stage	Yes Training < Baseline	Yes Training > Baseline	Yes Training < Baseline
Session	Yes	Yes	Yes
Stage by Session Interaction Effect	Yes Baseline 1 < 5-10 2 < 6-10 Training 3 < 9	Yes Training 1 < 10	Yes Baseline 1 < 5-10 2 < 6, 9, 10

2.5. Suppression Training Summary

The within sessions in comparison to baseline analyses showed agreement in all three measures and suggested an increase in alpha over time (see Table 29 for a summary of the findings). Given that suppression training should ideally show a decrease over time these results are not indicative of successful suppression training, but Figures 19-21 reveal that even though participants show an increase in each measure towards baseline, as opposed to the ideal of away from baseline, they nonetheless all show a below baseline performance throughout training which in itself is indicative of suppression. The within sessions data also shows agreement amongst the three measures about there being an increase in alpha over time, with each showing a main effect of *Period*, although the measures disagree on whether there are any other effects. The amplitude measure, for instance, suggests a main effect of *Segment* whereas the per cent time measure does not and the integrated alpha measure suggests that there is a marginal main effect of *Segment.* In contrast the per cent time measure shows a *Segment* by *Period* interaction effect whereas the amplitude and integrated alpha measures do not.

With regards to the across sessions data (see Table 33 for a summary of the findings) there is disagreement amongst the three measures as to whether participants showed a change over time with both the amplitude and per cent time measures indicating that they did but, interestingly, the integrated alpha measure, which is meant to be an amalgamation of them both, suggesting that they did not. Once baseline is added, however, all three measures are in agreement about there being a change over time and suggest that participants spent significantly less time in alpha during training and produced significantly lower amplitudes and amounts of integrated alpha during training than they did during their baselines. This is the pattern which would be hoped for during suppression training. However, although all three measures indicate that there was a change over time and a *Stage* by *Session* interaction effect the majority of the effects appear to be due to an increase over time during baseline from the first and second sessions to the later sessions and the only change during training over time appears to result from an increase over time from earlier sessions to later sessions which is once more in the opposite direction to that which would be hoped for during suppression training.

3. Further Analyses 1 – The Initial Suppression of Alpha

What is particularly noticeable from the results are the large below baseline decreases which occur at the start of each segment (i.e. periods 1_{s1} and 1_{s2}). Regardless of which measure is used, participants' alpha shows a marked drop below that which they produce normally when they are not trying to influence their alpha. This occurred at the start of each Segment, whether or not participants were enhancing or suppressing their alpha, and occurred throughout the entire course of the training regime, even in the later sessions. A similar pattern was seen by Vernon and Withycombe (2006) and Plotkin (1978) too also describes how in each of his participants' 10 sessions there was always an initial drop at the start which he puts down to orientating to the feedback and anxiety about their performance.

It is known that attending to stimuli, which in this case is the feedback given during the course of the training, can cause a drop in alpha (Jasper & Shagass, 1941) and Plotkin (1978) suggests that participants therefore need to become habituated to what has previously been called the distraction of the feedback tone (Plotkin, 1976a). Orientating to the feedback is also the explanation Prewett and Adams (1976) give as to why their participants showed a drop in the time their participants spent in alpha at the start of training in comparison to their baseline. Because Prewett and Adams' (1976) participants were only given the one session of training the below baseline drop in alpha seen at the start of their training could have been due to the newness of the situation and/or undertaking a new task. Both of which being things which Paskewitz and

Orne (1973) and Fell et al. (2002) put forward as having a suppressing effect on alpha. Gunkelman and Johnstone (2005) add that if participants are trying hard to do well they may end up inhibiting their performance because, as Lynch and Paskewitz (1971) point out, concentrating too hard often results in a suppression of alpha. Anxiety and tension, which may well accompany the above potential reasons for a below baseline drop in alpha at the start of training, also reduces alpha activity (Hare et al., 1982).

Whilst these are reasons which may explain why alpha would show a below baseline decrease at the start of the first one or two training sessions, it is likely that these effects would decrease over time as participants become more accustomed to the experience and thus that the suppressing effect seen on alpha would decrease as sessions progressed. This does not appear to be the case here, however. As with Plotkin's (1978) study, the drop was seen at the start of each of the 10 sessions and, as already mentioned, after each break (i.e. the start of each separate segment too).

An alternative explanation, in that case then, is the difference which may occur in participants' attentional focus depending on the stage of the training session that they are at. It is generally thought that external attention produces a decrease in alpha magnitude whereas internal attention sees an increase (Bollimunta et al., 2011). For instance, both Aftanas and Golocheikine (2001) and Cooper et al. (2003) showed that externally directed attention produced a decrease in the amplitude of alpha whereas internally directed attention produced an increase. The enhancement of alpha has often been associated with reducing attention on the external environment (Lynch & Paskewitz, 1971). Participants may begin their training with the intention of trying to produce a particular response, such as eliciting the audio feedback. This may lead them to focus their attention externally as they wait to hear it occur. As the session proceeds and the feedback begins, it may reassure them that they are getting the desired results. As a result, their sense of anticipation, waiting for the validation of the initial response, disappears and they become less externally focused on the feedback itself and more internally focused on the strategies they are using to try and produce the feedback.

On a related point, it was demonstrated by Tyson (1987) that anticipation has a deleterious effect on alpha. He showed that participants who learned to anticipate alpha before they learned to control it performed better than those who were asked to anticipate it at the same time as controlling it. More recently, Klimesch (1999) also provided a discussion of the alpha suppressing effect of anticipation. The previously described anticipation which may occur at the start of each training session, then, as participants wait for the feedback to first occur, may in itself be the reason for the large below-baseline drops seen at the start of each within sessions segment, as opposed to a greater shift in the ratio of externally to internally focused attention throughout the course of each segment per se.

In light of this below baseline drop at the start of each segment, which is uncharacteristic of the remainder of each segment, an argument can be made for excluding the first period of each segment from the analysis in order to focus on the participants' pattern of learning. The within sessions and within sessions in comparison to baseline analyses (which are the most noticeably affected by this initial pattern of alpha suppression as opposed to the across and across sessions in comparison to baseline analyses where the periods of each session are merged as one so the effects each individual period has are reduced), above, were therefore reanalysed with periods 1_{s1} and 1_{s2} excluded in order to see whether their exclusion had any effect on the overall results or conclusions.

3.1. Enhancement

3.1.1. Within Sessions

3.1.1.1. Amplitude

There was a marginal main effect of *Segment*, $F(1, 51) = 3.79$, $p = .057$, $MS_E = .004$, *partial* $\mu^2 = .07$, due to participants producing a higher mean amplitude in *Segment 2* ($M = 2.10$, $SE = .05$) than in *Segment 1* ($M = 2.09$, $SE = .05$). There was a significant main effect of *Period*, $F(2.17, 110.76) = 6.66$, $p = .001$, $MS_E = .002$, *partial* $\mu^2 = .12$. There was no *Segment* by *Period* interaction effect, $F(3, 153) = .61$, $p = .610$, $MS_E = .001$, *partial* $\mu^2 = .01$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $2_{s1, s2}$ participants produced a significantly smaller amplitude than during *period* $3_{s1, s2}$ ($p = 002$, $d = .04$), and *period* $4_{s1, s2}$ ($p < .001$, $d = .06$). No other differences were found to be significant.

3.1.1.2. Per Cent Time

There was a significant main effect of *Segment*, $F(1, 51) = 5.35$, $p = .025$, $MS_E = 15.40$, *partial* $\mu^2 = .10$ due to participants spending more time over threshold in *Segment 2* ($M = 43.29$, $SE = 1.12$) than in *Segment 1* ($M = 42.40$, $SE = 1.13$). There was a significant main effect of *Period*, $F(2.15, 109.51) = 5.56$, $p = .004$, $MS_E = 9.83$, *partial* $\mu^2 = .10$. There was no *Segment* by *Period* interaction effect, $F(3, 153) = .91$, $p = .438$, $MS_E = 4.26$, *partial* $\mu^2 = .02$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $2_{s1, s2}$ participants spent significantly more time over threshold than during *period* $3_{s1, s2}$ (*p* = .007, *d* = .13) and *period* $4_{s1, s2}$ (*p* = .003, *d* = .16) and marginally less time over threshold in *period* $5_{s1, s2}$ than they did in *period* $4_{s1, s2}$ (*p* = .059, *d* = .05). The latter of which is in the opposite direction to be indicative of enhancement.

3.1.1.3. Integrated Alpha

There was a significant main effect of *Segment*, $F(1, 51) = 5.41$, $p = .024$, $MS_E = .02$, *partial* $\mu^2 = .10$ due to participants producing more integrated alpha in *Segment 2* (*M* = 1.25, *SE* = .06) than in *Segment 1* (*M* = 1.21, *SE* = .06). There was a significant main effect of *Period*, $F(2.20, 112.05) = 6.15$, $p = .002$, $MS_E = .01$, *partial* $\mu^2 = .11$. There was no *Segment* by *Period* interaction effect, $F(3, 153) = .79$, $p = .501$, $MS_E = .01$, *partial* $\mu^2 = .02$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $2_{s1, s2}$ participants produced significantly less integrated alpha than during *period* $3_{s1, s2}$ (*p* = .004, *d* = .10) and *period* $4_{s1, s2}$ (*p* = .003, *d* = .12). No other significant differences were found.

3.1.2. Within Sessions Compared to Baseline

3.1.2.1. Amplitude

There was a main effect of *Segment*, $F(1, 51) = 4.81$, $p = .033$, $MS_E = .01$, *partial* $\mu^2 = .09$ due to participants producing a smaller difference in amplitude between baseline and training in *Segment 1* (*M* = 1.60, *SE* = .04) than in *Segment 2*

(M = 1.63, SE = .03). There was a main effect of *Period*, $F(2.34, 119.41) = 4.53$, p = .009, MS_E = .01, *partial* μ^2 = .08. There was no *Segment* by *Period* interaction effect, $F(3, 153) = .78$, p = .506, MS_E = .003, *partial* μ^2 = .02.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $2_{s1, s2}$ participants produced a significantly smaller difference in amplitude between baseline and training than during *period* $3_{s1, s2}$ (p = 006, d = .13), and *period* $4_{s1, s2}$ (p = .020, d = .12). No other differences were found to be significant.

3.1.2.2. Per Cent Time

There was a significant main effect of *Segment*, $F(1, 51) = 5.35$, p = .025, MS_E = 15.40, *partial* μ^2 = .10 due to participants producing a larger difference between baseline and training in *Segment 2* (M = 1.77, SE = 1.17) than in *Segment 1* (M = .88, SE = 1.18). There was a significant main effect of *Period*, $F(2.15, 109.51) = 5.56$, p = .004, MS_E = 9.83, *partial* μ^2 = .10. There was no *Segment* by *Period* interaction effect, $F(3, 153) = .91$, p = .438, MS_E = 4.26, *partial* μ^2 = .02.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $2_{s1, s2}$ participants showed a smaller difference between baseline and training than during *period* $3_{s1, s2}$ (p = .007, d = .13) and *period* $4_{s1, s2}$ (p = .003, d = .15) and marginally smaller difference between baseline and training in *period* $5_{s1, s2}$ than they did in *period* $4_{s1, s2}$ (p = .059, d = .10). No other differences were found to be significant.

3.1.2.3. Integrated Alpha

There was a significant main effect of *Segment*, $F(1, 51) = 5.70$, $p = .021$, $MS_E = .02$, *partial* $\mu^2 = .10$ due to participants producing a larger difference in integrated alpha between baseline and training in *Segment 2* ($M = 1.64$, $SE = .04$) than in *Segment 1* ($M = 1.61$, $SE = .04$). There was a significant main effect of *Period*, $F(2.25, 114.93) = 5.07$, $p = .006$, $MS_E = .01$, *partial* $\mu^2 = .09$. There was no *Segment* by *Period* interaction effect, $F(3, 153) = .89$, $p = .448$, $MS_E = .00$, *partial* $\mu^2 = .02$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $2_{s1, s2}$ participants produced a significantly smaller difference in integrated alpha between baseline and training then during *period* $3_{s1, s2}$ ($p = .009$, $d = .12$) and *period* $4_{s1, s2}$ ($p = .011$, $d = .13$). No other significant differences were found.

3.1.3. Enhancement Summary

In the case of enhancement training, when periods 1_{s1} and 1_{s2} are excluded from the within sessions and within sessions in comparison to data analysis, the only difference found was in the amplitude measure whereby the main effect of *Segment* went from being significant in the within sessions analysis to marginal (see Table 34, below). It therefore does not make a difference to the overall conclusions regarding the analyses of participants' enhancement training if period 1_{s1} and period 1_{s2} are excluded from the analyses.

Table 34

Summary of the findings for the enhancement training for each measure within sessions and within sessions in comparison to baseline when periods 1_{s1} and 1_{s2} were excluded from the analyses. All main and interaction effects which differ from the original analyses (i.e. the analyses where periods 1_{s1} and 1_{s2} were included) are highlighted in green. Where an effect was found to be significant the significant pairwise comparisons (with Bonferroni corrections) which were found are listed. Of these, any effects indicative of a pattern opposite to that which would be expected for 'successful' training are highlighted in yellow.

	Enhancement		
	Amplitude	**Per Cent Time**	**Integrated Alpha**
Within Sessions			
Segment	Marginal 1 < 2	Yes 1 < 2	Yes 1 < 2
Period	Yes 2 < 3-4	Yes 2 < 4 5 < 4	Yes 2 < 3-4
Segment by Period	No	No	No
Within Sessions Comparison to Baseline			
Segment	Yes 1 < 2	Yes 1 < 2	Yes 1 < 2
Period	Yes 2 < 3-4	Yes 2 < 3-4	Yes 2 < 3-4
Segment by Period	No	No	No

3.2. Suppression

3.2.1. Within Sessions

3.2.1.1. Amplitude

There was a significant main effect of *Segment*, $F(1, 51) = 5.92$, $p = .019$, $MS_E = .00$, *partial* $\mu^2 = .10$ due to participants producing a smaller amplitude in *Segment 1* ($M = 1.99$, $SE = .04$) than in they did in *Segment 2* ($M = 2.00$, $SE = .04$), which is the opposite to which would ideally be hoped for during suppression training. There was a significant main effect of *Period*, $F(2.37, 120.92) = 5.13$, $p = .005$, $MS_E = .00$, *partial* $\mu^2 = .09$. There was no *Segment* by *Period* interaction effect, $F(3, 153) = 1.20$, $p = .312$, $MS_E = .00$, *partial* $\mu^2 = .02$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $2_{s1, s2}$ participants produced a significantly smaller amplitude than during *period* $3_{s1, s2}$ ($p = .047$, $d = .05$), and *period* $4_{s1, s2}$ ($p = .011$, $d = .05$) which again is the opposite pattern to what would ideally be hoped for during suppression training. No other differences were found to be significant.

3.2.1.2. Per Cent Time

There was no main effect of *Segment*, $F(1, 51) = 2.46$, $p = .123$, $MS_E = .03$, *partial* $\mu^2 = .05$. There was a significant main effect of *Period*, , $F(3, 153) = 3.55$, $p = .016$, $MS_E = .01$, *partial* $\mu^2 = .07$. There was no *Segment* by *Period* interaction effect, $F(3, 153) = 2.19$, $p = .091$, $MS_E = .01$, *partial* $\mu^2 = .04$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $2_{s1, s2}$ participants produced a marginally larger difference between baseline and training than during *period 3* $_{s1, s2}$ (p = .068, d = .07) and *period 4* $_{s1, s2}$ (p = .052, d = .08). No other differences were found to be significant.

3.2.1.3. Integrated Alpha

There was a significant main effect of *Segment*, $F(1, 51) = 5.03$, p = .029, MS_E = .01, *partial* μ^2 = *.09* due to participants producing more integrated alpha in *Segment 2* (M = 1.90, SE = .04) than in *Segment 1* (M = 1.88, SE = .04). There was a significant main effect of *Period*, $F(2.51, 128.09) = 4.99$, p = .005, MS_E = , *partial* μ^2 = .90. There was no *Segment* by *Period* interaction effect, $F(3, 153) = 1.73$, p = .163, MS_E = .00, *partial* μ^2 = .03.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. It was found that during *period* $2_{s1, s2}$ participants produced significantly less integrated alpha than during *period 3* $_{s1, s2}$ (p = .043, d = .06) and *period 4* $_{s1, s2}$ (p = .015, d = .07). No other significant differences were found.

3.2.2. Within Sessions Compared to Baseline

3.2.2.1. Amplitude

There was a significant main effect of *Segment*, $F(1, 51) = 2.98$, p = .090, MS_E = .01, *partial* μ^2 = .06 due to participants producing a smaller difference between baseline and training in *Segment 2* (M = 1.73, SE = .03) than they did in *Segment 1* (M = 1.74, SE = .03). There was a significant main effect of *Period*, $F(2.42, 123.20) = 3.42$, p = .028, MS_E = .00, *partial* μ^2 = .06. There was no *Segment* by *Period* interaction effect, $F(3, 153) = .82$, p = .483, MS_E = .00, *partial* μ^2 = .02.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. However, no significant differences were found.

3.2.2.2. Per Cent Time

There was no main effect of *Segment*, $F(1, 51) = 2.69$, $p = .107$, $MS_E = .01$, *partial* $\mu^2 = .05$. There was no main effect of *Period*, $F(1.60, 81.50) = 1.69$, $p = .195$, $MS_E = .01$, *partial* $\mu^2 = .03$. There was no *Segment* by *Period* interaction effect, $F(1.53, 78.23) = 1.73$, $p = .190$, $MS_E = .01$, *partial* $\mu^2 = .03$.

3.2.2.3. Integrated Alpha

There was no main effect of *Segment*, $F(1, 51) = 2.18$, $p = .146$, $MS_E = .00$, *partial* $\mu^2 = .04$. There was a significant main effect of *Period*, $F(2.50, 127.28) = 3.26$, $p = .031$, $MS_E = .00$, *partial* $\mu^2 = .06$ There was no *Segment* by *Period* interaction effect, $F(3, 153) = 1.32$, $p = .269$, $MS_E = .00$, *partial* $\mu^2 = .03$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed but no significant differences were found.

Table 35

Summary of the findings for suppression training for each measure within sessions and within sessions in comparison to baseline when periods 1_{s1} and 1_{s2} were excluded from the analyses. All main and interaction effects which differ from the original analyses (i.e. the analyses where periods 1_{s1} and 1_{s2} were included) are highlighted in green. Where an effect was found to be significant the significant pairwise comparisons (with Bonferroni corrections) which were found are listed. Of these, any effects indicative of a pattern opposite to that which would be expected for 'successful' training are highlighted in yellow.

		Suppression	
	Amplitude	**Per Cent Time**	**Integrated Alpha**
Within Sessions			
Segment	Yes 1 < 2	No	Yes 1 < 2
Period	Yes 2 < 3-4	Yes	Yes 2 < 3-4
Segment by Period	No	No	No
Within Sessions Comparison to Baseline			
Segment	Yes 1 < 2	No	No
Period	Yes	No	Yes
Segment by Period	No	No	No

3.3. Suppression Summary

In the case of suppression training, when periods 1_{s1} and 1_{s2} are excluded from the within sessions and within sessions in comparison to data analysis, there were four differences found when compared to the original analyses (see Table 35, above). Specifically, the integrated alpha measure went from showing a marginal effect of *Segment* within sessions to a main effect of *Segment*, the per cent time measure went from showing a *Segment* by *Period* interaction effect to showing no *Segment* by *Period* interaction effect and a main effect of *Period* to no main effect of *Period*, and the amplitude measure went from showing no effect of *Segment* to a main effect of *Segment* due to participants producing a lower alpha amplitude in *Segment 1* than they did in *Segment 2.* The latter of which is the opposite pattern to what would be predicted for suppression training. None of this, however, alters the overall conclusions from the original analysis.

4. Further Analyses 2 – The Correlation Between Amplitude and Per Cent Time

As discussed in the introduction section of this chapter, previous research has shown that amplitude and per cent time sometimes show opposing results (e.g. Brown, 1970; Cram et al., 1977) and the above data also show some discrepancies between the two (see for example, Table 26, above). It would be interesting, therefore, to see if participants' performance as measured by the per cent time measure correlate with their results utilising the amplitude measure. If they do then it suggests that there is a relationship between the two, if they do not then the implications would be that the two measures – although both reflecting participants' alpha – may be measures reflecting two different things.

Given the large differences in the scale for the per cent time measure compared to the amplitude measure (see, for example, Table 20, above) all the data was first transformed to z scores and then, due to the fact that, as mentioned at the start of the results section, above, all but the per cent time data for the enhancement training was non-normally distributed (all $p < .003$ for the results of the Shapiro-Wilks tests) Spearman's Rho correlations were performed between the z scores for the average amplitude each participants produced during training overall and the z scores for the average percentage of time participants spent over/under threshold overall.

4.1. ***Enhancement***

In order to compare participants' alpha during training within sessions using amplitude as a measure of their alpha to when using per cent time as a measure a Spearman's rho correlation was performed. This showed that participants showed a non-significant, small positive correlation between the amplitude and per cent time measure, $\rho = .205$, $p = .145$ (see Figure 25 for an illustration).

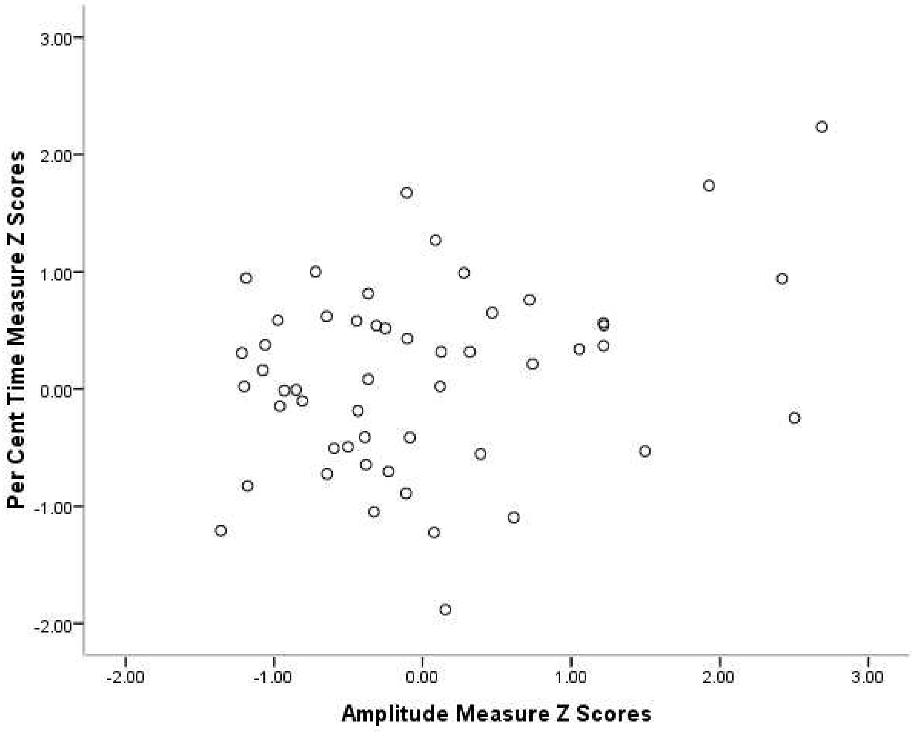

Figure 25. Scattergraph to show the relationship between the amount of alpha produced by each of the participants within sessions during their enhancement training using amplitude as the measure to the amount of alpha produced using per cent time as the measure.

4.2. Suppression

As with the enhancement training, a Spearman's rho correlation was performed on the data for each of the two measures. This showed that participants showed a significant, moderate positive correlation between the amplitude and per cent time measure, $\rho = .484$, $p < .001$ (see Figure 26 for an illustration).

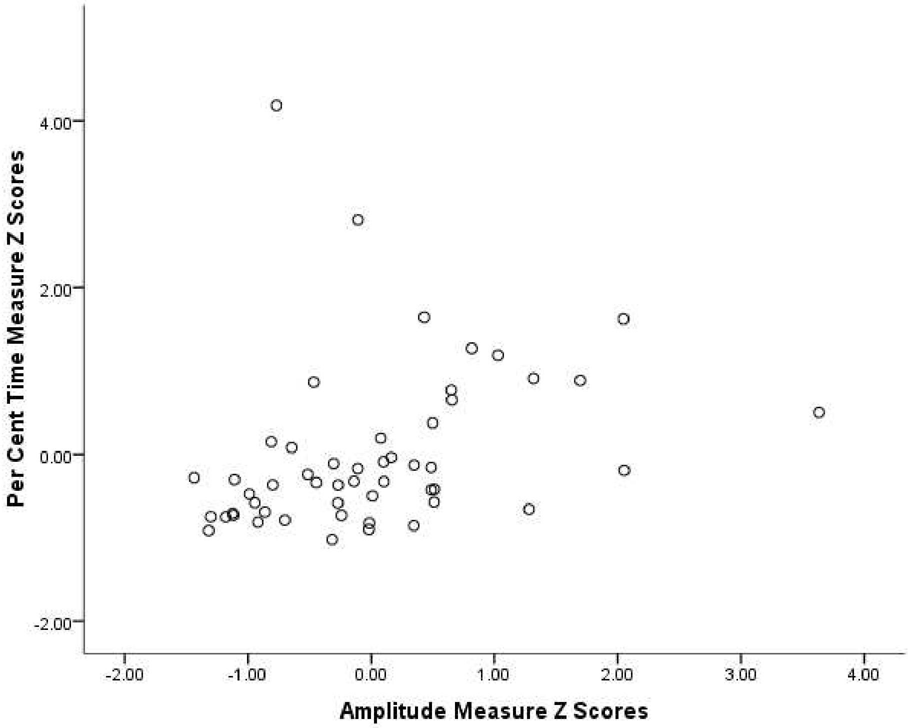

Figure 26. Scattergraph to show the relationship between the amount of alpha produced by each of the participants within sessions during their suppression training using amplitude as the measure to the amount of alpha produced using per cent time as the measure.

Discussion

When looking at participants' performance using the within sessions analysis to track change over time, participants showed evidence of learning to enhance their alpha but not to suppress it; this was the case regardless of whether amplitude, per cent time, or integrated alpha were taken as the way in which to measure their performance. In the case of enhancement, participants produced higher amplitudes of alpha and spent more time over threshold in the second half (segment 2) of their training sessions than in the first (segment 1) and an increase over time within the segments themselves. An increase in the amount of alpha within the sessions themselves and a decrease in the time spent under threshold was also seen in the suppression data, however, which is the opposite as to what would be expected for successful suppression. The incorporation of baseline measures, however, somewhat undermines any conclusions which could be drawn from the within sessions analyses. Whilst all three measures again showed a change over time using the within sessions in comparison to baseline analysis as a way of looking at the data, with participants showing an increase from segment 1 to segment 2 during their enhancement training, the strongest effects resulted from how big the difference was between baseline and training in period 1 than in any of the other periods. At the start of each segment, participants' alpha drops below that which occurs naturally (i.e. during their baseline) and it is only from the second period onwards in each segment that their alpha increases beyond their natural resting levels. This is not an uncommon occurrence (see for example, Plotkin, 1978; Vernon & Withycombe, 2006) and reasons why this may be are discussed at the start of the Further Analysis 1 section of the results, above. When the within sessions and the within sessions comparison to baseline data were re-run to see the impact of excluding the first period in each segment, however, although there were a couple of differences in specific main or interaction effects, particularly in the case of the suppression training, the overall conclusions of the analysis remained the same. In other words, during their enhancement training participants showed an increase in all three measures from the first to the second segment and they also showed an increase between periods 2 to periods 3 and 4. All of this is suggestive of enhancement. Likewise in the case of their suppression training, even with the first periods of each segment excluded from the analysis, the overall conclusions from the original analysis remain the same. That is, that during the suppression training the participants alpha was increasing rather than decreasing over time which is the opposite to what would be hoped for during suppression training. Thus although the initial below baseline suppression seen in each session at the start of each segment could be argued to be a reaction to the situation and not of learning per se, the inclusion of the data or not makes no overall difference to the conclusions of the analyses. It could also be argued, especially in light of the fact that it occurs elsewhere in the literature and not just in this study specifically, that it demonstrates part of the natural neurofeedback training process and to exclude it from the data is akin to removing an important reflection of the training process as a whole.

It is interesting to note that as well as an initial decrease in alpha activity at the start of each Segment that, although not generally found to be below baseline levels (aside from when using per cent time as a measure for the participants' enhancement training), participants showed a decrease in each segment from the penultimate to last periods in all three of the measures. Again, the reason for this can only be surmised here but it may be that participants were by that point in need of a break and showing a resulting drop in performance which could suggest that contrary to Hardt and Kamiya's (1976b) belief that participants should train for 10 minutes at a time before breaks are given, 7.5 minutes may be too long for participants to train for without being given a break.

As the Further Analyses 1 section of the results section shows, even when period 1 is excluded, comparisons between the later periods still showed evidence of participants learning to enhance their alpha within sessions, even when baselines were incorporated into the analyses. The inclusion of baselines within sessions for the suppression data, however, was more contradictory. Although all three of the measures were still in agreement about participants producing more alpha over time and spending less time below threshold (i.e. the opposite of successful suppression), it is interesting to note that the participants managed to keep their alpha activity below baseline levels for the entirety of their suppression training. That the participants successfully kept their alpha activity below baseline levels during the suppression training could be argued as a case for them learning to suppress their alpha but the fact that their alpha crept up nearer and nearer to baseline levels during the course of each session makes that a questionable conclusion. It could be that participants found suppression initially easier but that whatever method they were using was not something they were able to sustain to the same extent for more than a couple of minutes at a time. Another possibility is that participants were unable to learn to suppress their alpha but that something about the alpha training situation itself had a suppressing effect on alpha so unless participants are actively trying to enhance their alpha, it shows an initial drop then increases towards baseline again as they habituate. Only when they are actively trying to enhance their alpha does this increase exceed baseline. Although talking about eyes closed rather than eyes open training, Plotkin (1979) has presented this argument before stating that training has a significantly suppressing effect on alpha resulting in participants' alpha dropping below that seen during baseline and that they take a while for them to adjust and their natural baseline levels to return to normal.

Whatever the reason for the pattern seen during the suppression training it is clear that the inclusion of baselines provides helpful information. Without a baseline, the suppression data suggests alpha enhancement. With the incorporation of baseline information it reveals a more complex pattern whereby participants do show an in increase in alpha over time but that they nonetheless keep all measures of alpha below baseline levels.

Although all three of the measures were in agreement for the within sessions and within sessions comparison to baseline data for the participants' enhancement training, this was not the case when it came to the across sessions and across sessions comparison to baseline data. Here only the amplitude measure showed any change over time across sessions, supporting Hardt and Kamiya's (1976a) argument that studies failing to find an effect of learning may have done so because they only looked at per cent time and did not take amplitude in to account. They used this to justify the use of integrated alpha, which incorporates both, but interestingly in the cases where the per cent time and amplitude measures differed as to whether there was an effect or not, the integrated alpha measure agreed with per cent time measure that there was no change over time for the across sessions analysis but with the amplitude measure that there was a change of time for the across sessions compared to baseline analysis. Paradoxically, when it came to the suppression training, the integrated alpha measure disagreed with both the amplitude and per cent time measures about whether there was an effect of *Session* for the across sessions analyses but all three measures were in agreement about there being a change over time when baseline was taken in to account.

The discrepancies found between the measures for some of the analyses supports the findings of both Brown (1970) and Cram et al. (1977), who showed that evidence of learning depended on how alpha was measured. Fell et al. (2002) have pushed for an investigation in to the area. Why such discrepancies exist is a question which has not yet been answered (Fell et al., 2002) although perhaps it is because different aspects of alpha may be related to different things (e.g. Angelakis et al., 2007). Or it may be due to Hardt and Kamiya's (1976a) assertion that per cent time is less sensitive to changes in alpha than amplitude is.

At least to the degree of change in alpha. They suggest that participants who exhibit brief increases in the amplitude of their alpha rhythm, in line with the aim of the neurofeedback training, may be showing evidence of learning, but because such changes are brief the amount of time spent over the threshold may be insufficient for them to be classified as learners when looking only at per cent time.

Another reason for the difference between amplitude and per cent time may also be related to the type of feedback given. To take the present study as an example, feedback was given in the form of a moving bar which changed colour when it reached a pre-set threshold. In addition, when the bar exceeded the threshold, a tone also sounded and the frequency of this tone changed as the bar continued to move up or down above the threshold. In this instance the moving bar represents changes in amplitude, the changing colour of the bar represents time spent in alpha and the tone provides information on both amplitude and time. Notwithstanding the argument that the absence of feedback may itself be construed as feedback, it may be that participants received more information regarding changes in amplitude than they did concerning the amount of time spent above threshold (certainly in the case of the audio-only feedback group). This may have made it easier for participants to alter the amplitude of their alpha activity but not the time they spent in alpha. Such a suggestion is consistent with the notion that changes based on continuous feedback may provide more information (Hardt & Kamiya, 1976a). However, there has yet to be any research addressing the question of whether feedback based on amplitude alone compared to an equal amount of feedback based on time spent above threshold would show discrepancies between the measures.

A possible solution to this, if it is in fact the cause, is the recommendation by those such as Hardt and Kamiya (1976a) of providing participants with an online score in addition to their feedback in order for them to learn from. In addition, if participants find it hard to tell how they are doing from one moment to the next or from one session to another because feedback is more about what the participants are doing at that moment in time rather than cumulatively over time, then a score would also potentially be more helpful as it gives participants a more tangible and objective way of measuring their own success as well as a goal for them to try and beat.

It is interesting to note that when the amplitude and per cent time data were correlated (see Further Analyses 2 section of the results section, above) the enhancement data indicated that there was no linear relationship between the two and that participants' performance using one measure could therefore not be used to predict their performance in the other. When the two measures were correlated using the data from the suppression training, however, a significant moderate positive correlation was found between them suggesting that there might be a relationship between the two measures after all. Correlations to look for a relationship between the two measures do not appear to have been reported in the alpha neurofeedback literature before and it is unclear why this discrepancy regarding whether they are related or not would occur. Perhaps though it is related to training ability; more specifically, to training success. The enhancement data suggest that participants were successful at learning to consciously increase their alpha whereas the suppression data is equivocal and arguably does not, suggesting instead that during suppression training participants showed a natural increase in their alpha back towards baseline levels as they became habituated to the training situation. If this is the case, then habituation may influence the relationship between the two measures. If participants' alpha is returning to baseline at a natural rate then this natural rate may thus be equivalent for all measures of alpha, or at the very least for these two. With enhancement training however the change in alpha is a conscious influence and that influence may not, for whatever reason, be equally effective on the magnitude of alpha as it is on the per cent time at or over threshold.

Whatever the cause, it is because of the possibility for discrepancy between amplitude and per cent time measures that calls have been made to use a measure which takes both into account (e.g. Hardt & Kamiya, 1976a), i.e. integrated alpha. A potential problem with this, however, is that when the amplitude and per cent time measures are in disagreement, the integrated alpha may – as with the across sessions comparison to baseline enhancement data here – show an effect but it may also – as in the case of the across sessions enhancement data discussed above – show no effect. This is problematic because when integrated alpha shows an effect it does not indicate whether that effect is due to participants increasing the amount of alpha they produce, the amount of time they spent over threshold, or both. When integrated alpha shows no effect it likewise fails to indicate whether that is due to there being no change/not enough change over time in the amplitude measure, due to there being no/not enough change in the per cent time measure, or due to there being no/not enough change in both. Without any evidence to suggest the relative importance of per cent time over amplitude or vice versa it seems wise to include both. The argument then becomes not one of amplitude versus per cent time versus integrated alpha but of amplitude *and* per cent time versus integrated alpha. If the goal is to provide a neat 'yes' or 'no' answer as to whether participants enhanced or suppressed their alpha then integrated alpha is arguably the better measure to use because if does just that whilst taking into account both amplitude and per cent time. At the same time it circumnavigates the problem of having to decide whether or not amplitude or per cent time is a more valid measure to justify the use of one over the other. However, if the goal is to provide a clearer picture of what is going on during training rather than a simple 'yes' or 'no' answer, it would be more informative to use both the per cent time and amplitude measures when analysing the data, but to keep them separate rather than combining them both into one measure. With no evidence to the contrary that enhancing/suppressing the amplitude of alpha may have a differing effect in comparison to enhancing the amount of time spent above/below naturally occurring levels of alpha, it would thus seem more advantageous to know if there is a difference between the two. This would allow the identification of any patterns when comparing any findings suggesting alpha neurofeedback training may have an effect on some aspect of behaviour or cognition. Either way, measuring both seems wise but combining them into one measure seems less so, given the possibility integrated alpha has for 'hiding' potentially useful information.

Finally, with regards to what the across sessions and across sessions comparison to data revealed about participants' ability to influence their alpha in a particular direction, there was some evidence for both enhancement and suppression but, as stated above, it depended on the measure used. During their enhancement training, participants showed an increase in the amplitude they produced across the sessions, regardless of whether baseline was taken into account or not. This effect was only seen when comparing the earlier sessions to the later ones, however, with no significant difference shown when just looking at session 4 onwards. Given that the incorporation of baseline as a factor failed to show any difference between baseline and training, though, this would suggest that participants' baselines were increasing over time in parallel to the training rather than their enhancement ability per se. There are several possible explanations for this. Firstly, it may be that participants are increasing their alpha and that this may be leaving a residual effect resting alpha. In other words, consciously attempting to enhance alpha amplitude during neurofeedback training may result in greater levels of alpha amplitude beyond the training session itself. Cho et al. (2008) found that participants' alpha amplitude at the end of each weekly training session positively correlated with the level of alpha amplitude seen in the next session's baselines. The higher the amplitude of their participants' alpha at the end of each session the higher the amplitude of their alpha during the eyes open baseline in the next session. The long-term effects of alpha neurofeedback training on the brain outside of the training sessions themselves are not yet known (Vernon, 2008) but it could be that learning to consciously increase a particular component of cortical activity produces changes in that component which outlast the session itself (see Chapter 1, section 3.8.4. for further discussion of this point). If this is the case, then it means that trying to identify an index of learning by focusing on across sessions changes may not be the most effective approach. Possible changes across sessions due to neurofeedack training may be confounded by concurrent changes in baselines. Thus, within sessions comparisons to baseline may represent a more effective method to use when looking for the evidence of learning to alter alpha amplitude via neurofeedback because this provides a picture of the changes seen during the training session rather than the difference from one session to the next. Although if the baselines are rising as participants' ability to enhance their alpha improves then this may mean that training to enhance over baseline becomes harder with each session and/or the degree of ability to enhance their alpha is somewhat masked by the effect of that ability. Indeed, the within sessions comparison to baseline data did show some evidence for participants enhancing their alpha whereas the across sessions comparison to baseline data did so far less strongly. As discussed in the introduction section of this chapter, however, the alternative ways of incorporating a baseline in to analyses are also problematic. For instance, comparing each session to one baseline taken before the first session (e.g. Zoefel et al., 2011) gives rise to the possibility of comparing performance to an artificially suppressed representation of natural alpha levels due to the novelty and anticipation likely to be experienced in the first session. Also, given the natural fluctuations seen in alpha due to day and time of day etc. (Gertz & Lavie, 1983) using a baseline from a different time than that which the training took place in leaves open the possibility that participants may show improvement simply because their alpha is naturally different on that day rather than because of any actual ability to consciously alter their alpha. Also, the point of enhancement/suppression training is for an individual, for whatever ultimate reason, to learn to exert a conscious control over their own alpha. Even if the training does alter their baseline levels, they should arguably be able to still demonstrate an ability to influence those levels if they have truly learned what they need to do to be able to exert a conscious influence over them. At least until a maximum capacity has been reached, if there even is such a thing (see the related discussion in the next chapter).

Another explanation as to the reason for the rising baselines relates to the conditions of the baseline recordings themselves. That is, participants were not monitored as to what they were doing during their resting baselines and it is plausible that whatever they did to pass the time, e.g. letting their mind wander, may have been more conducive to enhancing their alpha amplitude than what they were doing during the neurofeedback training itself. The issue of what constitutes an appropriate baseline is one that has received some discussion (see e.g., Plotkin, 1976a) but has yet to be resolved. Until the issue has been resolved it might be worth questioning participants to ascertain what, if anything, they are doing during the recording of their baseline to see if any patterns emerge.

One final explanation as to why participants' baselines may increase over time relates to Fell et al.'s (2002) suggestion, as mentioned above, that the novelty of the situation may have a suppressing effect on alpha. If this is the case it would therefore be expected that baselines taken in the initial sessions, when participants are unfamiliar with the experimental context, are suppressed in comparison to later sessions when participants have habituated to the situation. Alternatively, and relatedly, the increase in baseline amplitude across sessions could be the result of a change in focus from external to internal events, keeping in mind that baseline measures were taken with eyes open. Initially, when participants attend feedback sessions in the lab and are attached to sensors their focus may be externally orientated, looking around the room, taking in their surroundings, and so on. However, as their surroundings become more familiar with each session their attention during baseline recordings may become more internally focused towards, for instance, daydreaming, and this transition from external to internal sources may be what results in the increase in alpha amplitude across the sessions (see for example, Cooper et al., 2003). Given that the changes over time found here are a result of differences found when comparing the initial 2 or 3 sessions to the later ones but are not seen between sessions 4 and 10 themselves, this could well be the case.

In contrast to the enhancement data, the suppression data did show a difference between baseline and training across the sessions for all three measures, with participants showing a suppression of each measure during training in comparison to their baseline. The same pattern was seen for the suppression training as for the enhancement, however, with the effect of *Session* once baseline was incorporated as a factor resulting from a change in performance between the first couple of sessions and the following sessions rather than from a significant change from one session to the next. The involvement of baselines as the crucial factor here is suggested by the interaction shown by all three measures between *Stage* (baseline versus training) and *Session* with the majority of the effects in the most part appearing to be due to an increase in baseline rather than of the training itself particularly. Figures 22-24 are particularly illuminating as they show that there is a large increase in baseline amplitude and, to a lesser extent, integrated alpha, as sessions increase, which is not present during the training sessions themselves. In contrast, for the per cent time measure, participants do not show any difference in the amount of time they spend below threshold during their baselines but they do during the suppression training itself. This serves not only to again highlight the difference in per cent time and amplitude measures but also to show the difference that taking baselines into account can make to interpreting the data.

To summarise, in the case of enhancement training, whilst all three of the most common ways of measuring alpha (amplitude, per cent time and integrated alpha) were in agreement for the within sessions and within sessions comparison to baseline data, the across sessions and across sessions comparison to baseline data showed differences. For the suppression training, all three measures were in agreement for the analyses incorporating baselines they were not always in agreement for the analyses which did not. Given that it is still unknown whether or not one is more important than the other with regards to alpha neurofeedback training it seems prudent to include details of both amplitude and per cent time and to discuss them as separate measures in order to try and identify any potential patterns that would be 'hidden' if the information from each was combined together to form one single measure like integrated alpha. In addition, the inclusion of baseline information when analysing the data was shown to be important to any conclusions drawn. For instance, participants appeared to be enhancing their alpha within the sessions when they were meant to be suppressing it until baseline was incorporated as a factor, whereupon it became clear that it was more complicated than that with the rise in alpha seen nonetheless being continually maintained at a suppressed level in comparison to baseline. Further, when baseline was taken in to account the impressive enhancement seen from the first period in each segment was revealed to be due to an initial below baseline decrease at the start of each segment. Although it should be noted that the exclusion of the first periods from analyses did not change the overall results found. The obvious potential difference baseline information can make to any patterns seen in the data argues for their inclusion in future analysis, regardless of whether the data is analysed across sessions or within.

Finally, analyses of the within sessions comparison to baseline data produced differing results to when the across sessions comparison to baseline data. The within sessions comparison to baseline analyses showed that participants enhanced their alpha but the across sessions comparison to baseline data did not support this as strongly in the case of the amplitude and the integrated alpha measures, or at all in the case of the per cent time measure. The suppression data was more equivocal in its interpretation and therefore conclusions with regards to whether participants were successful at suppressing their alpha were arguably not able to be drawn regardless of which of the two ways of analysing data (within sessions in comparison to baseline or across sessions in comparison to baseline) was used.

Conclusion

On the basis of the analyses presented here, amplitude and per cent time will be the two measures used in all of the following experiments but they will be analysed as two separate measures rather than combined to form one. Participants' baseline levels of each will be included in all analyses in order to provide a comparison between what their alpha is doing when they are trying to exert a conscious control over it and what their alpha is doing when they are not. Finally, because the within sessions comparison to baseline and across sessions comparison to baseline data are both methods that are used in the literature and do not always agree on whether learning has occurred or not, and as there is as yet no definitive empirical answer as to which is a better way of defining success, both will be used in the remaining experiments as a way of determining participants' success, or not, at enhancing and/or suppressing their alpha.

Chapter 4: Experiment 2 - Eyes Open vs. Eyes Closed Training

Introduction

Now that a way of measuring alpha and a way of defining success has, for the purposes of this thesis, been established, the next step is to establish whether or not there is an optimum methodology for training alpha via neurofeedback. As can be seen from Chapter 1, there are many variations in the neurofeedback training methodology but one of the fundamental ways of delineating how neurofeedback training can be conducted is training with eyes open versus training with eyes closed and it makes more sense to address this question first before moving on to other issues relating to training (see Chapter 1, Figure 4).

As can be seen from Table 8 (see Chapter 1), although fairly evenly split there are more alpha neurofeedback studies utilising eyes open training (n = 45) than there are utilising eyes closed (n = 35). The distinction is important because there is evidence to suggest that having eyes open or closed may affect individuals' ability to exert a conscious influence on their alpha (e.g. Cram et al., 1977). Strayer et al. (1973) thus argue that the present use of both in the literature makes interpreting the difference in results between studies problematic. In fact, Ancoli and Kamiya (1978, 1979) advise that the results of training in one condition (i.e. eyes open/eyes closed) should not be compared to the results of training in the other. Danko (2006) agrees, stating that eyes open and eyes closed conditions are two functionally difference states and are therefore not suitable for comparison.

Despite this, Chisholm et al. (1977) conducted one 24 minute session of eyes open training, after which participants were shown to be able to enhance their alpha (8-13Hz) with their eyes closed both with and without feedback, suggesting that eyes open and eyes closed training may be linked. However, it is unclear from the paper whether participants actually enhanced their alpha over baseline and if they did not then the enhancement seen in both the eyes open and eyes closed conditions may simply have been a reflection of unconscious habituation, as discussed in the previous chapter, rather than of conscious learning.

Indeed, a study by Travis, Kondo and Knott (1974b) indicated that there is in fact no correlation between participants' ability to enhance their alpha with their eyes open and their ability to enhance their alpha with their eyes closed. They gave their participants one 50 minute session of eyes open alpha (8-13Hz) enhancement training and one 50 minute session of eyes closed alpha enhancement training and found that participants' ability to enhance their alpha during each session was not correlated.

Whether or not an individual's ability to train alpha with their eyes closed is related to their ability to train with their eyes open, a more important question is whether it is better to utilise one rather than the other. There is an assumption present in some of the alpha neurofeedback literature that eyes closed alpha neurofeedback training has a better chance of success than eyes open (e.g. Prewett & Adams, 1976). This is due to the amplitude of alpha automatically increasing when eyes are closed (Plotkin, 1976a). In point of fact one of the characteristics used to identify an alpha brain wave as such is the suppression in amplitude when going from an eyes closed to an eyes open state (Kaiser, 2002). This natural drop in alpha amplitude seen when eyes are open led to eyes open conditions being described as an alpha blocking/attenuating/suppressing state (e.g. Hardt & Kamiya, 1976a) which is presumably further reason why some may assume eyes closed training is more conducive to alpha enhancement at least.

On the other hand, it is for this alpha-inducing effect that some researchers suggest eyes open training is the most advantageous approach for alpha. For instance, Travis, Kondo and Knott (1974a) argue that eyes open training may leave 'more room for increase' (p171) than eyes closed due to the naturally lower starting point. This is similar to the discussion in Chapter 1 (section 3.3.) regarding why those with naturally higher levels of alpha may be better at suppressing their alpha and why those with naturally lower levels of alpha may be better at enhancing their alpha (see for example, Lynch & Paskewitz, 1971). Specifically, it relates to the discussion of 'the law of initial values' (Valle & DeGood, 1977, p5). If there is a limit on how high alpha can be enhanced, Vernon et al. (2009) explain, then the nearer participants are to that point when starting the harder they may find it to reach it. Although measures cannot go below zero (for instance it is not possible to suppress alpha below 0µv) and therefore there is obviously a minimum limit, there does not yet appear to be any research showing whether or not there is an upper limit although Chatrian et al. (1974) claim that it is 50 µv. If there is an upper limit then the increase in alpha seen with eyes closed and decreased amplitude seen with eyes open would make an argument for training to enhance alpha with eyes open and to suppress alpha with eyes closed.

Then again, given that eyes open conditions are naturally alpha suppressing (Hardt & Kamiya, 1976a) and eyes closed are therefore naturally alpha enhancing then it may be that the opposite is true. That is, eyes open conditions may be easier for suppression training due to the natural decrease seen when eyes are open anyway and eyes closed conditions may be easier for enhancement training due to the natural increase seen when eyes are closed. This counter-argument does, however, to some extent presuppose that training ability is a function of participants' natural alpha at the start of training. A more in-depth discussion of this topic can be found in Chapter 1 (section 3.11.1.) but, in brief, whilst there is some evidence for this in relation to participants' baselines specifically (e.g. Marcovska-Simoska et al., 2008, found that participants with higher baseline alpha levels on the measures they used were better at enhancing alpha), there is also evidence to the contrary (e.g. Strayer, Scott and Bakan, 1973, found that participants spent less time in alpha during their baselines were the ones who were better at enhancing their alpha during training) so the likelihood of this is currently unclear.

If Travis, Kondo and Knott (1974a, 1974b, 1974c) are right about eyes open conditions being better for learning to enhance alpha because it permits a greater amount of enhancement between initial abundance and the maximum potential abundance, it follows that the naturally higher baseline amplitude in eyes closed conditions would be more facilitative for learning to suppress alpha due to permitting a greater reduction in alpha between the initial starting point and zero. There does not, in actuality, appear to have been any comment made on this point in the literature with regards to suppression but either way Hare et al. (1982) argue that alpha neurofeedback training should be conducted with eyes open anyway because, they claim, it has higher ecological validity. Given that people do not walk around with their eyes closed then it is in eyes open situations when they are likely to want their alpha at optimum levels to improve their performance so they state that training should therefore be done with eyes open. Of course, this argument assumes that the need to exert a conscious influence on alpha for the purposes of optimal performance training is a skill which is required at the specific instance when performance needs to be optimised. For example, if someone was using alpha neurofeedback training in order to improve their mental rotation ability then Hare et al.'s argument (1982) assumes that in order to improve mental rotation ability the individual needs to alter their alpha whilst they are performing the mental rotation task. Alternatively, it may be more important for training to affect a person's natural levels of alpha (see Chapter 1, section 3.8.4. for a more in-depth discussion of the influence of neurofeedback training in the long-term). This latter idea is more in line with research on the relationship between alpha and cognition (e.g. Klimesch's [1999] discussion of better memory performers showing higher alpha power when at rest than those with worse memories) as can be seen from the discussion in Chapter 1, section 1.3.

Even if Hare et al.'s (1982) argument regarding ecological validity is not relevant, they also suggest that eyes closed conditions increase the chance of participants becoming drowsy and that eyes open training should be conducted as a way to avoid this. Plotkin (1976a) also posited that eyes open training is less likely to result in drowsiness and although it is rare for studies to justify why they chose eyes open over eyes closed training or vice versa, this has been used as a rationale. As an example, Paskewitz and Orne (1973) stated that the reason that they conducted eyes open training was in order to stop participants from falling asleep. Again, there does not appear to be empirical evidence examining the issue of drowsiness potential during neurofeedback training and those who comment on it (e.g. Plotkin, 1976a) do so in anecdotal way. However, aside from the obvious potential drowsiness could have for hindering learning, drowsiness itself causes a decrease in alpha (Canterbo, Atienza, & Salas, 2002). It is well known that a drowsy person shows greater theta in the EEG and less alpha. If eyes closed training does encourage a state of drowsiness, then for this reason alone it would seem like a good argument as to why it would be better to train with eyes open.

Indeed, eyes open training has been found by some to be the more successful method of the two. Research by Nowlis and Kamiya (1970) indicated that eyes open training was better for both alpha (8-13Hz) enhancement and alpha suppression. In their study they conducted a single neurofeedback session using 16 eyes closed participants and 10 eyes open. For both the enhancement and the suppression training, eyes open conditions were found to be more optimal for training. However, participants were only assigned to the eyes open group if they were judged as having particularly high eyes closed baselines therefore it is possible that the difference between the eyes open and eyes closed groups' performance was due to natural differences in their alpha rather than whether they trained with their eyes open or closed. It is also not clear what they meant by particularly high and particularly low baselines. Further, this use of only a single session may not necessarily give an accurate picture of how training would progress if more sessions were given (see, for example, Hardt & Kamiya, 1976b; Knox, 1980) (see section 3.6.3. for further discussion of this point).

Nonetheless, Cram et al. (1977) also found evidence to suggest that eyes open training may be better than eyes closed. They had 21 eyes open participants and 21 eyes closed undertake six 4 minute trials, with each trial alternating between alpha (8-12Hz) enhance and alpha suppress training. Eyes open training was found to be better for both enhance and suppress training but this result only held when per cent time was used as the dependent measure. When amplitude was looked at neither eyes open nor eyes closed training produced any significant evidence of learning and the authors were therefore cautious about drawing any conclusions in relation to the eyes open versus eyes closed debate.

As with the findings of Cram et al.'s (1977) aforementioned study, there is other evidence to suggest that rather than it being a simple case of eyes open versus eyes closed per se, it may be that there are other factors relating to the methodology which influence whether it is eyes open or eyes closed training which will be likely to produce more optimal training results. For instance, of their 56 participants (32 experimental and 24 control), Travis et al. (1974b) trained 16 participants using contingent feedback and 16 using continual feedback. Each participant completed two alpha (8-13Hz) enhance sessions recorded at position Oz, incorporating one 50 minute session with eyes open and one 50 minute session with eyes closed. The order of the sessions was counterbalanced so that half trained with their eyes open first and half with their eyes closed. Travis et al. (1974b) found that contingent feedback was better for eyes open training and continual feedback was better for eyes closed. Overall, however, participants were found to produce larger differences in integrated alpha during training eyes open training than during eyes closed. The authors attribute this to eyes open conditions producing smaller baselines and therefore a larger scope for increase than eyes closed conditions where participants had naturally larger baselines due to their eyes being closed.

Interestingly, individual participants' ability to enhance their alpha with their eyes open did not correlate with their ability to enhance their alpha with their eyes closed. Travis et al. (1974b) suggest that this may be because the two types of training utilise different mechanisms within the brain but, as mentioned earlier, Chisholm et al. (1977) disagree. Their participants showed that they were better able to control their alpha with their eyes closed than they had been before their training despite the fact that until that point the only training they had received had been undertaken with their eyes open. Given that this increase above pre-training baseline was still seen during without-feedback trials, however, during which time their alpha, although higher than before baseline, decreases across trials, it leaves open the possibility that the enhanced alpha may be due to a carryover effect from the training onto baseline levels (i.e. training temporarily increasing resting alpha levels is what is being demonstrated rather than a conscious increase of alpha). Eyes closed training was also carried out during trials where electric shocks were present and therefore making a clear conclusion about the relationship between eyes open and eyes closed training on the basis of this study is difficult.

Finally, it is not just variations in the methodology that have been posited to interact with the potential benefits of eyes open versus eyes closed training. Yamaguchi (1980) hypothesised that it may depend on a person's locus of control as to whether they are better at training with their eyes open or with their eyes closed. Similarly to Travis et al.'s (1974b) suggestion that eyes open training may utilise a different mechanism to eyes closed, Yamaguchi (1980) theorised that people with an internal locus of control would do better with eyes open training and people with an external locus of control would do better with their eyes closed due to their different approaches in trying to alter alpha (see also Chapter 1, section 3.11.2., for further discussion of how locus of control may influence the effectiveness of neurofeedback training). Specifically, he said that those with an internal locus of control took a more active approach and externals a more passive approach, thus suiting eyes open and eyes closed procedures respectively. Although no examples were offered as to what the difference would be between an 'active' and 'passive' approach, this, presumably, is the difference between people actively trying to elicit the feedback by attempting various strategies compared to those who wait for the feedback to occur and attempting to work out if there are any correlations in their mental activity (as an example) at those times.

According to Strayer, Scott, and Bakan (1973), until it can be established that there is indeed a difference between eyes open and eyes closed training, then interpretation of the literature is hindered because it is difficult to compare studies or confidently account for discrepancies in the literature.

In order to further our understanding of putative differences, a second experiment was designed to provide a direct comparison between eyes open and eyes closed alpha neurofeedback training in order to investigate whether there are any differences between the two in participants' ability to learn to exert a conscious control over their alpha. It will also address the issue of eye closure in relation to training direction by looking at whether there is a difference between alpha enhancement training and alpha suppression training with regards to which, if either, is found to be more facilitative for showing an improvement over time in participants' ability to exert a conscious control over their alpha waves.

Method

Participants

The specific details regarding the number and age of participants can be seen in Figure 27.

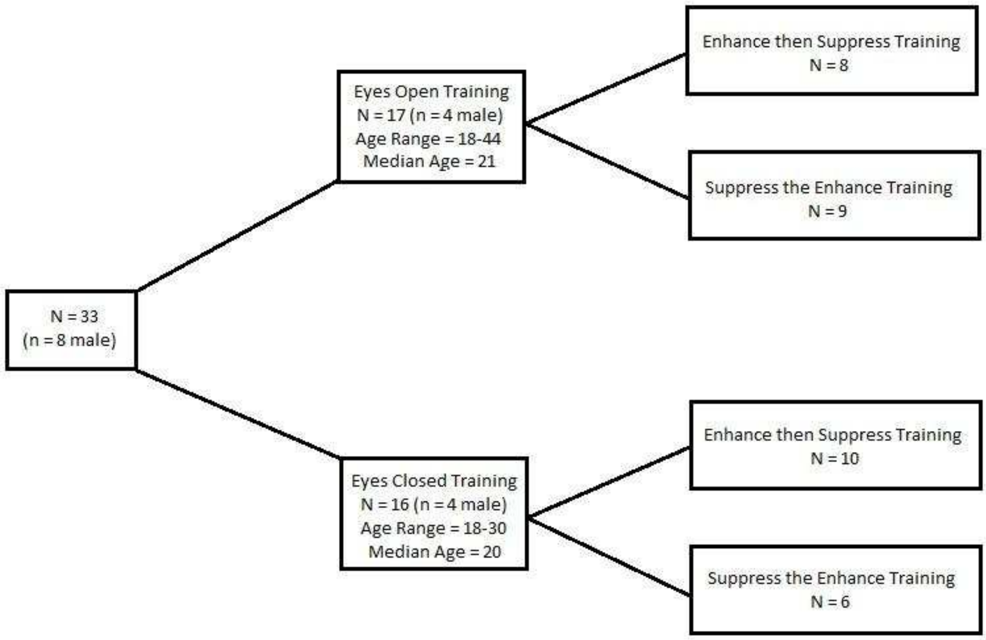

Figure 27. The number, gender, age, and training order (i.e. enhancement training first or suppression training first) of the participants in the eyes open and the eyes closed training groups.

Of the 33 participants, 15 of the 17 participants in the eyes open group completed all 10 sessions, 1 completed 6 sessions, and 1 completed 7 sessions. In the eyes closed group, 14 participants completed all 10 sessions, 1 completed 4, and 1 completed 9 sessions. The inclusion, or not, of the 4 participants who did not complete all 10 of the sessions was not found to have any impact on the results of the analyses, so their data was not removed.

As can be seen from Figure 27, there were an unequal number of participants who suppressed their alpha first during the course of each session to those who enhanced their alpha first. The order participants trained in was originally counterbalanced equally, but this could not be maintained following participant attrition.

With regards to recruitment, all the details are the same as in Chapter 2. As with the previous experiment (see Chapter 3), although the ideal would have been to have an equal number of males and females in the sample, the sample population was predominantly female and the number of male volunteers was far fewer.

Procedure

Because it is not possible to incorporate visual feedback in to eyes closed training, audio-only training was chosen as the feedback for the eyes open group in order to keep the training conditions as similar as possible to the eyes closed group's training conditions. Had audio-visual or visual feedback been utilised it would have been unclear if any differences in the results were due to the difference between having the eyes open or closed, the difference between the types of feedback (i.e. audio vs visual vs audio-visual), or a combination of both (this issue will be looked at in the next chapter).

All details regarding equipment, montage, scalp preparation, setting of thresholds, instructions to participants, and training schedule are the same as described in Chapter 2.

The stages of the training sessions themselves were the same as in the previous Chapter's experiment but a reminder is given in Figures 8 and 9 (see Chapter 2).

Results

It was established in the previous experiment that the analyses for the remaining experiments in this thesis would use amplitude and per cent time to measure alpha and that learning would be assessed by looking both at within sessions and across sessions changes. Further, any changes over time would be assessed in relation to the baselines which were taken for each participant at the start of each session.

Due to the normal pattern of amplitude increasing with eye closure (Plotkin, 1976a), an initial check was made to see if the same effect occurred in the data for this experiment. A paired samples *t* test revealed that it did, with participants producing significantly more alpha amplitude during their eyes closed baselines (M = 16.88, SD = 6.41) than they did during their eyes open baselines (M = 9.14, SD = 4.09), $t(32) = 10.34$, $p < .001$, as can be seen from Figure 28. This was also the case even if the eyes open and eyes closed participants' baseline data was examined separately (in both cases $p < .001$). Given this naturally occurring difference in alpha amplitude between eyes open and eyes closed conditions, it seemed prudent to follow Ancoli and Kamiya's (1978, 1979) advice about not comparing eyes open training to eyes closed baselines and eyes closed baselines to eyes open training. For the following experiment, then, the eyes open group's performance during training was compared to their eyes open baselines and the performance of the eyes closed group during training was compared to their eyes closed baselines for both measures.

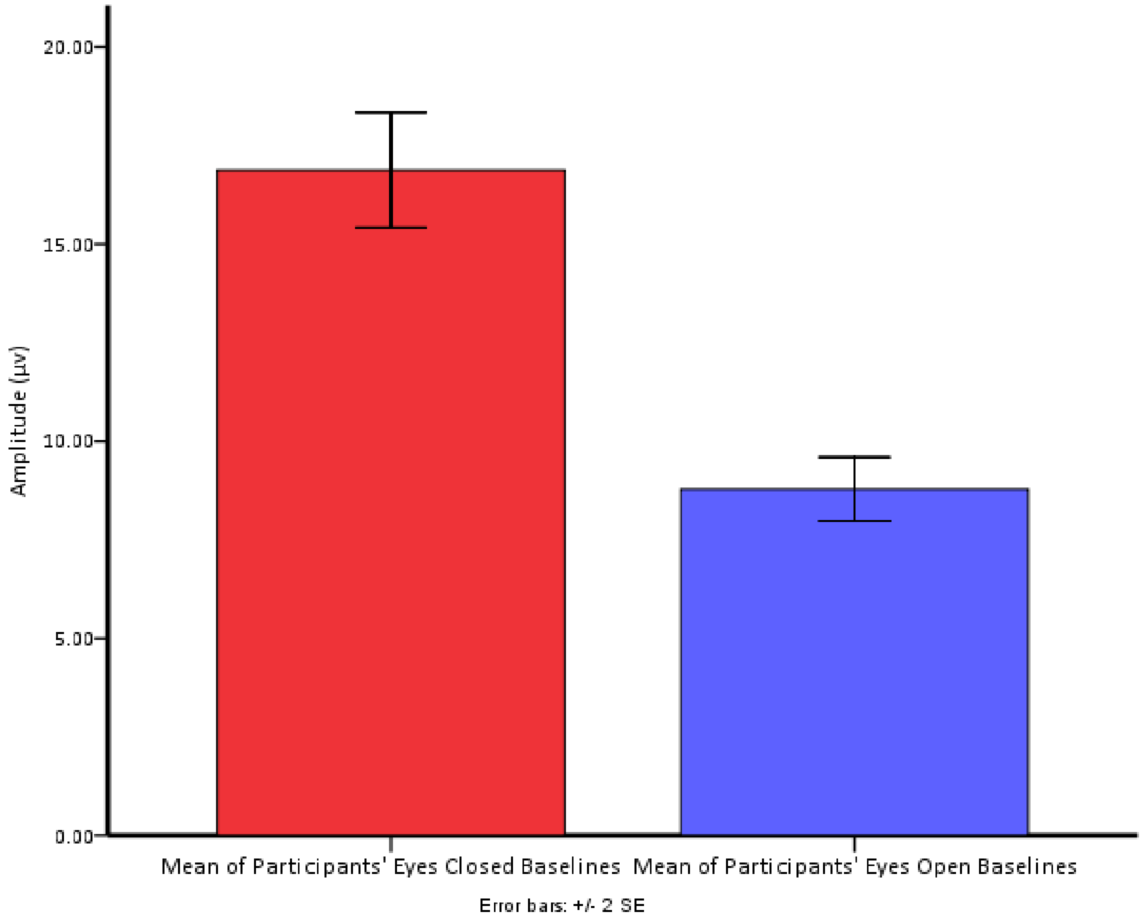

Figure 28. The mean amplitude participants' produced during their eyes closed compared to their eyes open baselines.

Before analyses commenced, checks on the normality of distribution were performed. Regardless of the measure used, the eyes closed participants' data was found to be normally distributed for both their enhancement and their suppression training. The eyes open participants, on the other hand, only showed a normal distribution of data for their enhancement training and only when per cent time was used as the measure. The eyes open participants' data was therefore log transformed when amplitude was used as the measure for analysis.

In addition, the eyes open participants' data was log transformed for the per cent time measure when their performance during suppression training was being analysed (see Table 36, below).[5] It should be noted that where the analyses were performed on log transformed data, all means reported with the analyses are referring to the log transformed means used in the analyses. All tables and figures, however, report the original (i.e. non log-transformed) data in order to give the reader an idea of the true amplitudes and percentage of time spent over/under threshold during training and therefore a more meaningful idea of how the participants performed during the training sessions themselves.

Table 36

Results of normality of distribution checks performed on the data. In all instances where data was found to be non-normally distributed (highlighted in yellow in the table) the data was log transformed before analyses were carried out.

	Measure Used	
	Amplitude	**Per Cent Time**
Eyes Open Participants		
Enhancement Training	Non-normally distributed	Normally distributed
Suppression Training	Non-normally distributed	Non-normally distributed
Eyes Closed Participants		
Enhancement Training	Normally distributed	Normally distributed
Suppression Training	Normally distributed	Normally distributed

[5] As it happens, whether or not the data was log transformed did not change the overall conclusions which would have been drawn from the analyses had the original data been used.

For all analyses a Greenhouse Geisser correction was used if Mauchley's Test of Sphericity was found to be significant and Cohen's *d* was used to calculate the effect sizes of any a priori pairwise comparisons (with Bonferroni corrections) found to be significant.

1. Enhancement Training

During enhancement training the aim is for participants to learn to increase the amount of alpha they produce. If they have been successful, then one would expect to see an increase over time, regardless of type of measure (i.e. amplitude or per cent time) or analysis (i.e. within sessions in comparison to baseline or across sessions in comparison to baseline).

1.1. Within Sessions Compared to Baseline

The data for the within sessions comparison to baseline calculations were calculated the same way as in Chapter 2. However, because of the natural increase in alpha amplitude when eyes are closed mentioned above (see Figure 28) the eyes open participants' data for the within sessions comparison to baseline calculations were therefore obtained by subtracting each of their within sessions periods from their overall eyes open baseline. The data used for the eyes closed participants' within sessions comparison to baseline calculations were obtained by subtracting each of their within sessions periods from their overall eyes closed baseline in order to provide the comparison to baseline scores (see Tables 47 and 48).

Whilst it is possible to compare the eyes open versus eyes closed groups' within sessions data directly using a 2 (Group: eyes open vs. eyes closed) x 2 (Baseline: eyes open vs. eyes closed) x 2 (Segment: seg1 vs. seg2) x 5 (period: 1-5) mixed ANOVA with *Group* as the between participants factor and *Baseline, Segment* and *Period* as the within participants factors, the natural differences between eyes open and eyes closed conditions discussed above (and as illustrated in Figure 28, above) necessitating the use of the eyes open baseline as a comparison for the eyes open group and the eyes closed baseline as a comparison for the eyes closed group (see discussion on page 230) means that this would make the results difficult to interpret. Further, the incorporation of 30 levels (2 x 2 x 2 x 5 = 30) into the ANOVA was considered to be unnecessarily elaborate given that 10 of the levels were inappropriate for the eyes open group (i.e. the 10 levels relating to comparing the eyes closed baseline to training) and 10 of the levels were inappropriate for the eyes closed group (i.e. the 10 levels relating to comparing the eyes open baseline to training). Results of the analysis did show a main effect of *Group* ($p < .001$), as well as a main effect of *Baseline* ($p < .001$), a *Period* by *Group* interaction effect ($p < .001$), and a *Segment* by *Period* by *Group* interaction effect ($p = .009$) for the amplitude data (see Appendix K). It also showed a main effect of *Group* ($p < .001$), a main effect of *Baseline* ($p < .001$), and a *Period* by *Group* interaction effect ($p < .001$) for the per cent time data (see Appendix K). However these would all be expected even without training given the natural differences which occur between eyes open and eyes closed conditions and make it difficult to untangle the natural differences from the effects of training. So whilst there is a significant difference between the eyes open and eyes closed training groups, given the complications involved in directly comparing eyes open to eyes closed conditions it was decided that the two groups' data should examined separately to see whether they both show different patterns of learning via neurofeedback and therefore whether there's any indication that the significant differences between the eyes open and eyes closed groups are suggestive of anything other than natural differences in amplitude due to the effect of simply closing their eyes.

The within sessions compared to baseline analyses were therefore calculated separately for each group using a 2 (Segment: *Segment 1* vs. *Segment 2*) x 5 (Period: *Period 1 – Period 5*) repeated measures analysis of variance (ANOVA) rather than analysing them together with *Group* (eyes open vs. eyes closed) and *Baseline* (eyes open vs. eyes closed) as factors.

1.1.1. Amplitude

The mean amplitude during each training period and during baseline for the eyes closed and the eyes open participants can be seen in Figure 29.

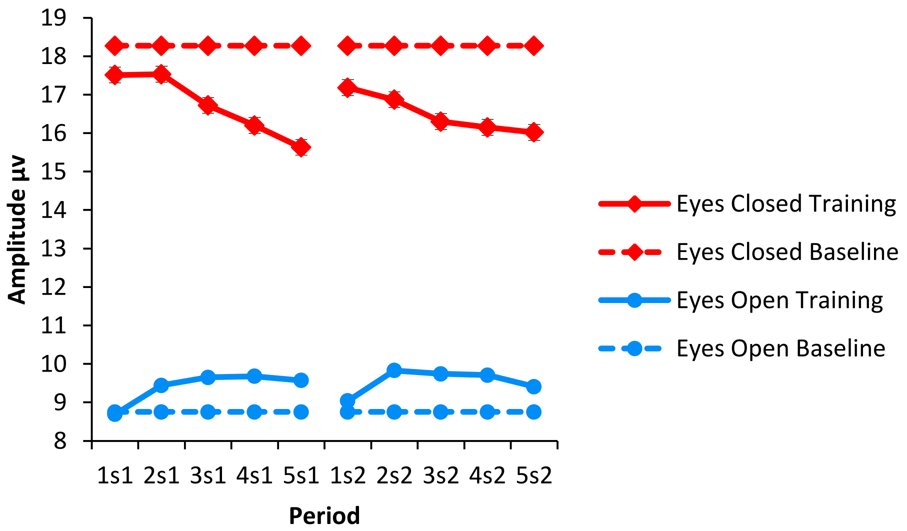

Figure 29. Mean amplitude (with standard error bars) for each period during baseline and during enhancement training for the eyes open and the eyes closed participants (where error bars cannot be seen this is due to them being large enough to be visible on the graph)

Table 37

Within sessions comparison to baseline means and standard deviations (SD) for the eyes open and eyes closed participants during their enhancement training for the amplitude measure. Any negative scores indicate where participants' mean training amplitude was less than their mean baseline amplitude.

Period	Eyes Open Mean	Eyes Open SD	Eyes Closed Mean	Eyes Closed SD
1_{s1}	-0.05	1.3	-0.76	2.16
2_{s1}	0.69	1.44	-0.74	2.36
3_{s1}	0.90	1.67	-1.55	2.75
4_{s1}	0.94	1.69	-2.07	2.89
5_{s1}	0.83	2.03	-2.64	2.71
1_{s2}	0.30	1.78	-1.09	2.10
2_{s2}	1.08	1.92	-1.40	2.68
3_{s2}	0.99	1.68	-1.97	2.82
4_{s2}	0.96	1.84	-2.11	2.86
5_{s2}	0.66	1.56	-2.24	2.88

1.1.1.1. Eyes Open Participants

There was no main effect of *Segment,* $F(1, 16) = 1.04$, $p = .322$, $MS_E = .02$, partial $\mu^2 = .06$. There was a main effect of *Period,* $F(1.64, 26.20) = 8.11$, $p = .003$, $MS_E = .05$, partial $\mu^2 = .34$. There was no *Segment* by *Period* interaction effect $F(2.31, 36.97) = .56$, $p = .603$, $MS_E = .01$, partial $\mu^2 = .03$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. These revealed that participants showed a smaller difference between baseline and training in *period* $1_{s1, s2}$ than they did in *periods* $2_{s1, s2}$ (p = .041, d = .50), $3_{s1, s2}$ (p = .047, d = .59), and $5_{s1, s2\, s2}$ (p = .049, d = .43) and a marginally smaller difference between baseline and training in *period* 1 than they did in *period* 4 (p = .055, d = .39). No other differences were found to be significant.

1.1.1.2. Eyes Closed Participants

There was no main effect of *Segment,* $F(1, 13)$ = .335, p = .572, MS_E = 4.70, partial μ^2 = .025. There was a main effect of *Period,* $F(1.68, 21.80)$ = 8.50, p = .003, MS_E = 3.33, partial μ^2 = .395. There was a marginal *Segment* by P*eriod* interaction F(2.10, 27.32) = 2.92, p = .069, MS_E = .738, partial μ^2 = .183.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. These revealed that participants produced a significantly smaller difference between baseline and training in *period* $1_{s1, s2}$ compared to *period* $5_{s1, s2}$ (p = .052, d = .64), a significantly smaller difference between baseline and training in *period* $2_{s1, s2}$ compared to *periods* $3_{s1, s2}$ (p = .022, d = .27), $4_{s1, s2}$ (p = .003, d = .40), and $5_{s1, s2}$ (p < .001, d = .54), and a significantly smaller difference between baseline and training in *period* $3_{s1, s2}$ compared to *period* $5_{s1, s2}$ (p = .038, d =.25). It is worth noting, however, that a look at Figure 29 reveals that the eyes closed participants' amplitude is actually moving in the opposite direction to what would be hoped for during enhancement training.

In order to investigate the S*egment* by *Period* interaction effect a one way repeated measures ANOVA, split by *Segment,* was performed on the *Period* data. This revealed that in *Segment 1* participants showed a main effect of *Period*, $F(1.95, 29.31)$ = 12.39, p < .001, MS_E = .3.32, partial μ^2 = .45. In order to investigate this, pairwise comparisons with Bonferroni corrections were performed. They revealed that participants produced a smaller difference between baseline and training in *period 1*$_{s1, s2}$ than they did in *period 5* $_{s1, s2}$ (*p* = .009, *d* = .91), a smaller difference between baseline and training in *period 2* $_{s1, s2}$ than they did in *periods 3* $_{s1, s2}$ (*p* = .029, *d* = .45), *4* $_{s1, s2}$ (*p* = .016, *d* = .70), and *5* $_{s1, s2}$ (*p* = .003, *d* = .96), and a smaller difference between baseline and training in *period 3* $_{s1, s2}$ than they did in *period 5* $_{s1, s2}$ (*p* = .003, *d* = .50). No other differences were found to be significant. It is also worth noting that a look at Figure 29 reveals that all of these effects are actually in the opposite direction to what would be hoped to be seen during enhancement training.

In *Segment 2* participants showed a main effect of *Period*, *F*(1.71, 25.71) = 6.94, *p* = .005, MS_E = .3.76, partial μ^2 = .32. In order to investigate this, pairwise comparisons with Bonferroni corrections were performed. However, no differences were found to be significant.

1.1.2. Per Cent Time

The mean differences in the percentage of time spent over threshold during each period during training and during baseline for the eyes closed and the eyes open participants can be seen in Figure 30.

1.1.2.1. Eyes Open Participants

There was no main effect of *Segment, F*(1, 14) = 1.57, *p* = .231, MS_E = 27.72, partial μ^2 = .101. There was a main effect of *Period, F*(2.20, 30.86) = 10.13, *p* < .001, MS_E = 23.24, partial μ^2 = .420. There was no S*egment* by P*eriod* interaction *F*(4, 56) = 1.80, *p* = .142, MS_E = 6.16, partial μ^2 = .114.

Pairwise comparisons with Bonferroni corrections were carried out in order to investigate the main effect of *Period.* These found that participants produced a significantly smaller difference between baseline and training in *period 1* $_{s1, s2}$ compared to *periods* 2 $_{s1, s2}$ (*p* = .004, *d* = .58), *3* $_{s1, s2}$ (*p* = .011, *d* = .62), *4* $_{s1, s2}$ (*p* = .013, *d* = .64), and *5* $_{s1, s2}$ (*p* = .039, *d* = .50). No other differences were found to be significant.

Table 38

Within sessions comparison to baseline means and standard deviations (SD) for the eyes open and eyes closed participants during their enhancement training for the per cent time measure. Any negative scores indicate where participants spent less time over threshold during training than they did during baseline

Period	Eyes Open Mean	Eyes Open SD	Eyes Closed Mean	Eyes Closed SD
1	-0.10	7.47	-3.49	9.44
2	4.49	7.85	-3.01	10.78
3	5.85	8.53	-6.72	12.40
4	6.07	7.79	-9.58	12.93
5	4.70	8.46	-12.18	11.73
6	2.27	8.88	-5.47	10.73
7	6.86	9.01	-5.85	12.78
8	5.95	7.72	-8.65	12.50
9	5.95	8.01	-9.49	12.36
10	5.36	8.07	-10.00	12.76

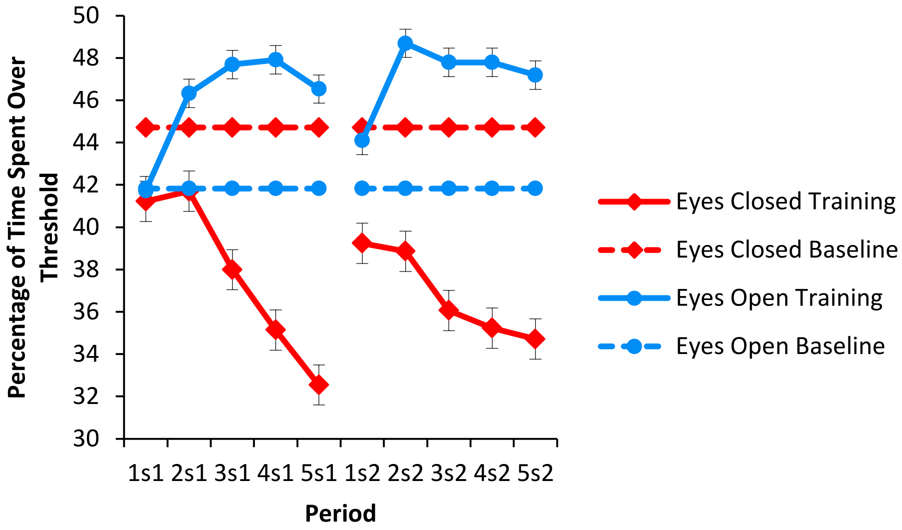

Figure 30. Mean percentage of time spent over threshold (with standard error bars) for each period during baseline and during enhancement training for the eyes open and the eyes closed participants

1.1.2.2. Eyes Closed Participants

There was no main effect of *Segment,* $F(1, 13) = .356$, $p = .561$, $MS_E =$ 78.59, partial $\mu^2 = .027$. There was a main effect of *Period,* $F(2.02, 26.25) = 11.07$, $p < .001$, $MS_E = 44.51$, partial $\mu^2 = .460$. There was a marginal *Segment* by *Period* interaction F(2.10, 27.24) = 3.31, $p = .050$, $MS_E = 16.58$, partial $\mu^2 = .203$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. These showed that participants produced a significantly smaller difference between baseline and training in *period* $1_{s1, s2}$ than in *periods* $4_{s1, s2}$ ($p = .047$, $d = .30$) and $5_{s1, s2}$ ($p = .026$, $d = .62$). They also produced a significantly smaller difference between training and baseline in *period* $2_{s1, s2}$ than in *periods* $3_{s1, s2}$ ($p = .004$, $d = .28$), $4_{s1, s2}$ ($p = .001$, $d =$ .44), and $5_{s1, s2}$ ($p < .001$, $d = .57$) and a significantly smaller difference between baseline and training in *period* $3_{s1, s2}$ than in *period* $5_{s1, s2}$ ($p = .045$, $d = .28$). No other differences were found to be significant. It should also be noted that, as can be seen from Figure 30, the direction of these differences are in the opposite direction as what would be hoped for during enhancement training.

In order to investigate the marginal *Segment* by P*eriod* interaction a one way repeated measures ANOVA was run on the period data, split by *Segment*. This revealed that in *segment 1* there was a main effect of *Period,* $F(1.97, 25.57) = 12.87$, $p < .001$, $MS_E = 34.14$, partial $\mu^2 = .498$. Pairwise comparisons with Bonferroni corrections performed to investigate this revealed that participants showed a significantly smaller difference between training and baseline in *period* $1_{s1, s2}$ compared to *period* $5_{s1, s2}$ ($p = .007$, $d = .82$), a significantly smaller difference between baseline and training in *period* $2_{s1, s2}$ than in *periods* $3_{s1, s2}$ ($p = .016$, $d = .32$), $4_{s1, s2}$ ($p = 003$, $d = .55$), and $5_{s1, s2}$ ($p < .001$, $d = .81$), and significantly smaller difference between baseline and training in *period* $3_{s1, s2}$ than in *period* $5_{s1, s2}$ ($p = .001$, $d = .45$). No other differences were found to be significant. Again, the direction of these differences is in the opposite direction to be taken as indicative of enhancement training.

In *segment 2* there was also a main effect of *Period,* $F(4, 52) = 4.28$, $p = .005$, $MS_E = 14.37$, partial $\mu^2 = .248$ although pairwise comparisons with Bonferroni's corrections found no significant effects.

1.2. Across Sessions Comparison to Baseline

Although a 2 (*Group*: eyes open vs. eyes closed) x 3 (*Stage*: eyes open baseline vs. eyes closed baseline vs. training) x 10 (*Session*: 1-10) mixed ANOVA with *Group* as the between participants factor and *Stage* and *Session* as the within participants factors revealed a significant main effect of *Group* ($p = .039$), a significant main effect of *Stage* ($p < .001$), and a significant *Stage* by *Session* interaction effect ($p < .001$) for the amplitude data and a significant main effect of *Group* ($p < .001$), a significant main effect of *Stage* ($p < .001$), a significant *Stage* by *Group* interaction effect ($p < .001$), and a significant *Stage* by *Session* interaction effect ($p = .030$) (see Appendix K) this could simply be due to the natural differences in amplitude seen between eyes open and eyes closed conditions rather than as a result of the training itself (see discussion in section 1.1. above). As with the within sessions comparison to baseline analyses, then, the across sessions comparison to baseline analyses were also split by *Group* due to the eyes open group's training needing to be compared to eyes open baselines and the eyes closed group's training needing to be compared to eyes closed baselines. The across sessions comparison to baseline data was therefore performed using a 2 (*Stage*: baseline vs. training) x 10 (*Session*: 1-10) repeated measures ANOVA on first the eyes open and then the eyes closed data separately.

1.2.1. Amplitude

The mean amplitudes obtained in each session and during each baseline for the eyes open and the eyes closed participants can be seen in Figure 31, below.

1.2.1.1. Eyes Open Participants

The means and SDs of the eyes open participants' amplitudes during each individual session's baseline and training can be seen in Table 39.

There was a main effect of *Stage,* $F(1, 14) = 5.15$, $p = .040$, $MS_E = .07$, partial $\mu^2 = .27$ due to participants producing a lower amplitude during baseline ($M = 2.06$, $SE = .11$) than they did during training ($M = 2.13$, $SE = .13$). There was a main effect of *Session,* $F(9, 126) = 4.96$, $p < .001$, $MS_E = .02$, partial $\mu^2 = .226$. There was no *Stage* by *Session* interaction $F(9, 126) = .994$, $p = .449$, $MS_E = .01$, partial $\mu^2 = .07$.

In order to investigate the main effect of *Session,* pairwise comparisons with Bonferroni corrections were performed. These revealed that participants produced a significantly lower amplitude in *session* 1 than in *session* 9 ($p = .030$, $d = .29$) and a marginally lower amplitude in *session 1* than in *session 5* ($p = .066.$, $d = .40$). No other differences are found to be significant.

Table 39

Mean amplitude and standard deviation (SD) for each session of the eyes open group's enhancement training and baselines

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	7.19	2.72	8.43	3.68
2	7.96	3.70	8.93	4.68
3	9.11	4.93	9.52	4.65
4	8.50	4.25	9.49	5.01
5	8.64	4.12	9.56	4.73
6	9.65	5.23	10.15	5.29
7	8.95	4.51	9.44	4.74
8	9.15	4.86	9.60	4.91
9	9.38	4.27	9.93	5.09
10	8.92	4.12	9.55	4.75

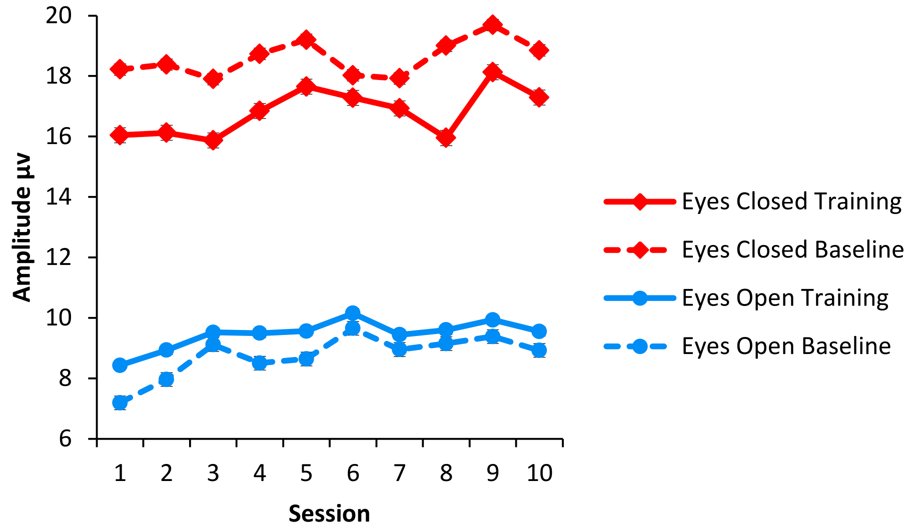

Figure 31. Mean amplitude (with standard error bars) during each session during baseline and during enhancement training for the eyes open and the eyes closed participants (where error bars cannot be seen this is due to them being large enough to be visible on the graph)

1.2.1.2. Eyes Closed Participants

The means and SDs of the eyes closed participants' amplitudes during each individual session's baseline and training can be seen in Table 40.

There was a main effect of *Stage,* $F(1, 12) = 6.83$, $p = .023$, $MS_E = 30.16$, partial $\mu^2 = .363$ due to participants producing a larger amplitude during their baseline ($M = 18.59$, $SE = 1.62$) than during their training ($M = 16.81$, $SE = 1.72$). There was no main effect of *Session,* $F(9, 108) = 1.46$, $p = .174$, $MS_E = 6.85$, partial $\mu^2 = .108$. There was no *Stage* by *Session* interaction F(9, 108) = 1.28, $p = .258$, $MS_E = 2.23$, partial $\mu^2 = .096$.

Table 40

Mean amplitude and standard deviation (SD) for each session of the eyes closed group's enhancement training and baselines

Session	Mean Baseline	Baseline SD	Training Mean	Training SD
1	18.22	6.94	16.04	5.82
2	18.38	6.23	16.12	6.60
3	17.90	5.93	15.87	6.10
4	18.73	6.10	16.84	6.25
5	19.20	7.23	17.65	7.58
6	18.02	6.21	17.28	6.08
7	17.92	5.18	16.93	6.10
8	19.00	5.55	15.95	5.77
9	19.69	5.72	18.13	6.98
10	18.85	6.53	17.29	7.40

1.2.2. Per Cent Time

The mean percentage of time participants spend over threshold during each training session and during each session's baseline for the eyes open and the eyes closed participants can be seen in Figure 32 below.

1.2.2.1. Eyes Open Participants

The means and SDs of the amount of time the eyes open participants spent over threshold during each session during their training and during their baselines can be seen in Table 41.

Table 41

Means and standard deviations (SD) for the percentage of time participants spent over threshold in each session of the eyes open group's enhancement training and baselines

Session	Mean Baseline	Baseline SD	Training Mean	Training SD
1	40.41	2.61	50.74	9.05
2	41.58	2.61	45.84	8.20
3	42.34	2.72	44.63	9.74
4	42.59	3.81	45.78	8.14
5	41.99	2.11	45.06	10.52
6	42.39	1.94	44.84	7.68
7	41.07	3.95	43.63	7.80
8	42.79	3.34	44.83	6.41
9	42.37	3.32	43.59	11.4
10	41.71	2.32	45.31	6.40

There was a main effect of *Stage,* $F(1, 13) = 4.70$, $p = .049$, $MS_E = 182.49$, partial $\mu^2 = .265$ due to participants spending more time over threshold during training ($M = 45.42$, $SE = 1.37$) than during baseline ($M = 14.93$, $SE = .48$. There was no main effect of *Session,* $F(9, 117) = .647$, $p = .754$, $MS_E = 29.89$, partial $\mu^2 = .047$. There was no S*tage* by S*ession* interaction F(9, 117) = 1.49, $p = .160$, $MS_E = 30.51$, partial $\mu^2 = .103$.

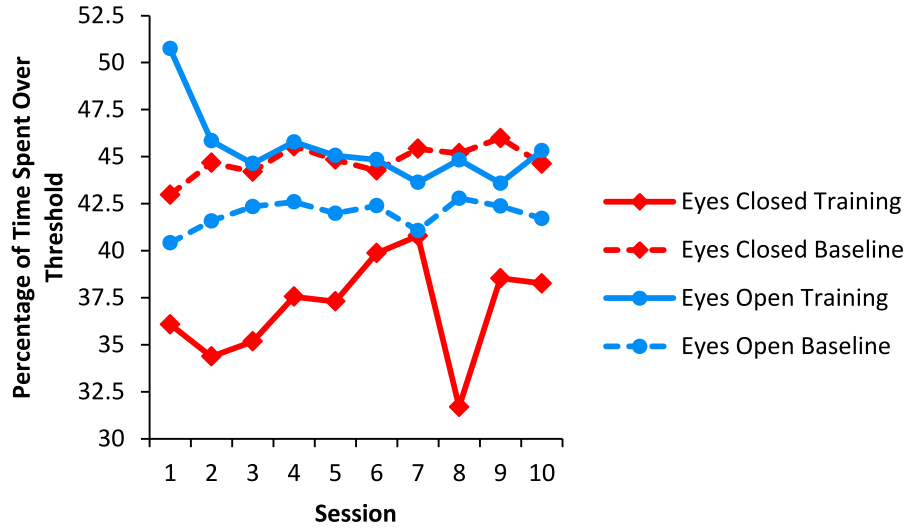

Figure 32. Mean percentage of time spent over threshold (with standard error bars) during each session during baseline and during enhancement training for the eyes open and the eyes closed participants (where error bars cannot be seen this is due to them being large enough to be visible on the graph)

1.2.2.2. Eyes Closed Participants

The means and SDs of the amount of time the eyes closed participants spent over threshold during each session during their training and during their baselines can be seen in Table 42.

There was a main effect of *Stage,* $F(1, 12) = 6.19$, $p = .029$, $MS_E = 640.35$, partial $\mu^2 = .340$ due to participants spending more time over threshold during baseline ($M = 44.77$, $SE = .49$) than during training ($M = 36.96$, $SE = 3.23$) which is in the opposite direction which one would expect for successful enhancement training. There was no main effect of *Session,* $F(9, 108) = 1.78$, $p = .081$, $MS_E = 32.77$, partial $\mu^2 = .129$. There was no *Stage* by *Session* interaction F(9, 108) = 1.38, $p = .207$, $MS_E = 34.00$, partial $\mu^2 = .103$.

Table 42

Means and standard deviations (SD) for the percentage of time participants spent over threshold in each session of the eyes closed group's enhancement training and baselines

Session	Mean Baseline	Baseline SD	Training Mean	Training SD
1	42.97	6.89	36.08	13.63
2	44.67	2.14	34.37	14.78
3	44.20	2.94	35.17	12.47
4	45.54	2.34	37.55	15.15
5	44.84	2.60	37.30	11.20
6	44.26	2.38	39.87	11.70
7	45.42	2.09	40.79	14.09
8	45.18	2.74	31.69	12.25
9	45.99	1.77	38.53	14.88
10	44.62	2.86	38.26	16.37

1.3. Enhancement Training Summary

A summary of the findings can be seen in Tables 43 and 44.

The eyes open participants showed a main effect of *Period* for both the amplitude and the per cent time measures due to participants showing a larger difference between baseline and training in *periods* $1_{s1, s2}$, $2_{s1, s2}$, $3_{s1, s2}$, $4_{s1, s2}$, and $5_{s1, s2}$ than they did in *period* $1_{s1, s2}$ for the per cent time measure and in *periods* $2_{s1, s2}$, $3_{s1, s2}$, and $5_{s1, s2}$ than they did in *period* $1_{s1, s2}$ for the amplitude measure. Both measures also showed a main effect of *Stage* across sessions due to participants producing more alpha during their training than they did during their baseline. Only the amplitude measure showed a main effect of *Session*, however, due to participants producing more alpha in *session* 9 than *session* 1.

The eyes closed participants also showed a main effect of *Period* for both the amplitude and the per cent time measures. However, both measures showed the opposite pattern to that which would be hoped for during enhancement training. This pattern of suppression, as opposed to the enhancement that would have been hoped for, was also apparent for both measures across sessions with each showing a main effect of *Stage* due to participants producing more alpha during baseline than they did during training.

Table 43

Summary of the findings for the enhancement training using the amplitude measure. Where an effect was found to be significant any significant pairwise comparisons (with Bonferroni corrections) which were found have been reported. All effects which are in the opposite direction to be indicative of enhancement training are highlighted in yellow.

	Amplitude	
	Eyes Open	**Eyes Closed**
Within Sessions Comparison to Baseline		
Segment	No	No
Period	Yes	Yes
	1 < 2, 3, 5	1 < 5
		2 < 3, 4, 5
		3 < 5
Segment by Period	No	Marginal
		Segment 1
		1 < 5
		2 < 3, 4, 5
		3 < 5
		Segment 2
Across Sessions Comparison to Baseline		
Stage	Yes	Yes
	Baseline < Training	Baseline > Training
Session	Yes	No
	1 < 9	
Stage by Session	No	No

Table 44

Summary of the findings for the enhancement training using the per cent time measure. Where an effect was found to be significant any significant pairwise comparisons (with Bonferroni corrections) which were found have been reported. All effects which are in the opposite direction to be indicative of enhancement training are highlighted in yellow.

	Per Cent Time	
	Eyes Open	**Eyes Closed**
Within Sessions Comparison to Baseline		
Segment	No	No
Period	Yes	Yes
	1 < 2, 3, 4, 5	1 < 4, 5
		2 < 3, 4, 5
		3 < 5
Segment by Period	No	Marginal
		Segment 1
		1 < 5
		2 < 3, 4, 5
		3 < 5
		Segment 2
Across Sessions Comparison to Baseline		
Stage	Yes	Yes
	Baseline < Training	Baseline > Training
Session	No	No
Stage by Session	No	No

2. Suppression Training

The aim of alpha suppression neurofeedback training is for the participants to learn to consciously decrease the amount of alpha they produce and to increase the time they can do so for. For the amplitude measure, then, suppression is indicated by a decrease over time. For the per cent time measure, however, the aim is still, as with enhancement training, to see an increase over time, although with suppression training this is an increase in the amount of time participants spent under threshold rather than over.

All the same calculations and analyses performed on the enhancement data, above, were performed in the same way here for the suppression data in order to maintain consistency and for the same reasons discussed in the enhancement analyses sections, above. For the results of the overarching omnibus ANOVAS providing direct comparisons between the eyes open and the eyes closed conditions for the suppression training, however, see Appendix K.

2.1. Within Sessions Comparison to Baseline

As with the enhancement data, because baseline was a constant with no variability (see Figures 33-34) it therefore could not be added to the analysis as a separate factor and so for the within sessions in comparison to baseline analyses each within sessions period was therefore subtracted from the corresponding baseline (i.e. eyes open baseline in the case of the eyes open training group, eyes closed baseline in the case of the eyes closed training group) in order to provide a comparison to baseline score (see Tables 45 and 46). Once more, changes within sessions in comparison to baseline were then examined using a 2 (Segment: *Segment 1* vs *Segment 2*) x 5 (Period: *Period 1 – Period 5*) repeated measures analysis of variance (ANOVA) on each of the two measures. And this was, again, done separately for the eyes closed and the eyes open participants for the same reasons discussed in section 1.1., above.

2.1.1. Amplitude

The mean amplitude during each period during training and during baseline for the eyes closed and the eyes open participants can be seen in Figure 33.

Table 45

Within sessions comparison to baseline means and standard deviations (SD) for the eyes open and eyes closed participants during their suppression training for the amplitude measure

Period	Eyes Open Mean	Eyes Open SD	Eyes Closed Mean	Eyes Closed SD
1	1.07	1.44	2.17	2.92
2	0.73	1.14	2.37	2.94
3	0.69	1.24	3.04	2.84
4	0.73	1.21	3.60	3.02
5	0.64	1.13	3.75	3.31
6	1.26	1.72	2.93	3.01
7	0.72	1.09	2.61	3.12
8	0.66	1.13	3.24	3.20
9	0.69	1.24	4.00	3.29
10	0.74	1.23	4.07	3.47

2.1.1.1. Eyes Open Participants

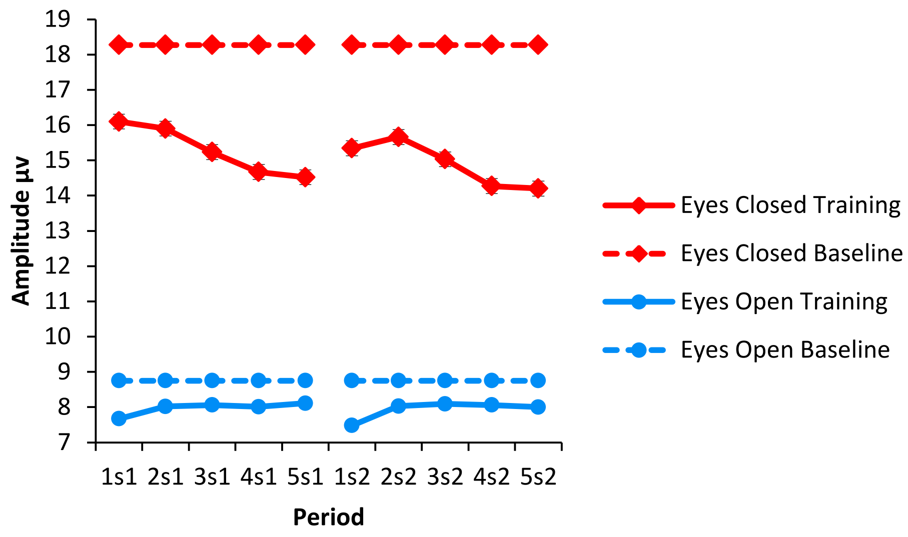

Figure 33. Mean amplitude (with standard error bars) for each period during baseline and during suppression training for the eyes open and the eyes closed participants (where error bars cannot be seen this is due to them being large enough to be visible on the graph)

There was no main effect of *Segment,* $F(1, 16) = .02$, $p = .884$, $MS_E = .01$, partial $\mu^2 = .00$. There was a main effect of *Period,* $F(2.26, 36.12) = 12.20$, $p < .001$, $MS_E = .01$, partial $\mu^2 = .43$. There was no *Segment* by P*eriod* interaction effect $F(4, 64) = 1.25$, $p = .300$, $MS_E = .00$, partial $\mu^2 = .07$.

In order to investigate the main effect of *Period*, pairwise comparisons with Bonferroni corrections were performed. These showed that there was a larger difference in amplitude between baseline and training in *period* $1_{s1, s2}$ than in *periods* $2_{s1, s2}$ ($p = .033$, $d = .23$), $3_{s1, s2}$ ($p = .001$, $d = .36$), $4_{s1, s2}$ ($p = .006$, $d = .33$), and $5_{s1, s2}$ ($p = .002$, $d = .37$). However, a look at Figure 33 shows that these changes over time, although nonetheless below baseline, were not in the right direction to be taken as indicative of suppression. No other differences were found to be significant.

2.1.1.2. Eyes Closed Participants

There was no main effect of *Segment,* $F(1, 13) = 2.69$, $p = .125$, $MS_E = 1.92$, partial $\mu^2 = .172$. There was a main effect of *Period,* $F(1.22, 15.88) = 5.55$, $p = .026$, $MS_E = 7.44$, partial $\mu^2 = .299$. There was no *Segment* by P*eriod* interaction $F(2.38, 30.95) = 1.06$, $p = .368$, $MS_E = .553$, partial $\mu^2 = .075$.

In order to investigate the main effect of *Period,* pairwise comparisons with Bonferroni corrections were performed. These revealed that there was a marginally smaller difference between baseline and training in *period* $3_{s1, s2}$ than in period $4_{s1, s2}$ ($p = .052$, $d = .22$). No other differences were found to be significant.

2.1.2. Per Cent Time

The difference in the mean percentage of time spent under threshold during each period during training and during baseline for the eyes open and the eyes closed participants can be seen in Figure 34.

2.1.2.1. Eyes Open Participants

There was no main effect of *Segment,* $F(1, 16) = .08$, $p = .787$, $MS_E = .01$, partial $\mu^2 = .01$. There was a main effect of *Period,* $F(1.21, 19.29) = 4.55$, $p = .040$, $MS_E = .04$, partial $\mu^2 = .22$. There was no S*egment* by P*eriod* interaction $F(1.61, 25.71) = .97$, $p = .375$, $MS_E = .01$, partial $\mu^2 = .06$.

In order to investigate the main effect of *Period,* pairwise comparisons with Bonferroni's corrections were performed but no significant effects were found. It can be seen from Figure 34, however, that any changes over time were moving in the opposite direction as to what would ideally be expected for suppression training (i.e. ideally during suppression there should be an increase in the amount of time participants spent under threshold, not a decrease).

Table 46

Within sessions comparison to baseline means and standard deviations (SD) for the eyes open and eyes closed participants during their suppression training for the per cent time measure

Period	Eyes Open Mean	Eyes Open SD	Eyes Closed Mean	Eyes Closed SD
1	-4.79	7.66	-8.82	8.73
2	-3.23	5.14	-9.25	8.29
3	-2.85	5.15	-11.41	8.71
4	-3.23	5.10	-14.24	9.08
5	-2.85	4.64	-14.41	10.79
6	-5.21	7.28	-11.61	10.50
7	-3.21	4.67	-11.15	10.17
8	-2.65	4.04	-12.67	10.95
9	-2.59	4.06	-16.62	12.70
10	-3.25	5.72	-16.19	13.28

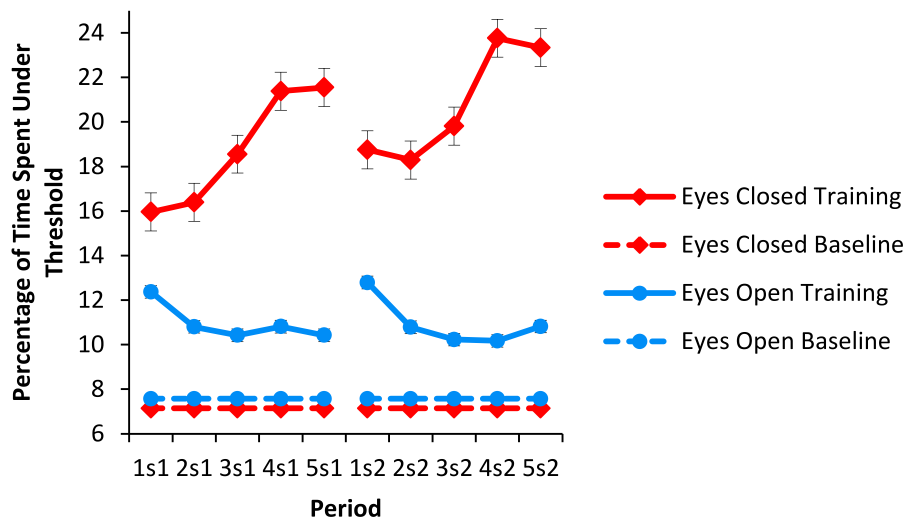

Figure 34. Mean percentage of time spent below threshold (with standard error bars) for each period during baseline and during suppression training for the eyes open and the eyes closed participants (where error bars cannot be seen this is due to them being large enough to be visible on the graph)

2.1.2.2. Eyes Closed Participants

There was no main effect of *Segment,* $F(1, 13) = 3.26$, $p = .094$, $MS_E = 43.94$, partial $\mu^2 = .201$. There was a main effect of *Period,* $F(1.25, 16.20) = 6.97$, $p = .013$, $MS_E = 87.20$, partial $\mu^2 = .349$. There was no *Segment* by P*eriod* interaction $F(4, 52) = .441$, $p = .778$, $MS_E = 5.40$, partial $\mu^2 = .033$.

In order to investigate the main effect of P*eriod*, pairwise comparisons with Bonferroni's corrections were performed. These revealed that participants showed a smaller difference between baseline and training in *period* $2_{s1, s2}$ than in *period* $4_{s1, s2}$ ($p = .013$, $d = .33$) and a smaller difference between baseline and training in *period* $3_{s1, s2}$ than in *period* $4_{s1, s2}$ ($p = .010$, $d = .34$). No other differences were found to be significant.

2.2. Across Sessions in Comparison to Baseline

As with the enhancement training data analyses, above, the across sessions in comparison to baseline analyses were performed by calculating the mean value for each of the 10 sessions during each sessions' corresponding baseline (i.e. eyes open for the eyes open participants, eyes closed for the eyes closed participants) and separately during the suppression training itself (see Tables 47 and 48). A 2 (Stage: *Baseline* vs *Training*) x 10 (Session: *Session 1 – Session 10*) repeated measures ANOVA was then conducted separately for the eyes open and the eyes closed participants, for the same reasons discussed in section 1.2., above.

2.2.1. Amplitude

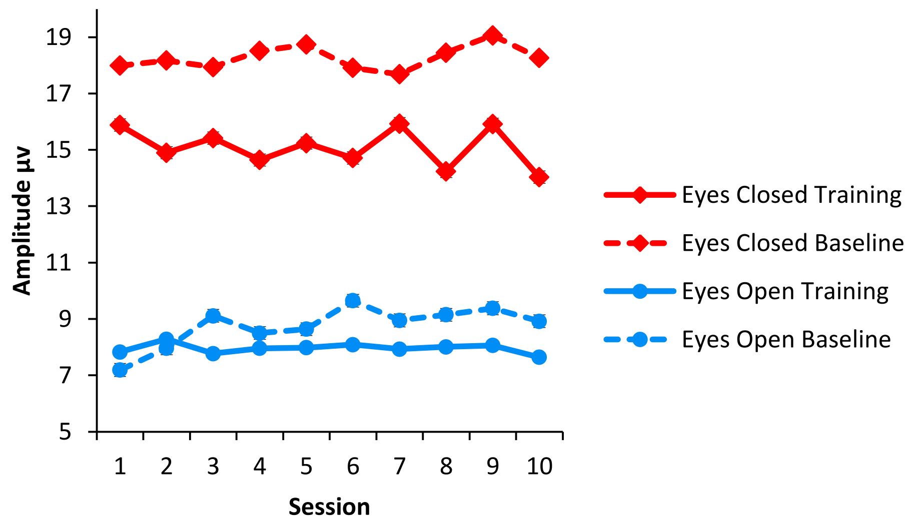

Figure 35. Mean amplitude (with standard error bars) during each session during baseline and during suppression training for the eyes open and the eyes closed participants (where error bars cannot be seen this is due to them being large enough to be visible on the graph)

The mean amplitudes obtained in each session and during each session's baseline for the eyes open and the eyes closed participants can be seen in Figure 35, above.

2.2.1.1. Eyes Open Participants

The means and SDs of the eyes open participants' amplitudes during each individual session's baseline and training can be seen in Table 47.

Table 47

Mean amplitude and standard deviation (SD) for each session of the eyes open group's suppression training and baselines

Session	Mean Baseline	Baseline SD	Training Mean	Training SD
1	7.19	2.72	7.83	3.32
2	7.96	3.70	8.28	4.12
3	9.11	4.93	7.77	3.76
4	8.50	4.25	7.96	3.41
5	8.64	4.12	7.98	3.40
6	9.65	5.23	8.09	3.72
7	8.95	4.51	7.93	3.40
8	9.15	4.86	8.01	3.69
9	9.38	4.27	8.06	3.15
10	8.92	4.12	7.64	2.68

There was a main effect of *Stage,* $F(1, 14) = 4.95$, $p = .043$, $MS_E = .07$, partial $\mu^2 = .26$ due to participants producing a higher amplitude during their baseline (*M* = 2.06, *SE* = .11) than during their training (*M* = 2.00, *SE* = .10). There was a main effect of *Session,* *F*(9, 126) = 2.03, *p* = .041, MS_E = .02, partial μ^2 = .13. There was a *Stage* by *Session* interaction effect *F*(2.80, 39.19) = 3.86, *p* = .018, MS_E = .03, partial μ^2 = .22.

In order to investigate the *Stage* by *Session* interaction effect, a one-way ANOVA, split by *Stage.* was performed on the *Session* data. For the baseline data this showed a main effect of *Session,* *F*(4.34, 60.72) = 4.74, *p* = .002, MS_E = .03, partial μ^2 = .25. Pairwise comparisons with a Bonferroni correction performed in order to investigate this effect, however, found no significant effects. For the training data there was no main effect of *Session,* *F*(3.56, 49.83) = .26, *p* = .881, MS_E = .04, partial μ^2 = .02.

2.2.1.2. Eyes Closed Participants

The means and SDs of the eyes closed participants' amplitudes during each individual session's baseline and training can be seen in Table 48.

There was a main effect of *Stage,* *F*(1, 13) = 16.67, *p* = .001, MS_E = 42.43, partial μ^2 = .562 due to participants producing a lower amplitude during their training (*M* = 15.09, SE = 1.52) than during their baseline (*M* = 18.27, *SE* = 1.53). There was no main effect of *Session,* *F*(9, 117) = .571, *p* =.819 , MS_E = 7.60, partial μ^2 = .042. There was no *Stage* by *Session* interaction F(3.96, 51.50) = 1.35, *p* = .263, MS_E = 8.28, partial μ^2 = .094.

Table 48

Mean amplitude and standard deviation (SD) for each session of the eyes closed group's suppression training and baselines

Session	Mean Baseline	Baseline SD	Training Mean	Training SD
1	17.99	6.72	15.88	6.39
2	18.17	6.04	14.90	6.43
3	17.94	5.70	15.42	5.89
4	18.51	5.92	14.64	6.16
5	18.74	7.16	15.24	6.80
6	17.91	5.98	14.71	5.94
7	17.68	5.06	15.93	6.24
8	18.45	5.72	14.24	5.04
9	19.06	5.97	15.91	6.37
10	18.26	6.65	14.03	6.02

2.2.2. Per Cent Time

The mean percentage of time participants spent under threshold during each training session and during each session's baseline for the eyes open and the eyes closed participants can be seen in Figure 36, below.

2.2.2.1. Eyes Open Participants

The means and SDs of the amount of time the eyes open participants spent under threshold during each session during their training and during their baselines can be seen in Table 49.

Table 49

Means and standard deviations (SD) for the percentage of time participants spent over threshold in each session of the eyes open group's suppression training and baselines

Session	Mean Baseline	Baseline SD	Training Mean	Training SD
1	7.37	3.35	6.52	4.04
2	7.18	3.48	7.55	4.79
3	7.13	3.36	13.19	9.48
4	7.94	3.89	10.25	7.06
5	8.01	3.94	10.75	8.34
6	7.84	3.81	12.23	9.72
7	7.72	3.31	11.48	9.59
8	7.45	3.58	11.74	11.48
9	7.27	3.02	12.67	9.68
10	7.82	2.79	13.20	12.71

There was a main effect of *Stage,* $F(1, 14) = .490$, $p = .044$, $MS_E = .51$, partial $\mu^2 = .26$ due to participants spending more time under threshold during training ($M = 2.11$, $SE = .17$) than during baseline ($M = 1.93$, $SE = .10$). There was no main effect of *Session,* $F(4.19, 58.59) = 2.25$, $p = .072$, $MS_E = .32$, partial $\mu^2 = .14$. There was a *Stage* by S*ession* interaction $F(4.34, 60.71) = 2.80$, $p = .030$, $MS_E = .19$, partial $\mu^2 = .17$.

In order to investigate the *Stage* by *Session* interaction effect, a one way repeated measures ANOVA, split by *Stage*, was performed on the eyes open group's *Session* data. The baseline data showed no main effect of *Session, F*(3.89, 54.43) = .54, p = .703, MS_E = .18, partial μ^2 = .04. The training data showed a main effect of *Session, F*(9, 126) = 3.38, p = .001, MS_E = .16, partial μ^2 = .19. In order to investigate this effect, pairwise comparisons with Bonferroni's corrections were performed. These revealed that participants spent significantly more time under threshold during training in *session 3* than they did in *session 1* (p = .036, d = .94). No other differences were found to be significant.

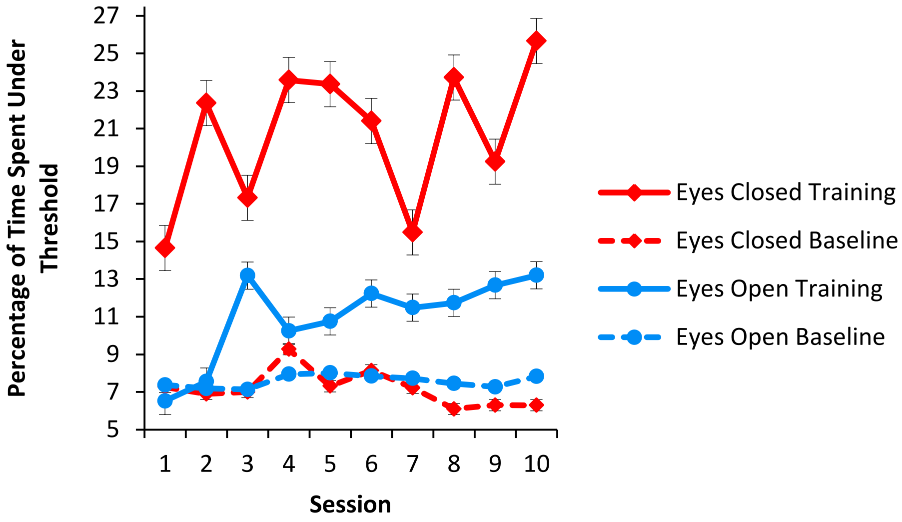

Figure 36. Mean percentage of time spent under threshold (with standard error bars) during each session during baseline and during suppression training for the eyes open and the eyes closed participants (where error bars cannot be seen this is due to them being large enough to be visible on the graph)

2.2.2.2. Eyes Closed Participants

The means and SDs of the amount of time the eyes closed participants spent under threshold during each session during their training and during their baselines can be seen in Table 50.

Table 50

Means and standard deviations (SD) for the percentage of time participants spent under threshold in each session of the eyes closed group's suppression training and baselines

Session	Mean Baseline	Baseline SD	Training Mean	Training SD
1	7.26	2.72	14.65	10.02
2	6.89	2.42	22.36	15.93
3	7.00	2.02	17.33	9.56
4	9.27	7.53	23.58	13.72
5	7.31	2.56	23.37	14.56
6	8.14	2.03	21.41	15.17
7	7.22	2.34	15.49	11.38
8	6.09	2.25	23.72	13.97
9	6.30	1.98	19.25	14.99
10	6.29	1.58	25.66	19.54

There was a main effect of *Stage,* $F(1, 12) = 26.99$, $p < .001$, $MS_E = 439.10$, partial $\mu^2 = .692$ due to participants spending more time below threshold during their training ($M = 20.68$, $SE = 2.96$) than during their baseline ($M = 7.18$, $SE = .54$). There was no main effect of *Session,* $F(3.96, 47.47) = 1.92$, $p = .123$, $MS_E = 117.80$, partial $\mu^2 = .138$. There was no *Stage* by S*ession* interaction, F(3.80, 45.62) = 1.91, $p = .127$, $MS_E = 123.23$, partial $\mu^2 = .138$.

Table 51

Summary of the findings for the suppression training for the amplitude measure. Where an effect was found to be significant any significant pairwise comparisons (with Bonferroni corrections) which were found have been reported. All effects which are in the opposite direction to be indicative of successful suppression training are highlighted in yellow.

	Amplitude	
	Eyes Open	**Eyes Closed**
Within Sessions Comparison to Baseline		
Segment	No	No
Period	Yes 1 > 2, 3, 4, 5	Yes
Segment by Period	No	No
Across Sessions Comparison to Baseline		
Stage	Yes Baseline > Training	Yes Baseline > Training
Session	Yes	No
Stage by Session	Yes Baseline	No

Table 52

Summary of the findings for the suppression training for the per cent measure. Where an effect was found to be significant any significant pairwise comparisons (with Bonferroni corrections) which were found have been reported.

	Per Cent Time	
	Eyes Open	**Eyes Closed**
Within Sessions Comparison to Baseline		
Segment	No	No
Period	Yes	Yes 2 < 4 3 < 4
Segment by Period	No	No
Across Sessions Comparison to Baseline		
Stage	Yes Baseline < Training	Yes Baseline < Training
Session	No	No
Stage by Session	Yes Training: 1 < 3	No

2.3. Suppression Training Summary

A summary of the findings can be seen in Tables 51 and 52.

The eyes open participants showed a main effect of *Period* within sessions in comparison to baseline for both the amplitude and the per cent time measures. However, although both measures show that participants' alpha stays below baseline, as would be ideally hoped for during suppression training, in both cases the change seen over time moves in the wrong direction as would be expected for alpha suppression; as can be seen in Figures 35 and 36.

For the across sessions in comparison to baseline analyses, both measures indicated that the eyes open participants showed a main effect of *Stage* due to participants spending more time below threshold during training than during baseline and producing less amplitude during training than during baseline, both of which are indicative of suppression. A main effect of *Session* was seen when using amplitude as the measure but the *Stage* by *Session* interaction effect revealed that this was due to a change over time during the baseline rather than during the training. Interestingly the per cent time measure also showed a *Stage* by *Session* interaction due to participants spending less time under threshold during training in session 1 than they did in session 3.

With regards to the eyes closed participants, both measures revealed a main effect of *Period* with the per cent time measure indicating that this was due to participants spending more time under threshold in period $4_{s1,\ s2}$ than in periods $2_{s1,\ s2}$ and $3_{s1,\ s2}$. As with the eyes open participants, the across sessions in comparison to baseline analyses showed that both measures showed a main effect of *Stage* due to participants producing less alpha during training than during baseline although neither measure showed a main effect of *Session* nor a *Stage* by *Session* interaction effect.

3. Further Analyses – Eyes Closed Enhancement versus Suppression Training Amplitudes

In order to investigate whether or not the eyes closed participants showed any significant difference between the amplitude of the alpha they produced in their enhancement training compared to the amplitude of the alpha they produced in their suppression training both a within and an across sessions analyses were performed on the eyes closed participants' data. The reason these analyses were only performed using amplitude as the dependent measure (i.e. excluding per cent time) was because the differing thresholds used in each type of training made a direct comparison between enhancement and suppression inappropriate for the per cent time measure. The thresholds for the enhancement training were set at 100% of the average amplitude produced during baselines whereas the thresholds for suppression training were set at 40% of the average amplitude produced during baselines. This difference in threshold means that the percentage of time participants spent over a threshold set at 100% of their baseline amplitude is not an equivalent comparison to the time they spent under one set at 40% of that same baseline amplitude.

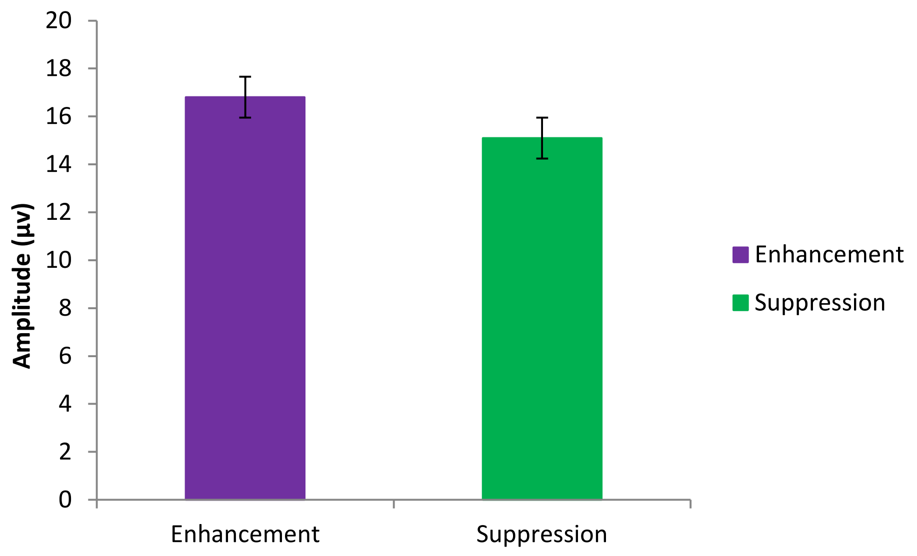

Figure 37. Bar graph (with standard error bars) to show the mean amplitude produced by the eyes closed participants during their enhancement training compared to during their suppression training.

3.1. Within Sessions Analyses

As the point of the comparison was to compare the amplitude participants produced during their training sessions, baselines were not included in the calculations. The mean amplitude for each period (collapsed across segments) can be seen in Table 53, below. Because there was no significant effect of *Segment* this was removed as a factor from the analyses and the period data was collapsed across segments in order to simplify the analyses. To look for any evidence of a difference in amplitude within sessions between the enhancement training and the suppression training, then, a 2 (*Direction*: enhancement vs. suppression) x 5 (*Period*: 1-5) repeated measures ANOVA was performed on the eyes closed participants' period data, collapsed across segments.

Table 53

Mean amplitude and accompanying standard deviations (SD) obtained by the eyes closed participants in each period, collapsed across segments, during their enhancement and during their suppression training

Period	**Enhance Mean**	**Enhance SD**	**Suppress Mean**	**Suppress SD**
$1_{s1, s2}$	17.34	5.87	15.72	6.26
$2_{s1, s2}$	17.2	6.03	15.78	5.95
$3_{s1, s2}$	16.51	6.08	15.13	5.53
$4_{s1, s2}$	16.18	6.18	14.47	5.5
$5_{s1, s2}$	15.83	6.08	14.36	5.55

The within sessions analysis revealed a main effect of *Direction,* $F(1, 13) = 5.13$, $p = .041$, $MS_E = 15.77$, partial $\mu^2 = .283$, due to participants producing a larger amplitude during their enhancement training ($M = 16.61$, $SE = 1.61$) than during their suppression training ($M = 15.09$, $SE = 1.52$) (see Figure 37 for an illustration of this). They showed a main effect of *Period,* $F(1.37, 17.78) = 9.53$, $p = .004$, $MS_E = 3.71$, partial $\mu^2 = .423$. There was no *Direction* by *Period* interaction $F(2.11, 27.40) = .24$, $p = .797$, $MS_E = 1.07$, partial $\mu^2 = .018$.

In order to investigate the main effect of *Period,* pairwise comparisons with Bonferroni corrections were performed. These revealed that the eyes closed participants produced a significantly larger amplitude during *period* $2_{s1, s2}$ than during *periods* $3_{s1, s2}$ ($p = .035$, $d = .11$), $4_{s1, s2}$ ($p = .004$, $d = .20$) and $5_{s1, s2}$ ($p = .004$, $d = .24$) and a significantly larger amplitude during *period* $3_{s1, s2}$ than during *periods* $4_{s1, s2}$ ($p = .019$, $d = .08$) and $5_{s1, s2}$ ($p = .010$, $d = .13$).

3.2. Across Sessions

Again, because the aim of the comparison was to compare the amplitude participants produced during their training sessions, baseline was not included in the calculations. In order to look for any evidence of a difference in amplitude across the sessions between the enhancement training and the suppression training, then, a 2 (*Direction*: enhancement vs. suppression) x 10 (*Session*: 1-10) repeated measures ANOVA was performed on the eyes closed participants' session data. The mean amplitude for each session during enhancement training and during suppression training can be seen in Table 54, below.

The results of the across sessions analysis showed that there was a main effect of *Direction,* $F(1, 12) = 6.02$, $p = .030$, $MS_E = 31.49$, partial $\mu^2 = .334$, due to participants producing a larger amplitude during enhancement training ($M = 16.81$, $SE = 1.72$) than during suppression training ($M = 15.10$, $SE = 1.64$) (see figure 13 for an illustration of this). There was no main effect of *Session,* $F(9, 108) = 1.22$, $p = .292$, $MS_E = 8.08$, partial $\mu^2 = .092$. There was a *Direction* by *Session* interaction $F(3.86, 46.26) = 2.66$, $p = .046$, $MS_E = 5.00$, partial $\mu^2 = .181$.

In order to investigate the *Direction* by *Session* interaction, a one way repeated measures ANOVA, split by *Direction* (enhancement vs. suppression) was performed on the *Session* data. This revealed that there was no significant effect of *Session,* $F(4.56, 55.02) = 1.94$, $p = .108$, $MS_E = 8.22$, partial $\mu^2 = .139$, for the *enhancement* data. For the *suppression* data there was also no significant main effect of *Session* found, $F(4.29, 55.74) = 1.12$, $p = .356$, $MS_E = 12.66$, partial $\mu^2 = .080$.

Table 54

Mean amplitude and accompanying standard deviations (SD) obtained by the eyes closed participants in each session during their enhancement and during their suppression training

Session	Enhance Mean	Enhance SD	Suppress Mean	Suppress SD
1	16.04	5.82	15.88	6.65
2	16.12	6.60	14.69	6.65
3	15.87	6.10	15.16	6.04
4	16.84	6.25	14.49	6.39
5	17.65	7.58	15.38	7.06
6	17.28	6.08	14.64	6.17
7	16.93	6.10	16.07	6.47
8	15.95	5.77	14.34	5.24
9	18.13	6.98	16.22	6.52
10	17.29	7.40	14.15	6.25

3.3. Further Analyses Summary

As can be seen from Table 55, both within and across sessions the eyes closed participants produced larger amplitudes of alpha during their enhancement training than they did during their suppression training. Despite this, within sessions the amplitude of participants' alpha decreased over time regardless of whether they were enhancing or suppressing their alpha. Whilst this is what would be expected during successful suppression training it is not what would be expected during successful enhancement. Across sessions no change in amplitude over time was found for either the enhancement nor the suppression training. Although a *Direction* by *Session* interaction was found the pairwise comparisons, with Bonferroni's corrections, failed to identify where this was from.

Table 55

Summary of the findings for the further analyses section comparing the difference in amplitude for the eyes closed participants during enhancement training to during suppression training. Any significant main effects are listed in the table and the results of any resulting pairwise comparisons (with Bonferroni's corrections) which were found to be significant are also included.

	Findings
Within Sessions	
Direction	Yes
	Enhancement > Suppression
Period	Yes
	2 > 3, 4, 5
	3 > 4, 5
Direction by Period	No
Across Sessions	
Direction	Yes
	Enhancement > Suppression
Session	No
Direction by Session	Yes

Discussion

When the within sessions in comparison to baseline analyses are used as the way of looking for evidence of learning during enhancement training, both the eyes open and the eyes closed participants showed a change in both the amount of alpha they produced and the amount of time they spent producing it within the sessions themselves. However, only the eyes open participants showed a change over time that could be taken to be indicative of enhancement. In contrast, instead of increasing their alpha over time, the eyes closed participants actually decreased it and whereas the eyes open participants increased their alpha over baseline levels, the eyes closed participants did not.

The eyes closed participants also failed to show evidence of learning to enhance their alpha across sessions. Although showing a significant difference between the amount of time they spent over threshold and the amount of alpha they produced when comparing their baselines to training, this was again in the wrong direction to be indicative of enhancement. That is, the eyes closed participants produced more alpha during their baselines and spent more time over threshold during their baselines than they did during their training, which is the wrong direction to be taken as indicative of alpha enhancement.

In contrast, the eyes open participants were found to produce higher mean amplitudes during their training than during their baselines and spent more time over threshold during their training than during their baselines which is what would be expected during 'successful' enhancement training. Interestingly, though, the eyes open participants did not show any evidence of a change over time across the sessions when using the per cent time measure, suggesting that although they enhanced the time they spent over threshold, they did so from the first session and that this ability did not increase with each session. The eyes open participants did, however, show an increase in the amplitude of their alpha as sessions progressed but only when comparing the ninth session to the first. Potentially, then, this could be taken to suggest that had more sessions been run a stronger across sessions effect might have been found and supports the argument that studies which fail to find evidence of learning may do so because they do not run enough sessions, at least where across sessions analyses are used as the way of measuring training 'success'. For example, in Vernon, Egner, et al.'s (2004) study whereby 8 sessions of alpha (8-12Hz) enhancement neurofeedback training did not show any evidence of participants learning to enhance their alpha.

With regards to suppression training, it was actually the eyes closed participants who were shown to be the more successful of the two groups. When the within sessions in comparison to baseline analyses was used to look for evidence of learning, both groups did show a change in time regardless of which measure was used (i.e. amplitude or per cent time). However, in direct contrast to the findings from the enhancement training, this time it was only the eyes closed participants who demonstrated a change in the right direction. The goal of suppression training is to keep the amount of alpha produced during training below that which is produced during baseline and to spend more time below threshold during training than they do during baseline. It can clearly be seen from Figures 33 and 34 that this did happen, but when change over time is taken into account the expectation of 'successful' suppression training would be to show a decrease in the amplitude of alpha over time and an increase in the amount of time spent below threshold. Only the eyes closed participants did this. The eyes open participants in actual fact showed an increase in the amplitude of their alpha back towards baseline levels and a decrease in the amount of time they spent under threshold. It could potentially be argued that the eyes open participants' suppression data is an indication that they were successful at suppressing their alpha from the start but that the method they used was not one that they had yet learned to be able to sustain for very long. On the other hand, as already discussed in the previous chapter with regards to suppression training, it may be that participants did not learn to suppress their alpha but that some aspect of alpha neurofeedback training results in a drop in alpha and, unless actively enhancing their alpha, participants' alpha gradually increases back towards baseline levels over the course of the session as they start to habituate to whatever it is about the training situation which causes the drop in the first place. Taken with the data from the previous chapter's experiment, this latter explanation seemed the most likely of the two. However, whereas the sample used in that experiment showed a marked below-baseline drop in their measures at the start of each segment in each training session, an inspection of Figures 29 and 30 show that this is not the case for the eyes open sample used in this experiment. Why this may be is unclear but may be to do with the type of feedback used in this current experiment. Whereas the participants in this experiment had audio-only feedback, in the previous experiment two thirds of the participants received visual feedback as well as/instead of audio. It could be that this initial suppression in alpha seen at the start of each segment, as reported in the previous chapter, is specific to training which incorporates a visual element. This would tie in with both Walsh (1974) and Mullholland and Eberlin (1977) who argue that visual feedback has a suppressing effect on alpha. The contrast between the previous experiment, where there was a pronounced drop in participants' alpha at the start of each segment, and this one, where there was not, is certainly noteworthy and something which will be looked at further in the next experiment.

Returning to the results of this experiment, then, the across sessions in comparison to baseline analyses also indicated, regardless of the measure used, that both the eyes open and eyes closed participants did produce significantly lower alpha amplitudes during training than during baseline and did spend significantly more time below threshold during training than during baseline. Both of these are indicative of suppression. The eyes closed group did not, however, show any evidence of change over time indicating that although they were suppressing their alpha this was not an ability that improved regardless of the number of sessions they underwent. In contrast, the eyes open participants did show a change over time in amplitude although this was due to a change in participants' baseline and not due to anything which was happening during training. Interestingly the per cent time measure did not show a significant effect of *Session* for the eyes open group although the interaction effect indicated that participants spent less time under threshold during their training in session 1 than they did in session 3. Why this might be is unclear although given that there was no overall main effect of *Session* found is not strong enough evidence to be taken as a change over time.

It is interesting to note at this point that it was also only in relation to whether or not there was a main effect of *Session* that the two measures disagreed when it came to the enhancement training. Reasons for such discrepancies have been discussed in more depth in the previous chapter but, in brief, this could indicate that amplitude is the more sensitive of the two measures to detecting change which is in support of previous assertions by Hardt and Kamiya (1976a) and also by Plotkin (1976a) who argued that per cent time is not as sensitive as some other measures when looking for evidence of learning. On the other hand, it may be that neurofeedback training does not have an equal effect on the amount of alpha produced as it does on the amount of time it is produced for. In the discussion for the previous experiment, it was suggested that this may be due to the feedback providing more information regarding one measure than it does in comparison to another (Hardt & Kamiya, 1976a). However, it should be pointed out that both groups in the experiment here received audio-only feedback but it was only the eyes open group who showed a discrepancy between the measures, so this argument seems less likely as an explanation for the difference here.

To summarise so far, then, whilst the eyes open participants show evidence of learning to enhance their alpha the eyes closed participants do not, in fact, the latter show evidence of suppressing it instead. For the suppression training, the opposite is true. That is, the eyes closed participants show evidence of suppressing their alpha whereas the results of the eyes open participants' training is more equivocal and cannot be taken as evidence of suppression given that any changes in alpha they show over time are in the wrong direction to be indicative of suppression.

The eyes closed participants showing evidence for alpha suppression rather than enhancement during their enhancement training is unexpected and given the association between drowsiness and a decrease in alpha activity (Canterbo et al., 2002) this may suggest that Paskewitz and Orne's (1973) concern about participants becoming drowsy in eyes closed situations is valid. If this is the case it may be because having eyes closed encourages drowsiness (Hare et al., 1982) or it may be due to the length of time participants had to keep their eyes closed for before they were allowed a break as opposed to them training with their eyes closed per se. Each training session involved the participants in the eyes closed group training for a total of thirty minutes with only 3 short eyes open breaks in between. This may have been too long for participants to have their eyes closed for without encouraging drowsiness and may mean that at the very least they needed shorter segments. Perhaps segments of 5 minutes rather than 7.5 minutes might have helped. That said, alpha suppression – regardless of the measure used - was evident from the start of the sessions which not only indicates that 5 minutes may still be too long but that, potentially, eyes closed training is not a good idea. An examination of participants' theta activity would help shed light on participants' suppression because theta becomes more dominant in the EEG with drowsiness as alpha becomes less so. Unfortunately no other bandwidths were examined as part of the experiment so it is thus difficult to be sure whether or not participants were falling asleep but this extent of alpha suppression during enhancement training is certainly suggestive in itself that the participants were experiencing drowsiness.

If the participants having their eyes closed does encourage them to be drowsy and therefore causes an automatic suppression in their alpha, this puts a question mark over the results from the suppression training. Although apparently unable to enhance their alpha, the eyes closed participants were able to suppress it. However, given that they suppressed their alpha when they were meant to enhance it, it is possible that drowsiness rather than conscious control is responsible for the suppression of alpha in both the enhancement and suppression conditions. The fact that participants produced a significantly lower alpha amplitude of alpha during their suppression training sessions than they did during their enhancement training sessions (see the Further Analyses section, above), however, lends support to the idea that the suppression was conscious rather than due to drowsiness. Or at the very least that it may not have been drowsiness alone which can account for the suppression given that the order of training was counterbalanced and one would expect the effect to therefore be equal to both types of training if suppression was an unconscious result of drowsiness. Unless, of course, the participants realised that falling asleep was having a negative impact on their ability to utilise alpha and were attempting to stop it during the enhancement training but were encouraging it during the suppression training.

It is interesting that, in contrast to their suppression training, having eyes closed seemed to have a detrimental effect on participants' ability to enhance their alpha. Travis et al. (1974a, 1974b, 1974c) have previously theorised that eyes open training is more optimal for alpha neurofeedback training due to the tendency for individuals to have lower amplitudes of alpha with their eyes open than with their eyes closed. Assuming that there is a limit as to how high participants' amplitude would ever be able to go they suggest that training with eyes open is more optimal for enhancement training as the lower starting point offers "more room for increase" (Travis et al, 1974a, p171). This hypothesis could nonetheless explain why eyes closed training might be more advantageous for alpha suppression because the higher starting point provides more opportunity for participants to decrease their amplitude. For instance, a participant with an eyes open suppression threshold of 2µv might exhibit a floor effect due to having a maximum of less than 2µv to manoeuvre in whereas if that same participant's eyes closed suppression threshold was 8µv this would give them four times as much space to learn in whilst still being below threshold. Eyes open training being more optimal for alpha enhancement than eyes closed concurs with the previous findings by Nowlis and Kamiya (1970) and Cram et al. (1977) as discussed in the introduction section, above. Although unlike Cram et al. (1977), who only found this to be the case using per cent time as the measure, the experiment here found this to be true regardless of whether amplitude or per cent time were used as the dependent measure.

Also of note is that although there is evidence for the eyes open participants learning to enhance their alpha over time within sessions, the evidence across sessions was not as strong. The across sessions analyses agreed that they produced more alpha during training than during baselines, regardless of the measure used, but only the amplitude measure showed evidence of a change over time and then only in comparison between session 1 and session 9. The same can be said for the eyes closed participants' ability to suppress their alpha, showing a change over time within sessions but none across sessions despite the fact that they did show an overall suppression of alpha from session 1 onwards when comparing their training sessions to their baselines. As well as highlighting the differences between these two methods of defining learning as discussed in the previous chapter, it also supports research by those such as Cott, Pavloski and Goldman (1981) who found that no additional learning effects were shown by their (eyes closed) participants beyond that evident in the first session of training. This may be because one session is enough for participants to learn to alter their alpha in and that it is not possible for participants to learn to further alter their alpha beyond that or it may be because it takes longer for learning to be seen across sessions than it does within sessions. Weber et al. (2011) found that a minimum of 10 sessions were needed in order to be able to distinguish the learners from the non-learners and predict their success in future sessions. Although their study focused on SMR rather than alpha training it nonetheless indicates that it is not unreasonable to believe that more than 10 sessions of neurofeedback training may be needed before evidence of learning across sessions can be established.

To summarise, it would appear that, in contrast to the claims of those such as Hardt and Kamiya (1976a) and Prewett and Adams (1976), eyes open training is the more preferable method for enhancing alpha. This supports Travis et al.'s (1974a, 1974b, 1974c) suggestion that eyes open conditions offer participants more potential for enhancement. Training to enhance with eyes closed appeared to have the opposite effect, with participants instead displaying alpha suppression. In the case of alpha suppression training itself, however, eyes closed conditions were found to be preferable although it is worth noting two things. Firstly that it cannot be certain that the suppression shown by the eyes closed participants was due to conscious suppression as such rather than drowsiness (or, perhaps more likely given the significant difference in their alpha amplitudes between the enhancement and suppression training, conscious attempts to become drowsy in order to suppress their alpha). Secondly, that the eyes open participants did show evidence for suppressing their alpha but that this alpha suppression ameliorated over time within the sessions and showed no evidence of improvement from one session to another.

Conclusion

In conclusion, eyes open training was found to be more optimal for alpha enhancement than eyes closed but the results regarding alpha suppression are less clear cut. Given that there is a danger that the eyes closed conditions may actually have been impeding participants' ability to learn due to encouraging them to become drowsy, however, it seems safer to have them keep their eyes open during neurofeedback training, even in the case of suppression training. The next experiment then will utilise an eyes open training strategy only.

Chapter 5: Experiment 3 - Audio versus Visual versus Audio-Visual Training

Introduction

The previous chapter argued that eyes open alpha neurofeedback training is more preferable to eyes closed. However, whilst eyes closed training only has the potential for use for audio feedback, eyes open training allows for the addition of a visual element to the feedback. So whereas with eyes closed training the choice is for audio-alone feedback, the choice for eyes open training is audio feedback, visual feedback, or audio-visual feedback. As eyes open training has been shown to be more optimal for learning, it therefore seems pertinent to see if it is eyes open audio feedback specifically which is the most conducive to learning or if either visual and/or audio-visual feedback are more preferable.

Although broadly falling under the categories of visual, audio, or audio-visual feedback, there are, in fact, various forms of each. For instance, examples of visual feedback are squares which change in the colour intensity (e.g. Hanslmayr et al., 2005) or in the colour and the colour intensity (e.g. Zoefel et al., 2011) the nearer the participant's alpha power/amplitude is to the required threshold or a light which goes on and off depending on whether the participant's target aspect of alpha exceeds threshold or not (e.g. Jackson & Eberly, 1982). The sound of applause every time the individual exceeds their threshold (Markovska-Simoska et al., 2008) or a tone varying in volume in line with variations in the power of the individual's alpha (e.g. Konareva, 2005, 2006) are examples of audio feedback. Audio-visual feedback is, as would be expected, a combination of both types of feedback. For instance, a moving bar on the screen which increases and decreases in height as the individual's alpha increases and decreases in amplitude, changing in colour when their alpha amplitude exceeds threshold, with a simultaneous tone which sounds whenever the threshold is crossed in the desired direction (Dempster & Vernon, 2008; Vernon & Withycombe, 2006).

As can be seen from Table 9 (see Chapter 1), above, the most common type of feedback utilised in the alpha neurofeedback literature to date is, by far, audio training (n = 68 studies of the studies reviewed). Visual feedback is the second most commonly utilised (n = 17), and audio-visual the least common (n = 9). The fact that such a small proportion of the studies reviewed actually use audio-visual feedback is noteworthy because there are some who hypothesise that giving the participant both audio and visual feedback may be the most advantageous of the three for neurofeedback training (e.g. Vernon, 2008). Lal et al. (1998) suggest that providing feedback to two difference sense modalities has an advantage over feedback to one via an increase in attention. So if attention in one modality wanders it can be recaptured by the other and drawn back to the training. Although they were talking about biofeedback rather than neurofeedback specifically, it is reasoning which is echoed by Vernon et al. (2004) in their discussion of neurofeedback training. Although providing no evidence to support their claim, they state that there is general agreement that combining both audio and visual feedback may be the most advantageous way of making the individual aware of the activity of their EEG as opposed to audio-only or visual-only neurofeedback training. They do, however, go on to point out that there is a lack of definitive research in the area and a more thorough investigation to compare the three is needed. Interestingly, when Lal et al. (1998) did a comparison of audio versus visual versus audio-visual feedback for biofeedback training, despite their hypothesis mentioned above, they found visual and audio-visual training to be more effective than audio-alone training. The addition of the audio component made no difference. The crucial factor was the presence of visual feedback. Blanchard and Young (1972) also found that there was no difference between visual and audio-visual feedback in terms of efficacy. However, these studies utilise biofeedback rather than neurofeedback specifically. Lal et al. (1998) were investigating blood pressure biofeedback and Blanchard and Young (1972) were looking at heart rate biofeedback. Different physiological components may respond differently to the different types of feedback, something which is supported by O' Connell et al. (1979) who showed that it depends on the type of biofeedback training as to which is the most effective modality of feedback, and so it remains to be seen which is the most effective for alpha neurofeedback training.

In terms of neurofeedback specifically, Breteler, Manolova, de Wilde, Caris, and Fowler (2008) also failed to find any significant differences in the amplitude produced using visual feedback and the amplitude produced using audio-visual feedback. Their training was conducted using SMR rather than alpha neurofeedback, however, and it would have been interesting to see how their results would have compared had they also included audio-alone feedback as one of their conditions.

Actual empirical evidence investigating the efficacy of one type of feedback modality compared to another appears to be sparse when it comes to neurofeedback. Thus, those such as Vernon (2005) have called for research providing a direct comparison between the three.

A comparison of visual versus audio alpha neurofeedback training has been conducted previously, however. Lynch et al. (1974) discovered that visual alpha (8-12Hz) neurofeedback was better than audio. Whereas participants who received visual feedback showed an increase in alpha across trials, audio participants did not. However, there were only 5 audio participants compared to the 16 visual participants so the audio group may have been too small to make generalisations from. In addition, each participant only received one session incorporating ten 2 minute trials, and basing interpretations on a single session of neurofeedback training with trials as short as 2 minutes leaves their study open to criticism. Firstly, for not providing enough training to form firm conclusions from and secondly for inhibiting their learning ability by interrupting them too frequently (see Chapter 1, section 3.6. for discussion of these points).

Lynch et al.'s (1974) findings that visual feedback produces evidence of learning when audio feedback does not nonetheless supports an hypothesis made by Travis et al. (1974) that the two types of feedback may produce differing results. However, it does contrast with the argument by some in the field that visual presentation is the least effective type of feedback for alpha enhancement training due to the suppression of alpha which visual stimuli is known to have. Both Walsh (1974) and Mullholland and Eberlin (1977) argue that visual feedback suppresses alpha and Mullholland et al. (1983) go as far as calling visual feedback 'negative feedback' (p597). It is not clear whether this negative effect of visual feedback they talk about is exclusive to occipital regions of the brain, due to the role the occipital lobe plays in visual processing, or it if applies to other regions of the brain too. Although, notably, Tyson (1982) hypothesizes that training conducted via parietal brain areas may be more sensitive to audio feedback than occipital areas. Either way, given that Lynch et al. (1974) did not show evidence of learning above baseline levels means that caution is needed in interpreting their results, as the authors themselves point out (see Chapter 3 for a more in-depth discussion of the role of baselines in the analyses of neurofeedback training).

In sum, then, despite suggestions that the type of feedback modality may make a difference to the individual's ability to learn (e.g. Travis et al., 1974), current research in the area is either not specific to neurofeedback (e.g. Lal et al., 1998) or fails to either provide a comparison between all three (e.g. Breteler et al., 2008) and/or show evidence of learning for any of the feedback groups (e.g. Lynch et al., 1974) making conclusions about which is the most effective for learning hard to establish. For this reason, researchers have argued for a direct comparison between the three (e.g. Vernon, 2005; Vernon et al., 2004).

The aim of this current experiment is to do just that: to investigate if any differences in learning to exert a conscious control on the amplitude of alpha are influenced by whether or not feedback is in audio, visual or audio-visual form, and to see if one of the three therefore turns out to be more optimal for alpha neurofeedback training.

Method

Participants

The specific details regarding the number and age of participants can be seen in Figure 38.

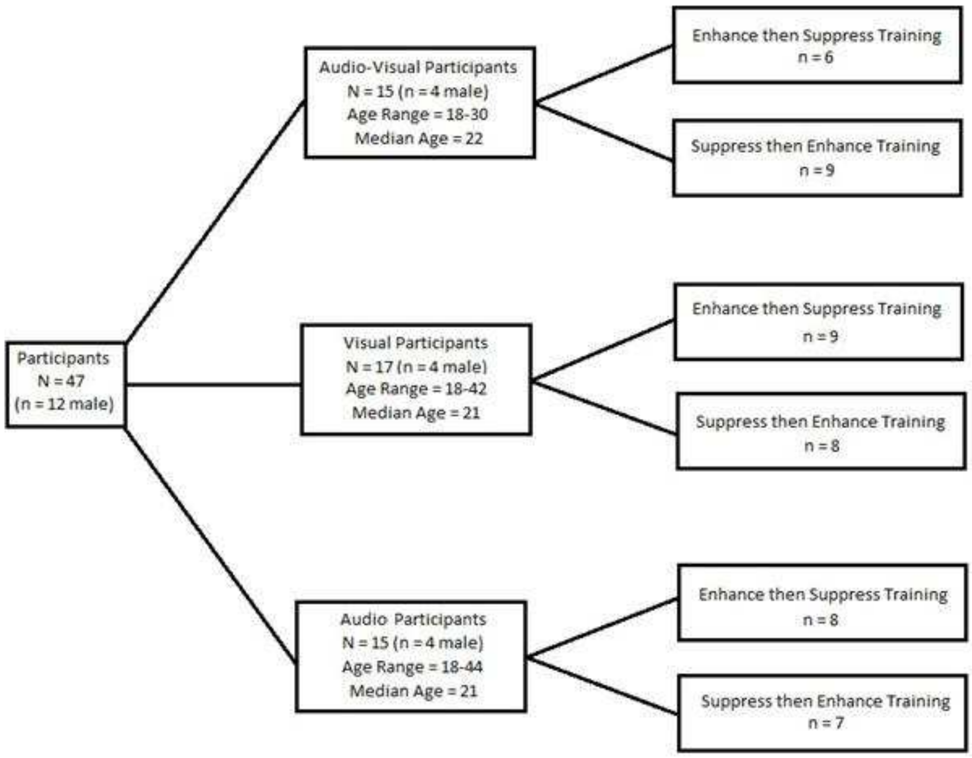

Figure 38. The number, gender, age, and training order (i.e. enhancement first or suppression first) of the participants in each of the feedback groups.

As can be seen from Figure 38, there was an unequal number of participants who suppressed their alpha first during the course of each session when compared to the number who enhanced their alpha first. The order participants trained in was originally counterbalanced equally but participants dropping out of the study before their training commenced resulted in an unequal number per training order group.

With regards to recruitment, all the details are the same as in Chapter 2. As with the previous experiments (see Chapters 3 and 4), although the ideal would have been to have an equal number of males and females in the sample the student population they were sampled from (i.e. psychology students from

Canterbury Christ Church University) were predominantly female and the number of male volunteers was consequently far less than the number of female.

Procedure

All details regarding equipment, montage, scalp preparation, setting of thresholds, instructions to participants, and training schedule are the same as described in Chapter 2.

The stages of the training sessions themselves were the same as in the previous experiments but a reminder is given in Figures 8 and 9 (Chapter 2).

Results

Before analyses were performed, normal distribution checks were conducted. As can be seen from Table 56, below, only the visual participants' data was normally distributed. The audio participants' data was only normally distributed for their enhancement training and only when per cent time was used as the measure. For the audio-visual participants, the enhancement data was normally distributed but the suppression data was only normally distributed for the across sessions comparison to data and only when amplitude was used as the measure. In light of this then, as with the preceding experiments, all non-normally distributed data were log transformed before the analyses.[6]

For all analyses, if Mauchley's Test of Sphericity was found to be significant then a Greenhouse Geisser correction was used. In the case of the a

[6] To note, where any data was log transformed, the means reported alongside the analyses are referring to the means of the log transformed data. In order to provide a more meaningful picture to the reader with regards to their amplitudes and percentage of time spent over/under threshold during training and during baseline, however, all tables and figures use the original means.

priori pairwise comparisons (with Bonferroni corrections), Cohen's *d* was used to calculate the effect sizes of any which were found to be significant.

1. Enhancement Training

As with the previous experiments, the aim of the enhancement training was for the participants to increase the amplitude of their alpha above baseline levels and to spend more time in alpha over their threshold during training than they did during baseline. If they have been successful at this task, then, the expectation would be for them to show an increase over time, regardless of which measure is used (i.e. amplitude or per cent time) and regardless of the type of analysis performed (i.e. within sessions in comparison to baseline and across

Table 56

Results of the normality of distribution checks for each measure for each analyses for each of the three feedback conditions. Data which were found to be non-normally distributed are highlighted in yellow

	Amplitude		Per Cent Time	
	Within Sessions Comparison to Baseline	Across Sessions Comparison to Baseline	Within Sessions Comparison to Baseline	Across Sessions Comparison to Baseline
Enhancement				
Audio-Visual	Normal	Normal	Normal	Normal
Visual	Normal	Normal	Normal	Normal
Audio	Not Normal	Not Normal	Normal	Normal
Suppression				
Audio-Visual	Not Normal	Normal	Not Normal	Not Normal
Visual	Normal	Normal	Normal	Normal
Audio	Not Normal	Not Normal	Not Normal	Not Normal

sessions in comparison to baseline).

Given that the data for the audio condition needed to be log transformed whereas the data for the visual and audio-visual groups did not, it was therefore not appropriate to analyse the three conditions together.[7] Although this discrepancy did not occur for the per cent time data (i.e. when the per cent time measure was used none of the data needed to be log transformed), for the purposes of consistency the analyses were performed in the same way as with the amplitude measure in order to try and make the data between the two measures as comparable as possible. So although a direct comparison between the three different feedback groups did reveal a significant main effect of *Group* within sessions for both the amplitude data (p = .045) and the per cent time data (p = .024) and a significant *Segment* by *Group* interaction effect for both the amplitude (p = .023) and the per cent time (p = .004) data (see Appendix L) and a significant main effect of *Group* across sessions for the per cent time data (p = .027) (although not for the across sessions amplitude data)(see Appendix L), it was decided that analysing the data for the three feedback groups separately would be more informative.

1.1. Within Sessions in Comparison to Baseline

The analyses for the within sessions in comparison to baseline data were performed the same way as in the previous experiments (see Chapter 3). That is, the data of the corresponding period in each session (i.e. all the period 1_{s1}s in each session, all the period 2_{s1}s in each session . . . etc.) were collapsed across sessions and the average eyes open baseline for the sessions were then deducted

[7] Although this is possible if all the original data is converted in to z scores first, this method was decided to be too conservative and an approach which did not involve the use of z scores was thought to be more useful, in terms of being more sensitive to changes in the data, instead.

from each of these 10 scores (see Tables 57 and 58)[8]. Changes within sessions in comparison to baseline were then examined separately for each of the three conditions (i.e. audio, visual, and audio-visual) via a 2 (Segment: *Segment 1* vs *Segment 2*) x 5 (Period: *Period 1 – Period 5*) repeated measures analysis of variance (ANOVA) on each of the two measures (i.e. amplitude and per cent time).

Table 57

Within sessions comparison to baseline means and standard deviations (SD) for the audio-visual, visual, and audio feedback groups during their enhancement training for the amplitude measure. Negative numbers are indicative of where the mean amplitude during training was less than that of the mean amplitude during baseline.

Period	Audio-Visual Mean	Audio Visual SD	Visual Mean	Visual SD	Audio Mean	Audio SD
1_{s1}	-1.05	1.15	-0.59	0.71	-0.05	1.30
2_{s1}	-0.41	1.09	-0.01	0.86	0.69	1.44
3_{s1}	-0.16	1.10	0.10	0.87	0.90	1.67
4_{s1}	-0.05	1.01	0.17	0.92	0.94	1.69
5_{s1}	-0.23	0.94	-0.03	0.99	0.83	2.03
1_{s2}	-0.47	1.33	-0.53	0.72	0.30	1.78
2_{s2}	-0.06	1.31	-0.08	0.89	1.08	1.92
3_{s2}	0.16	0.99	-0.01	0.92	0.99	1.68
4_{s2}	0.23	1.21	0.06	0.86	0.96	1.84
5_{s2}	0.18	0.99	-0.10	0.78	0.66	1.56

[8] For justification as to why baseline was incorporated in this way and not added as a separate factor see Chapter 3, section 1.3.

1.1.1. Amplitude

The difference in mean amplitude between baseline and training produced by each of the three feedback groups can be seen in Table 57 and is illustrated in Figure 39, below.

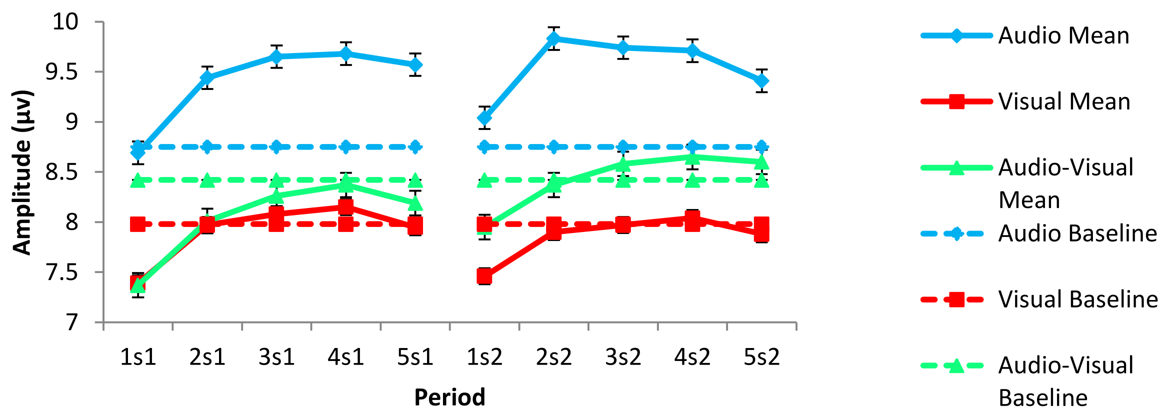

Figure 39: Mean amplitude (with standard error bars) for each period during training and during baseline for each of the three feedback groups during their enhancement training (where error bars cannot be seen this is due to them being large enough to be visible on the graph)

1.1.1.1. Audio-Visual Participants

Audio-visual participants showed a main effect of *Segment*, $F(1, 14) = 7.05$, $p = .019$, $MS_E = .82$, *partial* $\mu^2 = .34$, due to participants producing a larger difference between baseline and training in *Segment 1* ($M = -.38$, $SE = .26$) than in *Segment* 2 ($M = .01$, $SE = .29$) although a look at Figure 39 reveals that they were nonetheless moving in the expected direction for enhancement training (i.e. their amplitude during their training itself showing an increase over time). They also showed a main effect of *Period*, $F(2.05, 28.64) = 19.00$, $p < .001$, $MS_E = .36$, *partial*

μ^2 = .58. There was no *Segment* by *Period* interaction effect, $F(4, 56) = 1.25$, p = .30, MS_E = .08, *partial* μ^2 = .08.

In order to investigate the main effect of *Period,* pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that the audio-visual participants showed a larger difference in amplitude between baseline and training in *period* $1_{s1, s2}$ than they did in periods $2_{s1, s2}$ (p = .003, d = .43), $3_{s1, s2}$ (p < .001, d = .66), $4_{s1, s2}$ (p < .001, d = .74) and $5_{s1, s2}$ (p = .005, d = .66). They also showed a larger difference between baseline and training in *period* $2_{s1, s2}$ than they did in *period* $4_{s1, s2}$ (p = .020, d = .28). Despite this, again, a look at Figure 39 reveals that they were nonetheless showing an increase in their alpha during training over time. No other differences were found to be significant.

1.1.1.2. Visual Participants

There was no main effect of *Segment*, $F(1, 16) = 1.15$, p = .299, MS_E = .12, *partial* μ^2 = .07. There was a main effect of *Period*, $F(1.84, 29.4) = 21.41$, p < .001, MS_E = .24, *partial* μ^2 = .57. There was no *Segment* by *Period* interaction effect, $F(2.98, 47.68) = .73$, p = .536, MS_E = .08, *partial* μ^2 = .04.

In order to investigate the main effect of *Period*, pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that participants showed a larger difference between baseline and training in *period* $1_{s1, s2}$ than they did in *periods* $2_{s1, s2}$ (p = .002, d = .64), $3_{s1, s2}$ (p = .002, d = .74), $4_{s1, s2}$ (p < .001, d = .83) and $5_{s1, s2}$ (p = .001, d = .61). They also produced a larger difference between baseline and training in period $4_{s1, s2}$ than they did in *periods* $2_{s1, s2}$ (p = .005, d = .18) and $5_{s1, s2}$ (p = .019, d =.02). A look at Figure 39 reveals that only the significant difference between *periods 4* and *5* were in the wrong direction to be indicative of enhancement (i.e. all the other significant differences are, in fact, all due to participants amplitude during training increasing over time). No other differences were found to be significant.

1.1.1.3. Audio Participants

The audio participants showed no main effect of *Segment*, $F(1, 14) = 1.23$, $p = .287$, $MS_E = .02$, *partial* $\mu^2 = .08$. They showed a significant main effect of *Period*, $F(1.50, 20.95) = 7.07$, $p = .008$, $MS_E = .06$, *partial* $\mu^2 = .34$. They showed no *Segment* by *Period* interaction effect, $F(4, 56) = 1.45$, $p = .229$, $MS_E = .01$, *partial* $\mu^2 = .09$.

In order to investigate the main effect of Period, pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that participants showed a marginally smaller difference in amplitude between baseline and training in *period* $1_{s1, s2}$ than they did in *period* $2_{s1, s2}$ ($p = .069$, $d = .52$). No other differences were found to be significant.

1.1.2. Per Cent Time

The difference in the amount of time spent over threshold during baseline and during training shown by each of the three feedback groups can be seen in Table 58 and is illustrated in Figure 40, below.

Table 58

Within sessions comparison to baseline means and standard deviations (SD) of the amount of time participants in each of the feedback groups spent over threshold during their enhancement training. Negative numbers are indicative of where the mean time spent over threshold during training was less than that of the mean time spent over threshold during baseline.

Period	Audio-Visual Mean	Audio Visual SD	Visual Mean	Visual SD	Audio Mean	Audio SD
1_{s1}	-8.43	8.09	-5.35	7.77	-0.10	7.47
2_{s1}	-3.11	7.31	-0.09	8.61	4.49	7.85
3_{s1}	-1.07	7.44	0.82	9.04	5.85	8.53
4_{s1}	0.00	6.84	0.91	9.16	6.07	7.88
5_{s1}	-1.01	7.01	-0.85	9.46	4.70	8.46
1_{s2}	-4.53	9.31	-5.21	7.96	2.27	8.88
2_{s2}	-0.29	8.81	-1.02	9.24	6.86	9.01
3_{s2}	1.39	6.62	-0.37	8.66	5.95	7.72
4_{s2}	2.07	7.82	0.51	8.60	5.95	8.01
5_{s2}	1.71	6.67	-1.02	8.19	5.36	8.07

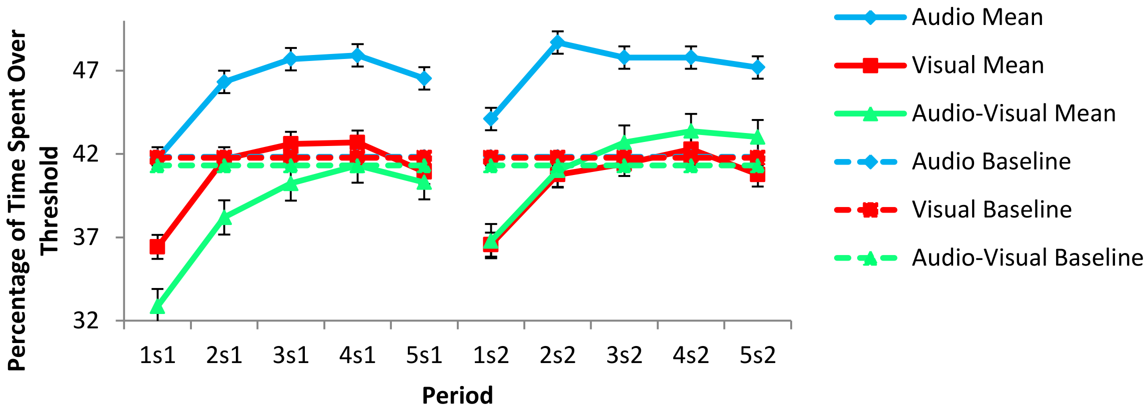

Figure 40: Mean percentage of time spent over threshold (with standard error bars) for each period during training and during baseline for each of the three feedback groups during their enhancement training

1.1.2.1. Audio-Visual Participants

The audio-visual participants showed a significant main effect of *Segment*, $F(1, 14) = 11.48$, $p = .004$, $MS_E = 25.47$, *partial* $\mu^2 = 47$ due to participants showing a larger difference between baseline and training in *Segment 1* ($M = -2.72$, $SE = 1.80$) than in *Segment 2* ($M = .07$, $SE = 1.92$). As can be seen from *Figure 40*, however, this is nonetheless in a direction which is indicative of enhancement (i.e. due to an increase from below baseline to above baseline levels from one *Segment* to the next). There was a significant main effect of *Period*, $F(1.64, 22.96) = 24.62$, $p < .001$, $MS_E = 27.72$, *partial* $\mu^2 = .64$. There was no *Segment* by *Period* interaction effect, $F(4, 56) = .75$, $p = .563$, $MS_E = 4.73$, *partial* $\mu^2 = .05$.

In order to investigate the main effect of *Period*, pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that participants showed a larger difference between baseline and training in *period* $1_{s1, s2}$ than they did in *periods* $2_{s1, s2}$ ($p < .001$, $d = .57$), $3_{s1, s2}$ ($p < .001$, $d = .84$), $4_{s1, s2}$ ($p < .001$, $d =$

.93), and *5* $_{s1, s2}$ (*p* = .002, *d* = .87). They also showed a significantly larger difference between baseline and training in *period 2* $_{s1, s2}$ than they did in *period 4* $_{s1, s2}$ (*p* = .012, *d* = .35) and a marginally larger difference in *period 2* $_{s1, s2}$ than they did in *period* 3 $_{s1, s2}$ (*p* = .056, *d* = .25). Because these changes represented an increase over time during training, however, they were nonetheless in a direction indicative of enhancement, as can be seen from Figure 40. No other differences were found to be significant.

1.1.2.2. Visual Participants

The visual participants showed no main effect of *Segment*, *F*(1, 16) = 1.20, *p* = .290, MS_E = 9.31, *partial* μ^2 = .07. They showed a significant main effect of *Period*, *F*(2.55, 40.83) = 25.15, *p* < .001, MS_E = 12.09, *partial* μ^2 = .61. There was no *Segment* by *Period* interaction effect, *F*(4, 64) = .51, *p* = .733, MS_E = 5.07, *partial* μ^2 = .03.

In order to investigate the main effect of *Period*, pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that participants showed a larger difference between baseline and training in *period 1* $_{s1, s2}$ than they did in *periods 2* $_{s1, s2}$ (*p* < .001, *d* = .56), *3* $_{s1, s2}$ (*p* < .001, *d* = .66), *4* $_{s1, s2}$ (*p* < .001, *d* = .71), and *5* $_{s1, s2}$ (*p* = .001, *d* = .52). They also showed a larger difference between baseline and training in *period 5* $_{s1, s2}$ then they did in *period 4* $_{s1, s2}$ (*p* = .010, *d* = .19). All but the difference between periods *4* and *5*, however, were in the direction which would be expected to be seen during enhancement training; as Figure 40 reveals. No other differences were found to be significant.

1.1.2.3. Audio Participants

The audio participants showed no main effect of *Segment*, $F(1, 14) = 1.57$, $p = .231$, $MS_E = 27.72$, *partial* $\mu^2 = .10$. They showed a significant main effect of *Period*, $F(2.20, 30.86) = 10.13$, $p < .001$, $MS_E = 23.24$, *partial* $\mu^2 = 10$. There was no *Segment* by *Period* interaction effect, $F(4, 56) = 1.80$, $p = .142$, $MS_E = 6.16$, *partial* $\mu^2 = .11$.

In order to investigate the main effect of *Period*, pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that participants produced a significantly smaller difference between training and baseline in *period* $1_{s1, s2}$ than they did in *periods* $2_{s1, s2}$ ($p = .004$, $d = .55$), $3_{s1, s2}$ ($p = .011$, $d = .59$, $4_{s1, s2}$ ($p = .013$, $d = .61$), and $5_{s1, s2}$ ($p = .039$, $d = .48$). No other effects were found to be significant.

1.2. Across Sessions in Comparison to Baseline

The analyses for the across sessions in comparison to baseline data were performed in the same way as described in Chapter 3. That is, the mean value for each of the two measures (i.e. amplitude and per cent time) were calculated for each of the 10 sessions' baselines and each of the 10 sessions' training sessions themselves (see Tables 59-64). A 2 (Stage: *Baseline* vs *Training*) x 10 (Session: *Session 1 – Session 10*) repeated measures ANOVA was then conducted for each measure on each of the three feedback conditions separately.

1.2.1. Amplitude

The mean amplitude produced by each of the three feedback groups during each session's training and each session's baseline can be seen in Tables 59-61 and is illustrated in Figure 41, below.

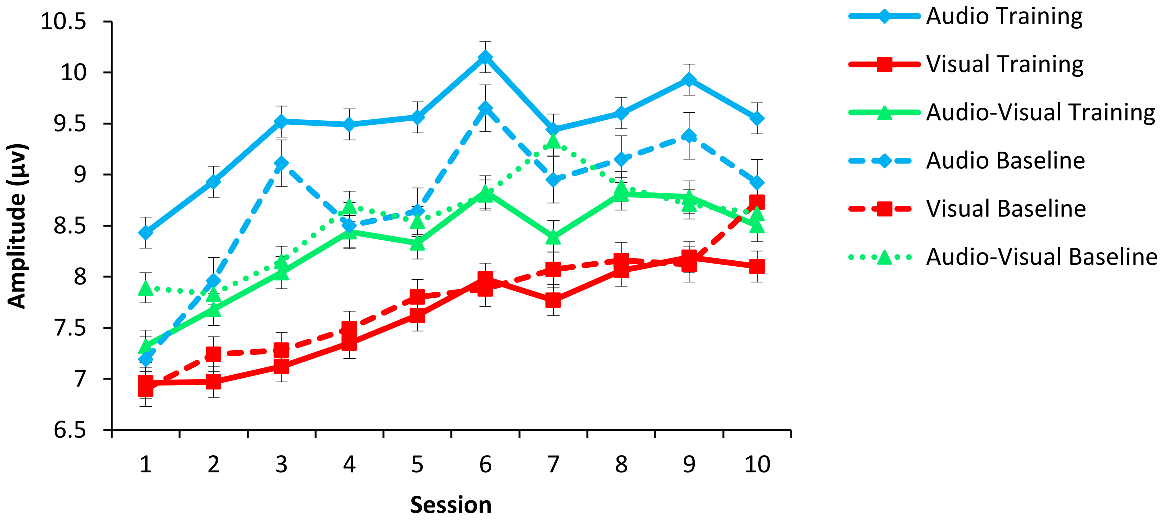

Figure 41: Mean amplitude (with standard error bars) for each session during enhancement training and during baseline for each of the three feedback groups

1.2.1.1. Audio-Visual Participants

The audio-visual participants showed no main effect of *Stage*, $F(1, 13) = .67$, $p = .427$, $MS_E = 5.34$, *partial* $\mu^2 = .05$. They showed a main effect of *Session*, $F(9, 117) = 2.75$, $p = .006$, $MS_E = 2.14$, *partial* $\mu^2 = .18$. They showed no *Stage* by *Session* interaction effect, $F(2.90, 37.64) = .58$, $p = .629$, $MS_E = 3.49$, *partial* $\mu^2 = .04$.

Pairwise comparisons with a Bonferroni's adjustment performed to investigate the main effect of *Session*, however, revealed no significant effects.

Table 59

Mean amplitude and accompanying standard deviations during each of the audio-visual participants' enhancement sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	7.89	2.91	7.32	2.15
2	7.83	3.37	7.68	2.66
3	8.15	2.54	8.04	2.57
4	8.69	2.94	8.44	2.83
5	8.54	2.97	8.33	2.83
6	8.80	3.12	8.83	3.30
7	9.33	3.39	8.39	2.83
8	8.88	3.18	8.81	3.25
9	8.71	2.64	8.78	2.97
10	8.62	3.09	8.50	2.73

1.2.1.2. Visual Participants

There was no main effect of *Stage*, $F(1, 14) = .50$, $p = .493$, $MS_E = 3.56$, *partial* $\mu^2 = .03$. There was a significant main effect of *Session*, $F(3.14, 43.88) = 5.44$, $p = .003$, $MS_E = 3.98$, *partial* $\mu^2 = .28$. There was no *Stage* by *Session* interaction effect, $F(3.56, 49.80) = .58$, $p = .658$, $MS_E = 1.52$, *partial* $\mu^2 = .04$.

In order to investigate the main effect of *Session*, pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that participants showed that participants produced a higher amplitude in *session 7* than they did in *session 1* ($p = .017$, $d = .20$). No other differences were found to be significant.

Table 60

Mean amplitude and accompanying standard deviations during each of the visual participants' enhancement sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	6.90	1.65	6.96	1.75
2	7.24	1.59	6.97	1.79
3	7.28	1.71	7.12	1.86
4	7.49	1.73	7.35	2.48
5	7.80	2.22	7.62	2.66
6	7.88	2.43	7.98	2.23
7	8.07	2.13	7.77	1.88
8	8.16	2.01	8.06	2.39
9	8.12	2.14	8.19	2.41
10	8.73	2.95	8.10	2.18

1.2.1.3. Audio Participants

The audio participants showed a significant main effect of *Stage*, $F(1, 14) = 5.15$, $p = .040$, $MS_E = .07$, *partial* $\mu^2 = .27$ due to participants producing a higher amplitude during training ($M = 2.13$, $SE = .13$) than they did during their baseline ($M = 2.06$, $SE = .11$). They showed a significant main effect of *Session*, $F(9, 126) = 4.96$, $p < .001$, $MS_E = .02$, *partial* $\mu^2 = .26$. There was no *Stage* by *Session* interaction effect, $F(9, 126) = .99$, $p = .449$, $MS_E = .01$, *partial* $\mu^2 = .07$.

In order to investigate the main effect of *Session*, pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that participants produced significantly more amplitude in *session 9* than they did in *session 1* (p = .030, d = .17). No other differences were found to be significant.

Table 61

Mean amplitude and accompanying standard deviations during each of the audio participants' enhancement sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	7.19	2.72	8.43	3.68
2	7.96	3.70	8.93	4.68
3	9.11	4.93	9.52	4.65
4	8.50	4.25	9.49	5.01
5	8.64	4.12	9.56	4.73
6	9.65	5.23	10.15	5.29
7	8.95	4.51	9.44	4.74
8	9.15	4.86	9.60	4.91
9	9.38	4.27	9.93	5.09
10	8.92	4.12	9.55	4.75

1.2.2. Per Cent Time

The mean amount of time spent over threshold for each of the three feedback groups during each session's training and each session's baseline can be seen in Tables 62-64 and is illustrated in Figure 42, below.

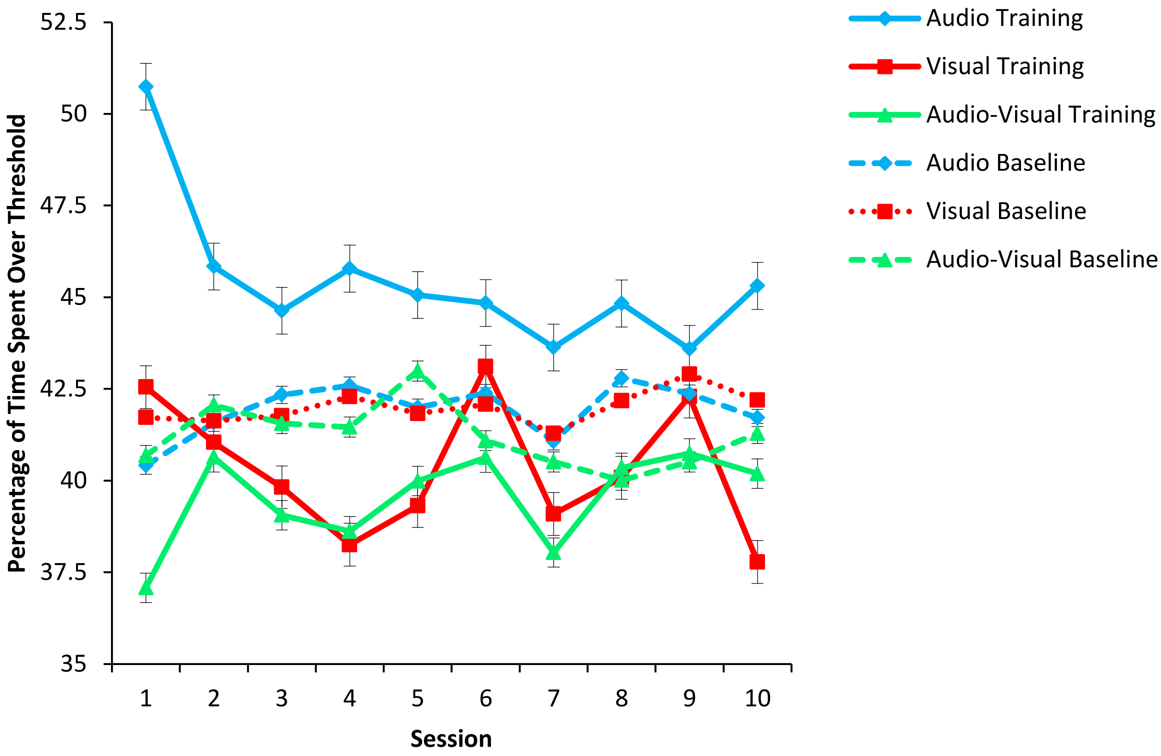

Figure 42: Mean percentage of time spent over threshold (with standard error bars) for each session during enhancement training and during baseline for each of the three feedback groups

1.2.2.1. Audio-Visual Participants

The audio-visual participants showed no main effect of *Stage*, $F(1, 13) = .78$, $p = .394$, $MS_E = 255.41$, *partial* $\mu^2 = .06$. They showed no main effect of

Session, $F(4.17, 54.17) = .51$, $p = .735$, $MS_E = 81.83$, *partial* $\mu^2 = .04$. They showed no *Stage* by *Session* interaction effect, $F(4.56, 59.27) = .39$, $p = .840$, $MS_E = 70.18$, *partial* $\mu^2 = .03$.

Table 62

Mean percentage of time spent over threshold, with accompanying standard deviations, during each of the audio-visual participants' enhancement sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	40.68	2.60	37.08	8.77
2	42.06	2.76	40.64	9.65
3	41.56	2.86	39.06	7.07
4	41.46	2.72	38.62	8.91
5	42.99	2.94	39.99	9.30
6	41.09	3.06	40.63	11.54
7	40.51	4.73	38.04	13.05
8	40.01	4.64	40.35	6.04
9	40.51	3.56	40.74	8.56
10	41.29	2.28	40.19	10.51

1.2.2.2. Visual Participants

The visual participants showed no main effect of *Stage*, $F(1, 14) = .53$, $p = .479$, $MS_E = 387.76$, *partial* $\mu^2 = .04$. There was no main effect of *Session*, $F(9, 126) = .74$, $p = .673$, $MS_E = 39.31$, *partial* $\mu^2 = .05$. There was no *Stage* by *Session* interaction effect, $F(9, 126) = .65$, $p = .749$, $MS_E = 38.53$, *partial* $\mu^2 = .05$.

Table 63

Mean percentage of time spent over threshold, with accompanying standard deviations, during each of the visual participants' enhancement sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	41.72	2.06	42.55	8.79
2	41.63	1.98	41.04	13.64
3	41.77	2.20	39.82	12.52
4	42.29	1.75	38.25	14.35
5	41.83	2.88	39.31	11.78
6	42.08	1.61	43.11	12.68
7	41.29	1.91	39.09	12.54
8	42.18	2.30	40.08	13.15
9	42.90	2.29	42.29	8.69
10	42.19	2.29	37.78	10.62

1.2.2.3. Audio Participants

The audio participants showed a significant main effect of *Stage*, $F(1, 13) = 4.70$, $p = .049$, $MS_E = 182.49$, *partial* $\mu^2 = .27$ due to participants spending more time over threshold during training ($M = 41.93$, $SE = .48$) than they did during baseline ($M = 45.42$, $SE = 1.37$). They showed no main effect of *Session*, $F(9, 117) = .65$, $p = .754$, $MS_E = 29.89$, *partial* $\mu^2 = .05$. They showed no *Stage* by *Session* interaction effect, $F(9, 117) = 1.49$, $p = .160$, $MS_E = 30.51$, *partial* $\mu^2 = .10$.

Table 64

Mean percentage of time spent over threshold, with accompanying standard deviations, during each of the audio participants' enhancement sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	40.41	2.61	50.74	9.05
2	41.58	2.61	45.84	8.20
3	42.34	2.72	44.63	9.74
4	42.59	3.81	45.78	8.14
5	41.99	2.11	45.06	10.52
6	42.39	1.94	44.84	7.68
7	41.07	3.95	43.63	7.80
8	42.79	3.34	44.83	6.41
9	42.37	3.32	43.59	11.4
10	41.71	2.32	45.31	6.40

1.3. Enhancement Training Summary

A summary of the results for the enhancement training can be seen in Tables 65 and 66, below.

Only the participants in the audio-visual group showed a main effect of *Segment* with both participants producing a larger difference between baseline and training in segment *1* than in segment *2* using both amplitude and per cent time as the measure. This was due to participants going from below baseline levels at the start of training to above baseline levels as training progressed and therefore is nonetheless indicative of enhancement. All three groups showed a main effect of *Period* for both the amplitude and the per cent time measure. However, in the case of the audio-visual and visual groups this is due to participants showing a larger difference between baseline and training in periods 1 and 2 than in later periods. Once more they go from below baseline to above baseline levels as training progresses so, again, these results are indicative of enhancement. None of the feedback groups showed any *Segment* by *Period* interactions.

Across sessions, only the audio participants showed a main effect of *Stage* due to participants spending more time over threshold during enhancement training than they did during baseline and producing a larger mean amplitude during training than they did during baseline. Only the amplitude measure showed a main effect of *Session* although the only significant effects revealed when pairwise comparisons with Bonferonni's adjustments were performed to investigate this were with visual participants producing a greater amplitude in *Session 7* than in *Session 1* and audio participants producing a greater amplitude in *Session 9* than in *Session 1*. None of the feedback groups showed a *Stage* by *Session* interaction.

Table 65.

Summary of the main effects shown by each of the three feedback groups (audio-visual versus visual versus audio) for both the amplitude and the per cent time measure within sessions in comparison to baseline during participants' enhancement training. All significant main effects are listed and where there are main effects any resulting pairwise comparisons (with a Bonferroni's adjustment) found to be significant are listed. All effects which represent a change in the opposite direction to that which would be indicative of enhancement are highlighted in yellow.

	Amplitude			**Per Cent Time**		
	Audio-Visual	**Visual**	**Audio**	**Audio-Visual**	**Visual**	**Audio**
Segment	Yes Seg 1 > Seg 2	No	No	Yes Seg 1 > Seg 2	No	No
Period	Yes 1 > 2-5 2 > 4	Yes 1 > 2-5 4 > 2 4 > 5	Yes	Yes 1 > 2-5 2 > 4	Yes 1 > 2-5 5 > 4	Yes 1 > 2-5
Segment by Period	No	No	No	No	No	No

Table 66.

Summary of the main effects shown by each of the three feedback groups (audio-visual versus visual versus audio) for both the amplitude and the per cent time measure across sessions in comparison to baseline during participants' enhancement training. All significant main effects are listed and where there are main effects any resulting pairwise comparisons (with a Bonferroni's adjustment) found to be significant are listed.

	Amplitude			**Per Cent Time**		
	Audio-Visual	**Visual**	**Audio**	**Audio-Visual**	**Visual**	**Audio**
Stage	No	No	Yes Training > Baseline	No	No	Yes Training > Baseline
Session	Yes	Yes 1 > 7	Yes 1 > 9	No	No	No
Stage by Session	No	No	No	No	No	No

2. Suppression Training

As with the experiments in the previous chapters, the aim of suppression training was for the participants to learn to consciously decrease the amplitude of the alpha they produced and to increase the amount of time they produced alpha at below-threshold levels. For the amplitude measure, then, a decrease over time is the goal but with the per cent time measure an increase over time is the goal except this time it is an increase in time spent *below* threshold as opposed to with the enhancement training where it was an increase in the amount of time spent *above* threshold.

All the same calculations and analyses performed on the enhancement data, above, were performed in the same way here for the suppression data in order to maintain consistency. For the results of the overarching omnibus ANOVAS providing direct comparisons between the the three training conditions, however, see Appendix L.

2.1. Within Sessions in Comparison to Baseline

The within sessions data (i.e. training minus baseline) for each of the three feedback groups can be seen in Tables 67 and 68, below.

As with the enhancement data, a 2 (Segment: *Segment 1* vs *Segment 2*) x 5 (Period: *Period 1 – Period 5*) repeated measures analyses of variance (ANOVA) were performed on each of the two measures (i.e. amplitude and per cent time) in order to look for changes within sessions in comparison to baseline. Again, this was done for the analyses of each of the three feedback groups separately due to the audio and audio-visual participants' data needing to be log transformed whereas the visual group's data did not.[9]

2.1.1. Amplitude

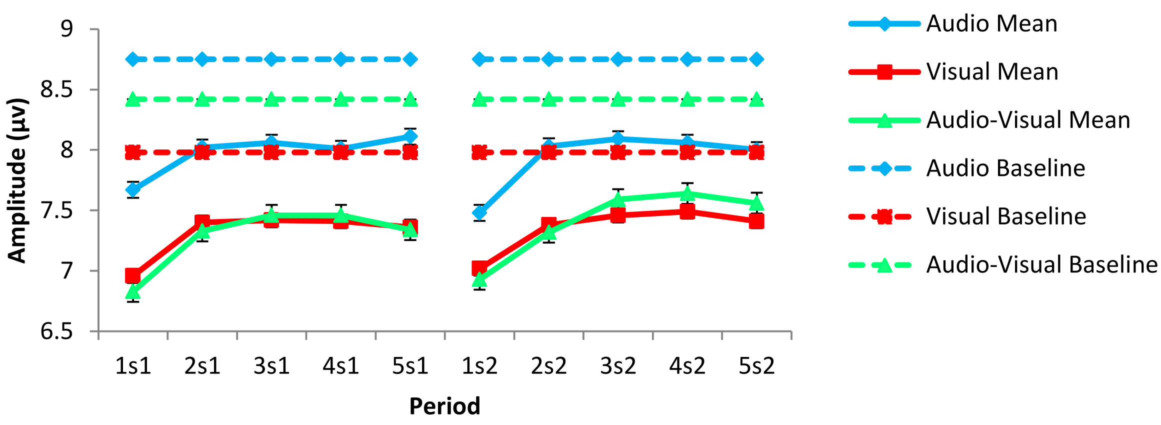

Figure 43: Mean amplitude (with standard error bars) for each period during training and during baseline for each of the three feedback groups during their suppression training (where error bars cannot be seen this is due to them being large enough to be visible on the graph)

2.1.1.1. Audio-Visual Participants

The audio-visual participants showed no main effect of *Segment*, $F(1, 14) = 3.68$, $p = .076$, $MS_E = .00$, *partial* $\mu^2 = .21$. They showed a significant main effect of *Period*, $F(2.41, 33.77) = 17.90$, $p < .001$, $MS_E = .01$, *partial* $\mu^2 = .56$. They showed no *Segment* by *Period* interaction effect, $F(1.98, 27.76) = 1.01$, $p = .376$, $MS_E = .00$, *partial* $\mu^2 = .07$.

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[9] The same reason for not using z scores to enable feedback group to be included as a factor in the analyses applies here as it did for the enhancement training (see footnote 7).

Pairwise comparisons with a Bonferroni's adjustment to investigate the main effect of *Period* revealed that participants showed a larger difference between baseline and training in *period* $1_{s1, s2}$ than they did in *periods* $2_{s1, s2}$ (p = .004, d = .28), $3_{s1, s2}$ (p = .001, d = .42), *period* $4_{s1, s2}$ (p < .001, d = .45) and $5_{s1, s2}$ (p = .006, d = .37).

Table 67

Within sessions comparison to baseline means and standard deviations (SD) for the audio-visual, visual, and eyes open audio feedback groups during their suppression training for the amplitude measure. Negative numbers are indicative of where the mean amplitude during training was less than that of the mean amplitude during baseline.

Period	Audio-Visual Mean	Audio Visual SD	Visual Mean	Visual SD	Audio Mean	Audio SD
1_{s1}	-1.59	1.74	-1.02	0.93	-1.07	1.44
2_{s1}	-1.09	1.65	-0.58	0.85	-0.73	1.14
3_{s1}	-0.96	1.61	-0.57	0.87	-0.69	1.24
4_{s1}	-0.96	1.70	-0.57	0.8	-0.73	1.21
5_{s1}	-1.08	1.56	-0.62	0.97	-0.64	1.13
1_{s2}	-1.49	1.84	-0.96	0.85	-1.26	1.72
2_{s2}	-1.10	1.63	-0.60	0.90	-0.72	1.09
3_{s2}	-0.83	1.62	-0.52	0.99	-0.66	1.13
4_{s2}	-0.78	1.45	-0.49	0.88	-0.69	1.24
5_{s2}	-0.86	1.60	-0.57	0.96	-0.74	1.23

2.1.1.2. *Visual Participants*

The visual participants showed no main effect of *Segment*, $F(1, 16) = .81$, $p = .382$, $MS_E = .09$, *partial* $\mu^2 = .05$. They showed a significant main effect of *Period*, $F(4, 64) = 32.07$, $p < .001$, $MS_E = .04$, *partial* $\mu^2 = .67$. There was no *Segment* by *Period* interaction effect, $F(2.47, 39.52) = .26$, $p = .816$, $MS_E = .07$, *partial* $\mu^2 = .02$.

In order to investigate the main effect of *Period*, pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that participants produced a larger difference in amplitude between baseline and training in *period* $1_{s1, s2}$, than they did in *periods* $2_{s1, s2}$ ($p < .001$, $d = .46$), $3_{s1, s2}$ ($p < .001$, $d = .44$), $4_{s1, s2}$ ($p < .001$, $d = .53$) and $5_{s1, s2}$ ($p < .001$, $d = .43$). No other differences were found to be significant.

2.1.1.3. *Audio Participants*

The audio participants showed no main effect of *Segment*, $F(1, 14) = .08$, $p = .777$, $MS_E = .75$, *partial* $\mu^2 = .01$. They showed a significant main effect of *Period*, $F(1.71, 23.88) = 8.95$, $p = .002$, $MS_E = .35$, *partial* $\mu^2 = .39$. They showed no *Segment* by *Period* interaction effect, $F(4, 56) = .80$, $p = .530$, $MS_E = .10$, *partial* $\mu^2 = .05$.

In order to investigate the main effect of Period, pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that participants produced a larger difference between baseline and training in *period* $1_{s1, s2}$ than they did in *periods* $3_{s1, s2}$ ($p = .016$, $d = .35$), $4_{s1, s2}$ ($p = .031$, $d = .32$), and $5_{s1, s2}$ ($p = .021$, $d = .34$).

2.1.2. Per Cent Time

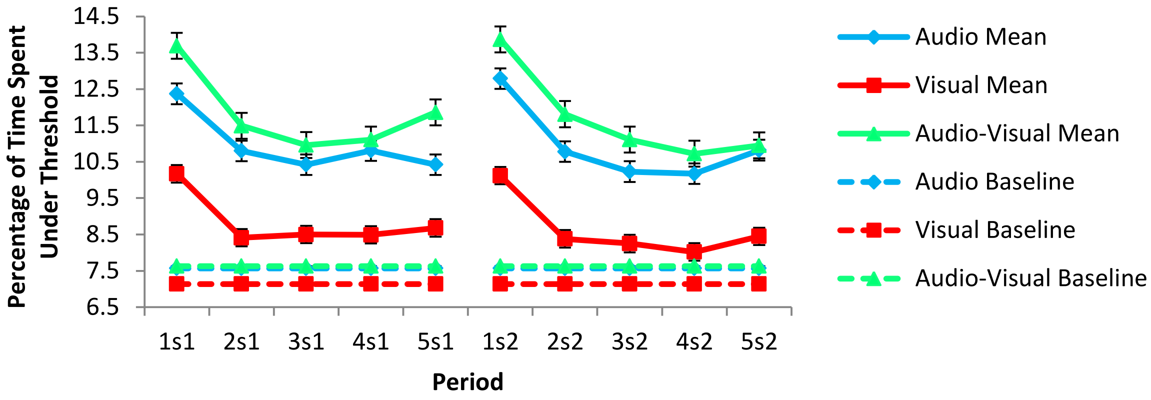

Figure 44: Mean percentage of time spent under threshold (with standard error bars) for each period during training in comparison to baseline for each of the three feedback groups during their suppression training

2.1.2.1. Audio-Visual Participants

The audio-visual participants showed no main effect of *Segment*, $F(1, 14) = .88$, $p = .363$, $MS_E = .04$, *partial* $\mu^2 = .06$. They showed no main effect of *Period*, $F(1.02, 14.31) = 2.64$, $p = .126$, $MS_E = .31$, *partial* $\mu^2 = .16$. They showed no *Segment* by *Period* interaction effect, $F(1.07, 15.00) = .88$, $p = .372$, $MS_E = .07$, *partial* $\mu^2 = .06$.

2.1.2.2. Visual Participants

There was no main effect of *Segment*, $F(1, 16) = 1.10$, $p = .309$, $MS_E = 1.63$, *partial* $\mu^2 = .07$. There was a significant main effect of *Period*, $F(2.22, 35.46) = 25.94$, $p < .001$, $MS_E = 1.48$, *partial* $\mu^2 = .62$. There was no *Segment* by *Period* interaction effect, $F(4, 64) = .43$, $p = .787$, $MS_E = .60$, *partial* $\mu^2 = .03$.

In order to investigate the main effect of *Period*, pairwise comparisons with a Bonferroni's adjustment were performed. These revealed that participants showed a larger difference between baseline and training in *period* $1_{s1, s2}$ than they did in *periods* $2_{s1, s2}$ ($p < .001$, $d = .64$), $3_{s1, s2}$ ($p < .001$, $d = .64$), $4_{s1, s2}$ ($p < .001$, $d = .71$) and $5_{s1, s2}$ ($p < .001$, $d = .56$). This decrease in the amount of time participants spent under threshold as training progressed is in the opposite direction to what would be hoped for during suppression training. No other differences were found to be significant.

Table 68

Within sessions comparison to baseline means and standard deviations (SD) of the amount of time participants in each of the feedback groups spent under threshold during their suppression training.

Period	Audio-Visual Mean	Audio Visual SD	Visual Mean	Visual SD	Audio Mean	Audio SD
1_{s1}	6.05	8.96	3.04	3.05	4.79	7.66
2_{s1}	3.85	7.98	1.28	2.14	3.23	5.14
3_{s1}	3.33	7.75	1.37	2.25	2.85	5.15
4_{s1}	3.48	7.58	1.35	2.24	3.23	5.1
5_{s1}	4.23	7.89	1.54	2.56	2.85	4.64
1_{s2}	6.24	8.60	2.99	3.02	5.21	7.28
2_{s2}	4.17	7.67	1.24	2.63	3.21	4.67
3_{s2}	3.48	8.34	1.11	2.76	2.65	4.04
4_{s2}	3.09	6.59	0.89	2.34	2.59	4.06
5_{s2}	3.32	6.85	1.32	2.72	3.25	5.72

2.1.2.3. Audio Participants

The audio participants showed no main effect of *Segment*, $F(1, 14) = .06$, $p = .808$, $MS_E = .01$, *partial* $\mu^2 = .00$. They showed a significant main effect of *Period*, $F(1.20, 16.85) = 4.39$, $p = .046$, $MS_E = .04$, *partial* $\mu^2 = .24$. They showed no *Segment* by *Period* interaction effect, $F(1.56, 21.81) = .61$, $p = .514$, $MS_E = .01$, *partial* $\mu^2 = .04$.

In order to investigate the main effect of *Period*, pairwise comparisons with a Bonferroni's adjustment were performed. However, no significant differences were found.

2.2. Across Sessions in Comparison to Baseline

As with the analyses on the enhancement training data in section 1, above, the across sessions in comparison to baseline data was analysed using a 2 (Stage: *Baseline* vs *Training*) x 10 (Session: *Session 1 – Session 10*) repeated measures ANOVA on each of the two measures for each of the three feedback groups separately. Again, feedback group could not be added as a factor in the analyses due to the visual group having normally distributed data and the audio group – in the case of the amplitude measure – and the audio and audio-visual group – in the case of the per cent time measure – having non-normally distributed data and therefore needing to be log transformed prior to anlayses.[10]

[10] The same reason for not using z scores to enable feedback group to be included as a factor in the analyses applies here as it did for the enhancement training (see footnote 9).

2.2.1. Amplitude

The mean amplitudes produced by each feedback group during each session's baseline and training can be seen in Tables 69-71 and are illustrated in Figure 45, below.

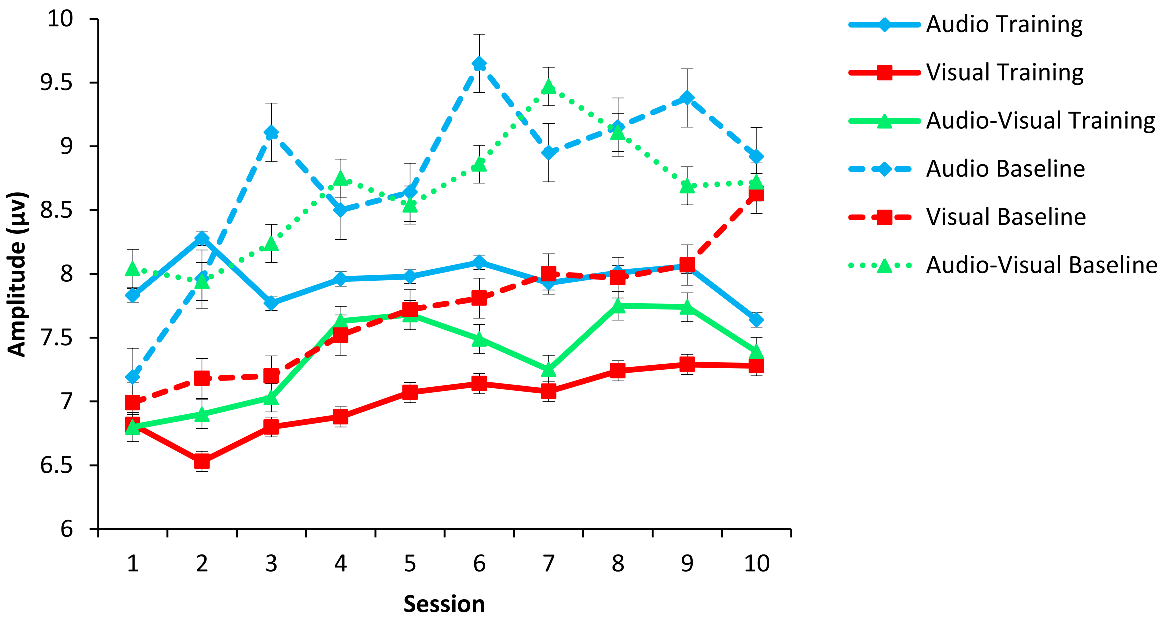

Figure 45: Mean amplitude (with standard error bars) for each session during suppression training and during baseline for each of the three feedback groups

2.2.1.1. Audio-Visual Participants

The audio-visual participants showed a main effect of *Stage*, $F(1, 12) = 7.89$, $p = .016$, $MS_E = 13.32$, *partial* $\mu^2 = .40$ due to participants producing a higher amplitude during their baseline ($M = 8.64$, $SE = .77$) than they did during their training ($M = 7.37$, $SE = .55$). They showed no main effect of *Session*, $F(4.22, 50.59) = 2.00$, $p = .16$, $MS_E = 3.89$, *partial* $\mu^2 = .14$. They showed no *Stage* by

Session interaction effect, $F(3.14, 37.63) = .90$, $p = .452$, $MS_E = 2.96$, *partial* $\mu^2 =$ .07.

Table 69

Mean amplitude and accompanying standard deviations during each of the audio-visual participants' suppression sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	8.04	2.97	6.80	1.93
2	7.94	3.48	6.90	2.37
3	8.24	2.63	7.03	2.10
4	8.75	3.05	7.63	2.15
5	8.54	3.09	7.68	2.16
6	8.86	3.23	7.49	2.26
7	9.47	3.49	7.25	1.79
8	9.11	3.19	7.75	2.07
9	8.69	2.75	7.74	2.21
10	8.72	3.18	7.39	2.02

2.2.1.2. Visual Participants

The visual participants showed a significant main effect of *Stage*, $F(1, 15) = 9.96$, $p = .007$, $MS_E = 3.90$, *partial* $\mu^2 = .40$ due to participants producing a larger amplitude during baseline ($M = 7.71$, $SE = .45$) than they did during training ($M = 7.01$, $SE = .37$). They showed a significant main effect of *Session*, $F(9, 135) = 3.77$,

$p < .001$, $MS_E = 1.11$, *partial* $\mu^2 = .20$. They showed a marginal *Stage* by *Session* interaction effect, $F(9, 135) = 1.90$, $p = .057$, $MS_E = .40$, *partial* $\mu^2 = .11$.

Table 70

Mean amplitude and accompanying standard deviations during each of the visual participants' suppression sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	6.99	1.63	6.82	1.63
2	7.18	1.55	6.53	1.58
3	7.20	1.68	6.80	1.52
4	7.52	1.67	6.88	1.46
5	7.72	2.17	7.07	1.66
6	7.81	2.37	7.14	1.54
7	8.00	2.08	7.08	1.42
8	7.97	2.09	7.24	1.69
9	8.07	2.08	7.29	1.71
10	8.63	2.88	7.28	1.78

In order to investigate the main effect of *Session*, pairwise comparisons with a Bonferroni's adjustment were performed. However, no differences were found to be significant.

In order to investigate the marginal *Stage* by *Session* interaction effect, a one way repeated measures ANOVA, split by *Stage*, was performed on the *Session* data. This revealed that during their baseline participants showed a significant main effect of *Session*, *F*(9, 135) = 3.63, $p < .001$, MS_E = 1.09, *partial* μ^2 = .20. Pairwise comparisons with Bonferroni's corrections to investigate this, however, did not reveal any significant effects. During their training, participants showed a marginal main effect of *Session*, *F*(3.93, 58.96) = 2.37, $p = .064$, MS_E = .96, *partial* μ^2 = .14. Pairwise comparison's with Bonferroni's corrections performed to investigate this, however, found no significant differences.

2.2.1.3. Audio Participants

Table 71

Mean amplitude and accompanying standard deviations during each of the audio participants' suppression sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	7.19	2.72	7.83	3.32
2	7.96	3.70	8.28	4.12
3	9.11	4.93	7.77	3.76
4	8.50	4.25	7.96	3.41
5	8.64	4.12	7.98	3.40
6	9.65	5.23	8.09	3.72
7	8.95	4.51	7.93	3.40
8	9.15	4.86	8.01	3.69
9	9.38	4.27	8.06	3.15
10	8.92	4.12	7.64	2.68

The audio participants showed a significant main effect of *Stage*, $F(1, 14) = 4.95$, $p = .043$, $MS_E = .07$, *partial* $\mu^2 = .26$ due to participants producing a larger amplitude during baseline ($M = 2.06$, $SE = .11$) than they did during training ($M = 2.00$, $SE = .10$). They showed a significant main effect of *Session*, $F(9, 126) = 2.03$, $p = .041$, $MS_E = .02$, *partial* $\mu^2 = .13$. They showed a significant *Stage* by *Session* interaction effect, $F(2.80, 39.19) = 3.86$, $p = .018$, $MS_E = .03$, *partial* $\mu^2 = .22$.

In order to investigate the main effect of *Session,* pairwise comparisons with a Bonferroni's adjustment were performed. However, no significant differences were found.

In order to investigate the *Stage* by *Session* interaction effect, a one way repeated measures ANOVA, split by *Stage*, was performed on the *Session* data. These revealed that during their baseline, participants showed a significant main effect of *Session*. Pairwise comparisons with a Bonferroni's adjustment performed to investigate this, however, found no significant effect. During their training, participants showed no main effect of *Session,* $F(3.56, 49.83) = .26$, $p = .881$, $MS_E = 0.04$, *partial* $\mu^2 = .02$.

2.2.2. Per Cent Time

The mean amount of time participants in each of the three feedback groups spent below threshold during each session's training and each session's baseline can be seen in Tables 72-74 and is illustrated in Figure 46, below.

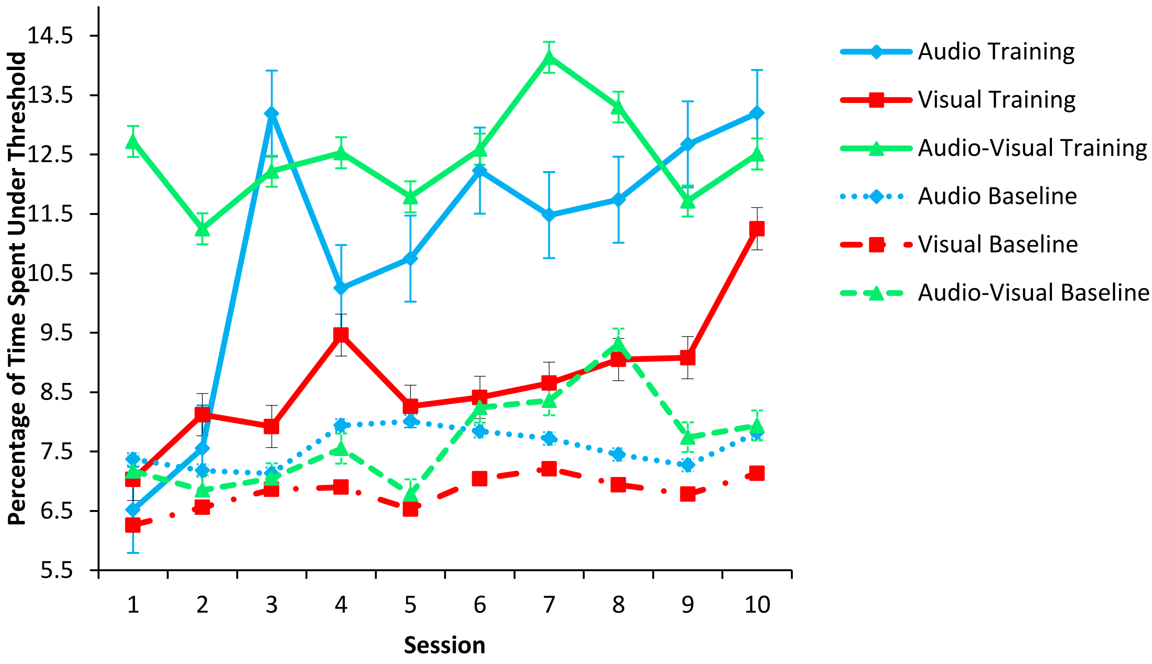

Figure 46. Mean percentage of time the participants in each of the three feedback groups spent under threshold (with standard error bars) during each session during suppression training

2.2.2.1. Audio-Visual Participants

The audio-visual participants showed a main effect of *Stage*, $F(1, 12) = 7.35$, $p = .019$, $MS_E = .79$, *partial* $\mu^2 = .38$ due to participants spending more time under their threshold during their training ($M = 2.29$, $SE = .16$) than during their baseline ($M = 1.99$, $SE = .07$). They showed no main effect of *Session*, $F(9, 108) = 1.32$, $p = .234$, $MS_E = .12$, *partial* $\mu^2 = .10$. There was no *Segment* by *Period* interaction effect, $F(9, 108) = .50$, $p = .871$, $MS_E = .06$, *partial* $\mu^2 = .04$.

Table 72

Mean percentage of time spent under threshold, with accompanying standard deviations, during each of the audio-visual participants' suppression sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	7.17	2.58	12.72	12.01
2	6.85	1.43	11.25	8.98
3	7.05	1.51	12.22	9.45
4	7.55	2.21	12.53	12.34
5	6.78	2.21	11.79	12.73
6	8.24	2.49	12.59	9.60
7	8.36	3.48	14.14	10.81
8	9.32	3.41	13.30	13.13
9	7.74	2.23	11.72	8.89
10	7.94	3.70	12.51	7.75

2.2.2.2. Visual Participants

There was a main effect of *Stage*, $F(1, 15) = 12.06$, $p = .003$, $MS_E = 24.00$, *partial* $\mu^2 = .45$ due to participants spending more time under threshold during training ($M = 6.82$, $SE = .41$) than they did during baseline ($M = 8.72$, $SE = .89$). There was no main effect of *Session*, $F(3.33, 49.91) = 1.45$, $p = .238$, $MS_E = 26.71$, *partial* $\mu^2 = .09$. There was a marginal *Stage* by *Session* interaction effect, $F(9, 135) = 1.86$, $p = .064$, $MS_E = 3.91$, *partial* $\mu^2 = .11$.

In order to investigate the marginal *Stage* by *Session* interaction effect, a one way repeated measures ANOVA, split by *Stage*, was performed on the *Session* data. This revealed that during their baseline participants showed no main effect of *Session*, $F(4.47, 67.03) = .52$, $p = .740$, $MS_E = 5.38$, *partial* $\mu^2 = .03$. During their training they also showed no main effect of *Session*, $F(3.57, 53.61) = 1.82$, $p = .146$, $MS_E = 27.97$, *partial* $\mu^2 = .11$.

Table 73

Mean percentage of time spent under threshold, with accompanying standard deviations, during each of the visual participants' suppression sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	6.26	1.20	7.03	3.16
2	6.56	1.58	8.12	4.45
3	6.86	2.36	7.92	3.12
4	6.90	2.59	9.46	5.45
5	6.53	1.92	8.26	4.14
6	7.04	1.81	8.41	5.55
7	7.21	2.36	8.65	3.49
8	6.94	2.57	9.05	4.25
9	6.78	2.65	9.08	3.85
10	7.13	2.99	11.25	7.97

2.2.2.3. Audio Participants

The audio participants showed a significant main effect of *Stage*, $F(1, 14) = 4.90$, $p = .044$, $MS_E = .51$, *partial* $\mu^2 = .26$ due to participants spending more time under threshold during training (*M* = 2.11, *SE* = .17) than they did during baseline (*M* = 1.93, *SE* = .10). There was no main effect of *Session*, $F(4.19, 58.59) = 2.25$, $p = .072$, $MS_E = .32$, *partial* $\mu^2 = .14$. There was a *Stage* by *Session* interaction effect, $F(4.34, 60.71) = 2.80$, $p = .030$, $MS_E = .19$, *partial* $\mu^2 = .17$.

Table 74

Mean percentage of time spent under threshold, with accompanying standard deviations, during each of the audio participants' suppression sessions, both during the baselines and during the training

Session	Baseline Mean	Baseline SD	Training Mean	Training SD
1	7.37	3.35	6.52	4.04
2	7.18	3.48	7.55	4.79
3	7.13	3.36	13.19	9.48
4	7.94	3.89	10.25	7.06
5	8.01	3.94	10.75	8.34
6	7.84	3.81	12.23	9.72
7	7.72	3.31	11.48	9.59
8	7.45	3.58	11.74	11.48
9	7.27	3.02	12.67	9.68
10	7.82	2.79	13.20	12.71

In order to investigate the main effect of *Session,* a one way repeated measures ANOVA, split by *Stage*, was performed on the *Session* data. This revealed that during baseline participants showed no main effect of *Session*, $F(3.89, 54.43) = .54$, $p = .703$, $MS_E = .18$, *partial* $\mu^2 = .04$. During their training they showed a significant main effect of *Session,* $F(9, 126) = 3.38$, $p = .001$, $MS_E = .16$, *partial* $\mu^2 = .19$. Pairwise comparisons with a Bonferroni's adjustment performed to investigate this main effect of *Session* during training showed that participants spent less time under threshold during *Session 1* than they did during *session 3* ($p = .036$, $d =$) but no other effects were found to be significant.

2.3. Suppression Training Summary

A summary of the results for the suppression training can be seen in Tables 75 and 76, below.

None of the feedback groups showed a main effect of *Segment* or a *Period* by *Segment* interaction effect, regardless of the measure used. All the feedback groups showed a main effect of *Period* using the amplitude measure and only the audio-visual group did not show a main effect of *Period* when per cent time was used as the measure. In each case, however, pairwise comparisons using Bonferroni's corrections revealed that this was due to there being a larger difference between baseline and training in *period 1* than in later *periods* which is the opposite to what would be hoped for during suppression training.

Across sessions all groups showed a main effect of *Stage* for both the amplitude and the per cent time measures. This was due to participants in each group spending more time under threshold during training than they did during baseline and producing lower amplitudes during training than during baseline, both of which are indicative of suppression training. The only main effects of *Session* were seen when amplitude was used as the measure and only for the visual and the audio groups, not the audio-visual group. The visual group showed a marginal *Stage* by *Session* interaction effect for both the amplitude and the per cent time measure although this was due to a significant effect of *Session* during

Table 75.

Summary of the main effects shown by each of the three feedback groups (audio-visual versus visual versus audio) for the amplitude measure within- and across sessions in comparison to baseline during participants' suppression training. All significant main effects are listed and where there are main effects any resulting pairwise comparisons (with a Bonferroni's adjustment) found to be significant are listed. All effects which represent a change in the opposite direction to that which would be indicative of enhancement are highlighted in yellow.

	Amplitude		
	Audio-Visual	**Visual**	**Audio**
Within Sessions in Comparison to Baseline			
Segment	No	No	No
Period	Yes	Yes	Yes
	1 > 2-5	1 > 2-5	1 > 3-5
Segment by Period	No	No	No
Across Sessions in Comparison to Baseline			
Stage	Yes	Yes	Yes
	Baseline > Training	Baseline > Training	Baseline > Training
Session	No	Yes	Yes
Stage by Session	No	Marginal	Yes
		Baseline	Baseline

Table 76.

Summary of the main effects shown by each of the three feedback groups (audio-visual versus visual versus audio) for the per cent time measure within- and across sessions in comparison to baseline during participants' suppression training. All significant main effects are listed and where there are main effects any resulting Pairwise comparisons (with a Bonferroni's adjustment) found to be significant are listed. All effects which represent a change in the opposite direction to that which would be indicative of enhancement are highlighted in yellow.

		Per Cent Time	
	Audio-Visual	**Visual**	**Audio**
Within Sessions in Comparison to Baseline			
Segment	No	No	No
Period	No	Yes 1 > 2-5	Yes
Segment by Period	No	No	No
Across Sessions in Comparison to Baseline			
Stage	Yes Training > Baseline	Yes Training > Baseline	Yes Training > Baseline
Session	No	No	No
Stage by Session	No	Marginal	Yes Training 1 < 3

baseline for the visual participants. The audio group showed a significant *Stage* by *Session* interaction effect for both measures but interestingly whereas this was due to a main effect of *Session* during baselines when amplitude was used as the measure it was due to a main effect of *Session* during training when per cent time was used as the measure.

3. Further Analyses – Within Sessions t Tests

Although the within sessions in comparison to baseline analyses takes baseline in to account, unlike the across sessions in comparison to baseline it does not actually check to see if the difference between baseline and training is a significant one or not. So in the case of the audio feedback group, it is clear that, unlike the other 2 feedback groups, they spend the majority of their time over baseline levels during their enhancement training. Whilst the results of the analyses so far have shown that they are increasing their alpha over time within sessions and that this change is over baseline, what the analyses do not say is whether or not that difference is a significant one in comparison to baseline. In order to investigate this, then, one way *t* tests were performed to compare the difference between baseline and training (seen in Table 57 for amplitude and Table 58 for per cent time) to zero with baseline being taken as zero and the difference score taken as representing training. Only the period with the highest difference score and the period with the lowest difference score were compared to zero in order to reduce the number of comparisons which needed to be made, with the assumption that if both of those periods were found to be significantly different to zero then the remaining periods with scores in between would also be. In order to reduce the chances of making a Type 1 error, unless otherwise stated, $p < .025$ was taken as the significance level instead of $p < .05$ in order to adjust for making 2 comparisons each time.

3.1. Enhancement Training

3.1.1. Amplitude

Given that the aim of enhancement training is to try and increase the amplitude of alpha over that which occurred naturally during baseline, only the *Periods* which were above baseline levels were looked at.

3.1.1.1. Audio-Visual Participants

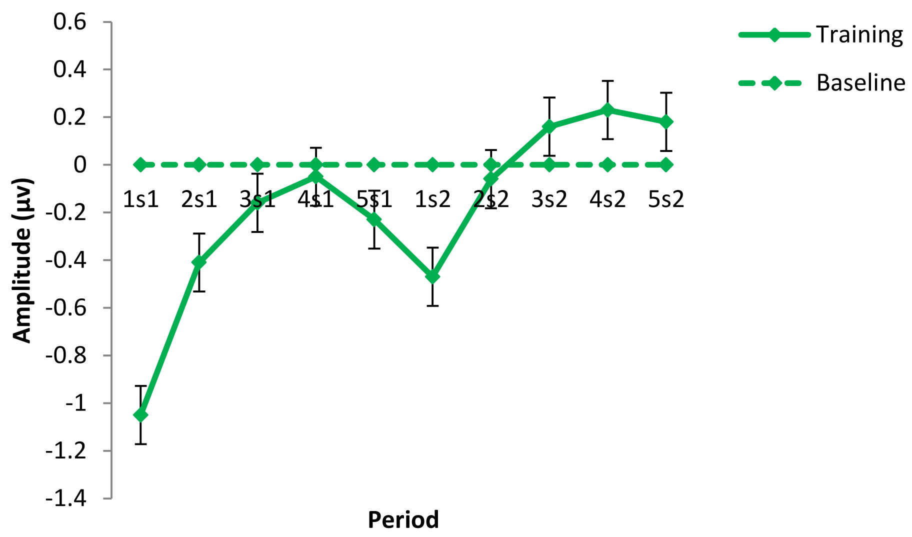

Figure 47. The difference between baseline and training using the amplitude measure for the audio-visual participants during their enhancement training

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 3_{s2} and 4_{s2} respectively (see Figure 47, above). One sample *t* tests to compare the average amplitude of each of these *periods* during training to zero revealed that neither *period* 3_{s2}, $t(14) = .64$, $p = .533$, nor *period* 4_{s2}, $t(14) = .75$, $p = .468$, showed a significant difference to zero.

3.1.1.2. Visual Participants

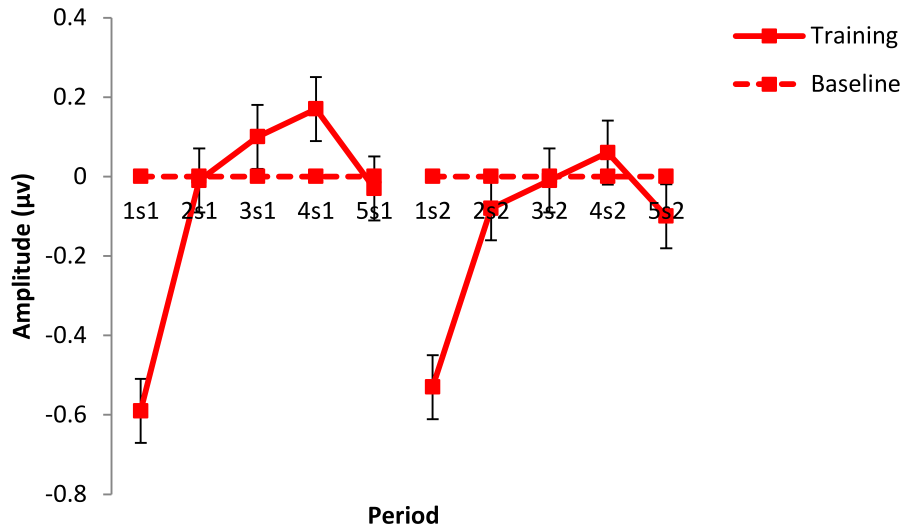

Figure 48. The difference between baseline and training using the amplitude measure for the visual participants during their enhancement training

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 4_{s2} and 4_{s1} respectively (see Figure 48, above). One sample *t* tests to compare the average amplitude of each of these *periods* during training to zero revealed that neither *period* 4_{s2}, $t(16) = .27$, $p = .792$, nor *period* 4_{s1}, $t(16) = .75$, $p = .464$, showed a significant difference to zero.

3.1.1.3. Audio Participants

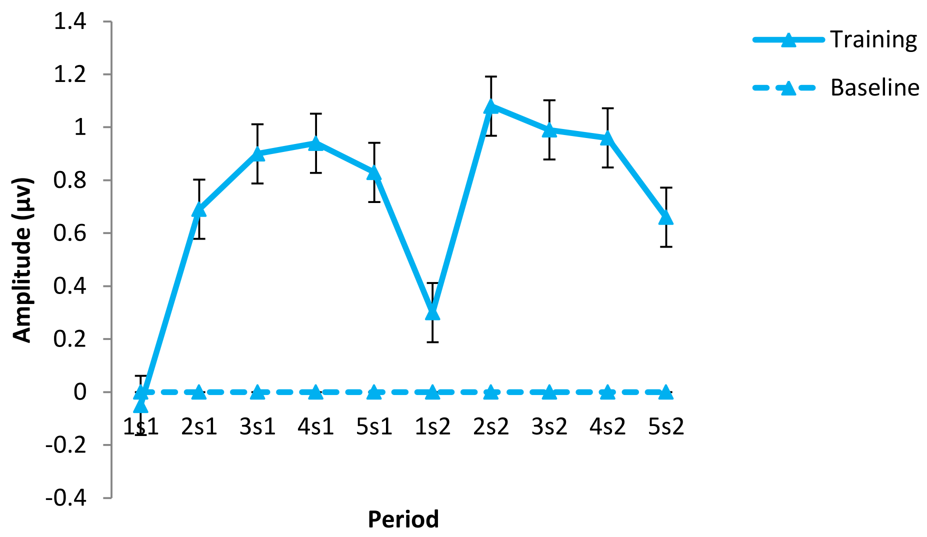

Figure 49. The difference between baseline and training using the amplitude measure for the audio participants during their enhancement training

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 1_{s2} and 2_{s2} respectively (see Figure 49, above). One sample *t* tests to compare the average amplitude of each of these *periods* during training to zero revealed that both *period* 1_{s2}, $t(14) = 19.14$, $p < .001$, and *period* 2_{s2}, $t(14) = 25.92$, $p < .001$, showed a significant difference to zero.

3.1.2. Per cent Time

3.1.2.1. Audio-Visual Participants

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 3_{s2} and 4_{s2} respectively (see Figure 50, below). One sample *t* tests to compare the average per cent time measure of each of these *periods* during training to zero revealed that neither *period* 3_{s2}, $t(14) = .81$, $p = .431$, nor *period* 4_{s2}, $t(14) = 1.02$, $p = .323$, showed a significant difference to zero.

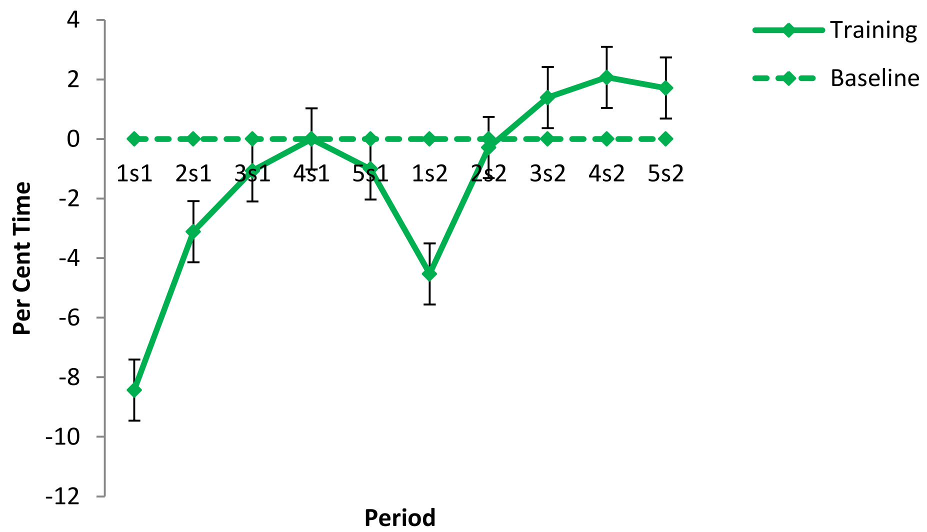

Figure 50. The difference between baseline and training in the amount of time participants spent over threshold for the audio-visual participants during their enhancement training

3.1.2.2. Visual Participants

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 4_{s2} and 4_{s1} respectively (see Figure 51, below). One sample *t* tests to compare the average per cent time measure of each of these *periods* during training to zero revealed that neither *period* 4_{s2}, $t(16) = .24$, $p = .811$, nor *period* 4_{s1}, $t(16) = .41$, $p = .687$, showed a significant difference to zero.

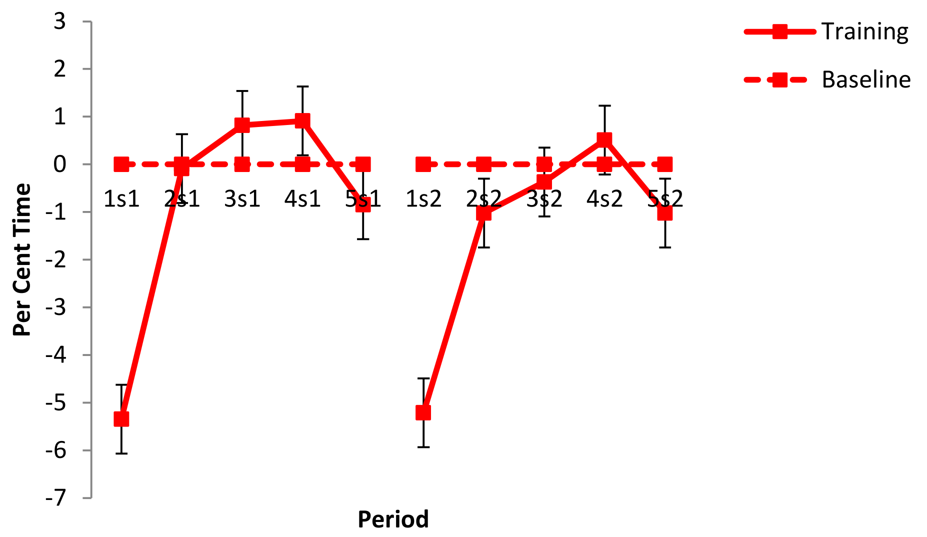

Figure 51. The difference between baseline and training in the amount of time participants spent over threshold for the visual participants during their enhancement training

3.1.2.3. Audio Participants

Unlike the preceding sections, all the effects discussed here in relation to the audio participants' data using the per cent time measure are done so using $p < .0125$ as the significance level in order to adjust for making 4 comparisons.

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 1_{s2} and 2_{s2} respectively (see Figure 52, below). One sample *t* tests to compare the average per cent time measure of each of these *periods* during training to zero revealed that although *period* 1_{s2}, $t(14) = .99$, $p = .339$, did not show any significant difference to zero, *period* 2_{s2}, $t(14) = 2.95$, $p = .011$, did. *Period* 3_{s2} (the fourth largest period) showed a significant difference to zero, $t(14) = 2.99$, $p = .010$, whereas *period* 3_{s1} (the fifth largest period) did not, $t(14) = 2.66$, $p = .019$.

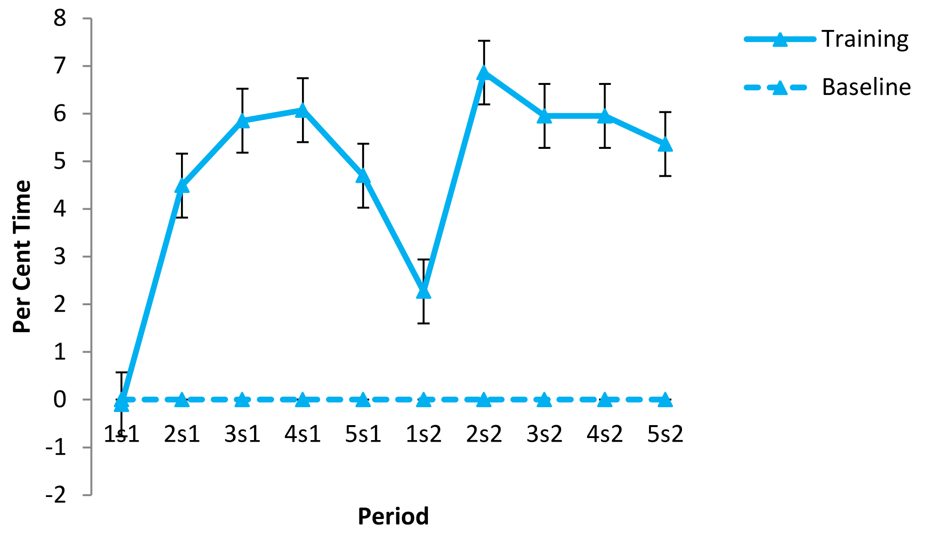

Figure 52. The difference between baseline and training in the amount of time participants spent over threshold for the audio participants during their enhancement training

3.1.3. Enhancement Training Summary

A summary of the results can be seen in Table 77, below.

The results of the one sample *t* tests revealed that neither the audio-visual nor the visual participants showed a significant difference between baseline and training when they were successfully keeping their alpha over baseline levels, regardless of whether amplitude or per cent time was the measure used. The audio participants, however, showed a significant difference to baseline in the amount of amplitude they produced during training for all but the first *period* of the first *Segment*. They also significantly enhanced their alpha over baseline levels when per cent time was used as the measure but only for some of the *periods* in each *Segment* as opposed to all of them.

Table 77

The results of the t tests to indicate whether or not any of the three feedback groups showed evidence of producing significantly more alpha within sessions during their enhancement training than they did during their baselines.

	Enhancement	
	Amplitude	**Per Cent Time**
Audio	Yes	Partly
Visual	No	No
Audio-Visual	No	No

3.2. Suppression Training

3.2.1. Amplitude

3.2.1.1. Audio-Visual Participants

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 4_{s2} and 1_{s1} respectively (see Figure 53, below). One sample *t* tests to compare the average amplitude of each of these *periods* during training to zero revealed that both *period* 4_{s2}, $t(14) = 31.03$, $p < .001$, and *period* 1_{s1}, $t(14) = 30.33$, $p < .001$, showed a significant difference to zero.

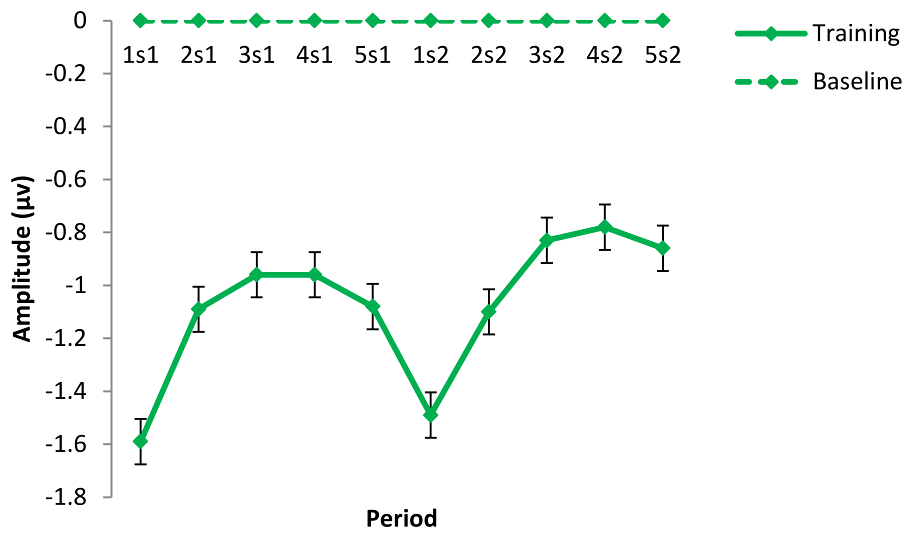

Figure 53. The difference between baseline and training using the amplitude measure for the audio-visual participants during their suppression training

3.2.1.2. Visual Participants

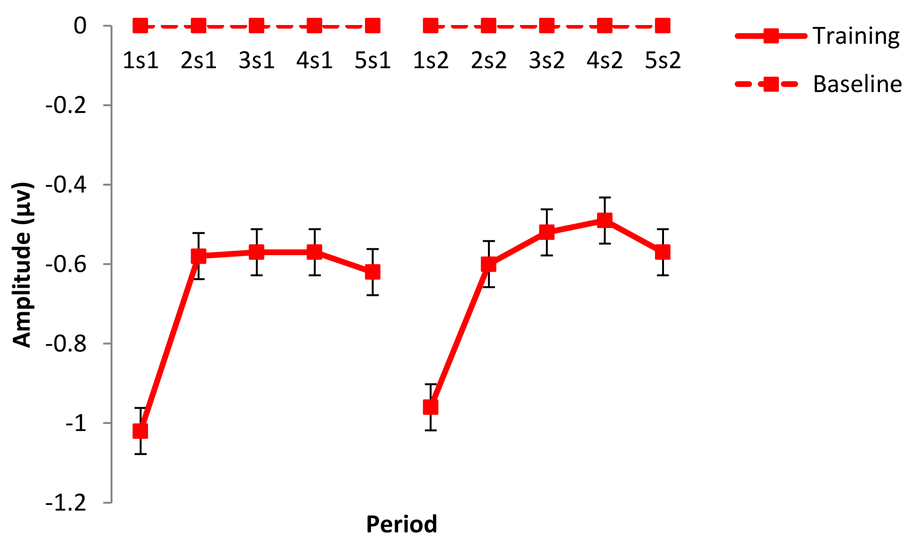

Figure 54. The difference between baseline and training using the amplitude measure for the visual participants during their suppression training

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 4_{s2} and 1_{s1} respectively (see Figure 54, above). One sample *t* tests to compare the average amplitude of each of these *periods* during training to zero revealed that both *period* 4_{s2}, $t(16) = 25.79$, $p < .001$, and *period* 1_{s1}, $t(16) = 26.80$, $p < .001$, showed a significant difference to zero.

3.2.1.3. Audio Participants

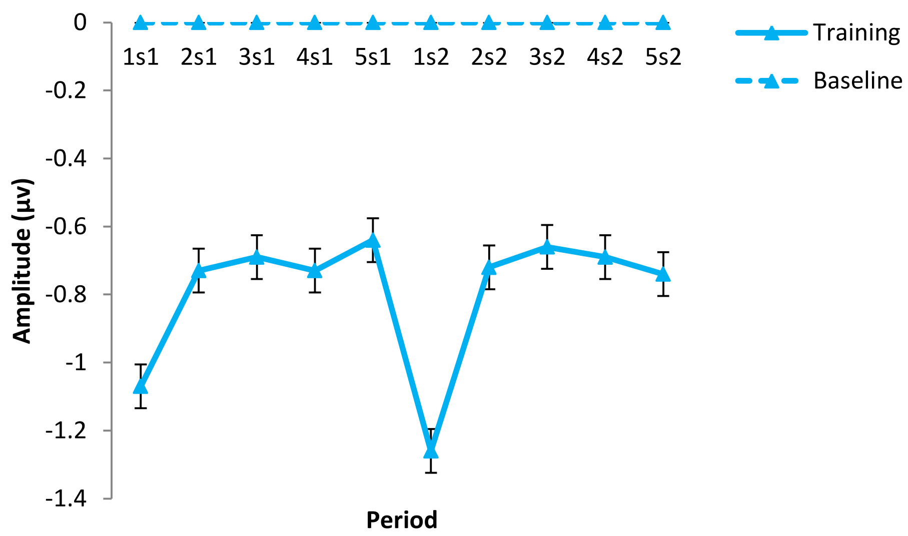

Figure 55. The difference between baseline and training using the amplitude measure for the audio participants during their suppression training

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 5_{s1} and 1_{s2} respectively (see Figure 55, above). One sample *t* tests to compare the average amplitude of each of these *periods* during training to zero revealed that both *period* 5_{s1}, $t(14) = 34.99$, $p <$

.001, and *period* 1_{s2}, $t(14) = 27.83$, $p < .001$, showed a significant difference to zero.

3.2.2. Per cent Time

3.2.2.1. Audio-Visual Participants

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 4_{s2} and 1_{s2} respectively (see Figure 56, below). One sample *t* tests to compare the average per cent time measure of each of these *periods* during training to zero revealed that both *period* 4_{s2}, $t(14) =$ 44.85, $p < .001$, and *period* 1_{s2}, $t(14) = 19.82$, $p < .001$, showed a significant difference to zero.

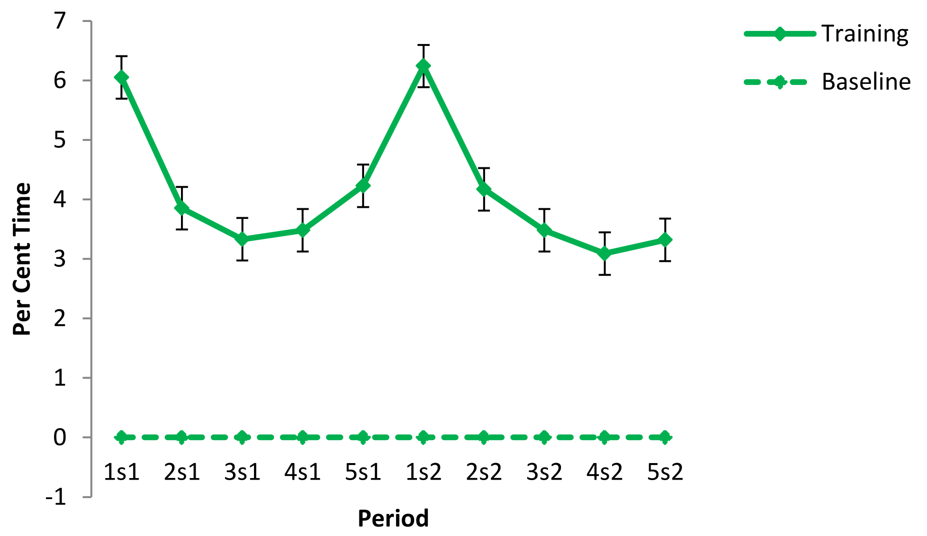

Figure 56. The difference between baseline and training in the amount of time participants spent under threshold for the audio-visual participants during their suppression training

3.2.2.2. Visual Participants

Unlike the preceding sections discussing suppression training, all the effects discussed here in relation to the visual participants' data using the per cent time measure are done so using $p < .0125$ as the significance level in order to adjust for making 4 comparisons.

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 4_{s2} and 1_{s1} respectively (see Figure 57, below). One sample *t* tests to compare the average per cent time measure of each of these *periods* during training to zero revealed that whereas *period* 4_{s2}, $t(16) = 1.57$, $p = .137$, did not show a significant difference to zero, *period* 1_{s1}, $t(16) = 4.11$, $p = .001$, did. *Period* 1_{s2} (the second largest *period*) showed a significant difference to zero, $t(16) = 4.09$, $p = .001$, whereas *period* 5_{s1} (the third largest *period*), did not, $t(16) = 2.49$, $p = .024$.

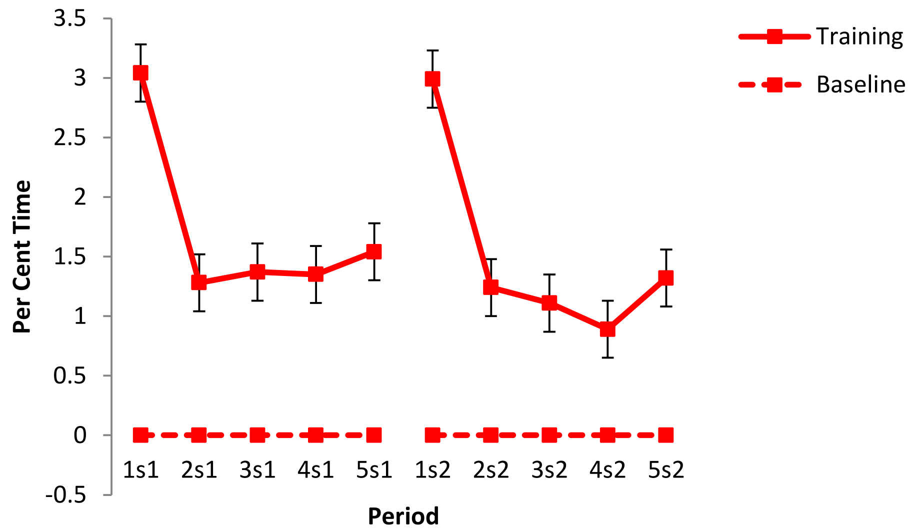

Figure 57. The difference between baseline and training in the amount of time participants spent under threshold for the audio-visual participants during their suppression training

3.2.2.3. Audio Participants

The two *periods* identified as having the smallest and highest (above baseline) difference scores were *periods* 4_{s2} and 1_{s2} respectively (see Figure 58, below). One sample *t* tests to compare the average amplitude of each of these *periods* during training to zero revealed that both *period* 4_{s2}, $t(14) = 103.28$, $p < .001$, and *period* 1_{s2}, $t(14) = 45.00$, $p < .001$, showed a significant difference to zero.

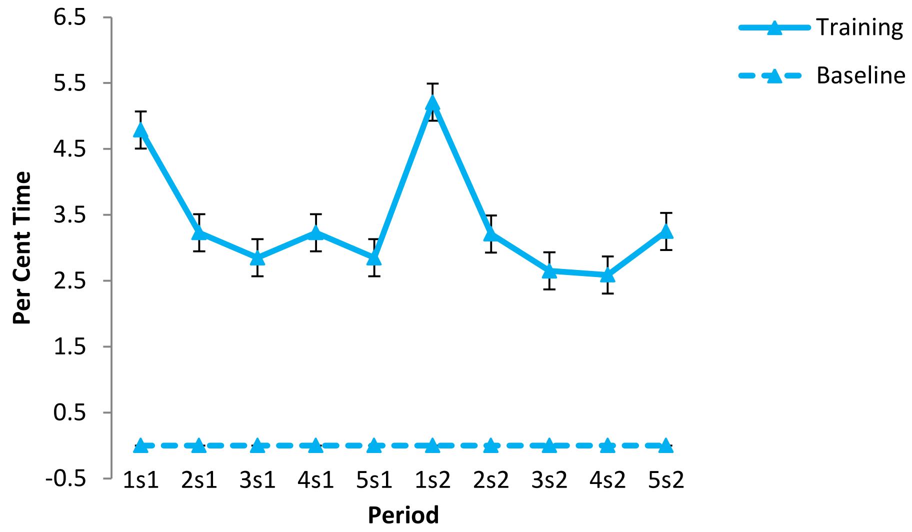

Figure 58. The difference between baseline and training in the amount of time participants spent under threshold for the audio participants during their suppression training

3.3. Suppression Training Summary

A summary of the results can be seen in Table 78, below.

The results of the one sample *t* tests revealed that both the audio-visual and the audio participants showed a significant difference to baseline in the amount of alpha that they produced, regardless of whether per cent time or amplitude was used as the measure. The visual participants, on the other hand, showed a significant difference between baseline and training when amplitude was used as the measure but when per cent time was used they only showed a significant difference between baseline and training in the first *period* of each *segment*.

Table 78

The results of the t tests to indicate whether or not any of the three feedback groups showed evidence of producing significantly less alpha within sessions during their suppression training than they did during their baselines.

	Suppression	
	Amplitude	**Per Cent Time**
Audio	Yes	Yes
Visual	Yes	Partly
Audio-Visual	Yes	Yes

Discussion

During the enhancement training, participants showed an increase over time within sessions. Interestingly, though, only the audio group spent the majority of their time above baseline levels whereas the audio-visual and visual participants spent most of theirs at or below baseline levels. Further, only the audio group showed a significant difference in the amount of alpha they produced within sessions during training compared to the amount of alpha they produced during baseline, as can be seen from section 3.1. of the results section, above. This was true of all above-baseline periods when amplitude was used as the measure although not for the entirety of their training when the per cent time was the measure used. Nonetheless, however, the audio group did show the ability to significantly enhance their amplitude over baseline levels within sessions and to show an increase in the amount of alpha they produced over time. The visual and audio-visual groups did show evidence of increasing their alpha over time within sessions but this increase is more attributable to a return to baseline after an initial suppression of alpha at the start of each segment rather than because they were showing the ability to increase it above their natural levels per se.

The lack of initial suppression in alpha at the start of each training *segment* which is shown by the audio group is interesting given the results from the previous experiments in this thesis. In the first experiment (see Chapter 3), it was noted that during every session at the start of each training segment participants showed an initial suppression in alpha below baseline. In other words, when they started trying to consciously increase their alpha, their alpha initially showed a drop below that which they were producing when they were not consciously trying to increase it (i.e. during their baselines). This is something which can be seen in the data presented by Vernon and Withycombe (2006) and is something which has also previously been reported by Plotkin (1978). The latter also, as in the first experiment here (see Chapter 3) showing that even after as many as 10 sessions participants' alpha can be seen to drop at the start of their training. This issue has already been discussed in depth in the Further Analysis 1 section of Chapter 4 but to summarise, Plotkin (1978) attributes the effect to participants needing to orientate themselves to the feedback and showing anxiety about their performance. Prewett and Adams (1976) also concur with the idea that participants' alpha will show an initial below-baseline increase due to needing to acclimatise to the feedback.

As already discussed in Chapter 3, one explanation for this effect is that participants may start each training segment with a more external focus whilst they wait for their feedback to occur. Once it has and they start to relax in to the situation and concentrate on what to do to elicit the feedback as opposed to waiting for the first initial validating response from the feedback, their attention becomes more internally orientated. Given that external attention is linked to a decrease in alpha and internal to an increase (Aftanas & Golocheikine, 2001; Bollimunta et al., 2011; Cooper et al., 2003) this is a plausible explanation.

Likewise, and on a related point, it has previously been noted that anticipation can have a suppressing effect on alpha (Klimesch, 1999; Tyson, 1987). The anticipation of waiting for the feedback to first occur and reassure the participants that they are doing the 'right' thing could therefore be having a suppressing effect via the anticipation element as opposed to, or even in addition to, the suppression being related to the focus of attention as such. In both instances, however, one would expect that the resulting suppressing effect would be seen regardless of the form the feedback was in (i.e. audio versus visual versus audio-visual). Interestingly, though, in the second experiment of this thesis (see Chapter 4) the initial alpha-suppression effect was not seen. It was therefore suggested that it could be to do with the type of feedback given. In experiment 1 the participants either received audio, visual, or audio-visual feedback whereas in experiment 2 they only received audio feedback. Both Walsh (1974) and Mullholland & Eberlin (1977) have posited that visual feedback has a suppressing effect on alpha with the latter going as far as calling visual feedback 'negative feedback' (Mullholland & Eberlin, 1977, p597). Approximately two thirds of the participants in the first experiment had visual feedback incorporated into their feedback which could explain why the sample showed this initial suppression effect when those in the second experiment, where visual feedback was not incorporated, did not. The results of the third experiment reported here support that notion with both the visual and audio-visual groups showing the initial alpha suppression at the start of each segment but the audio group not. Whether this relates back to focus of attention, i.e. perhaps attending to visual feedback is by its nature more externally orientating than audio which may offer the potential for a more internal focus, or some other difference between them is unclear.

The audio participants being the only one out of the three feedback groups to show a significant difference between baseline and training is also supported by the across sessions in comparison to baseline analyses. Here only the audio group showed a main effect of *Stage* due to participants producing more alpha during training than they did during baseline, regardless of the measure used. When it came to changes over time across sessions, however, only the amplitude measure showed any effects with all three feedback groups showing a change over time (although as can be seen from Figure 40 it was again only the audio group who consistently maintained their alpha above baseline levels as sessions progressed). Across sessions then there was no change in the amount of time participants spent over threshold as sessions progressed, and although there was a change in the amplitude of the alpha they produced, the lack of *Stage* by *Session* interaction suggests that whatever changes occurred, occurred simultaneously in the baseline and in the training. Potential reasons for this were discussed in the discussion section of Chapter 3 but as a reminder, given the evidence of enhancement shown by the within sessions in comparison to baseline data, this could mean that participants were enhancing their alpha from session 1 but that their ability to do so did not improve. If this is the case it may be because they are unable to increase their alpha any further than they did in session 1 or because they need more than 10 sessions to be able to do so. Alternatively it may be that as participants are learning to increase their alpha with each session, the effect of doing so is having a knock-on effect on their baseline alpha. This is something which has previously been reported by Cho et al. (2008) who found that the amplitude of participants' alpha at the end of their training sessions showed a positive correlation with the amplitude of their alpha in the eyes open baselines taken at the start of the next (see Chapter 1, section 3.8.4. for further discussion of the potential long-term effects of alpha neurofeedback training). Unfortunately, the idea that participants' baselines may be increasing due to their enhancement training is not one which can be definitively determined with the data in this current experiment due to the potential contamination from the suppression training. All the participants' sessions involved both increasing and decreasing their alpha and so if training alpha in one direction does have a knock-on effect on their resting levels of alpha then arguably so might training it in the other direction; making any effects difficult to pinpoint specifically. In fact, when correlations were performed on the data from this current experiment (see Appendix M) it was found that all participants showed a positive correlation between the amplitude of their alpha during each enhancement session to the amplitude of their alpha in the eyes open baselines at the start of the next session (see Tables 81-83). Whilst this supports Cho et al.'s (2008) findings it is noticeable that in fact nearly all of the eyes open baselines correlated with participants' performance in nearly all of the sessions. Given this, then, the most which could be said is that the amplitude of participants' resting alpha shows a correlation with the amplitude of their alpha during their enhancement training as opposed to specifically indicating that their performance during training shows a distinct relationship to their next sessions' baselines per se. Interestingly, when the participants' baselines at the end of each session were correlated with their baselines at the start of the next session some differences were shown as a function of whether participants trained to enhance or suppress their alpha first. For those whose training sessions involved enhancing and then suppressing their alpha each session (see Tables 84-86), the audio-visual participants showed no significant correlations, the visual participants showed significant correlations for the middle group of their sessions (i.e. sessions 3 through to 7), and the audio participants showed correlations between the baseline readings at the end of each session and the baselines taken at the start of the next session for all but the first session. For those whose training sessions involved suppressing and then enhancing their alpha each session (see Tables 87-89), the audio-visual participants showed significant correlations between the amplitude of their alpha in their baselines at the end of each session in comparison to the start of the next from session 2 onwards (with the exception of their alpha at the end of session 6 in comparison to at the start of session 7 where the correlation was only found to be marginally significant). The visual participants' alpha also showed significant correlations between their resting alpha at the end of each session in comparison to the start of the next and from session 2 onwards the audio participants likewise showed significant correlations between their baseline alpha at the end of each session when compared to their baselines at the start of the next. Although these findings again support Cho et al.'s (2008) and suggest that the effect is more pronounced for those who trained to enhance (as opposed to trained to suppress) their alpha directly before their end of session baselines – implying that the order they trained their alpha in (enhance then suppress versus suppress then enhance) had an effect on their baselines – again it should be noted that these were not the only correlations which were found to be significant. As can be seen from Tables 82-87, quite a few of the post-session baselines correlated with non-consecutive pre-session baselines which means directly attributing the results to an effect of training is not possible and may simply indicate that participants' alpha amplitudes on one day to another are related. In light of this it would be interesting to know if Cho et al.'s (2008) results were exclusively showing a relationship between the participants' alpha at the end of each training session to the start of the next session or if, had other correlations had been performed, participants' baselines were generally just correlating with each other and with the training. The former would indicate that training may have long-term effects, the latter could just mean that participants' alpha showed such a relationship for some other reason unrelated to the training itself. This would seem to be the case from the data in this experiment but, as already stated, the fact that – unlike in Cho et al's (2008) study – participants in this current experiment trained to both enhance and suppress their alpha means that no firm conclusions can be drawn in relation to why participants' baselines were rising alongside their training amplitudes.

With regards to their suppression training, both the audio and the visual groups showed a change over time within sessions both in the amplitude they produced and in the amount of time they spent under threshold. The audio-visual group, however, only showed a change over time within sessions in their amplitude, not in the amount of time they spent under their threshold. Unfortunately, however, this change in time within sessions was in the wrong direction to what would be hoped for during suppression training and was, in actual fact, due to participants showing an increase in the amplitude of their alpha and a decrease in the amount of time they spent below threshold. Interestingly, however, all three groups nonetheless produced significantly lower mean amplitudes during training than they did during their baselines which is indicative of successful alpha suppression. Both the audio and the audio-visual groups also spent significantly more time under threshold within sessions during their training than they did during their baselines. This indicates that the participants were suppressing their alpha within the sessions but that their ability to do so decreased over time. This could be because participants are successfully suppressing their alpha but the method they are using is not one which can be sustained over time. In Chapter 3 unconscious habituation, as opposed to conscious learning, was put forward as an explanation for why the suppression results showed an initial drop in alpha at the start of each training segment before gradually increasing back towards baselines. This could potentially explain the results of the audio-visual and visual feedback groups. Particularly given that the visual participants only showed a significant suppression of alpha in relation to baseline for the first period of each segment. However, as with the previous experiment (see Chapter 4), this explanation is unlikely for the audio participants because they did not, as already mentioned above, show that initial suppression of alpha at the start of each training segment within sessions. The explanation that participants are able to suppress their alpha but unable to sustain that ability at a continued rate over time is the more likely of the explanations here, then. This could mean that they did not receive enough sessions or it could mean that they reached the limit of their suppression ability from the start.

The across sessions data also supported the within sessions results showing that all three of the feedback groups spent more time under threshold during their training and produced lower amplitudes during their training sessions than they did during their baselines. Both the visual and audio groups demonstrated a change in amplitude over time across sessions but in each case this was found to be due to changes in baseline rather than during the training sessions themselves. The per cent time data was more equivocal with regards to the across sessions analyses with no change over time identified when the main effects were looked at although there was some indication that the audio group showed a change over time during their training when the interaction effects were examined but this was only when the first session was compared to the third.

To summarise so far, then, although all three feedback groups showed evidence of increasing their alpha over time during their enhancement training, the audio-visual and visual groups were found to be exhibiting a return to baseline, most likely due to habituation to the feedback, after an initial below-baseline drop at the start of training. They did not show any evidence, neither within nor across sessions, of being able to significantly enhance their alpha above baseline levels. The audio group, on the other hand, did demonstrate the ability to significantly enhance their alpha above baseline levels, both within and across sessions, and to increase their alpha over time within the sessions themselves. Across sessions, however, they did not show any ability to increase their alpha over time with any changes which occurred occurring in their baselines as well as during their training.

Likewise, the audio group also showed evidence of being able to significantly suppress their alpha during their suppression training and although this was true throughout the course of their training their ability to do so did decrease as time went on within the sessions themselves. The audio-visual group also showed the ability to significantly suppress their alpha during training, although again this ability decreased as sessions progressed. The visual group on the other hand only managed to show a significant decrease in the amplitude of their alpha, not in the amount of time they spent under threshold, leaving open the possibility that the suppression they showed in their alpha may have been due to the training situation rather than to an ability to consciously control their alpha per se. The across sessions analyses confirmed that all three feedback groups succeeded in suppressing the amplitude of their alpha during training and the amount of time they spent under threshold during training when compared to baseline, but that their ability to do so did not change as sessions progressed. This could suggest that participants need more training or it could mean that it is not possible for participants to suppress their alpha more than they already learned to in their first session.

The results from this experiment suggest that audio feedback is the more preferable method to use for alpha neurofeedback training. This is in line with the suggestion by researchers such as Travis et al . (1974) that audio and visual feedback produce different results. However, although audio appears to be the most commonly used type of feedback for alpha neurofeedback training the few studies in the area which have attempted to compare the effectiveness of different feedback types have thus far never found audio feedback to be the most optimal. Indeed, it is more common to find that researchers implicate visual feedback as being the crucial component for feedback training. For instance, Lal et al.'s (1998) comparison of audio versus visual versus audio-visual feedback for the purposes of blood pressure biofeedback training found that it was the addition of visual feedback which made for a more optimal feedback method and that audio feedback did not provide any extra benefits. As O' Connell et al. (1979) point out, however, different physiological components may respond differently to different types of feedback and the type of feedback which is of most benefit for learning to exert a conscious influence over certain aspects of the brain may well not be the type of feedback which is of most benefit for trying to exert a conscious control over other physiological responses such as heart rate or blood pressure. Not least because consciously influencing heart rate is likely to involve a completely different method to consciously influencing brain waves.

Even research in to neurofeedback specifically, however, has previously shown evidence for the importance of visual over audio feedback. For instance, although Breteler et al. (2008) failed to find a difference between audio-visual and visual feedback they suggested that this was because visual feedback was the important component and concluded that audio feedback did not add anything extra to the feedback situation in terms of efficacy. Given that they did not find any significant evidence of learning their results need to be interpreted with caution but Lynch et al. (1974) also voiced support for the use of visual as opposed to audio feedback. In their study they found that only the visual participants showed any evidence of increasing their alpha over the course of their training session whereas the audio participants did not. However, given that their sample of audio participants was a third of the size of their visual participants (n = 5 versus n = 16) and that even the visual group did not show evidence of significantly increasing their alpha over baseline levels these results need to be treated with caution.

Even without the methodological limitations of the previous studies in the area, the results of this current experiment here are not altogether surprising given the already mentioned suppressing effect which visual stimuli can have on alpha (Mullholland & Eberlin, 1977; Walsh, 1974). Further, Tyson (1982) has speculated that neurofeedback training at parietal sites may actually be more sensitive to audio training, presumably due to the role of the parietal cortex in auditory functions such as auditory working memory (e.g. Alain, He, & Grady, 2008), and given that all the participants in this experiment trained at scalp location Pz this may be why they responded so well to auditory feedback over those which also incorporated a visual element as well/instead of.

It is also interesting to note that it has previously been theorised that auditory-visual feedback may be the more optimal type of feedback for neurofeedback training due to utilising the attention of more than one sense modality. So if attention in one sense modality (i.e. eyes versus ears) wanders then there is the attention of the other sense modality to recapture it back again (Lal et al., 1998, Vernon, Frick, & Gruzelier, 2004). Of course it could be that feedback to more than one sense at a time qualifies as a higher processing load resulting in distraction rather than an improvement to focus on the feedback. Of all the feedback groups the audio-visual group do seem to do particularly poorly so there is some tentative evidence to support this. At the very least, however, the use of visual feedback for alpha neurofeedback training – whether alone or in tandem with audio feedback – seems to be less desirable than utilising audio feedback alone.

Conclusion

To summarise, the purpose of the experiment outlined in this chapter was to investigate whether or not there was a difference between the three types of feedback used for alpha neurofeedback training. The limited research in the area suggested that incorporating visual feedback in to the training process may be the most beneficial method of the three and that audio-visual feedback may well be the most preferable overall due to the provision of information to both sense modalities and therefore providing the potential for capturing the attention of one sense modality even if the attention wanders from the other. However, the results from this experiment indicated that audio feedback was the most optimal of the three types of feedback for alpha neurofeedback training. Given the initial below-baseline levels of suppression seen at the start of each segment during each session it is likely that the reason for this is that visual feedback has a naturally suppressing effect on alpha which participants find hard to overcome and that this has a deleterious effect on their performance. It is therefore recommended that future studies utilise eyes open audio over visual or audio-visual feedback when conducting alpha neurofeedback training.

Chapter 6: General Discussion Chapter

The purpose of this thesis was to investigate whether or not there is an optimal way of conducting alpha neurofeedback training and if so what it is and how to measure it. There is evidence that alpha neurofeedback training may be of use in optimising individuals' performance in areas such as musical or cognitive performance but, as was discussed in Chapter 1 (section 3), there is wide variation in how alpha neurofeedback training has been carried out in these studies, which makes conclusions difficult to draw. Some studies have their participants train with their eyes open, some with their eyes closed; some give their participants continual feedback, some give them contingent feedback; some provide them with audio feedback, some with visual feedback, some with a combination of both; some use one active electrode, some use more; some have their participants train as little as once a week, some as often as every day; some base their results on one session of neurofeedback training, some on several.

Researchers also vary in the way in which they define alpha. Some are referring to the electrical activity of the brain which oscillates at between 8 and 12 Hz, and some at between 8 and 13Hz; others incorporate oscillations as low as 7Hz or as high as 14 or 15Hz; still others define the alpha bandwidth individually for each participant. Additionally, some prefer to treat the alpha bandwidth as a composite of 2 or more sub-bands rather than as one single bandwidth. To further complicate the distinction in definitions of alpha, some studies only classify participants as being 'successful' at alpha neurofeedback training if they increase/decrease their alpha over/under an arbitrary fixed threshold (which has ranged from 10µv to 40 µv depending on the study) whilst others instead base their threshold on the participants' own natural alpha (which again has varied from 20% to 100% of baseline amplitude depending on the study).

Justification of why researchers use particular combinations of the above variations in methodology are rare in the alpha neurofeedback literature and research in to what differences these variations in methodology can make is limited. There is evidence that such variations can influence the effectiveness of alpha neurofeedback training and, potentially, the outcome of the training (in terms of effects on behaviour and cognition), which is why previous researchers have recommended further investigation into the differences these variations can make (e.g. Vernon, 2005) and advise against comparing the results of studies utilising different methodologies in the meantime (e.g. Ancoli & Kamiya, 1978). In order for the potential uses of alpha neurofeedback to be investigated and utilised to maximum effect it therefore seems advisable for a standardised way of training to be established.

An investigation into every possible variation in conducting alpha neurofeedback training is beyond the scope of this thesis. However, an initial investigation to set the groundwork and investigate the idea that there actually may be an optimal way of training alpha via neurofeedback is not and it is thus that this thesis aimed to do.

The concept of an optimum training paradigm assumes that there are variations in the methodology which are more successful than others. This concept of success can be interpreted in two ways: success in terms of the outcome of the training on behaviour, cognition, etc., or success in terms of the participants' ability to actually learn to exert a conscious control over their own alpha waves. Until it has been established *how* to most effectively train alpha via neurofeedback it seems ill advised to establish behavioural/cognitive outcomes.

‘Success’ here then is taken to mean participants’ ability to exert a conscious control over their own EEG alpha activity rather than on any effects of training that alpha activity.

Before any experiments could be conducted into an optimal training paradigm for alpha neurofeedback training, therefore, the first decision to be made was how to the measure and define training ‘success’.

As with the variations in defining alpha and how the training is conducted, there also exists wide variation in how alpha is measured and how success is defined. The most common ways of measuring alpha in the neurofeedback literature are by looking at changes in the strength (i.e. synchronicity) of alpha, i.e. the amplitude of alpha, and/or in the amount of time participants spend altering their alpha in the required way. Arguments have been made for each (see Chapter 3) but as yet no definitive conclusion as to which is the most appropriate has been reached.

The most common ways of trying to identify learning in alpha neurofeedback training are to look for changes over time and/or to compare alpha produced during attempts at conscious manipulation compared to alpha produced when at rest (i.e. during baseline recordings). With regards to looking for changes over time the two most common methods are to see if participants show any change over time within the sessions themselves whilst they are training (‘within sessions’ changes) and/or in their alpha activity as sessions progress (‘across sessions’ changes). Combinations of all the above (i.e. within sessions learning with *no* baseline comparison, within sessions learning *with* a baseline comparison, across sessions learning with *no* baseline comparison, across sessions learning *with* a baseline comparison) have been utilised but very little research exists as to whether any are more useful or informative than the others and therefore suggesting if one would be more preferable to use for the purposes of identifying learning than the others.

The first experiment conducted for the purposes of this thesis, then, was carried out in order to establish an index of learning for use throughout the subsequent experiments in the thesis. In other words, to establish if per cent time, amplitude, or integrated alpha (a composite measure combining both per cent time and amplitude) differed in their ability to detect changes in alpha and therefore in their usefulness for identifying learning. Also, to see if looking for changes within sessions or across sessions, both with and without the incorporation of a baseline, produced different outcomes regarding the detection of changes in alpha. In experiment 1 (Chapter 3), 52 participants were given 10 once-weekly sessions of alpha (8-12Hz) neurofeedback training at scalp location Pz. Each training session involved 15 minutes of eyes open enhancement training (split into two 7.5 minute segments separated by a 30 second break) and 15 minutes of eyes open suppression training (split into two 7.5 minute segments separated by a 30 second break) with the order of training counterbalanced amongst the participants. The goal of participants' enhancement training was to learn to consciously increase the amplitude of their alpha over a threshold set at 100% of their own 3 minute eye open baseline taken at the start of that day's training session. The goal of participants' suppression training was to learn to consciously decrease the amplitude of their alpha over a threshold set at 40% of that same baseline.

The results of this first experiment supported previous research in the area (e.g. Cram et al., 1977) suggesting that conclusions regarding participants' ability to learn to exert a conscious control over their own alpha waves may differ depending on whether per cent time or amplitude is used as the measure. This was also noticeable in subsequent experiments (see Chapters 4 and 5), particularly, although not exclusively, in the case of the across sessions analysis (see Table 79, below).

Table 79

Instances in experiments 1-3 where the result of the amplitude measure have differed from the per cent time measure. The significant effects are highlighted in yellow.

	Amplitude Measure	**Per Cent Time Measure**
Experiment 1		
Enhancement Training		
Across Sessions Analyses	Main effect of Session	No main effect of Session
Across Sessions in Comparison to Baseline Analyses	Main effect of Session	No main effect of Session
Suppression Training		
Within Sessions Analyses	Main effect of Segment	No main effect of Segment
	No Segment by Period interaction effect	Segment by Period interaction effect
Further Analysis		
Enhancement Training		
Within Sessions Analyses	Marginal effect of Segment	Main effect of Segment
Suppression Training		
Within Sessions Analyses	Main effect of Segment	No main effect of Segment
Within Sessions in Comparison to Baseline Analyses	Main effect of Segment	No main effect of Segment
	Main effect of Period	No main effect of Period

Experiment 2		
Enhancement Training		
Eyes Open Participants	Main effect of Session	No main effect of Session
Suppression Training		
Eyes Open Participants	Main effect of Session	No main effect of Session
Experiment 3		
Enhancement Training		
All Groups	Main effect of Session	No main effect of Session
Suppression Training		
Audio-visual Group	Main effect of Period	No main effect of Period
Visual and Audio Groups	Main effect of Session	No main effect of Session

It is not yet clear why different measures produce different results. As can be seen from Table 79, with the exception of the discrepancies between amplitude and per cent time in the further analyses section of experiment 1, it is almost exclusively the case that any differences shown between the two measures in terms of training success are due to the amplitude measure showing an effect when the per cent time measure does not. Given this, it seems likely that Hardt and Kamiya's (1976a) assertion that amplitude is more sensitive at detecting change is the most likely explanation for these findings. As discussed in Chapter 3, it could also be the case that the feedback provides the participants with more information regarding amplitude than it does about per cent time, making it easier for them to learn to enhance the amplitude of their alpha rather than the time spent increasing that amplitude over threshold. However, it is not the case that amplitude and per cent time are continually in disagreement with each other through the analyses, only sometimes, suggesting that this is the least likely of the two explanations.

Table 80

Instances in experiment 1 where the integrated alpha measure differed from at least one other measure. The significant effects are highlighted in yellow.

	Amplitude	**Per Cent Time**	**Integrated Alpha**
Enhancement			
Across Sessions	Main effect of Session	No main effect of Session	No main effect of Session
Across Sessions in Comparison to Baseline	Main effect of Session	No main effect of Session	No main effect of Session
Suppression			
Within Sessions	Main effect of Segment	No main effect of Segment	No main effect of Segment
	No Segment by Period Interaction effect	Segment by Period Interaction effect	No Segment by Period Interaction effect
Across Sessions	Main effect of Session	Main effect of Session	No main effect of Session
Further Analysis			
Enhancement			
Within Sessions	Marginal effect of Segment	Main effect of Segment	Main effect of Segment

Suppression			
Within Sessions	Main effect of Segment	No main effect of Segment	Main effect of Segment
Within Sessions in Comparison to Baseline	Main effect of Segment	No main effect of Segment	No main effect of Segment
	Main effect of Period	No main effect of Period	Main effect of Period

As well as illustrating the differences between per cent time and amplitude, experiment 1 also provided a comparison with an alternative measure which combined both: integrated alpha.

Integrated alpha has been recommended by some (e.g. Hardt & Kamiya, 1976a) as a solution to the per cent versus amplitude debate. However, the potential problem with integrated alpha is that of 'hiding' information. As can be seen from Table 80, whilst it is more common for integrated alpha to show agreement with the amplitude measure than the per cent time measure this is not always the case. If integrated alpha shows a significant effect this could be due to participants significantly altering the amplitude *and* the time spent over/under threshold or it could be due to participants showing a change in only one. It is also possible, as can be seen from Table 80, that both amplitude and per cent time can show a change in alpha which is not apparent in the integrated alpha measure. If both amplitude and per cent time are going to be utilised then it therefore seems preferable to look at them separately in order to provide a clearer picture of what aspects of alpha are being altered by the training and in what way. Of course, given that it is likely that amplitude is a more sensitive measure to use than per cent time then it could be argued that it is unnecessary to include per cent time at all. However, as time spent 'in alpha' has been the most common measure utilised in previous literature, incorporating both amplitude and per cent time here enables a clearer comparison to a larger proportion of the previous research in the area and so it was decided to continue to measure both and to keep them as separate measures rather than to combine them in the form of one single measure.

As already stated, the second purpose of experiment 1 was to identify the differences shown between within sessions versus across sessions analyses. It was shown that within sessions analyses were more sensitive to changes in alpha than across sessions. Within sessions analyses showed clear evidence of participants learning to alter their alpha over time, whereas the results of the across sessions analyses were more equivocal. There was evidence of some change over time across session, but in some instances this change over time seen during training was also mirrored in the baselines. Arguably, 10 sessions may not be enough and although the participants were learning to alter their alpha they may, as those such as Rasey et al. (1996) suggest, need more than 10 sessions to show any change in performance from one session to the next. Or it may just be the case that participants' ability to alter their alpha reached its limit in the earlier sessions, hence why no across sessions changes were seen from session 4 onwards between any of the sessions. An alternative explanation for the increase in baseline alpha from one session to the next is that participants' ability to enhance their alpha had a knock-on effect on their natural alpha levels, causing an increase over time which then 'contaminated' any evidence of learning during the training itself due to increases in training being compared to higher and higher levels of alpha during baseline and therefore inhibiting the evidence of progress which the participants were in fact showing.

If future studies incorporated a larger number of sessions to see if evidence of learning across sessions becomes more apparent the more sessions that are run, this would tackle the first of the above explanatory scenarios. It would also potentially help address the second. Cho et al. (2008) point out that it is unlikely that alpha would continue to increase ad finitum and it would be interesting to see if the increase seen in baseline levelled off over time and if so how long it takes and whether performance during training remains in proportion to baseline or continues to increase to a larger extent.

Given the complication that baselines add to the analyses, an argument could be made for not incorporating them in to the analyses at all in order to simplify the interpretation of the data. The problem with this simplification, however, was identified in experiment 1 and then further highlighted in experiments 2 and 3. In experiment 1 it was found that, as with previous research (e.g. Plotkin, 1978; Vernon & Withycombe, 2006), some participants show a decrease in their alpha at the start of training below the levels which they show naturally. As the training session progresses and they acclimatise to the situation (Plotkin, 1978) their alpha increases back to their natural (i.e. baseline) levels. The danger, then, is that if a baseline measure is not incorporated into analysis it may appear that participants are successfully exerting a conscious control over their alpha when in actual fact all that is happening is that their alpha is habituating back to the level it is normally at when they are not trying to exert a conscious control over it. This is illustrated particularly well in experiment 3 (see Chapter 5). Looking at Figures 40 and 41 it can be seen that all the feedback groups show an increase in both their amplitude and in the percentage of time spent over threshold during training. Taken alone without the incorporation of baseline both the amplitude and per cent time measures taken during training would suggest that all groups successfully enhanced their alpha. When measures of baseline are included, however, it can be seen that only the audio feedback group demonstrated the ability to enhance their alpha over that which they produced naturally. The visual and audio-visual feedback groups, on the other hand, rarely, if ever, showed any evidence of producing more alpha when they were trying to consciously enhance it than when they were not with both the amplitude and per cent time measures consistently remaining at or below baseline throughout training.

Returning to the question of whether, as previous research has indicated, within sessions and across sessions analyses may produce differing conclusions with regards to whether participants show evidence of learning, however, then the answer is yes. Although the within sessions analyses appears to be a more sensitive measure of change over time, the across sessions analyses produce data which is of additional interest due to the pattern of increasing baselines which it reveals. It was therefore decided, then, to utilise both types of analyses when looking for evidence of learning in the remaining experiments. It was further decided that in each instance (i.e. analysing the data within sessions and analysing the data across sessions), baseline should be included as part of the analyses.

In sum, then, the aim of experiment 1 was to establish an index of learning for use in all successive experiments for the course of this thesis. It was decided that in order to identify whether participants demonstrate the ability to exert a conscious control over alpha in the successive experiments, evidence of learning would be looked for both within and across sessions, using amplitude and per cent time as the measures and taking participants' baselines into account.

The issue of what constitutes an appropriate baseline is a contentious one. As already discussed in Chapter 3, there are alternatives to the method used here. For example, one could take several baselines over the course of each session or compare training to a single baseline taken before any of the training sessions commenced. The former option, however, would not address the same potential problem identified with the baseline measure used in this thesis. That is, baselines may increase as a knock-on effect of the training. Depending on the latency of this effect and whether the strength of any knock-on effects on baseline alter over time, utilising baselines taken throughout the course of each session could show this effect even more acutely.

The alternative measure of baseline, comparing to one single baseline taken before any training has commenced, is also problematic due to the likelihood that it will be artificially suppressed due to the novelty of the situation and also because alpha fluctuates as a function of day and time of day (Gertz & Lavie, 1983).

Another approach, then, is to look at what it is the participants are doing during their baselines. Plotkin (1976a) warns that participants should be explicitly told not to practice their training strategies during their baselines and although participants were told at the start of each baseline taken for the purposes of this thesis what the purpose of them were (i.e. to get a measure of what their EEG activity is like when they are not purposefully trying to alter it) they were not questioned about what they did during the baseline recordings. It is therefore possible that they may have practiced strategies, which would have resulted in baseline measures which were not a true reflection of their natural alpha. Even if that is not what the participants did, Dempster and Vernon (2009) point out that what the participants did to pass the time whilst their baselines were being recorded, e.g. internal reflection, may actually have been more conducive to altering alpha than the strategies they were using. Relatedly, in order to keep the EMG readings as low as possible the participants were instructed to 'stay still' and 'relax' during their baselines. This in itself may have caused artificial elevation of baseline alpha over that of what they would otherwise have been.

Further, the idea of a baseline is to provide a measure of what participants' alpha is like when they are not consciously trying to alter it. However, what they are doing at any given moment will produce different levels of activity. Arguably, then, the baseline used for comparison needs to be taken in conditions as close to the training conditions as possible, so that only the element of conscious control is different. Having participants sit still without partaking in any activity with the bare minimum of external stimuli is not, then, the most comparable of conditions. Baselines with pre-recorded tones/images (i.e. pre-recorded auditory and/or visual feedback depending on the condition) may have been more suitable. This is an idea which has been previously used. For instance, Zoefel et al. (2011) had their participants focus on a colour changing square on the screen during their baseline and asked them to count how many times the square turned red. They did this both to try and prevent drowsiness and also to make their baseline conditions as similar to the training conditions[11] as possible.

It would certainly be interesting to conduct an experiment looking at the effect such permutations in baselines have both on the baselines themselves and also in terms of their relationship to training. For instance, the effect of being instructed to 'relax' compared no instructions; being given a task or not to perform; being given baselines with the same stimuli to the training itself in the same manner as Zoefel et al. (2011) versus minimising the external stimuli (as was

[11] which involved visual feedback in the form of a square which alternated between grey, blue, and red depending on whether participants' alpha was at, under, or over baseline levels respectively

the method used for baseline recordings taken during the experiments in this current study). In other words, if a similar approach was taken to Zoefel et al. (2011) would baselines still be seen to increase alongside the training as sessions progress?

For the purposes of this thesis, however, baseline recordings were kept the same as in experiment 1 and with the decision made as to how to measure alpha and how to look for evidence of training ‘success’, the next experiment focused on then second aim of this thesis. That is, investigating whether there is evidence that there is an optimum way of training alpha via neurofeedback.

With the wide variations in how alpha neurofeedback training is conducted, there are numerous arguments which could be made as to which of these variations to begin with. However, one of the main overarching ways of categorising or delineating alpha neurofeedback is by whether participants train with their eyes open or their eyes closed. And it makes more sense to address this question before others relating to the neurofeedback training methodology (see Chapter 1, Figure 4). The literature reviewed (see Chapter 1) is relatively evenly split with regards to how alpha neurofeedback is conducted, although eyes open training was found to be used slightly more often (n = 45 versus n = 35 studies of those which provided that information). Although comparison between the two types of training is rare there is some evidence (e.g. Cram et al., 1977) that the choice between the two may influence training success. Strayer et al. (1973) are among those who argue that this therefore makes interpretation of the literature, for example with regards to interpreting the reasons for differing findings, difficult.

Experiment 2 therefore aimed to provide a comparison between alpha neurofeedback training conducted with eyes open versus eyes closed. Thirty-three participants underwent 10 sessions of once-weekly alpha (8-12Hz) neurofeedback training at scalp location Pz with each session involving two 7.5 minute segments of alpha enhancement training either followed or preceded by two 7.5 minute segments of alpha suppression training (with the order of training counterbalanced among the participants). As in experiment 1, the goal of the enhancement training was for participants to increase the amplitude of their alpha over 100% of their mean amplitude for that day's pre-training baseline and decrease it to below 40% of that day's baseline amplitude. The participants were split into two groups with 17 conducting their training with their eyes open and 16 conducting their training with eyes closed. In order to make the conditions as comparable as possible, each group was given contingent audio-only feedback and the baselines used to set their thresholds were recorded during eyes closed conditions for the eyes closed participants and during eyes open conditions for the eyes open participants.

The results of this second experiment showed that eyes open participants demonstrated evidence of learning to enhance their alpha whereas the eyes closed participants appeared to be suppressing it instead. The most likely explanation for this is that the eyes closed group was experiencing drowsiness, something which is known to be associated with a decrease in alpha (Canterbo et al., 2002).

In contrast, the results of the suppression training in experiment 2 suggested that whereas the eyes closed participants showed evidence of alpha suppression the eyes open participants were not as successful. The eyes open participants did keep their alpha below baseline throughout the course of training but rather than showing a decrease over time in the amplitude of their alpha and an increase in the amount of time they spent below threshold, in both cases participants instead showed an increase over time back towards their baseline measures. This could mean that the eyes open participants were consciously suppressing their alpha but that the method they were using to do so was not one they were able to sustain over time or it could mean that they experienced an initial unconscious suppression at the start of training and their alpha was simply increasing back towards baselines as they acclimatised to the situation. This suppression of alpha seen at the start of training was first observed in experiment 1, although it has previously been apparent in other alpha neurofeedback research (e.g. Plotkin, 1978; Vernon & Withycombe, 2006). The results of experiment 3, however, indicated that this was likely due to the effect of being given visual feedback as it was not a pattern seen in participants who were given audio-alone feedback. In light of this, when the data from experiment 3 is taken in to account, the former suggestion that eyes open participants were able to consciously suppress their alpha but were not able to sustain that ability to the same extent for the whole length of each sessions seems the most likely of the two explanations.

Taken by itself the eyes closed participants' suppression data seems promising. However, given that they also suppressed their alpha when they were trying to enhance it, caution is therefore required. The amount of suppression they demonstrated during suppression training was significantly more than the amount of suppression demonstrated during enhancement training, which does lend support to the idea that in the case of their suppression training this effect may have been conscious. Or, at a minimum, that it was not just drowsiness by itself causing the suppression. There is also the possibility that participants realised that the drowsiness they seemed to be experiencing during their enhancement training was suppressing their alpha and were therefore purposefully encouraging that as a method for suppressing their alpha. Since falling asleep is arguably not the same as exerting a conscious influence over alpha activity as such then if this is, in fact, what they were doing then concluding that eyes closed participants demonstrated the ability to consciously suppress their alpha activity is too strong a conclusion.

In sum, then, the results of experiment 2 indicated that eyes open conditions are more preferable to eyes closed for alpha enhancement training. Although the results of the suppression training were more equivocal, given eyes open participants did show some ability to suppress their alpha and that eyes closed participants' ability to learn may have been impeded by drowsiness, it was argued that eyes open conditions are more preferable for alpha suppression training too. Eyes open training was therefore the only condition used in the third and final experiment of the thesis.

Although it was concluded in experiment 2 that eyes open training is more preferable to eyes closed, the audio-only feedback used in experiment 2 is not the only form possible for eyes open feedback. It is also possible to have visual feedback, or a combination of audio and visual feedback.

Although audio feedback is the most commonly utilised form of feedback in the alpha neurofeedback literature, it has been suggested that audio-visual feedback may be better due to the potential for the provision of more information due to feedback being presented to two sensory modalities rather than just one (e.g. Lal et al., 1998; Vernon, 2008). Although a direct comparison between all three is lacking, particularly with regard to the influence of feedback on alpha neurofeedback training, the studies which do exist in the area are suggestive of an advantage of incorporating visual feedback in to training.

The third experiment, then, set out to provide a comparison between audio, visual and audio-visual feedback to establish if they have differing effects on training or if any produce a more optimal outcome. A total of 47 participants undertook 10 sessions of once-weekly monopolar alpha (8-12Hz) neurofeedback training at Pz. Seventeen participants were given visual feedback, 15 were given audio feedback, and 15 were given a combination of both audio and visual feedback.

The results of experiment 3 suggest that, in contrast to the previous limited research in the area (e.g. Lynch et al., 1974), audio feedback is the most preferable for alpha neurofeedback training. Further, in line with Mullholland and Eberlin's (1977) description of visual feedback as 'negative feedback' (p597), it appeared that the incorporation of visual feedback actually resulted in an initial suppression of alpha at the start of each training session which participants then found hard to overcome. It is therefore recommended that future studies use audio feedback when conducting alpha neurofeedback training.

It is worth noting, however, that audio versus visual versus audio-visual are not the only possible variations in feedback type. Although the recommendation, then, is for the use of audio feedback an interesting follow-up experiment would be to see if the type of audio-feedback makes a difference to participants' performance. There is some evidence in the literature which suggests it might. For instance, Tyson (1982) found that although both of their training groups successfully enhanced over baseline, participants who received a sine wave (i.e. smooth) frequency tone did significantly better at enhancing their alpha than those who received a saw tooth (i.e. sharp and erratic) frequency tone as their feedback. This supports Breteler et al.'s (2008) work on SMR training whereby participants' training ability correlated with their ratings of how pleasant they found the type of sound being used for the audio component of their feedback. The audio used for the purposes of this thesis was simply a clarinet tone which increased in pitch as the participants' alpha increased and decreased, occurring only when the participants crossed their threshold in the desired direction. As it happens, a couple of the participants did comment that they did not like the sound of the audio-feedback used here so it would be interesting to see, therefore, if different types of audio make a difference to participants' performance. Being rewarded with the tune of their favourite song if they turn the feedback on, for instance, or the sound of calming music versus energetic music for use as the feedback sound.

It has also been argued that whether the feedback is contingent, as the audio feedback was here, or continuous can make a difference to participants' performance. Plotkin (1976a) has suggested that contingent feedback is distracting due to the way it interrupts periods of silence. He argues that continuous feedback, whereby the tone is always present but varies in pitch and/or volume alongside the accompanying increases and decreases in the participants' alpha, is better because its constant presence reduces the chance of taking the participant by surprise and distracting them. Travis, Kondo and Knott (1974b) support this idea, hypothesising that continuous feedback provides the participant with more information because it allows the participant to know what their alpha is doing (i.e. increasing or decreasing) even when they are not over threshold as well as when they are which may give them the help they need to cross threshold in the desired direction.

What is worth noting at this juncture is that whilst the audio participants in experiments 1, 2 and 3 were only provided with contingent feedback, the visual participants utilised continual feedback and audio-visual had both (continual visual and contingent audio). Whilst the most likely explanation for the audio participants' more optimal performance when compared to the visual and audio-visual feedback is that the visual feedback was having a hindering effect on the visual and audio-visual participants' performance, there is the possibility that the difference was due to being given contingent rather than continuous feedback. This is not a question which can be adequately addressed here. However, a direct comparison between the effect of contingent audio versus the effect of continual audio feedback therefore seems like the logical next step to take. Of further use may well be to see whether or not the addition of a scoring system, as suggested by Hardt and Kamiya (1976b), would further aid participants' ability to learn to enhance/suppress their alpha. Eleven of the alpha neurofeedback studies of those reviewed incorporated an online scoring system as part of their feedback and Hardt and Kamiya (1976b) argue that the benefit of this is twofold. Firstly, to keep participants motivated and on task and secondly because judging performance from one moment to the next may not necessarily be easy for the participants to judge whereas a score gives them something tangible to measure their performance against. Scoring could perhaps represent the number of times they have crossed the threshold in the desired direction during that session, the average amplitude they have produced in that session so far, or the total percentage of time they have so far spent over/under threshold during the course of the session. The use of the latter as a score would also address the potential issue raised in the discussion section of experiment 1 that the feedback provided to the participants may give them more information regarding changes in amplitude than per cent time. As a follow-up experiment to experiment 3, then, it would be worth seeing if variations in the form of audio feedback, whether in type of audio, continual versus contingent presentation, and addition or not of a score, produces the same results in terms of which is the most beneficial method, regardless of whether training is for enhancement or for suppression.

Although all the participants in all the experiments incorporated an equal amount of both alpha enhancement and alpha suppression in to their training, the differences in the thresholds set means that the two types of training cannot be directly compared. The thresholds for the experiments were kept consistent throughout each experiment and were based on the results of an initial pilot study (see Chapter 2, section 1). The point of having a threshold for the participants to enhance their alpha over/suppress their alpha under is to give them a goal to attain with the aim being that by learning to reach that goal they will subsequently learn how to exert a conscious influence over their own alpha activity. Participants therefore needed to be provided with enough feedback from which to learn, that is, to be able to work out what it is which is causing the feedback (Knox, 1980). However, it is also important that their goal (i.e. threshold) is not so easily attainable that they are lacking information regarding what it 'feels like' not to be producing the required level of feedback (Hord & Barber, 1971). With an absence of empirical evidence regarding the most optimal way of setting participants' thresholds in order to meet this criteria (Knox, 1980; Vernon et al., 2009), it was therefore decided that one of the goals of the pilot study should be to find out how high/low participants' thresholds could be set before they reported finding it too difficult. From this pilot study, then, it was decided that participants' thresholds for enhancement training should be set at 100% of that day's baseline and at 40% of that day's baseline for their suppression training. Aside from the question of whether the experience of the pilot participants regarding what was 'too hard' or 'too easy' may not, in retrospect, have been representative of the experimental participants' experience, this difference in the level at which the threshold were set means that no direct comparison can be made as to which of the two types of training is easier, if any. So, whilst the data from the three experiments found evidence for some of the participants learning to both enhance and/or suppress their alpha, the results of the enhancement data is more clear cut. That is, the participants in experiment 1, the eyes open participants in experiment 2, and the audio participants in experiment 3, all showed evidence of learning to enhance their alpha. The suppression data, however, was more equivocal. Ignoring the eyes closed data from experiment 2 (which although indicative of suppression carries with it, as already discussed, the problem of potential confound of drowsiness-induced suppression) the data from the experiments is suggestive of participants demonstrating the ability to suppress their alpha. However, although participants showed the ability to significantly suppress their alpha below baseline levels they did not show an improvement in this over time and did, in fact, show a decreasing ability to do so. This could mean that they were not successful at suppressing their alpha and that the effort of doing so did show an initial suppressing effect but one which dissipated as training progressed. It could, however, mean that participants were successful at suppressing their alpha but that the method they were using was not one which they could maintain over time. Whether their ability to do so for sustained periods is something which they would have shown an improvement on had they been given more sessions is a question for future study. The more immediate question, however, is whether, if the latter scenario is the case, this counts as a demonstration of successful alpha suppression or if the participants' inability to maintain that suppression to the same extent over a given period of time should not be counted as such as it indicates that participants were unable to consciously suppress their alpha at a constant rate. Either way, at face value the data supports evidence presented by those such as Hord and Barber (1971) and Cram et al. (1977) that alpha enhancement may be easier to learn than alpha suppression. However, trying to increase alpha over the amplitude participants produce naturally is not the equivalent of trying to decrease the amplitude of their alpha below 40% of what they produce naturally. Whilst it may be the case that enhancement training appeared to be easier for the participants than suppression training because alpha enhancement itself is easier than alpha suppression, it may also be the case that alpha enhancement training was more successful and produced less equivocal results than the suppression training because the way the thresholds were set made learning to enhance alpha easier than learning to suppress it. Comparing the results of the current study to participants who learned to enhance their alpha over a threshold set at 160% of their mean baseline amplitude and/or suppress their alpha under a threshold set at 100% of their mean baseline would enable such a comparison to be made. On a related point, a study to specifically examine if any differences in learning can be found in participants' performance when differing thresholds are used to train to would also be of value for future studies.

Also of potential use in further studies is the incorporation of a control group. It is not uncommon in the neurofeedback literature to include a control group who either receive fake feedback (e.g. Gilham, Wild, Bayer, Mitchell, Sandberg-Lewis, & Colbert, 2012), that is, feedback which is not actually based on the activity of the participant's own brain activity but (for example) is (unbeknown to the participant) simply a recording of another participants' brain activity, or who receive feedback training in a bandwidth which is different to that of the experimental group (e.g. Doppelmayr & Weber, 2011). The use of a control group tackles potential arguments that it is the motivation caused by the contact time with the experimenter, the instructions (e.g. Holmes, Burish, & Frost, 1980) and/or expectancies of the participants (e.g. Valle & Levine, 1975) which produce effects rather than the neurofeedback training itself. Given the differences seen in the experiments here between the eyes open training compared to the eyes closed training and between those who received audio and those who received visual or audio-visual feedback, however, the effects found here are suggestive of being due to the differences in the training itself rather than other extraneous variables. Employment of a control group in future experiments would nonetheless help to further support this argument.

A further way of supporting the findings here that there are differences between the feedback groups as a function of the type of training they receive (eyes open versus eyes closed, audio versus visual versus audio-visual training) would be to compare pre- and post- performance on various cognitive tasks which have been linked to alpha (see Chapter 1, section 2.2.) to see if there are differences between the groups based on their level of training success. This is something which has been done before in the alpha neurofeedback literature (e.g. Hanslmayr et al., 2005) with the rationale being that only those who show improvement in their alpha neurofeedback ability should show improvement in the cognition/behaviour linked to the production of alpha in the part(s) of the brain being trained; with a correlation between task performance and training ability (e.g. Hanslmayr et al., 2005). However, as mentioned in Chapter 1 (section 2.2.), it is advisable to address the methodological limitations which currently exist in the field in order to establish an optimum training methodology before looking ahead to look at an effect on cognition, behaviour, etc. Until a firm method for training has been established it is difficult to untangle the reason for non-significant effects on cognition.

The data from the experiments conducted here were analysed by group with no differentiation made between those who showed evidence of learning and those who did not within the groups themselves. The argument for doing this would be to provide a representative account of people's abilities to learn under the different training conditions. For example, if the eyes open group had shown that all their participants learned to enhance their alpha and the eyes closed participants had shown that only half of their participants had, then if only the learners were then selected for analysis and the eyes closed group were then shown to have learned to enhance their alpha to a greater extent than the eyes open would this mean that eyes closed was the more optimal condition to train in? Or would it mean that they were less optimal because a smaller number of participants were found to be able to learn in eyes closed conditions?

The argument for analysing the data from the learners and non-learners separately is one made by Zeier and Kocher (1979). They claimed that by only looking at the performance of the learners the effects of learning would be more apparent because the data from the non-learners would not be diluting the performance of the learners. Weber et al. (2010) concur, adding that it may not be possible for everyone to be able to learn how to exert a conscious control over their EEG, so it makes more sense to look at those who can and those who cannot separately. There is some precedent for this starting to appear in the alpha neurofeedback literature with both Hanslmayr et al. (2005) and Zoefel et al. (2011) dividing their participants into responders and non-responders with Hanslmayr et al. (2005) analysing the two groups separately and Zoefel et al. (2011) excluding the non-responders' data from analyses altogether.

Given that in experiments 1-3 there were occasions where main or interaction effects were found but the resulting pairwise comparisons were not always able to determine where those effects were coming from, it would certainly be worth reanalysing the data without the non-learners to see if this helps to identify where those effects are coming from. The likelihood is that the variance caused by analysing the data of the learners and non-learners together made narrowing down the cause of some of the effects too difficult to detect with the a priori analysis. Reanalysing the data without the presence of the non-learners' data would concentrate the effect of the sample and thus decrease the variance which is likely currently inhibiting the ability to detect where some of the effects are coming from.

Of course, in order to separate the learners from the non-learners, a way of classifying learners as such needs to be decided upon. As already discussed in Chapter 1 (see section 3.9), those who have done this have all utilised different methods. The most straightforward, however, is Hanslmayr et al. (2005) who simply compared participants' upper alpha power (the focus of their participants' alpha neurofeedback training) during training to during baseline. Those who did not show an increase over baseline were 'non-responders', those who did were 'responders' (i.e. 'learners').

If the separation of learners and non-learners becomes common practice it makes sense for a standardised way of classifying them as so to be adopted to ensure that when one study talks about alpha neurofeedback 'learners' they mean the same as when another study does so. Additionally, the separation of learners and non-learners could also help to elucidate the area of alpha neurofeedback training in other ways. For instance, if participants were asked what methods they used when trying to enhance/suppress their alpha during training and are then separated out into learners and non-learners it would then enable a comparison to be made of the methods being used by each. If there is a common method used by those who are identified as successfully enhancing their alpha or a commonality in the methods used by those successfully suppressing it then this could perhaps highlight a method which the non-learners could try to see if they experienced an improvement in performance. If the methods used by the learners and non-learners turn out to already be the same then this could suggest that, firstly, Weber et al. (2010) may be right when they suggest that not everyone may be able to exert a conscious control over their EEG activity via neurofeedback. Secondly, that it may not be the case that there is a guaranteed single method for how an individual can exert control over their own alpha activity but that it may be that it depends on the individual as to what method works and what method does not. Knowing the answer to these questions would thus help inform the field of alpha neurofeedback training in order to help establish an optimum training methodology for conducting alpha neurofeedback by.

As Weber et al. (2010) suggested, another reason for separating learners and non-learners is that it may enable the prediction of who will and will not be able to learn how to 'do' neurofeedback. In their own study of SMR (12-15Hz) neurofeedback training they classified 50% of their participants as learners and 50% as non-learners based on whether they had shown an across sessions increase in amplitude from session 1 to session 25 and whether they showed an 8% or more increase in amplitude over baseline during the last 5 training sessions. Using the data they gathered from this first sample they were then able to correctly predict the performance of all 14 of the sample in a second experiment.

The idea that it may be possible to predict the success of particular individuals links nicely in to the idea, discussed in Chapter 1 (see section 3.11), that there may be particular aspects of the individuals themselves which influence their ability to train their alpha. For instance in their baseline alpha (e.g. Lynch & Paskewitz, 1971) or locus of control (e.g. Yamaguchi, 1980). The division of learners and non-learners would enable the testing of such a prediction to see whether the two groups exhibited differences in their locus of control or baseline alpha activity, for example, which could then in turn be used to predict who would and would not be the most suitable candidates for alpha neurofeedback training in future.

In relation to individual differences amongst participants, a limitation of the experiments conducted here is that it is unclear whether or not the results can be applied to those researchers using individual alpha as the frequency to train their participants. As already pointed out in Chapter 1 (see section 3.1.2.), although the majority of the literature to date, as with the experiments here, have utilised traditional bandwidths to define the alpha frequency band, there is a growing number of researchers who define the alpha frequency range for each individual. This is the case in both the research on alpha generally (e.g. Klimesch, 1999) and alpha neurofeedback training specifically (e.g. Hanslmayr et al., 2005). The argument is that by not tailoring the frequency bandwidths to each individual, one leaves open the possibility that individuals may end up training one of the surrounding bandwidths rather than the one they intended to, thus hindering the effectiveness of their training (Bazanova & Aftanas, 2008b). So, for instance, the traditional bandwidth of SMR is 12-15Hz but for some individuals the 12-15Hz bandwidth may incorporate alpha activity as defined by using individual alpha techniques. Thus, Hanslmayr et al. (2005) argue, studies which have found effects on cognition due to SMR training (e.g. Vernon et al., 2003) may actually have done so because the participants were training their alpha waves. A direct comparison of individual alpha frequency bandwidth training versus tradition alpha frequency bandwidth training does not yet appear to have been done on healthy participants so caution is currently needed in applying the findings from this thesis to individual alpha neurofeedback training.

Another potential limitation in the scope of applicability of the findings from this thesis is with regards to the use of alpha sub-bands for neurofeedback training. Again, both the literature on alpha in general (e.g. Cremades & Pease, 2007) and on alpha neurofeedback specifically (e.g. Schauerhofer et al., 2011) have examined the idea of alpha as being comprised of two or more functionally different sub-bands rather than one single bandwidth. If, as research by those such as Krenn et al. (in review) suggest, training the different sub-bands of alpha separately have differential effects on cognition (for example) then it would perhaps be fruitful to see if the optimal method for training one sub-band is the same as the optimal method for training another; and, crucially, whether the optimal method for training those are the same as when training the alpha bandwidth as a whole.

Furthermore, whilst the focus of this thesis is on alpha neurofeedback training the alpha bandwidth is not the only bandwidth which has been put forward as being of potential use in the realm of optimal performance. There is literature positing the potential benefits of SMR (e.g. Doppelmayr & Weber, 2011), beta (e.g. Egner & Gruzelier, 2004) and theta (e.g. Beatty, Greenberg, Diebler, & O'Hanlon, 1974) neurofeedback training for optimal performance but it is as yet unknown whether the most optimal methodology for one would necessarily be the most optimal for another.

Finally, alpha neurofeedback here was conducted at Pz throughout the course of each experiment. It may be useful to compare the results found here to alpha neurofeedback training at other scalp locations to see if the optimum methodology for training alpha at one scalp location is applicable to the optimum methodology for training alpha at others.

It is clear then that although the experiments conducted here indicate that the variations which exist in the way alpha neurofeedback training is carried out do, in fact, make a different to participants' performance, there are still questions left to be answered. As can be seen from Chapter 1 (see section 3), the extent of potential variations in how neurofeedback can be conducted is beyond the scope of this thesis to cover in full. Questions such as how many sessions are needed, how long each training session should be conducted for and how often, what the effects of alpha neurofeedback in the long-term and on other areas of the scalp other than those which formed the basis of training have all also yet to be answered. We now, though, have greater clarity on the question of whether or not the current variations in neurofeedback training methodology have an effect on participants' ability to learn how to exert a conscious control over their alpha (8-12Hz) activity as it would appear that, in fact, they do.

Conclusion

To summarise, the purpose of this thesis was to investigate whether or not there is an optimum training methodology for alpha neurofeedback training. Utilising measurements of both alpha amplitude and percentage of time spent over/under threshold, participants training to both increase and decrease their alpha (8-12Hz) activity at scalp location Pz had their performance analysed both within sessions in comparison to baseline and across sessions in comparison to baseline to look for evidence of learning. From this it was established that eyes open training appears to be a more effective way of training alpha than eyes closed and, further, that the use of audio feedback during alpha neurofeedback training is more optimal than the use of either visual or audio-visual training. It was also recommended that a comparison of contingent versus continual feedback and the division of participants into learners versus non-learners would further aid clarity in the field of alpha neurofeedback training.

It is as yet unknown whether these findings are also applicable to individual alpha neurofeedback training or when training the sub-components of the alpha band via neurofeedback as opposed to the whole bandwidth. There are also questions still to answer in relation to training schedule, long-term effects, and globalisation of effects. However, the findings from the experiments carried out here indicate that the variations which currently exist in the literature do matter and that there does appear to be an optimum way of training alpha. Once it has been further established what that optimum method for training alpha via neurofeedback is, then the application for the use of alpha neurofeedback in the field of optimal performance training can truly start to be utilised to its full potential.

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Appendix A - Details of the studies reviewed for the purposes of the literature review in chapter 1

(Blank spaces indicate no information was given/the information was unclear/the information was not applicable)

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Albert et al.	**1974**	10 female	8-12Hz	Audio	Contingent	Over 29µv	Per cent time	Enhance	
Allen et al.	**2001**	18 female	8-13Hz	Audio	Continual, proportional pitch	So feedback tone on 20% of time	If specified hemisphere has more alpha than opposite one	Both	Monopolar
Ancoli & Green	**1977**	14	8-13Hz	Audio	Contingent	40µv and above	Time in alpha; enhance scores minus suppress scores	Both	Monopolar
Angelakis et al.	**2007**	3 peak alpha frequency enhance, 2 traditional bandwidth enhance, 1 false feedback control	Peak alpha frequency vs 8-13Hz	Audio-visual			Per cent time	Enhance peak alpha and inhibit alpha amplitude vs inhibit peak alpha and enhance amplitude	Monopolar
Bauer	**1976**	13	8.5Hz-12.5Hz	Audio	Contingent	At least 20µv	Per cent time	Enhance	Bipolar
Bear	**1977**	16 nft (neurofeedback), 8 control		Audio	Contingent			Both	
Beatty	**1971**	27 nft, 9 false feedback controls	8-12Hz	Audio	Continual, proportional volume		Number of alpha waves	Enhance	Monopolar

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Albert et al.	**1974**		20 minutes	5	90 seconds vs 24 hours then 24 hours between last 2 for everyone	20 minutes	20 minutes	1 hour 40 minutes	Closed	Yes
Allen et al.	**2001**	F3-F4	Yes	5	Daily	6 minutes	3 hours 44 minutes enhance, 1 hour 52 minutes suppress	5 hours 38 minutes		Yes
Ancoli & Green	**1977**	Oz	48 minutes	5	3 times a week	8 minutes/2 minutes	48 minutes	4 hours	Closed	No
Angelakis et al.	**2007**	POz	3 minutes eyes open, 3 minutes eyes closed	31-36	Once or twice a week	8 minutes	24 minutes	12 hours 24minutes to 14 hours 24 minutes	Open	Yes
Bauer	**1976**	P3-O1	Yes, length unspecified	4	Daily		1 hour	4 hours	Open	Yes
Bear	**1977**			4	Across 22 days		1 hour	4 hours		
Beatty	**1971**	Oz	5 minutes eyes open	1	n/a	200 seconds	16 minutes 40 seconds alpha training, same amount beta	16 minutes 40 seconds alpha training, same amount beta	Open	Yes

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Beatty	**1972**	27 nft, 18 control	8-12Hz	Audio	Continual, volume increase when alpha produced		Probability of alpha occurring	Enhance	Monopolar
Bridgwater et al.	**1975**	10	9-10.5Hz range of alpha amplitude was between 10 & 23 μvs	Audio	Contingent		Number of alpha waves	Enhance	Bipolar
Brolund & Schallow	**1976**	40 male nft; 20 fake feedback controls, 20 controls with feedback but not told what it was	8-13Hz	Audio	Contingent	15μv		Enhance	Monopolar
Brown	**1970**	47	7-15Hz	Visual	Contingent, proportional intensity of blue light	2.5 waves of 15μv or more	Per cent time	Enhance	Bipolar
Chisholm et al.	**1977**	12nft, 12 false feedback controls, 12 no feedback controls	8-13Hz	Audio	Contingent	20μv	Time in alpha	Enhance	Monopolar
Cho et al.	**2008**	9	8-12Hz	Audio	Contingent, proportional volume	70% of mean eyes closed baseline amplitude	Alpha amplitude	Enhance	Monopolar

*nft = neurofeedback training

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Beatty	**1972**	Oz	5 minutes eyes open	1	n/a	200 seconds	13 minutes 20 seconds alpha nft, 13 minutes 20 seconds beta nft	13 minutes 20 seconds alpha nft, 13 minutes 20 seconds beta nft	Open	Yes
Bridgwater et al.	**1975**	Right occipital between vertex and O2	Yes	1	n/a	4 x 10 minutes of actual training	40 minutes	40 minutes	Both	Not above baseline
Brolund & Schallow	**1976**	O2	4 minutes eyes open	1	n/a	4 minutes	20 minutes	20 minutes	Open	Yes
Brown	**1970**	Parieto-occipital in right hemisphere	5 minutes eyes open, 5 minutes eyes closed	1 (n=23), 2 (n=14), 4 (n=10)	7-90days	10 minutes	50 minutes	50/100/200 minutes	Open	Yes
Chisholm et al.	**1977**	Oz	2 minutes eyes closed, 2 minutes eyes open	1	n/a	12 minutes	24 minutes	24 minutes	Open	Yes
Cho et al.	**2008**	Midline parietal	2 minutes eyes closed for threshold, 2 minutes eyes open each session	11	Once Weekly	17.5 minutes	17.5 minutes	3 hours 12.5 minutes	Closed	Across sessions but not within sessions

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Cott, Pavloski & Black	**1981**	16	8-12Hz	Audio	Continual proportional tone vs contingent	2/3(enhance)/ 1/3 (suppress) max eyes closed baseline amplitude	Per cent time	Both	Bipolar
Cott, Pavloski & Goldman	**1981**	40	8-12Hz	Audio	Continual proportional pitch	2/3(enhance)/ 1/3 (suppress) max baseline amplitude	Per cent time	Both	Monopolar
Cram et al.	**1977**	42	8-12 Hz	Audio	Contingent	Level that participants were at 25-35% time during baseline	Per cent time and average amplitude	Both	Bipolar?
DeGood, Dale, et al.	**1983**	20	8-13Hz	Audio	Contingent, proportional pitch	10µv	Difference between enhance and suppress trials	Both	Monopolar
DeGood et al. (experiment 1)	**1977**	24	8-13Hz	Audio	Contingent	15µv	Seconds in alpha	Both	Monopolar
DeGood et al. (experiment 2)	**1977**	40 male	8-13Hz	Audio	Contingent, proportional volume			Both	

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Cott, Pavloski & Black	**1981**	01-P3	2 minutes	1	n/a	2 minutes	80 minutes (40 enhance, 40 suppress)	80 minutes (40 enhance, 40 suppress)	Closed	Suppress yes, enhance no
Cott, Pavloski & Goldman	**1981**	O1	5 minutes to set threshold then 2 minutes with tone and 2 minutes without tone off to get baseline alpha densities	1	n/a	2 minutes	80 minutes	80 minutes	Closed	Yes
Cram et al.	**1977**	O2 and T6	2mins eyes closed & 2mins eyes open ambient light, plus same lighting as in their training condition	1	n/a	4 minute trials alternating between suppress and enhance	12 minutes enhance, 12 minutes suppress	24 minutes (12 minutes enhance, 12 minutes suppress)	Both	Yes
DeGood, Dale, et al.	**1983**	Pz	5 minutes	4	Within a 4 week period	5 minutes	10 minutes (5 suppress and 5 enhance)	40 minutes (20 suppress and 20 enhance)		Yes across trials but unclear if significant
DeGood et al. (experiment 1)	**1977**	Midline occipital	2 minutes eyes closed, 2 minutes eyes open	2 (1 enhance, 1 suppress)		5 minutes	20 minutes (10 eyes open, 10 eyes closed)	40 minutes (20 enhance, 20 suppress)		Suppress yes, enhance no
DeGood et al. (experiment 2)	**1977**		2 minutes eyes closed, 2 minutes eyes open	4	Weekly		1 hour	4 hours	Closed	

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
DeGood & Valle	**1978**	40 male	8-13Hz	Audio	Contingent, proportional volume	10µv	Difference in time spent over/under threshold in last 2 minutes of each session	20 enhanced, 20 suppressed	Monopolar
Dempster & Vernon	**2008**	6 (4 male, 2 female)	8-13Hz	Audio	Contingent proportional	60% mean baseline amplitude	Amplitude	Enhance	Monopolar
Drennen & O'Reilly	**1986**	10 nft, 10 controls	Average of 9-11Hz	Audio	Contingent	Level which occurred 40% time during baseline		Enhance	
Fell et al.	**2002**	13	8-12Hz	Audio	Continuous, tone lower when in alpha	Mean alpha power during baseline	alpha power	Enhance	Monopolar
Gertz & Lavie	**1983**	10 participants, 3 frequency enhance, 7 frequency suppress		Audio	Continual - proportional volume and pitch		Mean frequency, amplitude, integrated amplitude	Both	Monopolar
Goesling et al.	**1974**	15 internal loc participants, 15 external loc participants	8-13Hz	Audio	Contingent	20µv	Seconds in alpha	Enhance	Bipolar

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
DeGood & Valle	**1978**	Midline occipital	2 minutes eyes closed	4	In 4 weeks		40 minutes	2 hours 40 minutes	Closed	Within sessions but not across sessions
Dempster & Vernon	**2008**	CPz	Eyes closed	10	Daily vs twice weekly vs weekly	15 minutes	15 minutes	150 minutes	Closed	Only the daily group
Drennen & O'Reilly	**1986**	F2, P2, T3, T4, O	5 minutes	3	Weekly	5 minutes	20 minutes	1 hour	Closed	In the opposite direction to that being trained!
Fell et al.	**2002**	Cz	4 x 1 min	1	n/a	2.5 minutes	22.5 minutes	22.5 minutes	Closed	Yes
Gertz & Lavie	**1983**	P4	Yes	1	n/a	5 mins	3 hours 45 minutes	3 hours 45 minutes	Both	No
Goesling et al.	**1974**	Occipital	8 minutes	1	n/a		40 minutes	40 minutes	Open	Yes

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Hanslmayr et al.	**2005**	18	Upper IAF	Visual	Continual - colour intensity	Magnitude of alpha power as a function of baseline	Average alpha power during training minutes alpha power during baseline	Enhance	Monopolar
Hardt & Kamiya	**1976**	16 male	8-13Hz	Audio-visual	Continual, proportional volume plus a score every 2 minutes	10µv?	Per cent time vs integrated alpha	Both	Monopolar
Hardt & Kamiya	**1978**	16 participants (8 high and 8 low in trait anxiety)	8-13Hz	Audio-visual	Continual, proportional volume plus a score every 2 minutes	10µv	Integrated amplitude and per cent time scores	Both	Monopolar
Holmes et al.	**1980**	44	8-13Hz	Audio	Contingent	10µv	Time in alpha	Enhance	Monopolar
Hord & Barber	**1971**	11		Audio	Contingent	Level which occurred 20% of the time during baseline	% time during enhance minus % time during suppress	Both	Monopolar

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Hanslmayr et al.	**2005**	F3, Fz, F4, P3, Pz, P4	2 minutes eyes closed, 2 minutes eyes open	1	n/a	5 minutes	20 minutes alpha, 20 minutes theta	20 minutes alpha, 20 minutes theta	Open	Yes
Hardt & Kamiya	**1976**	Oz	8 minutes	7	Daily	2 minutes	48 minutes (32 enhance, 16 suppress)	3 hours 44 minutes enhance, 1 hour 52 minutes suppress	Closed (but open for score)	Depends what measure used
Hardt & Kamiya	**1978**	Oz, O1, C3	8 minutes before each enhance and each suppress trial	7	Daily	2 minutes	32 minutes enhance, 16 minutes suppress	3 hours 44 minutes enhance, 1 hour 52 minutes suppress	Closed	Yes
Holmes et al.	**1980**	O1	10 minutes eyes open	1	n/a	10 minutes	20 minutes	20 minutes	Open	Yes
Hord & Barber	**1971**	Oz	8 minutes	2		8 minutes	16 minutes enhance, 8 minutes suppress	32 enhance, 16 suppress	Open	Yes

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Hord et al.	**1976**	20 (10 4-14Hz suppress, 10 alpha enhance)	8-12Hz	Audio-visual	Per cent time scores and contingent tone	Level obtained for 50% time during eyes open baseline	Per cent time	Both	Monopolar
Hord et al.	**1975**	7 nft, 7 yoked		Audio-visual	Per cent time score, contingent tone	Level obtained for 50% time during eyes open baseline	Per cent time	Enhance	Monopolar
Jackson & Eberly	**1982**	5	8-13Hz	Visual	Contingent (light on/off) plus visual counter	25% eyes closed baseline	Per cent time, number of alpha events	Suppress	Bipolar
Johnson & Meyer	**1974**	12 female nft, 12 female controls						Enhance	
Kondo et al.	**1973**	30						Enhance	
Knox	**1982**	25	8-12Hz	Audio	Continual proportional tone plus score at end of each trial		Integrated alpha	Enhance	Bipolar?
Konareva	**2005**	30 nft, 30 control	8-14Hz	Audio	Continual, proportional volume		Mean spectral power µv2/Hz	Enhance	Monopolar

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Hord et al.	**1976**	O2	Yes	Unclear	Twice a day for 2 days then for an hour per 2 hours 40 minutes?	1 hour	1 hour	Unclear	Open	Yes
Hord et al.	**1975**	O2	Yes	14	Daily morning and afternoon for 3 days, 2 day gap, then daily morning and afternoon for 4 days	45 minutes	45 minutes	10.5 hours	Open	Yes
Jackson & Eberly	**1982**	O1 - O3	5 minutes	5	Daily	5 minutes	5 minutes	25 minutes	Open	Yes
Johnson & Meyer	**1974**			3	Within 2 weeks		40 minutes	2 hours		Yes
Kondo et al.	**1973**			5			10 minutes	50 minutes	Open	Yes
Knox	**1982**	01-P3, O2-P4	10 minutes eyes closed	1	n/a	10 minutes	80 minutes	80 minutes	Closed	Yes
Konareva	**2005**	C3, C4	1 minute	1	n/a	3 minutes	3 minutes	3 minutes	Closed	Yes - for some

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Konareva	**2006**	30 nft, 30 control	8-14Hz	Audio	Continual, proportional volume		Mean spectral power µv2/Hz	Enhance	Monopolar
Kondo et al.	**1975**	40	8-13Hz	Audio	Continual, proportional pitch		Integrated alpha	Enhance	Monopolar
Kondo et al.	**1979**	10 real feedback, 10 inverted feedback	8-13Hz	Audio	Continual, proportional pitch		Number of epochs of integrated alpha	Both	Monopolar
Krenn et al.	**in review**	26nft, 25 controls	Individual upper and lower alpha bands	Visual	Continual	Baseline	Ratio of upper alpha to lower alpha power	Enhance upper alpha, suppress lower alpha	Monopolar
Kuhlman & Klieger	**1975**	29 nft & 11 no feedback controls	8-12Hz	Audio	Contingent	20µv	Per cent time	Enhance	Monopolar
London & Schwartz	**1984**	40 nft, 40 false feedback controls	8-12Hz	Audio	Contingent	Adjusted so tone would be on 50% of the time	Per cent time	Both	Monopolar
Lynch et al. (experiment 1)	**1974**	16 nft, 8 false feedback controls	8-12Hz	Visual	Contingent (coloured squares change from red to green if alpha)	15µv	Seconds of alpha	Enhance	Monopolar
Lynch et al. (experiment 2)	**1974**	13	8-12Hz	Visual	Contingent (coloured squares change from red to green if in alpha)	15µv	Seconds of alpha	Both	Monopolar
Lynch et al. (experiment 3)	**1974**	5 male	8-12Hz	Audio	Continual, proportional pitch	15µv	Seconds of alpha	Enhance	Monopolar

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Konareva	**2006**	C3, C4	1 minute	1	n/a	3 minutes	3 minutes	3 minutes	Closed	Yes - for some
Kondo et al.	**1975**	Oz		1	n/a	5 minutes	50 minutes	50 minutes	Closed	Yes
Kondo et al.	**1979**	Oz	2 x 5 minutes (one in dark, one in light)	1	n/a	40 minutes	40 minutes	40 minutes	Closed	Enhance yes, suppress no
Krenn et al.	**in review**	P3, P4	Yes	10	Twice a day for 5 consecutive days	3 minutes	18 minutes enhance, 18 minutes suppress	3 hours	Open	Yes
Kuhlman & Klieger	**1975**	Midway between Pz and Oz	32 minutes (taken one week before the session)	1	n/a	4 minutes	32 minutes	32 minutes	Closed	Yes
London & Schwartz	**1984**	Left-occipital	2 minutes eyes closed	1	n/a	60 seconds	10 minutes	10 minutes		Unclear
Lynch et al. (experiment 1)	**1974**	O2	3 minutes eyes open, 3 minutes eyes closed	1	n/a	2 minutes	20 minutes	20 minutes	Open	Yes but so did the controls
Lynch et al. (experiment 2)	**1974**	O2	3 minutes eyes open, 3 minutes eyes closed	1 (but had already participated in the previous experiment)	Week after first experiment	2 minutes	22 minutes enhance, 12 minutes suppress	22 minutes enhance, 12 minutes suppress	Open	Yes
Lynch et al. (experiment 3)	**1974**	O2	3 minutes eyes open, 3 eyes closed	1	n/a	2 minutes	20 minutes	20 minutes	Open (in dark)	No

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Markovska-Simoska et al.	**2008**	6 female music students, 6 female control music students	Individual Upper alpha	Audio (applause sound)	Contingent	Set so occurred 60% of the time	Alpha Power	Enhance	Bipolar
Marshall & Bentler	**1976**	32 nft, 48 controls	8-10Hz vs11-13Hz	Audio	Contingent	At least 15µv	Per cent time	Enhance	Bipolar
Martindale & Armstrong	**1974**	30 males	7-13Hz	Audio	Contingent	Over 20µv	Per cent time	Both	Bipolar
Martindale & Hines	**1975**	32 males	8-13Hz	Audio	Contingent	On or over 20µv	Per cent time	Both	Bipolar
Mullholland et al.	**1979**	6	8-13Hz	Visual	Contingent, coloured slide appeared when in alpha	At least 5-8µv and 10% vs 25% vs 40% maximum eyes closed baseline amplitude	Amplitude and time in alpha	Enhance	Bipolar
Mullholland & Eberlin	**1977**	10	Between 2Hz above and 2 Hz below each individual's dominant alpha frequency	Visual	Contingent	25% eyes closed baseline amplitude	Time, number of events, ratio of events to no events	Enhance	Bipolar

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Markovska-Simoska et al.	**2008**	F3-O1 and F4-O2	Yes	20	Spread over a 2 month period		30 minutes	10 hours	Closed	Yes
Marshall & Bentler	**1976**	01-T3	Yes	1	n/a	6 minutes	30 minutes	30 minutes	Closed	No
Martindale & Armstrong	**1974**	O2-P4	250 seconds	1	n/a	150 seconds	450 seconds enhance; 150 seconds suppress	10 minutes (2.5 minutes suppress, 7.5 minutes enhance)	Closed	Yes
Martindale & Hines	**1975**	O2 - P4	10 minutes eyes closed (session 1), 5 minutes eyes open (session 2)	1	n/a	5 minutes practice then 100 sec per trial	21 minutes 40 seconds (5 minutes practice, 8 minutes 20 enhance, 8 minutes 20 suppress)	21 minutes, 40 seconds	Open	Yes
Mullholland et al.	**1979**	O1-O2	30 alpha events in eyes open and eyes closed conditions	1	n/a	30 alpha durations	30 alpha durations	30 alpha durations	Open	Yes
Mullholland & Eberlin	**1977**	01-P3, O2-P4	30 alpha events in eyes open and eyes closed conditions	1	n/a	An alpha 'event'	30 alpha 'events'	30 alpha 'events'	Open	Yes

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Mullholland et al.	**1983**	16	8-13Hz	Visual	Contingent	25% maximum baseline amplitude	Time in alpha, alpha power	Enhance	Bipolar
Nowlis & Kamiya	**1970**	16 eyes closed and 10 eyes open	8-13Hz	Audio	Contingent	20µv	Number of seconds during test period	Both	Bipolar
Nowlis & Wortz	**1973**	16 male		Audio			Per cent time	Enhance	Monopolar
Orenstein & McWilliams	**1976**	13	8-13Hz	Audio-visual	Continual proportional pitch and shown per cent time in alpha	10µv, 15µv or 20µv if under 20%, 20-80% or over 80% time in alpha respectively	Per cent time	Enhance	Monopolar
Orne & Paskewitz	**1974**	22 male	8-12Hz	Audio-visual	Continuous proportional pitch, plus a total score between trials	15µv	Time in alpha	Enhance	Monopolar
Paskewitz et al.	**1970**	Over 25		Visual and audio				Both	

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Mullholland et al.	**1983**	01-P3	30 alpha and 30 non-alpha events in eyes closed and eyes open in the dark conditions	1	n/a	30 alpha and not alpha segments	30 alpha and not alpha segments	30 alpha and not alpha segments	Open	
Nowlis & Kamiya	**1970**	Right-side occipital-frontal or occipital central	2 minutes eyes closed (n=16), 2 minutes eyes closed then 2 minutes eyes open (n=10)	1 session	n/a	Up to 15 minutes	Up to 15 minutes	Up to 15 minutes	16 closed, 10 open	Yes
Nowlis & Wortz	**1973**	Midline Frontal, Pz, Oz	No	5-52 sessions	Twice a week	15 minutes	45 minutes (15 at each site)	At least 3 hours 45 minutes	Closed	Yes
Orenstein & McWilliams	**1976**	Occipital	3 minutes eyes open and 3 minutes eyes closed	7	Weekly	5 minutes, 2 minutes	25 minutes	2 hours 55 minutes	Open	No
Orne & Paskewitz	**1974**	O2	4 x 3 mins in eyes open, eyes closed and dark and light conditions	3		5 minutes	30/20/25 minutes	30 minutes (n=12), 1.25 hours (n=10)		No
Paskewitz et al.	**1970**									Yes but same pattern occurred in non-contingent controls and during rest periods

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Paskewitz & Orne	**1973**	16	8-12Hz	Audio-visual	Continuous proportional pitch, plus a total score between trials	15µv	Time in alpha	Enhance	Monopolar
Peper & Mulholland	**1970**	21	8-13Hz	Audio	Contingent	Above 25% maximum baseline amplitude	Per cent time	Both	Bipolar
Plotkin	**1976**	30 nft, 10 control		Audio	Continual - proportional volume			Both	Bipolar
Plotkin	**1978**	12		Audio	Proportional, also given score every 2 minutes		Integrated amplitude		Bipolar versus monopolar
Plotkin	**1980**	10 nft, 10 yoked, 40 other		Audio	Continual, proportional volume. Also given score every 2 minutes		Alpha amplitude	Enhance	Monopolar
Plotkin et al.	**1976**	48		Audio	Continual, proportional volume		Integrated amplitude	Enhance	Bipolar

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Paskewitz & Orne	**1973**	O2	2 x 3 minutes	6	Weekly	5 minutes/2 minutes	25 minutes	2 hours 30 minutes	Open	Yes
Peper & Mulholland	**1970**	O2-P4	eyes closed and eyes open, length unspecified	1 (n=13), 6 (n=5)		2 minute trials alternating between suppress and enhance	20 minutes (10 enhance, 10 suppress)	20 minutes (for 13 participants but 8 did 2hours)	Closed	Some participants
Plotkin	**1976**	O2-F4	3 minutes eyes closed, 3 minutes eyes open	2		3 minutes, alternating suppress and enhance trials	18 minutes enhance, 18 minutes suppress	72 minutes (36 enhance, 36 suppress)	Open	Yes
Plotkin	**1978**	O2-F4 vs Oz	20 minutes - session 1; 6 minutes for remaining sessions	10		4 minutes per trial - one group; all in one go - the rest	32 minutes - session 1; 52 minutes - remaining sessions	8 hours 10 minutes	Closed	No
Plotkin	**1980**	Oz	5 x 60 seconds	1	n/a		30 minutes	30 minutes	Closed	Yes
Plotkin et al.	**1976**	O2-F4	2 minutes eyes open, 2 minutes eyes closed	1	n/a	6 minutes	30 minutes	30 minutes	Open	Yes - for some

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Plotkin & Rice	**1981**	10 (some alpha, some beta)		Audio	Continual, proportional volume. Also given score every 2 minutes		Integrated amplitude	Both	Monopolar
Potolicchio, Jr. et al.	**1979**	14 nft (7 enhance, 7 suppress); 6 false feedback controls	8-13Hz	Audio-visual	Moving a bar and contingent on off tone	Amplitude which participant in 50% time during baseline	Alpha intensity ratio from baseline to trials	Enhance vs suppress	Bipolar
Pressner & Savitsky	**1977**	40 nft, 40 controls	7.5-12.5	Audio	Contingent			Enhance	Bipolar
Prewett, & Adams	**1976**	36	7.5-13Hz	Audio	Contingent	80% baseline amplitude for enhance; 20% baseline amplitude for suppress	Seconds in criterion alpha during suppression subtracted from seconds during enhance plus a constant	Both	Bipolar
Putnam	**2000**	77	8-12Hz	Visual	Continual, proportional to amplitude	n/a	Percentage of change over baseline	Enhance	Monopolar
Regestein, Buckland, & Pegram	**1973**	5	8-13Hz	Audio	Contingent		Per cent time	Both	
Regestein, Pegram, Cook, & Bradley	**1973**	31	8-13Hz	Audio	Contingent		Per cent time	Both	Bipolar

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Plotkin & Rice	**1981**	Oz	10 minutes eyes closed	5-7 sessions	In 3 weeks	2 minutes	40 minutes	3 hours 20 minutes to 4 hours 40 minutes	Closed	Only for one participant
Potolicchio, Jr. et al.	**1979**	C3-Cz	3 minutes eyes open, 3 minutes eyes closed	5-10 sessions	3-5 times per week	5 minutes	15 minutes	75-150 minutes	Open	Yes
Pressner & Savitsky	**1977**	Oz-C3		1	n/a	100 seconds	33 minutes 20 seconds	33 minutes 20 seconds		Yes
Prewett, & Adams	**1976**	P3 - O1	10 minutes eyes closed	1	n/a	2 minutes	10 minutes	10 minutes	Closed	No
Putnam	**2000**	Pz	Yes, length unspecified	1	n/a	12 minutes	12 minutes	12 minutes	Open	Yes
Regestein, Buckland, & Pegram	**1973**	Parietal-occipital		1 enhance, 1 suppress	One week apart	12 hours enhance, 12 hours suppress	12 hours enhance, 12 hours suppress	12 hours enhance, 12 hours suppress	Closed but allowed to open them	
Regestein, Pegram, Cook, & Bradley	**1973**	P3-O1 or P4-O2		3	Minimum of one week apart	4.5 hours, 12 hours and 12 hours	4.5 hours, 12 hours and 12 hours	4.5 hours, 12 hours and 12 hours	Closed but allowed to open them	4.5 hour session - no; 12 hour session - unclear

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Schauerhofer et al.	**2011**	13 nft females, 12 controls	Upper alpha, frequency unknown	Visual			Ration of upper alpha to lower alpha power	Enhance	
Schmeidler & Lewis	**1971**	13		Visual	Contingent		Seconds in alpha	Both	Monopolar
Schwartz et al.	**1976**	20	8-13Hz	Audio	Contingent	1/3 mean peak amplitude	Per cent time	Both	Hemisphere symmetry and asymmetry training
Strayer et al.	**1973**	20 nft, 20 false feedback controls	8-12Hz	Audio	Contingent		Number of seconds in alpha	Enhance	Monopolar
Suter	**1977**	20	8-13Hz	Audio	Contingent	3 consecutive cycles of mean baseline amplitude	Per cent time	Both	Bipolar
Suter & Dillingham	**1979**	12	8-13Hz	Audio	Contingent	3 consecutive alpha waves	Time in alpha	Both	Bipolar
Travis et al.	**1973**	16						Enhance	

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Schauerhofer et al.	**2011**		Yes	10					Open	Yes
Schmeidler & Lewis	**1971**	Right occiput	Yes	2	Once Weekly	15 minutes	15 minutes enhance, 15 minutes suppress	30 minutes enhance, 30 minutes suppress	Open	Yes
Schwartz et al.	**1976**	P3 & P4	none	1	n/a	3 minutes	36 minutes (12 minutes both off, 12 minutes left on right off, 12 minutes right on left off)	36 minutes	Closed	Yes
Strayer et al.	**1973**	Midline Occiput	2 minutes eyes closed	1	n/a	2 minutes	22 minutes with feedback	22 minutes with feedback	Closed	Yes
Suter	**1977**	O1-T3	7 minutes	1	n/a	5 minute trials alternating between enhance and suppress	40 minutes (20 enhance, 20 suppress)	40 minutes (20 enhance, 20 suppress)	Open	Yes
Suter & Dillingham	**1979**	T3-O1	Yes, unspecified length	12		5 minutes alternating enhance and suppress	40 minutes	8 hours	Open	Yes
Travis et al.	**1973**			5			10 minutes	50 minutes	Open	Unknown but changes shown in no-feedback sessions if warned it was a no feedback session

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Travis et al. (experiment 1)	**1974**	8 nft, 8 false feedback, 8 no feedback	8-13Hz	Visual	Contingent	50% of maximum baseline amplitude	Per cent time	Enhance	Monopolar
Travis et al. (experiment 2)	**1974**	14 nft, 14 false feedback	8-13Hz	Visual	Contingent	50% of maximum baseline amplitude	Per cent time	Enhance	Monopolar
Travis et al.	**1974**	56	8-13Hz	Audio	Continuous proportional pitch vs contingent	50% of maximum eyes closed resting amplitude	Criterion alpha and integrated alpha	Enhance	Monopolar
Travis et al.	**1974**	45	8-13Hz	Visual	Contingent	50% of maximum eyes closed resting amplitude	Seconds in alpha	Enhance	Monopolar
Tyson	**1982**	20 nft; 20 controls	8-13Hz	Audio	Contingent, proportional volume	10µv	Mean integrated amplitude	Enhance	Monopolar
Tyson	**1987**	40	8-13Hz	Audio	Continual, proportional volume	10µv	Integrated alpha, time in alpha, alpha amplitude	Enhance	Monopolar
Tyson & Audette	**1979**	20	8-13Hz	Audio	Continual, proportional volume	10µv	Mean integrated amplitude	Enhance	Monopolar
Valle & DeGood	**1977**	40 (20 enhance, 20 suppress)	8.5-13.5Hz	Audio	Contingent proportional volume	10µv	Per cent time	Both	Monopolar

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Travis et al. (experiment 1)	**1974**	Oz		2		10 minutes	50 minutes	100 minutes	Open	Yes
Travis et al. (experiment 2)	**1974**	Oz		1 (although some took part in the previous study)		10 minutes	50 minutes	50 minutes	Open	Yes
Travis et al.	**1974**	Oz		2		5 minutes	50 minutes	50 minutes eyes closed and 50 minutes eyes open	Both	Yes
Travis et al.	**1974**	Oz		5		10 minutes	10 minutes	50 minutes	Open	Yes
Tyson	**1982**	P4	2 x 1.5mins	1	n/a	5 minutes	30 minutes	30 minutes	Open	Yes
Tyson	**1987**	P4	14 minutes (28 x 30 seconds across 5 conditions)	1	n/a	5 minutes	40 minutes	40 minutes	Open	Yes
Tyson & Audette	**1979**	O2	5 minutes, eyes open	1	n/a	8 minutes	64 minutes	64 minutes	Open	Yes
Valle & DeGood	**1977**	Midline occipital	2 minutes eyes closed, 2 minutes eyes open	4 (n=34), 3 (n=5), 1 (n=1)	Weekly	2 minutes	40 minutes	2hours 40 minutes	Closed	Yes

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Valle & Levine	**1975**	40 males, 20 enhance, 20 suppress	8.5-13.5Hz	Audio	Contingent, proportional volume	10µv	Number of seconds	Both	Monopolar
Vernon & Withycombe	**2006**	5 experimental, 4 controls	8-12Hz	Audio-visual	Continuous visual, contingent proportional audio		Amplitude	Enhance	Monopolar
Wacker	**1996**	20 females, 10 alpha, 10 beta participants	8-13Hz	Audio	Contingent		Not used	Enhance	Monopolar
Wagner	**1975**	60	8-13Hz	Audio	Contingent		Number of seconds	Suppress	Bipolar
Walsh	**1974**	40		Audio	Contingent	25% baseline amplitude	per cent time	Both	Bipolar
Williams	**1977**	24 false feedback participants	8-12Hz	Audio	Fake contingent	10µv	per cent time	Enhance	Bipolar
Woodruff	**1975**	20 male experimental (10 old, 10 young) and 10 male fake feedback controls (5 old, 5 young)	Bandwidths between 1Hz above and 1Hz below: IAF modal frequency, IAF modal frequency plus 2Hz (fast group), IAF modal frequency minus 2Hz (slow group)	Audio	Contingent	Unspecified amplitude	Number of seconds	Enhance	Bipolar
Yamaguchi	**1980**	24: 12 with internal and 12 with external locus of control	8-12Hz	Audio	Continual proportional pitch	Over 20µv	per cent time	Enhance	Monopolar

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Valle & Levine	**1975**	Midline occipital	2 minutes eyes closed	4	Weekly	40 minutes	40 minutes	2 hours 40 minutes	Closed	Suppress yes, enhance no
Vernon & Withycombe	**2006**	CPz	No	10		5 minutes	10 minutes	100 minutes	Open	“Limited”
Wacker	**1996**	Left occipital	none	10	Across 5 weeks		20 minutes	3 hours 20 minutes	Open	
Wagner	**1975**	T3-T4		1	n/a	10 minutes	10 minutes	10 minutes	Unknown but they wore opaque goggles	No
Walsh	**1974**	01-P3, 02-P4	2 minutes	2		5 minutes	20 minutes	40 minutes	Both (1 session of each)	Suppression instruction group only
Williams	**1977**	02-P4	2 minutes eyes open	1	n/a	10 minutes	40 minutes	40 minutes	Open	Yes
Woodruff	**1975**	P3 - O1	16 minutes eyes closed	1-10 sessions in modal frequency band then 2-24 in others		2 minutes	1 hour	At least 3 hours		Yes
Yamaguchi	**1980**	Oz	6 minutes eyes closed	4	3 every 7 minutes then final session next day vs all 4 daily	15 minutes	15 minutes	1 hour with feedback	Closed	Yes

Authors	Year	Participants	Alpha Frequency Band	Feedback Modality	Feedback Type	Threshold	Alpha Measurement	Training Direction	Montage
Zeier & Kocher	**1979**	35	8-13Hz	Audio	Continual proportional pitch	Integrated alpha	Seconds in alpha	Enhance	Monopolar
Zirkel et al.	**1977**	12	8-12Hz	Audio	Continual proportional pitch		Mean amplitude, number of seconds, number of seconds over threshold in session minus number of seconds over threshold in baseline plus a constant	Enhance	Bipolar
Zoefel et al.	**2011**	12 nft, 10 controls	Individual upper alpha	Visual	Continual	Baseline	Amplitude	Enhance	Monopolar (but output was the average amplitude of the 5 training sites)

Authors	Year	Location	Baseline	No Sessions	Session Frequency	Trial Length	Session Length	Total Training Received	Eyes Open or Closed	Changes in Alpha?
Zeier & Kocher	**1979**	Pz	2 minutes eyes open, 2 minutes eyes closed	1	n/a	2 minutes	24 minutes with feedback	24 minutes	Open	Yes but only in 6 participants
Zirkel et al.	**1977**	O2-T4	3 minutes eyes closed	1	n/a	5minutes and 8minutes	21 minutes	21 minutes	Closed	Yes
Zoefel et al.	**2011**	P3, Pz, P4, O1, O2	Yes	5	Daily	5 minutes	25 minutes	2 hours 5 minutes	Open	Yes

Dept of Applied Social Sciences
Newingate House
Canterbury Christ Church University
Canterbury,
Kent
CT1 1QU

Participant Information Sheet

Study: A study examining methodological components of EEG biofeedback to entrain alpha EEG activity.

I'm currently undertaking my PhD at Canterbury Christ Church University investigating methodological components of electroencephalographic (EEG) biofeedback training (see paragraph 2, below). In particular, this study will compare types of feedback (audio vs visual vs audio-visual) in an attempt to ascertain which is the more effective at producing changes in the EEG.

I'm looking for volunteers to take part in my research. The training will consist of ten once-weekly EEG Biofeedback sessions with each session lasting approximately 1 hour. These sessions would involve you training to try and consciously alter your alpha brain waves and would be held at a mutually convenient time for both yourself and the researcher.

At the end of the ten weeks and once you have completed all your sessions you will receive £50 and all the RPS credits you need although it should be noted that this study is entirely voluntary and you are free to withdraw at any time without giving a reason if you so wish. Furthermore, any details collected from you will be coded so as to maintain your anonymity.
The results from the study are expected to be disseminated via international conferences and refereed journal publications. If you have any further questions/queries about this study you are welcome to contact me at the following:

Tammy Dempster
Psychology
Dept of Applied Social Sciences
Newingate House
Canterbury Christ Church University
Canterbury, Kent CT1 1QU
Email: td31@canterbury.ac.uk

Appendix C – Participant Screening Form

Participant Screening Form

Study: A study examining methodological components of alpha EEG biofeedback training

Please note that all the information you provide below is subject to absolute confidentiality. In order to devise a training program in a way that is beneficial to you, ***it is of great importance that you answer as truthfully as possible****. Thank you.*

Name

Date of Birth

Sex	Male	Female
Handedness	Left	Right

Have you ever been diagnosed with epilepsy, or is there any history of epilepsy in your family	Yes	No
Have you ever consulted a professional about a psychological problem? If yes please specify:	Yes	No
Are you currently taking any prescribed medication? If yes please specify:	Yes	No
Do you habitually take any non-prescribed medication (e.g., tranquilisers)? If yes please specify:	Yes	No

Are there any aspects regarding your general physical and mental health not covered by the above questions, but which you think may be of relevance, please elaborate below:

Appendix D – Participant Consent Form

Dept of Applied Social Sciences
Newingate House
Canterbury Christ Church University
Canterbury,
Kent
CT1 1QU

Participant Consent Form

Study: A study examining methodological components of alpha EEG biofeedback.

Have you read the information sheet?	Yes	No
Have you had the opportunity to ask questions and discuss the study?	Yes	No
Have you received satisfactory answers to all your questions?	Yes	No

To whom have you spoken? (write name) ……………………………………………

Do you understand that you are free to withdraw from the study at any time, without having to give a reason?	Yes	No
Do you agree to take part in the study?	Yes	No
Do you understand that this form may be examined by an Ethics Committee as part of the monitoring process	Yes	No

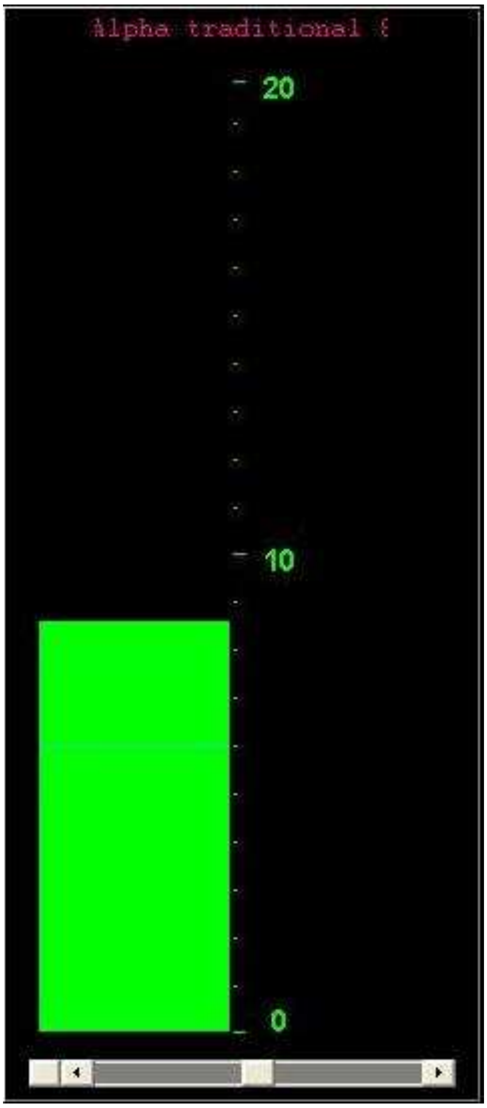
Your Name in Block Capital Letters: ……………………………………………………

Signature **Date**

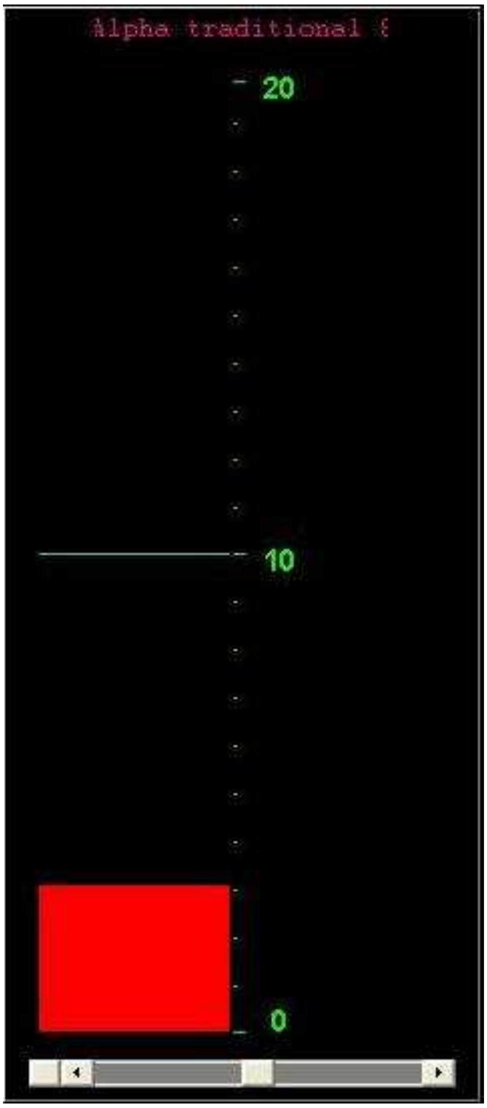
Name of person obtaining consent …………………………………………………..

Signature **Date**

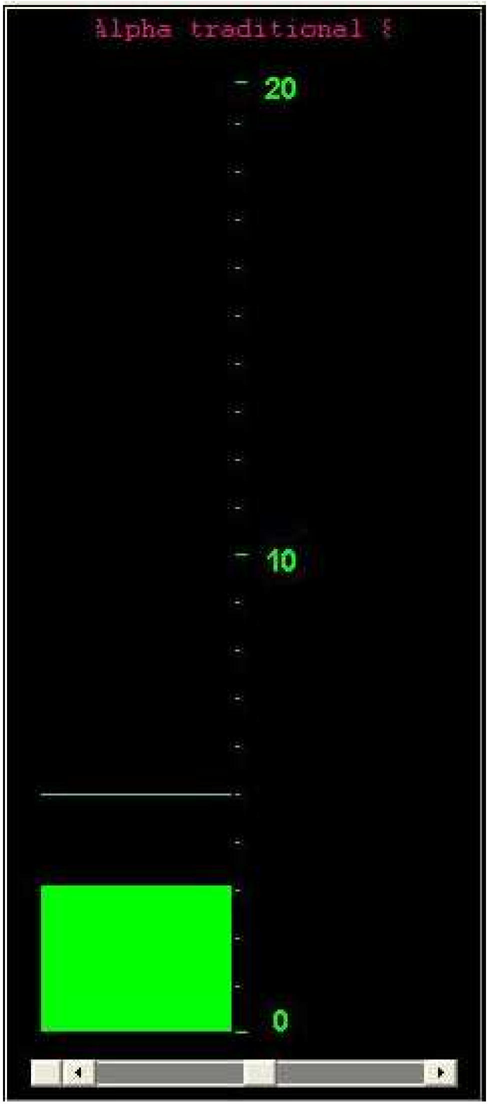
Appendix E – Example of what the visual feedback looked like when a participant was successfully enhancing their alpha over their threshold during enhancement training



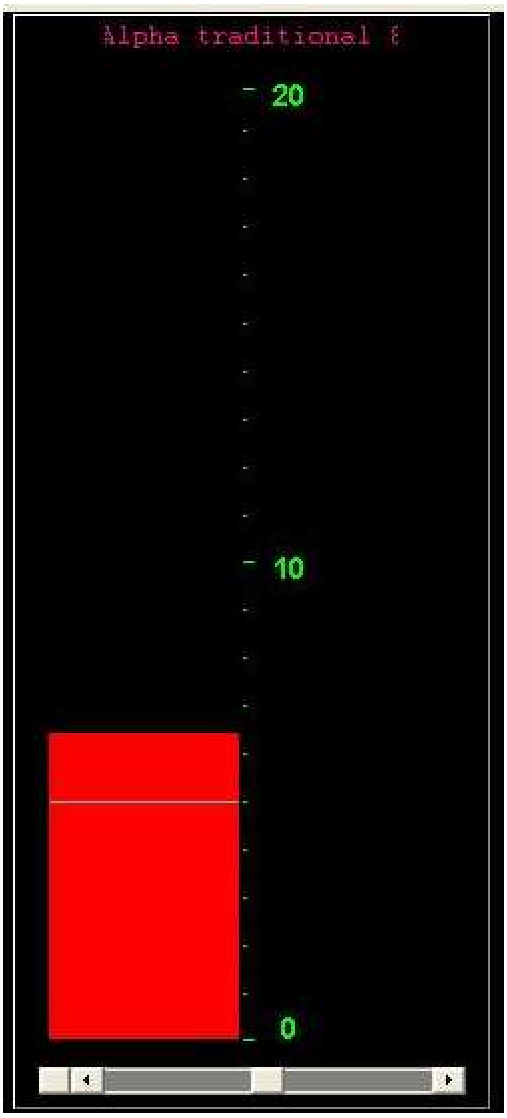
Appendix F – Example screenshot of what the visual feedback looked like when a participant's alpha was below threshold during their enhancement training



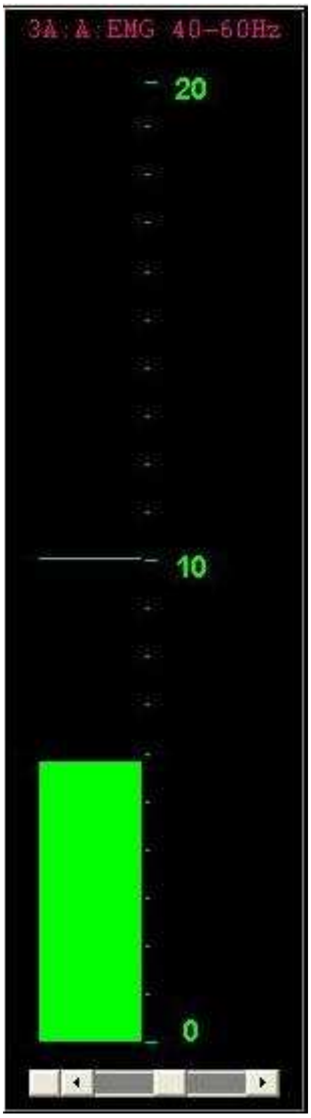
Appendix G - Example screenshot of what the visual feedback looked like when a participant was successfully suppressing their alpha below threshold during suppression training



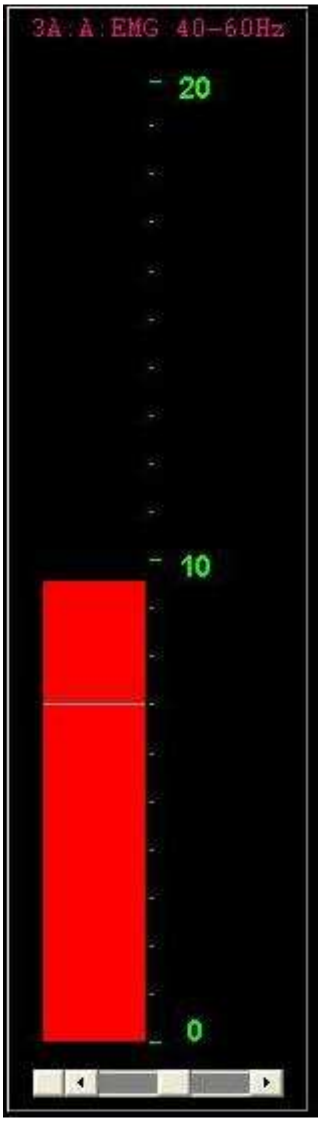
Appendix H – Example screenshot of what the visual feedback looked like when a participant's alpha was not being suppressed below threshold during their suppression training



Appendix I – Example screenshot of what the visual feedback looked like when the participant suppressed their EMG below threshold



Appendix J – Example screenshot of what the visual feedback looked like when the participant did not suppress their EMG below threshold



Appendix K

Overarching Omnibus Analyses for 'Chapter 4 – Experiment 2 - Eyes Open versus Eyes Closed Training' in order to provide a direct comparison between the two feedback conditions

1. Enhancement Training

1.1. Within Sessions Compared to Baseline

In order to provide a direct comparison between the eyes open and eyes closed feedback groups, a 2 (Group: *Eyes Open* versus *Eyes Closed*) x 2 (Baseline: *Eyes Open* versus *Eyes Closed*) x 2 (Segment: *Segment 1* versus *Segment 2*) x 5 (Period: *1-5*) mixed ANOVA, with *Group* as the between participants factor and *Baseline* and *Segment* as the within groups factors, was performed on the within sessions data. First using amplitude as the measure and then using per cent time as the measure.

1.1.1. Amplitude

There was a significant main effect of *Group, F* (1, 31) = 44.0, $p < .001$, $MS_E = 100.7$, partial $\mu^2 = .59$. This was due to the eyes closed participants producing a significantly larger difference in amplitude between baselines and training than the eyes open. There was also a significant main effect of *Baseline*, *F* (1, 31) = 112.2, $p < .001$, $MS_E = 88.9$, partial $\mu^2 = .79$. This is due to participants producing a larger difference in amplitude when their training was compared to the eyes closed baseline than when their training was compared to their eyes open baseline. There was also a main effect of *Period, F* (2, 57) = 47.4, $p = .002$, $MS_E = 6.8$, partial $\mu^2 = .18$. There was a significant *Period* by *Condition* interaction effect, F (2, 57) = 15.0, $p < .001$, $MS_E = 6.8$, partial $\mu^2 = .33$. There was a significant *Segment* by *Period* by *Group* interaction effect, F (3, 86) = 4.3, $p = .009$, $MS_E = 1.0$, partial $\mu^2 = .12$. None of the other main or interaction effects were found to be significant (all $p > .05$).

1.1.2. Per Cent Time

There was a significant main effect of *Group* F (1, 31) = 40.9, $p < .001$, $MS_E = 1975.1$, partial $\mu^2 = .57$. This was due to participants in the eyes open baseline producing larger differences in the amount of time spent over threshold between baseline and training than the eyes closed group did. There was a significant main effect of *Baseline*, F (1, 31) = 249.9, $p < .001$, $MS_E = 807.8$, partial $\mu^2 = .89$, due to participants spending more time over threshold when compared to the eyes closed baseline than when compared to the eyes open. There was also a significant main effect of *Period*, F (2, 77) = 7.4, $p < .001$, $MS_E = 67.2$, partial $\mu^2 = .19$. There was a *Period* by *Group* interaction effect, F (2, 77) = 20.6, $p < .001$, $MS_E = 67.2$, partial $\mu^2 = .40$. There was a marginal *Segment* by *Period* interaction effect, F (2, 81) = 2.8, $p = .054$, $MS_E = 28.9$, partial $\mu^2 = .08$. No other main or interaction effects were found to be significant.

1.2. Across Sessions Compared to Baseline

A 2 (Group: *Eyes Open* versus *Eyes Closed*) x 3 (Stage*: Eyes Open Baseline* versus *Eyes Closed Baseline* versus *Training*) x 10 (Session: *1-10*) mixed ANOVA, with *Group* as the between groups factor and *Stage* and *Session* as the within groups factors, was used to look at the across sessions in comparison to baseline data.

1.2.1. Amplitude

There was a significant main effect of *Group*, F (1, 26) = 4.7, p = .039, MS_E = 795.8, partial μ^2 =.15. This was due to the eyes closed participants producing larger amplitudes than the eyes open. There was a significant main effect of *Stage*, F (2, 52) = 67.3, p < .001, MS_E = 53.1, partial μ^2 = .72. This was due to participants producing larger amplitudes during training than during their eyes open baseline, larger amplitudes during their eyes closed baseline than during training, and larger amplitudes during their eyes closed baselines than during their eyes open baselines. There was a significant main effect of *Session*, F (5, 139) = 5.16, p < .001, MS_E = 8.4, partial μ^2 = .17. There was a *Stage* by *Session* interaction effect, F (2, 52) = 10.5, p < .001, MS_E = 53.1, partial μ^2 = .29. No other interaction effects were found to be significant.

1.2.2. Per Cent Time

There was a significant main effect of *Group*, F (1, 25) = 112.3, p < .001, MS_E = 950.5, partial μ^2 =.82, due to participants spending more time over threshold when their eyes were open than when their eyes were closed. There was a significant main effect of *Stage*, F (2, 40) = 100.1, $p < .001$, $MS_E = 13216.0$, partial μ^2 =.80, due to participants spending more time over threshold in their eyes closed baselines than in their eyes open baselines, more time over threshold in their eyes closed baselines than during training, and more time over threshold during training than during their eyes open baselines. There was a significant *Stage* by *Group* interaction effect, F (2, 40) = 14.41, p < .001, MSE = 917.3, partial μ2 =.37. There was a significant *Session* by *Group* interaction effect, F (9, 225) = 2.1, p = .03, MSE = 44.8, partial μ2 =.08. No other main or interaction effects were found to be significant.

2. Suppression Training

The same analyses performed on the enhancement data, above, was performed on the suppression data.

2.1. Within Sessions Compared to Baseline

2.1.1. Amplitude

There was a significant main effect of *Group* F (1, 31) = 18.3, $p < .001$, $MS_E = 170.2$, partial μ^2 = .38. This is due to participants producing a larger difference between the baselines and training in the eyes open group than in the eyes closed. There was a significant main effect of *Baseline*, F (1, 31) = 112.2, $p < .001$, $MS_E = 88.9$, partial μ^2 = .78. This is due to participants showing larger differences in amplitude when their training was compared to their eyes closed baselines than when their training was compared to their eyes open.

There was a marginal main effect of *Segment,* F (1, 31) = 4.08, p = .052, MS_E = 2.7, partial μ^2 = .12. There was a significant main effect of *Period,* F (1, 41) = 5.45, p = .016, MS_E = 6.64, partial μ^2 = .15. There was a significant *Period* by *Group* interaction effect, F (1, 41) = 10.84, p = .001, MS_E = 6.64, partial μ^2 = .26. No other interaction effects were found to be significant.

2.1.2. Per Cent Time

There was a significant main effect of *Group,* F (1, 31) = 5.48, p = .026, MS_E = 1051.9, partial μ^2 = .15, due to participants showing a larger difference between baseline and training in the eyes open group than in the eyes closed group. There was also a significant main effect of *Baseline*, F (1, 31) = 56.4, p < .001, MS_E = 1204.5, partial μ^2 = .65, due to participants showing a larger difference between baseline and training when training was compared to their eyes closed baselines than when compared to their eyes open baselines. There was a significant main effect of *Segment*, F (1, 31) = 5.07, p = .032, MS_E = 48.4, partial μ^2 = .15, due to participants showing a larger difference between baseline and training in their second segment than in their first. There was a significant main effect of *Period*, F (1, 45) = 5.9, p = .010, MS_E = 89.0, partial μ^2 = .16. There was a significant *Baseline* by *Group* interaction effect, F (1, 31) = 28.8, p < .001, MS_E = 1204.5, partial μ^2 = .48. There was a significant *Segment* by *Group* interaction effect, F (1, 31) = 5.2, p = .029, MS_E = 48.4, partial μ^2 = .15. There was a significant *Period* by *Condition* interaction effect, F (1, 45)

= 12.3, $p < .001$, $MS_E = 89.0$, partial $\mu^2 = .28$. No other interaction effects were found to be significant.

2.2. Across Sessions Compared to Baseline

2.2.1. Amplitude

There was a significant main effect of *Group*, F (1, 27) = 5.1, $p = .032$, $MS_E = 682.8$, partial $\mu^2 = .16$. This was due to the eyes closed participants producing larger amplitudes than the eyes open. There was a significant main effect of *Stage*, F (2, 54) = 62.3, $p < .001$, MS_E = 62.3, partial $\mu^2 = .70$. This was due to participants producing larger amplitudes in their eyes closed baselines than in their eyes open baselines, larger amplitudes in their eyes closed baselines than in their training, and larger amplitudes in their training than in their eyes open baselines. There was a significant main effect of *Session, F* (5, 145) = 2.5, $p = .031$, $MS_E = 8.0$, partial $\mu^2 = .08$. There was a significant *Session* by *Group* interaction effect, F (2, 54) = 9.2, $p < .001$, MS_E = 62.3, partial $\mu^2 = .26$. There was a significant *Stage* by *Session* interaction effect, F (7, 188) = 2.4, $p = .024$, $MS_E = 6.34$, partial μ^2 = .08. No other interaction effects were found to be significant.

2.2.2. Per Cent Time

There was a significant main effect of *Group*, F (1, 26) = 38.0, $p < .001$, $MS_E = 1130.9$, partial $\mu^2 = .59$, due to participants in the eyes closed condition spending more time over threshold than participants in the eyes open condition. There was a significant main effect of

Stage, *F* (2, 52) = 54.9, $p < .001$, $MS_E = 381.1$, partial μ^2 =.68, due to participants spending more time over threshold in the eyes open baseline than they did in the eyes closed, more time over baseline in the eyes open baseline than they did during training, and more time over baseline during training than they did in the eyes closed baseline. There was a significant *Stage* by *Group* interaction effect, *F* (2, 52) = 27.0, $p < .001$, $MS_E = 381.1$, partial μ^2 =.51. There was a significant *Stage* by *Session* interaction effect, *F* (6, 161) = 3.0, $p = .008$, MS_E = 88.2, partial μ^2 =.10. No other main or interaction effects were found to be significant.

Appendix L

Overarching Omnibus Analysis for 'Chapter 5 – Experiment 3 - Audio versus Visual versus Audio-Visual Training' in order to provide a direct comparison between the three feedback conditions

1. Enhancement Training

1.1. Within Sessions Compared to Baseline

In order to provide a direct comparison between the audio, visual, and audio-visual feedback conditions a 3 (Group: *Audio* versus V*isual* versus *Audio-Visual*) x 2 (Segment: *Segment 1* versus *Segment 2*) x 5 (Period: *1-5)* mixed ANOVA, with *Group* as the between participants factor and *Segment* and *Period* as the within participants factor, was performed. First using amplitude as the measure and then using per cent time.

1.1.1. Amplitude

There was a significant main effect of *Group*, F (2, 49) = 3.3, p = .045, MS_E = 14.4, partial μ^2 =.12, due to participants in the eyes open group producing a larger difference between baseline and training than the audio-visual. There was a significant main effect of *Segment*, F (1, 49) = 6.0, p = .018, MS_E = .51, partial μ^2 =.11, due to participants showing a larger difference between baseline and training in the second segment when compared to the first. There was a significant main effect of *Period*, F (2, 108) = 43.9, p < .001, MS_E = .43, partial μ^2 =.47. There was a significant *Segment* by *Group* interaction effect, F

(2, 49) = 4.1, *p* = .023, MS_E = .51, partial μ^2 =.14. No other interaction effects were found to be significant.

1.1.1. Per Cent Time

There was a significant main effect of *Group*, *F* (2, 49) = 4.0, *p* = .024, MS_E = 611.9, partial μ^2 =.14, due to participants in the eyes open audio group showing a larger difference between baseline and training in the audio group than in the audio-visual group. There was a significant main effect of *Segment*, *F* (1, 49) = 8.7, *p* = .005, MS_E = 18.8, partial μ^2 =.15, due to participants showing a larger difference between baseline and training in Segment 2 than in Segment 1. There was a significant main effect of *Period*, *F* (2, 116) = 60.0, *p* < .001, MS_E = 18.2, partial μ^2 =.55. There was a significant *Segment* by *Group* interaction effect, *F* (2, 49) = 6.1, *p* = .004, MS_E = 18.8, partial μ^2 =.20. No other interaction effects were found to be significant.

1.2. Across Sessions Compared to Baseline

In order to examine the across sessions in comparison to baseline data a 3 (Group: *Audio* versus *Visual* versus A*udio-Visual*) x 2 (Stage: *Baseline* versus Training) x 10 (Session: *1*-10) mixed ANOVA, with Group as the between participants factor and *Stage* and Session as the within participants factors, was performed on both the amplitude and then the per cent time data.

1.2.1. Amplitude

There was no main effect of *Group*, F (2, 41) = .77, p = .469, MS_E = 194.0, partial μ^2 =.04. There was, however, a significant main effect of *Session*, F (6, 229) = 10.25, p< .001, MS_E = 3.23, partial μ^2 =.20. No other main or interaction effects were found to be significant.

1.2.2. Per Cent Time

There was a significant main effect of *Group*, F (2, 40) = 4.0, p = .027, MS_E = 211.1, partial μ^2 =.17, due to participants in the audio group showing a larger difference between baseline and training than the audio-visual group. No other main or interaction effects were significant.

2. Suppression Training

The same analyses performed on the enhancement data, above, was also performed on the suppression data.

2.1. Within Sessions Compared to Baseline

2.1.1. Amplitude

There was no significant main effect of *Group*, F (2, 49) = 1.2, p = .319, MS_E = 15.3, partial μ^2 =.05. There was a significant main effect of *Period*, F (2, 120) = 49.0, p < .001, MS_E = .17, partial μ^2 =.50. No other main or interaction effects were significant.

2.1.2. Per Cent Time

There was no main effect of *Group*, F (2, 49) = 1.4, p = .257, MS_E = 280.1, partial μ^2 =.05. There was a significant main effect of *Period*, F (2, 101) = 37.6, p < .001, MS_E = 4.6, partial μ^2 =.43. There was a marginal *Segment* by *Period* effect, F (3, 150) = 2.4, p = .066, MS_E = 1.5, partial μ^2 =.05. No other main or interaction effects were found to be significant.

2.2. Across Sessions Compared to Baseline

2.2.1. Amplitude

There was no main effect of *Group*, F (2, 41) = .55, p = .579, MS_E = 141.0, partial μ^2 =.03. There was, however, a main effect of *Stage*, F (1, 41) = 23.8, p < .001, MS_E = 7.8, partial μ^2 =.37, due to participants producing a larger amplitude during their baselines than during their training. There was a significant main effect of *Session*, F (5, 208) = 5.4, p < .001, MS_E = 3.1, partial μ^2 =.12. There was a significant *Stage* by *Session* interaction effect, F (5, 186) = 3.5, p = .006, MS_E = 1.6, partial μ^2 =.08. No other interaction effects were found to be significant.

2.2.2. Per Cent Time

There was no main effect of *Group*, F (2, 41) = .99, p = .381, MS_E = 410.6, partial μ^2 =.05. There was a significant main effect of *Stage*, F (1, 41) = 16.3, p < .001, MS_E = 150.8, partial μ^2 =.28, due to participants spending more time under threshold during training than during baseline. There was a significant main effect of *Session*, F (5,

225) = 3.0, p = .010, MS_E = 24.1, partial μ^2 =.07. No interaction effects were found to be significant.

Appendix M – The Correlation Between Baseline and Training

Across sessions changes shown by participants in the three experiments appeared to be mirroring their baseline activity. In other words, although participants did show some evidence of an increase in amplitude across sessions during training they also showed an increase in their baseline amplitude as well. This could be because they were successful at enhancing alpha from the first session onwards but just did not shown an improvement in their ability to do so as sessions progressed. On the other hand, it may be that, as results by Cho et al. (2008) suggested, alpha neurofeedback enhancement training may result in rising baselines. The inclusion of suppression training in the experiments laid out in this thesis means that any effect of training in one direction may be contaminated by training in the other. However, given that the baselines seem to be rising across sessions in line with the training data it would at least be a point of interest to see whether or not there actually is a correlation between participants' alpha amplitudes during training and their alpha amplitudes during baseline. Additionally, Cho et al. (2008) showed that participants' alpha amplitudes at the end of their training sessions showed a positive correlation with their baseline amplitudes at the start of their next session. It would therefore be interesting to see if the same is true for the data in this current experiment. As well as performing correlations between the training data and the baseline data, then, this section will also see if participants' baseline alpha directly after each training session correlates with their baselines at the start of their next training session.

The following, then, are the results of the correlations performed in order to see whether or not the amplitude of participants' alpha either during their enhancement training sessions (Tables 79-81) or during their baselines straight after their training sessions (Tables 82-87) are correlated with the amount of alpha they produced at the start of their next training sessions. Each feedback group was analysed separately with the audio-visual and visual groups' data analysed using Pearson's correlations due to the normal distribution of their data and the audio groups' data analysed using Spearman's Rho Correlations due to the non-normal distribution of their data. In each case, the results which show a significant correlation between the participants amplitude during (in the case of Tables 79-81)/at the end of (Tables 82-87) their training sessions and at the start of the next are highlighted in blue and all the instances where there is non-significant correlation between the participants amplitude during (in the case of Tables 79-81)/at the end of (Tables 82-87) their training sessions and at the start of the next are highlighted in green. All other significant correlations are highlighted in yellow.

Table 81

Table to show the correlations between the amplitude of the audio-visual groups' alpha during each of their enhancement training sessions in comparison to the eyes open baseline (EOB1) taken at the start of the each training session (S). Figures in the tables represent the Pearson's value.

*** p < .001, * p < .01*

	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8	Session 9
EOB1 – S2	.896**	.920**	.847**	.684*	.903**	.761*	.637	.750*	.759*
EOB1 – S3	.898**	.833**	.913**	.716*	.867**	.729*	.672	.847**	.804**
EOB1 – S4	.893**	.876**	.894**	.862**	.913**	.795**	.660*	.848**	.831**
EOB1 – S5	.915**	.833**	.853**	.718*	.913**	.723*	.641*	.871**	.839**
EOB1 – S6	.901**	.930**	.913**	.787**	.880**	.859**	.701*	.791**	.748*
EOB1 – S7	.547	.548	.533	.422	.536	.368	.277	.425	.434
EOB1 – S8	.802*	.808**	.875**	.801**	.885**	.752*	.821**	.971**	.892**
EOB1 – S9	.804*	.798*	.810**	.761*	.878**	.686*	.715*	.862**	.911**
EOB1 – S10	.846**	.911**	.872**	.854**	.879**	.760*	.692*	.779*	.805**

Table 82

Table to show the correlations between the amplitude of the visual groups' alpha during each of their enhancement training sessions in comparison to the eyes open baseline (EOB1) taken at the start of the each training session (S). Figures in the tables represent the Pearson's value.

	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8	Session 9
EOB1 – S2	.725*	.559	.505	.410	.489	.534	.692*	.569	.502*
EOB1 – S3	.769*	.658*	.596	.628*	.695*	.582	.812**	.644	.690*
EOB1 – S4	.657*	.643*	.634*	.780**	.768**	.783**	.824**	.770**	.800**
EOB1 – S5	.797**	.717*	.690*	.860**	.917**	.719*	.879**	.833**	.862**
EOB1 – S6	.771*	.713*	.704*	.877**	.860**	.820**	.895**	.859**	.832**
EOB1 – S7	.827**	.606	.553	.670*	.684*	.540	.819**	.652*	.689*
EOB1 – S8	.839**	.499	.521	.845**	.849**	.764**	.902**	.859**	.860**
EOB1 – S9	.742*	.637*	.677*	.833**	.902**	.805**	.919**	.873**	.943**
EOB1 – S10	.708*	.570	.586	.848**	.897**	.845**	.904**	.885**	.888**

*** p < .001, * p < .01*

Table 83

Table to show the correlations between the amplitude of the audio groups' alpha during each of their enhancement training sessions in comparison to the eyes open baseline (EOB1) taken at the start of the each training session. Figures in the table represent the Spearman's rho values.

	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8	Session 9
EOB1 – S2	.736**	.726**	.673**	.631**	.710**	.663**	.794**	.748**	.649**
EOB1 – S3	.696**	.655**	.651**	.632**	.723**	.667**	.777**	.681**	.699**
EOB1 – S4	.682**	.675**	.687**	.790**	.789**	.735**	.791**	.778**	.810**
EOB1 – S5	.757**	.661**	.641**	.725**	.872**	.668**	.775**	.792**	.815**
EOB1 – S6	.680**	.702**	.696**	.758**	.681**	.820**	.805**	.734**	.665**
EOB1 – S7	.641**	.626**	.565*	.596**	.640**	.495*	.709**	.625**	.629**
EOB1 – S8	.762**	.658**	.674**	.849**	.866**	.783**	.887**	.893**	.837**
EOB1 – S9	.685**	.683**	.661**	.759**	.904**	.742**	.852**	.857**	.934**
EOB1 – S10	.745**	.739**	.680**	.780**	.853**	.735**	.889**	.867**	.839**

*** p < .001, * p < .01*

Table 84

Table to show the correlations between the amplitude of the audio-visual groups' alpha during the baselines taken at the end of each session (EOB2) and the baselines taken at the start of each session (EOB1) for the participants whose training each session (S) consisted of first enhancement and then suppression training. Figures in the table represent the Pearson's values.

	EOB2 – S1	EOB2 – S2	EOB2 – S3	EOB2 – S4	EOB2 – S5	EOB2 – S6	EOB2 – S7	EOB2 – S8	EOB2 – S9
EOB1 – S2	-	.885	.982*	.949	.851	.932	.878	.644	.708
EOB1 – S3	-	.910	.437	.479	.726	.845	.315	.509	.785
EOB1 – S4	-	.886	.777	.681	.742	.979	.513	.365	.972*
EOB1 – S5	-	.772	.676	.504	.585	.999*	.314	.194	.993*
EOB1 – S6	-	.865	.908	.837	.834	.988	.708	.548	.879
EOB1 – S7	-	-.319	.235	.112	-.004	.213	.138	.160	-.056
EOB1 – S8	-	.833	.604	.862	.970*	.871	.826	.908	.432
EOB1 – S9	-	.646	.715	.481	.497	.975	.299	.099	.977*
EOB1 – S10	-	.311	.972*	.786	.565	.745	.727	.331	.651

*** p < .001, * p < .01*

Table 85

Table to show the correlations between the amplitude of the visual groups' alpha during the baselines taken at the end of each session (EOB2) and the baselines taken at the start of each session (EOB1) for the participants whose training each session (S) consisted of first enhancement and then suppression training. Figures in the table represent the Pearson's values.

	EOB2 – S1	EOB2 – S2	EOB2 – S3	EOB2 – S4	EOB2 – S5	EOB2 – S6	EOB2 – S7	EOB2 – S8	EOB2 – S9
EOB1 – S2	-.880	-.880	-.318	.513	.375	.596	.590	-.089	.419
EOB1 – S3	-.211	-.211	.436	.733	.610	.760	.902*	.549	.723
EOB1 – S4	.502	.502	.915**	.824*	.799	.829*	.763	.989**	.762
EOB1 – S5	-.097	-.097	.565	.822*	.930*	.852*	.841*	.895*	.894*
EOB1 – S6	.706	.706	.432	.881*	.787	.948**	.789	.907*	.817
EOB1 – S7	.544	.544*	.544	.794	.629	.727	.931**	.588	.710
EOB1 – S8	-.069	-.069	-.007	.742	.565	.800	.792	.522	.714
EOB1 – S9	-.682	.501	.523	.819*	.835	.736	.837*	.842*	.744
EOB1 – S10	.943	.581	.834	.790	.757	.880*	.802*	.916*	.907*

*** p < .001, * p < .01*

Table 86

Table to show the correlations between the amplitude of the audio groups' alpha during the baselines taken at the end of each session (EOB2) and at the start of each session (EOB1) for the participants whose training each session (S) consisted of first enhancement and then suppression training. Figures in the table represent the Spearman's rho values.

	EOB2 – S1	EOB2 – S2	EOB2 – S3	EOB2 – S4	EOB2 – S5	EOB2 – S6	EOB2 – S7	EOB2 – S8	EOB2 – S9
EOB1 – S2	.800	.976**	.886	.821	.929*	.905*	.964**	.952**	-
EOB1 – S3	.800	.905*	.943*	.857	.810	.929*	.893*	.881*	.929*
EOB1 – S4	.800	.905*	.943*	.857	.810	.929*	.893*	.881*	.929*
EOB1 – S5	.800	.952**	.943*	.857	.952**	.929*	-	.976**	-
EOB1 – S6	.800	.952**	.943*	.857	.952**	.929*	-	.976**	-
EOB1 – S7	-	.833	.943*	.750	.952**	.857**	.893*	.905*	.893*
EOB1 – S8	.800	.881*	.943*	.821	.857*	.952*	.929*	.929*	.964**
EOB1 – S9	.800	.905*	.829	.893*	.905*	.833	.857	.833	.857
EOB1 – S10	.800	.929*	-	.857	.905*	.905*	.964**	.952**	.964**

*** p < .001, * p < .01*

Table 87

Table to show the correlations between the amplitude of the audio-visual groups' alpha during the baselines taken at the end of each session (EOB2) and start of each session (EOB1) for the participants whose training each session (S) consisted of first suppression and then enhancement training. Figures in the table represent the Pearson's values.

	EOB2 – S1	EOB2 – S2	EOB2 – S3	EOB2 – S4	EOB2 – S5	EOB2 – S6	EOB2 – S7	EOB2 – S8	EOB2 – S9
EOB1 – S2	.471	.979**	.836	.715	.923*	.779*	.903*	.792	.919**
EOB1 – S3	.479	.829	.967**	.863*	.864*	.793	.872*	.941**	.823*
EOB1 – S4	.804	.819	.898*	.955**	.745	.712	.887*	.882*	.779
EOB1 – S5	.496	.867*	.937*	.923	.921*	.782	.933**	.881*	.847*
EOB1 – S6	.637	.905*	.825	.856*	.874*	.896*	.951**	.819*	.795
*EOB1 – S7	.534	.804	.908*	.816*	.780	.623	.852*	.798	.789
EOB1 – S8	.637	.715	.760	.927**	.838*	.872*	.893*	.854*	.830*
EOB1 – S9	.681	.742	.865*	.888*	.770	.704	.847*	.906*	.870*
EOB1 – S10	.854	.824	.823	.831*	.690	.672	.840*	.847*	.827*

*** p < .001, * p < .01*

Table 88

Table to show the correlations between the amplitude of the visual groups' alpha during the baselines taken at the end of each session (EOB2) and the baselines taken at the start of each session (EOB1) for the participants whose training each session (S) consisted of first suppression and then enhancement training. Figures in the table represent the Pearson's values.

	EOB2 – S1	EOB2 – S2	EOB2 – S3	EOB2 – S4	EOB2 – S5	EOB2 – S6	EOB2 – S7	EOB2 – S8	EOB2 – S9
EOB1 – S2	.814	.968**	.861*	.596	.626	.852	.758	.635	.673
EOB1 – S3	.899	.958**	.939*	.849*	.797	.905*	.906*	.815	.856*
EOB1 – S4	.957*	.834	.967**	.857**	.938*	.990**	.911*	.861*	.914*
EOB1 – S5	.989**	.793	.861*	.966*	.944*	.896*	.966**	.978**	.982**
EOB1 – S6	.925*	.832	.946**	.937*	.944*	.940*	.982**	.922*	.941*
EOB1 – S7	.930*	.903*	.939*	.876*	.874	.937*	.952**	.873*	.907*
EOB1 – S8	.940*	.674	.765	.966**	.882*	.758	.933*	.954**	.932*
EOB1 – S9	.961*	.708	.829	.956**	.933*	.846	.939*	.932*	.978**
EOB1 – S10	.914	.717	.876*	.953**	.959*	.892*	.963**	.950**	.953**

*** p < .001, * p < .01*

Table 89

Table to show the correlations between the amplitude of the audio groups' alpha during the baselines taken at the end of each session (EOB2) and the baselines taken at the start of each session (EOB1) for the participants whose training each session (S) consisted of first suppression and then enhancement training. Figures in the table represent the Spearman's rho values.

	EOB2 – S1	EOB2 – S2	EOB2 – S3	EOB2 – S4	EOB2 – S5	EOB2 – S6	EOB2 – S7	EOB2 – S8	EOB2 – S9
EOB1 – S2	-	.943*	.857	.893*	.893*	.943*	.857	.857	.829
EOB1 – S3	-	.943*	.857	-	.893*	.771	.964**	.964**	-
EOB1 – S4	.900	.771	.893*	.857	.964**	.943*	.893*	.929*	.771
EOB1 – S5	-	.943*	.821	.964**	.857*	.829	.929*	.893*	.943*
EOB1 – S6	.900	.829	.929*	.964**	.964**	.829	.929*	-	.943*
EOB1 – S7	-	.943*	.857	-	.893*	.771	.964**	.964**	-
EOB1 – S8	-	.943*	.821	.964**	.857	.829	.929*	.893*	.943*
EOB1 – S9	-	.886	.786	.964**	.857	.771	-	.929*	.943*
EOB1 – S10	-	.886	.876	.964**	.857	.771	-	.929*	.943*

*** p < .001, * p < .01*

When comparing the participants' mean amplitudes during training to their mean amplitudes at the start of the next session all three of the feedback groups showed a correlation, with the exception of session 6 for the audio-visual group. However, nearly all of the training sessions in the case of the visual and audio-visual feedback groups and all of the sessions in the case of the audio feedback group correlated with the all the baselines.

When looking at the amplitude data of the participants who trained to enhance and then suppress their alpha each session, the audio-visual group showed no correlations between the amplitude they produced in their baselines at the end of training (post-training baselines) to those they produced in the baselines at the start of the next session (pre-training baselines). The visual group, however, showed correlations from session 3 onwards between their post-training baselines and the pre-training baselines from the next sessions. The audio group showed the same post- to pre- training baseline correlations from session 2 onwards. It should be noted, though, that both the visual and audio group also showed a large number of correlations between other pre- and post-training baselines.

In the case of the participants who trained to suppress and then enhance their alpha each neurofeedback session, the audio-visual and audio participants both showed correlations between their pre-training baselines and the previous sessions' post training baselines for all but two sessions. The visual participants showed correlations between all of their pre-training baselines and the previous session's post training baselines. Again, however, all three groups additionally showed correlations between a large number of the baselines outside of those.