

A comparison of alpha brainwave entrainment, with and without musical accompaniment.

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Submitted in partial fulfilment of the requirements of the BA Hons Degree in Psychology at
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March 2014

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Acknowledgments:

Firstly, I would like to thank my supervisor Dr. Jonathan Murphy for his time, guidance and professionalism throughout the process. Secondly, I would like to thank Michael Nolan for his assistance and support using the biofeedback lab. I also extend my gratitude to all the participants for their support.

I dedicate this work to my father, Bernard.

Abstract:

Brainwave entrainment (BWE) studies have measured the effectiveness of manipulating brainwave frequencies as an alternative to medicinal therapy. Isochronic tones are used to entrain; through monotonous, repetitive, pulse like qualities. This study compared the effectiveness of accompanying an isochronic tone with a musical composition; and an isochronic tone only. In this double blinded experiment, participants (N=31) were randomly assigned to a test group (musical composition with an isochronic tone) or control group (isochronic tone only). Both groups were measured by EEG, and the PANAS questionnaire was employed to measure mood. Data showed there was no significant difference between achieving BWE with musical composition or isochronic tone by itself; and pairing with music scored higher for comfort and positive affect.

INTRODUCTION:

Alternative therapies and interventions such as mindfulness, flotation tanks and brainwave entrainment (BWE) offer people the opportunity to achieve states of being that can assist in perspective and peace of mind; both therapeutically and recreationally. In Wahbeh, Elsas and Oken's (2008) study on the merits of alternative therapies, they noted that "Mind-body therapies are often implemented by patients because of the low physical and emotional risk, the relatively low cost, and their ability to allow patients to take a more active role in their treatment"(Wahbeh, Elsas and Oken, 2008). Furthermore, these interventions can occupy a space as viable alternatives to medicinal based therapy, as has been evidenced in a number of studies over the past decade (Siever, 2003; Siever and Berg, 2009; Ossebaard, 2000; Le Scouarenac, 2001). Entrainment is defined in physical systems as the process whereby "two interacting oscillating systems assume the same period" (Zhuang, Zhao and Tang, 2009). Brainwave entrainment employs audio-visual pulses delivered over a fixed period of time to induce or *entrain* particular endogenous frequencies in the human brain (Ossebaard, 2000). The frequency following activity correlates to the brains cortical evoked response (CER); when the brain encounters an exogenous stimulus, it matches, or evokes an internal, endogenous frequency response (Thut, Schyns and Gross, 2011).

The current study looked at the effectiveness of audio entrainment with a single, evenly spaced pulse; an isochronic tone (Manns, 1981) and compared this when the tone was

accompanied with a musical composition. There were a number of reasons why this should be investigated: the ability to place these pulses (or tones) below a musical composition provides an alternative aspect to entrainment; the saliency of the tone is greatly reduced. The monotony of listening to a single tone for a 40 or 60 minute session could be diminished if the listener could place the tone below a musical composition. Furthermore, to the best of the current researcher's knowledge, there has not been an investigation into using a musical composition when paired with an Isochronic tone for entrainment purposes. In addition to this, there is the ability to make this treatment more accessible for its clients; offering the ability to place the tones beneath compositions of their choosing, on a portable audio device. The ability for an individual to participate in actively exploring and altering their consciousness through BWE, was seen as a tertiary interest to the present study.

Measurements of the participants cortical activity was made by EEG. This study further employed the PANAS (positive and negative affect schedule) questionnaire (Watson, Clark and Tellegen, 1988) to assess how participants felt after the entrainment experience; their mood and/or psychological outcome. PANAS was selected for its reliability and ease of use. Finally, the question was asked if the participants of the study “found the audio experience comfortable or uncomfortable” in order to establish an aesthetic comparison between isochronic tone, and the tone with musical composition.

The next subsections of the introduction will cover: the nature of EEG and endogenous brainwave activity; the different frequencies and the corresponding states of being. The second section will look at the most common audio frequencies of induction; Isochronic tones and Binaural beats. The third section will focus on areas of previous

research with respect to therapeutic and recreational outcome. Sections four and five will look at the PANAS questionnaire, music and its effects on mood or temporary disposition. The final section will focus on the rationale for the present study and its potential use or contribution.

1.1 Electrical activity in the human brain:

Historically, Hans Berger's (1924) study on neural oscillations brought about his invention of the EEG (electroencephalogram) a device that can measure the brain's electrical activity. Each neuron produces an electrical charge, and the billions of neurons that make up the brain produce waves of frequency; electrical activity (Tudor, 2005). The EEG has the ability to measure and reflect the electrical activity of synchronous neuronal behaviour; and these frequencies are banded into distinct groups: Beta, Alpha, Theta and Delta (Siever, 2003; Zhuang, 2013). Each grouping corresponds with a particular frequency range, which in turn correlates to specific states of being (see Figure 1.1.1). Beta wave frequencies (ranging 13-38 Hz) are associated with waking, alert consciousness. Alpha wave frequencies in the human brain, (ranging between 8-12Hz) are associated with relaxed states or relaxed wakefulness. Theta waves (3 - 8 Hz) correspond with drowsy, meditative responses, or light sleep. Delta waves (ranging 0.2- 3 Hz) are associated with deep sleep. Evidence suggests (Ossebaard, 2000; Siever, 2003; Berg and Will, 2007) that when presented with a stimulus within a specific brainwave frequency range, occipital, parietal and temporal lobes display a frequency following or entrainment. These areas of the brain either resonate with that of the stimulus or enter within areas of sub-harmonic frequency. Patterson and Capel's (1983) study found that different neurotransmitters were triggered by different frequencies and wave forms. Their use of a 10Hz BWE signal increased serotonin production, leading to their

conclusion that "Each brain centre generates impulses at a specific frequency, based on the predominant neurotransmitters it secretes" (Patterson and Capel, 1983). A study by Berg and Will (2007) demonstrated how different brainwave frequencies correlated to different perceptual and cognitive states. Siever and Berg (2009) also noted how brainwaves have been shown to synchronise to external stimuli within brainwave frequency ranges in a phenomenon called brainwave entrainment (BWE). The reports from Charyton and Huang's (2008) comprehensive review of brainwave entrainment measured 20 studies and entrainments uses as a tool for affecting psychological outcomes of the participants; as an alternative to medicinal interventions.

Beta	12Hz-38Hz	Wide awake state
Alpha	8 Hz-12Hz	Awake but relaxed.
Theta	3Hz-8Hz	Light sleep or extreme relaxation.
Delta	0.2Hz-3Hz	Deep, dreamless sleep.

Fig.1.1.1: Brainwaves and corresponding states of mind (Siever, 2003)

1.2 Isochronic Tones, Binaural beats and selection:

There are number of manipulations of audio frequency that are employed with BWE. The most commonly applied of these are Isochronic tones and Binaural beats. An early study in this area (Manns, 1981) noted the entrainment capabilities of Isochronic tones; a tone of regular interval and frequency, providing a monotonous, pulse like effect (see Figure 1.2.1). “The effect excites the thalamus and causes a frequency following response, where the brain internally recreates the frequency and this re-shapes the level of conscious awareness” (Siever, 2003). This point being conducive with Patterson and Capels observations (1983) of the brains cortical evoked response.

The more established of the two methods of induction, with respect to the number of studies researched, are Binaural beats. Padmanabhan, Hildreth and Laws (2005) measured BWE with binaural beats (see Figure 1.2.2) stating:

“They are produced within the brain in response to two similar pure tones being presented separately to each ear. The rhythm of the binaural beat equals the difference between the two tones and, if sustained, this rhythm can be entrained throughout the brain. The frequency of the binaural beat can thus be selected to produce particular EEG-associated states” (Padmanabhan et al. 2005).

The Binaural beat is created through stereo response (left and right). For example, two altering frequencies, 100 Hz in the left ear and 90 Hz in the right ear would create a 10 Hz Binaural frequency in the brain.

The reasoning for selecting an isochronic tone over a binaural beat in the current study was that, the isochronic tone is implicit within the specified frequency, it is not subject to the perceptual effect; that is, the brain is not generating the effect. The exogenous isochronic tone triggers the brains frequency following patterns; rather than the perceptive creation of the binaural frequency. This means that even if headphones were not employed, the Isochronic tone could activate BWE.

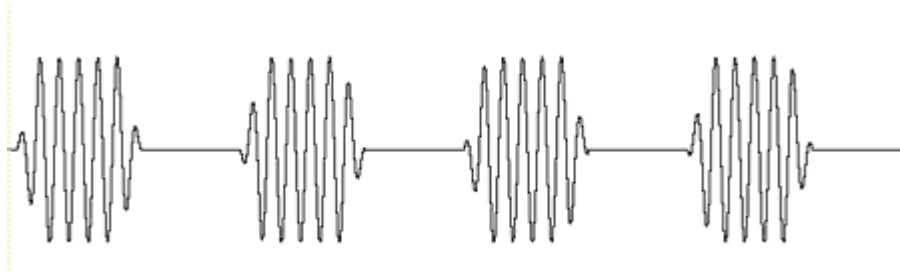


Fig.1.2.1: ISOCHRONIC TONE

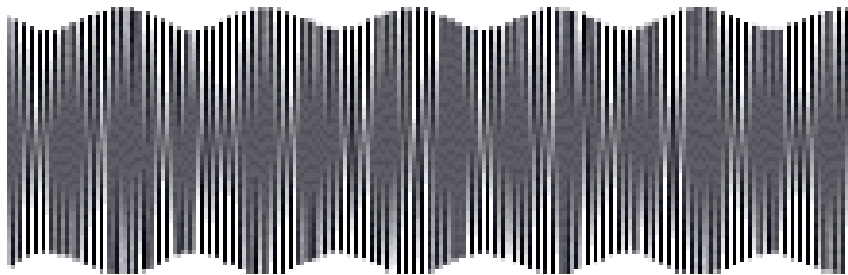


Fig.1.2.2: BINAURAL BEAT

1.3 Previous research on BWE on psychological outcome:

Audio-visual stimuli presented either in tandem or separately, are used regularly in brainwave entrainment studies and neuro-therapies (Siever, 2003) as an alternative to medication. These stimuli are presented as pulses at regular intervals; waveforms of light and/or sound. Previous studies (Calabreses, Wahbleh and Zwickey, 2007; Siever and Berg, 2009; Ossebard, 2000; Siever, 2003; Padmanabhan, Hildreth and Laws, 2005; Le Scouarenac, 2001; Berg and Will, 2007; Patterson and Capel, 1983) in BWE and AVE, have selected either isochronic tones or binaural beats as the method of induction.

A comprehensive review of twenty studies on BWE (Charyton and Huang, 2008), compiled data of experiments that had employed isochronic tones, binaural beats and also photic (visual) induction. Of that selection it was noted that “seventeen (of the) studies were developed to confirm or challenge a hypothesis that a specific frequency or protocol would have a beneficial effect on a specific outcome” (Charyton and Huang, 2008). The studies focused on areas of cognition, mood, pain, headaches (migraines), behavioural problems (ADHD), and attention. The length of the sessions ranged from 0.5 seconds to 60 minutes, and the length from studies ranged from single sessions, to 12 week periods. The design of these studies ranged from paired samples (before and after, test/re-test) to independent between group measurements.

One previous study (Calabreses, Wahbleh and Zwickey, 2007) on eight adult participants across a 60 day intervention of binaural beat BWE, investigated both psychological and physiological factors. The psychological aspects measured were

Depression (Beck Depression Inventory-2), Anxiety (State-Trait Anxiety Inventory), Mood (Profile of Mood States), Absorption (Tellegen Absorption Scale) and quality of Life (World Health Organization-Quality of Life Inventory) (Calbrese et.al, 2007). The resulting data showed a statistically significant decrease in trait anxiety and an increase in quality of life. The physiological aspects measured serotonin and dopamine levels, and found a significant reduction in the neuromodulators in stress responses from pre to post experiment (Calbrese et al. 2007). They concluded that Binaural beat technology may exhibit positive effect on self-reported psychologic measures, in particular anxiety.

With respect to Padmanabhan et al's. (2005) study, Binaural beats were used in conjunction with an audio piece to examine their effectiveness in pre-operative anxiety. They used a pre-existing BWE software and audio (Holosync) and administered this to 35 patients. Results from this experiment concluded "that binaural beat audio has the potential to produce anxiolysis in many preprocedural hospital settings in which pharmacological sedation is undesirable" (Padmanabhan et al.,2005). It is unknown what the choice of song was for this research and the potential priming / associative effects this could have on the participants. Furthermore, there is no mention of carrier pitch; the pitch of the binaural beats themselves. A carrier pitch is the pitch designated to the Isochronic tone or Binaural beat itself.

Siever and Berg's (2009) study used AVE (audio-visual entrainment) with Isochronic tones as an alternative to drug-dependent therapies for treatment of ADD (attention deficit disorder) and SAD (seasonal affective disorder). Their four week study utilised AVE for people suffering from SAD. Their particular experiment utilised a 1Hz AVE placebo for the first 2 weeks and compared this with 2 weeks of the test condition at 20 Hz AVE. Results

from the State-Trait Anxiety Inventory showed that a 20Hz AVE treatment condition reduced stress and anxiety of 74 individuals participating (Siever and Berg, 2009). In their earlier study (1999) over a 2 month period, they found Isochronic AVE sessions significantly reduced fatigue and anxiety in women suffering from Fibromyalgia Syndrome (FMS). By comparing three different methods of treatment: medicinal, nutritional and AVE, it was found that “the AVE Group, in the combination of all three comparative treatments, lowered anxiety, pain and fatigue the most” (Siever and Berg, 1999).

Ossebaards (2000) study looked at the effectiveness of 8-12 Hz alphawave entrainment on stress reduction and anxiety with employees at a Dutch addiction care centre. They noted the that “subjects showed a significant and immediate decrease in State-Trait anxiety as assessed by Spielbergers State-Trait Anxiety Inventory and reported a range of subjective effects” (Ossebard,2000).

Transcorp (Transparent Corporation), established in 2003, Columbus, Ohio, provides bio and neuro-feedback software, as well as providing peer reviewed research, both academic and clinical. Adam Hewett, director at Transcorp, states the purpose of their research, and their making available of BWE home software, is to “allow people to easily benefit from brainwave stimulation to achieve everyday goals like feeling more relaxed or being better able to concentrate, or big goals like making real personal and cognitive changes towards a better life”.

In consideration of mind- body therapies, such as mindfulness, flotation tanks and holistic approaches, there are now a number of studies that have investigated, and are continuing to investigate, the use of BWE as an alternative to medicinal therapeutic interventions. These are niche markets comparative to mainstream therapeutic practices such as CBT (Cognitive Behavioural Therapy), ACT (Acceptance and Commitment Therapy), Psychoanalytic psychotherapy and Psychiatry, however BWE can occupy a position as a scientifically testable alternative to medicinal therapy (Siever, 2003; Siever and Berg, 2009; Ossebaard, 2000; Le Scouarenac, 2001) and have potential to be further utilised for recreational or home activity.

1.4 PANAS and audio comfort

The PANAS questionnaire was selected for its internal reliability and consistency “the PANAS scales provide reliable, precise, and largely independent measures of Positive Affect and Negative Affect, regardless of the subject population studied or the time frame and response format used” (Watson, Clark and Tellegen, 1988) to capture the psychological outcome for each participant.

A short test that is easy to administer, the PANAS questionnaire lists 20 words; each word corresponding to a mood or feeling. A lexicon of 10 words associated with positive affect (e.g “Inspired” “Interested” “Active”) and 10 associated with negative affect (e.g “Anxious” “Ashamed” “Nervous”). Each positive and negative word is rated by each participant, by selecting how strongly they feel about that word /mood with reference to the present moment, or the past week. PANAS provides a numerical rating scale ranging from:

Very slightly /Not at All: 1, A Little: 2, moderately: 3, Quite a bit: 4 to extremely: 6 to which participants rate the mood or feeling. By totalling the scores, higher scores in positive affect represent positive psychological outcome, and high scores in negative affect represent negative psychological outcome.

In addition to responses on psychological outcome, at the end of the questionnaire there was an additional question asking participants how they would rate their audio experience; “comfortable” or “uncomfortable”. Participants circled which word corresponded to their audio experience.

1.5 Music, mood and effects temporary disposition

Music is well known for its emotional valence and ability for psychological, physiological arousal (Gabrielsson, 2001; Sloboda and Juslin, 2001; Husain, Thompson and Schellenberg, 2002). One study by Hussain, Thompson and Schellenberg (2002) looked at the effects of mode and tempo on mood and arousal. Participants listened to one of four renditions of a Mozart sonata. The four versions differed in tempo (speed of composition) and the mode (major or minor key). From their results, they concluded that tempo had no effect on mood, and mode had no effect on arousal, though conversely, mode did affect mood and tempo did affect arousal (Hussain et al, 2002). A major chord is generally associated with upbeat, positive feelings and conversely a minor chord is generally associated with downbeat, negative feelings. The complexity of measuring human mood with music was duly noted in Hussain et al’s 2002 study; although sad feelings can be elicited from minor keys, there can also be a satisfaction that comes from finding minor chords aesthetically pleasing. In

consideration of this, the composition used in the present study employed both major and minor chord sequences; so as not to bias mood in one particular direction. For 3.5 minutes of the composition a positive major scale in B flat was used, after which a new chord sequence was introduced blending minor notes to the piece, for the remaining duration.

1.6 Rationale:

Of the 17 studies that comprised Charyton and Huang's (2008) review, only 3 measured BWE with reference to mood (Wahbeh, 2007; Ossebaard, 2000; Le Scouarenac, 2001). Of the 3 that measured mood, none employed a musical composition; rather, rain sounds were used to reduce saliency of the isochronic tone. One important conclusion from Le Scouarenac's (2001) study was "Future studies should account for music preference among participants" this is further echoed in the comprehensive review "Studies are needed to compare the effects of auditory, photic and AVE stimulation, and to compare the clinical benefits of monaural, binaural and isochronic beats and the use of white noise vs. music as a background" (Charyton and Huang, 2008). The last point of "comparing an isochronic tone with music as a background" was foundational to the present study. The reasoning for the current research is to compare the effects of BWE with and without a musical composition; using an EEG as a quantitative measure, with a further measure of mood as psychological outcome. If the effects of isochronic BWE are successful with a musical composition, this could provide an alternative to those that wish to utilise this therapy. Its uses could extend not just to the therapeutic setting, but also recreationally, to enable people to layer compositions of their choosing.

Another aspect of the present study was the choice of musical composition. The choice to create an original composition was done to avoid participant biasing; to use a song from popular music (or any recorded genre) could immediately affect the participants mood if in fact they were primed or had particular associations to that song (Hussain, Thompson and Schellenberg, 2002). This is not to suggest this had been eliminated; how any piece of music may affect an individual, rather it is thought to have reduced the composition as a primed variable. In consideration of Padmanabhan et al's, (2005) study which utilised pre-programmed Binaural beats and audio, it is unknown what the choice of song was for this research and the potential priming / associative effects this could have on the participants. Popular sites and companies that provide home or recreational software such as Peak Genius or Braintune lay claim that "None of the pre-recorded tracks contain music because this interferes with the purity of the frequency" (Peak Genius, 2014). To the best of the current studies knowledge, no research has established whether music has an impact on BWE, or to what outcome, or what factors should be considered when attempting to blend Isochronic tones with musical composition. Furthermore, there is no mention of carrier pitch, or the pitch of the binaural beats themselves when blending with a composition. This was a felt to be a critical point towards the end of the present research; none of previous studies that have used music have mentioned the relationship between the pitch of the frequency and the pitch of the musical compositions.

The present study used the alpha frequency range 8- 12hz on the basis that this range is associated to calm, relaxed wakefulness "Alpha waves appear immediately and spread throughout the cortex when you close your eyes, which is part of the relaxation process leading to sleep". (Charyton and Huang, 2008). To achieve BWE in the alpha range, a median isochronic tone of 10Hz was created. By layering the isochronic tone within the musical

composition, the tones saliency was greatly reduced from the audible experience. The composition containing the isochronic tone had a run time of 7 minutes; the Brainwave Research Institute, London, England states “Within 7 minutes, your brain goes from a Beta to Alpha”. As a control a separate audio track was created; this was the isochronic tone in isolation, with duration of 7 minutes. The nature of the composition was ambient in genre; soft synth sounds, 90 BPM (beats per minute) and entirely instrumental. Quantitatively the EEG was employed to measure the output of Beta to Alpha frequency for each participant. The Positive and Negative Affect Schedule (PANAS) was selected to measure mood; to establish if the participants would feel any different from the time before the experiment, to the time after the experiment. Finally, an additional question was placed at the end of the questionnaire to identify if the tone or composition were perceived as “comfortable or uncomfortable”.

1.7 Hypotheses:

Previous studies (Le Scouarenac, 2001; Charyton and Huang, 2008; Padmanabhan et al, 2005) within the area of BWE have raised questions regarding the potential effectiveness of isochronic tones with music as background; the current study aims to investigate this proposition. Given the pulse like quality of both Isochronic tones and Binaural beats and the duration of existing therapeutic treatments of BWE, the ability to sit these frequencies below a musical composition is thought to provide a less salient entrainment experience. The existence of holistic treatments such as flotation tanks and mindfulness techniques suggests there is a niche market amongst the public to pursue non-ordinary states for relaxation and recreation. Therapeutically, studies by Siever (2003); Ossebaard (2000); Padmanabhan (2005) have shown how those suffering from depression and mild autism have responded to BWE,

the advantage of this study could make BWE more compatible and accessible to people that identify with this intervention.

(H 1A). It is hypothesised that the isochronic tone paired with the musical composition will effectively achieve brainwave entrainment amongst the participants.

The previous studies (Wahbeh, 2007; Ossebaard, 2000; Le Scouarenac, 2001) that have measured mood and BWE have not reported the effectiveness of BWE when paired with a musical composition. Furthermore, in the present study there is the potential to reduce the saliency of the tone itself could be used for therapeutic advantage (Siever, 2003; Charyton and Huang, 2008).

(H 1B). It is hypothesised that those participants exposed to isochronic tone with composition will have a stronger positive psychological outcome on PANAS questionnaire than those with tone.

Music's ability to affect temporary disposition has been noted in studies by Husain, Thompson and Schellenberg (2002); this hypothesis will examine if the musical composition had an effect on the participants' mood during BWE. Previous studies have used Binaural compositions as a carrier of the tone, however it has not been identified what effect this may have on the participant. Furthermore, no reference has been made to the scale of the compositions used in past research.

(H 1C). It is hypothesised that participants will perceive the isochronic tone paired with musical composition as a comfortable audio experience, compared to participants who listen to the isochronic tone in isolation.

The ability to place the tone beneath a musical composition is thought to appeal more to the listener than the isochronic tone itself. The tone in isolation can be perceived as a monotonous, pulse like sound (Mann,1981). By layering beneath the composition, the tone's saliency is greatly diminished.

Method:

2.1 Participants

In total, 31 people took part in the study (M=18, F=13). A random sampling method was employed. Ages ranged from 28 to 64. Participants were emailed and contacted through social media sites requesting their participation in the experiment. The message advised the participants the experiment involved an EEG machine, a seven minute audio piece and a questionnaire; with the total time taking no longer than 20 minutes. As a precaution, those taking part were advised that if they suffered from tinnitus or idiopathic partial epilepsy, they may wish to avoid participation. As a necessary deception, participants were not made aware of the presence of the isochronic tones, BWE or the randomised condition. This was to reduce participant bias to potential BWE effects.

2.2 Design

The study used a true experimental design that was between groups and double-blinded. The research variables were positive psychological outcome on the PANAS questionnaire and comfort of audio experience (dependent variables) and brainwave entrainment with and without musical composition (independent variables).

2.3 Apparatus:

Adinstruments MLAEC1 EEG cap and Adinstruments MLAE11 electro gel were used to capture brainwave activity. Adinstruments Labchart v8 and Adinstruments Powerlab 26/T

were used in conjunction with dual Compaq microtower computers and monitors to create the randomised experimental conditions (composition or tone) and for recording the brainwave activity. Labchart Reader V8.0 was used to review the mean EEG results for participants of both conditions, these items were provided by Dublin Business School and experiment delivered at the colleges bio feedback lab. The PANAS questionnaire was retrieved from: http://booksite.elsevier.com/9780123745170/Chapter%203/Chapter_3_Worksheet_3.1.pdf

JVC HA-5600 headphones were employed to deliver the tone and composition. The free audio software Audacity 2.0.5 was used to create the isochronic tone. Music production software Ableton 5.0 was used to record the composition, master and mix the tone. Each participant completed a consent form and the PANAS questionnaire, pens -BIC grip 1.0- were also provided. IBM PASW 20 (SPSS) was used to compile and analyse statistical data.

2.4 Materials:

An isochronic tone is defined as “a single tone with evenly spaced intervals” (Siever, 2009; Manns, 1981). Using the audio software program *Audacity 2.0.5*, a single tone was generated for a period of 0.05 seconds; this was then followed by silence for the same length or duration. By repeating this process of generating a tone, followed by a silent interval, on/off for 7 minutes 25 seconds, an evenly spaced isochronic tone is created. The pitch of the tone was selected at 466.16Hz (b flat), the root note of the musical composition. The isochronic was then saved as a WAV. tone.



2.1.2 A 10Hz Isochronic tone from Audacity

The original composition was composed using the *Ableton 5.0* audio production suite; the track duration was 7 minutes 25 seconds. The root note or key of the track was b flat. The track itself employed, minimalist, ambient synth sounds at 90 BPM. Once this had been recorded and mastered; the WAV. tone was placed below the mastered track. The volume of the tone steadily increased within the first 20 seconds of the audio track, so that its saliency was intact.

A.D instruments EEG machine and powerlab software were employed to measure participants brainwaves. With the EEG cap, the nodes at the temples were used to focus on brainwaves from the frontal lobes. The powerlab test was created to randomise one of two possible conditions from the time participants press the spacebar: to play the isochronic tone, or, to play the musical composition with the isochronic tone.

To measure and evaluate the psychological impact the tone and composition had on each participant, the Positive and Negative Affect Scale (PANAS) questionnaire was utilised. PANAS was selected for its “internal consistency, and excellent convergent and discriminant correlations” (Watson, Clark and Tellegen, 1988), as well as its ease to administer, and relatively short turnaround time for completion with each participant.

2.5 Procedure

The experiment took place at Dublin Business School's biofeedback room on Tuesday evenings between 5:45pm and 7:30pm and on Saturday mornings from 9:00am until 1:00pm. On arrival participants were first requested to sign a consent form. The form advised that the use of the EEG machine had been explained to them, that anonymity would remain intact and that withdrawal from the experiment could occur at any point from the start of the experiment, and up to two weeks after involvement.

The EEG cap was placed on the participants head, and the earth wire clipped to their ear. For improved conductivity, electro gel was syringed into the frontal-temple nodes. The EEG feed began once the participants were seated by the EEG machine. There were two computers, one monitor showing the EEG feed and the other delivering the instruction to commence the experiment. Before commencement, participants were told that they could keep their eyes open or closed for the duration of the audio recording. On the researcher's instruction, participants were asked to follow the screen instruction to "press the spacebar". Participants were then requested to signal a "thumbs up" when they heard audio. The researcher then left the room for the 7 minutes 20 second audio duration. On return to the lab room, the researcher requested the participants to remove the EEG cap and move to an adjacent desk to complete the PANAS questionnaire. Once the questionnaire had been completed and handed over, the researcher commenced debriefing. The average time for the experiment per participant was 15 minutes. Debriefing began by explaining the double blinded aspect of the experiment, the two possible conditions, an explanation of BWE and isochronic tones; their therapeutic and recreational possibilities, and the justification of the deception. The deception was employed to avoid both participant and experimenter bias; that to be aware of the possibilities of BWE prior to listening to the audio may affect the participant's response; and the researcher choosing what participants were listening to.

Results:

This first test of data analysis was to establish descriptive statistics, the normality of the distribution, with assumptions considered on each test variable. A visual check on the histogram and Q-Q plot confirmed the approximate normality on EEG and PANAS Data. The test variables for SPSS readout:

EEG - mean frequency reading per participant in the alpha range, 8-12Hz. **POSTOT** (Total positive affect scores on PANAS). **NEGTOT** (Total negative affect scores on PANAS).

COMF (comfort of audio; comfortable / uncomfortable). Table 1 shows descriptive Statistics for the variables.

Table 1 Descriptive Statistics for Variables

Variable	Group	N	Mean	Standard Deviation
EEG(Hz)	Comp	19	9.46	.183
	Tone	12	9.55	.151
POSTOT	Comp	19	32.21	7.92
	Tone	12	28.17	9.71
NEGTOT	Comp	19	20.74	3.26
	Tone	12	21.17	5.52
COMF	Comp	19	1.05	.229
	Tone	12	1.50	.522

3.1 Shapiro- Wilk data and distribution

A Shapiro Wilk test confirmed that the data was approximately normally distributed for scores of both positive (POSTOT) and negative (NEGTOT) affect with reference to BWE conditions COMP (composition) and TONE.

The skewness for POSTOT /COMP being -0.264 (SE =.524) and kurtosis -1.514 (SE=1.014) and the skewness of NEGOT /COMP being -.167 (SE= .524) with kurtosis being .592 (SE=1.014). The skewness for POSTOT /TONE was .043 (SE= .637) with kurtosis value -.105 (SE=1.232), and for NEGOT /TONE skewness being -.472 (SE= .637) with kurtosis being -.959 (SE= 1.232).

With these variables assumptions met, an independent-samples t-test was conducted to compare PANAS results with BWE COMP group and BWE TONE group. The secondary rationale for the independent t-test was to compare the EEG frequency readings of BWE with TONE, to BWE with COMP. Due to the comfort of audio (COMF) variable not meeting parametric criterion; this variable was measured using a Mann Whitney U test.

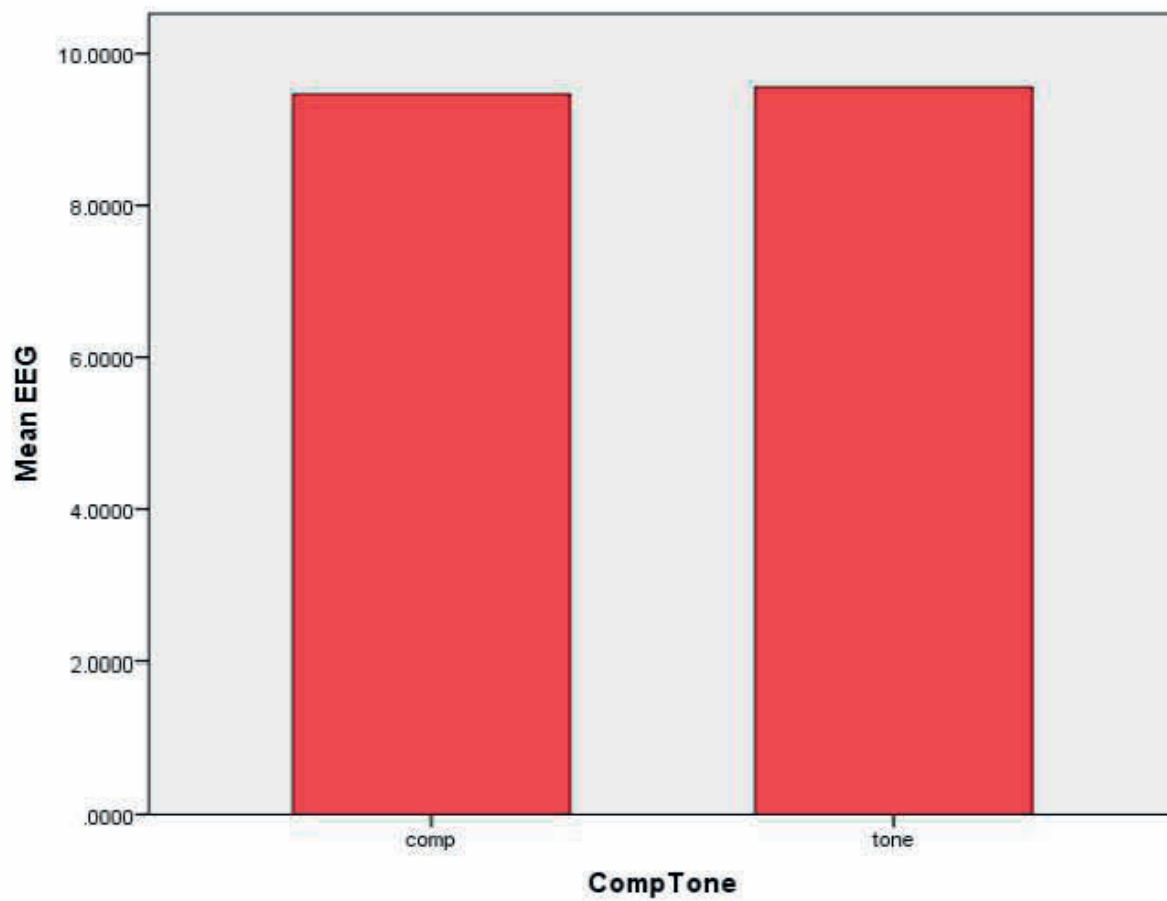
Table 2 represents an Independent Samples T-test, displaying the differences between, EEG readout, PANAS results for the TONE and COMP groups.

Variables	Groups	Mean	SD	t	df	p
POSTOT	TONE	28.17	9.713	1.269	29	.215
	COMP	32.21	7.920			
NEGTOT	TONE	21.17	5.524	-.273	15.91(adj)	.810
	COMP	20.74	3.263			
EEG	TONE	9.558	.1519070	-1.488	29	.147
	COMP	9.463	.1836977			

3.2 EEG frequency, BWE with and without musical accompaniment

Hypothesis (1A) of the current study was to establish whether BWE was effective with a musical accompaniment. To measure this, the spectrum analyser function in LabChart reader was used to search for active frequencies in the alpha range for both groups (8-12Hz). The mean results of both groups were then compared. The independent t test found there was not a significant difference in the frequency scores for BWE in the alpha range with TONE (M=9.558500, SD=.1519070) and BWE with COMP (M=9.463291, SD=.1836977) conditions; $t(29) = -1.49$, $p = 0.147$. These results suggested that BWE is equally effective in both conditions; isochronic tone with musical accompaniment and without musical accompaniment. This result was thought to have satisfied the first hypothesis.

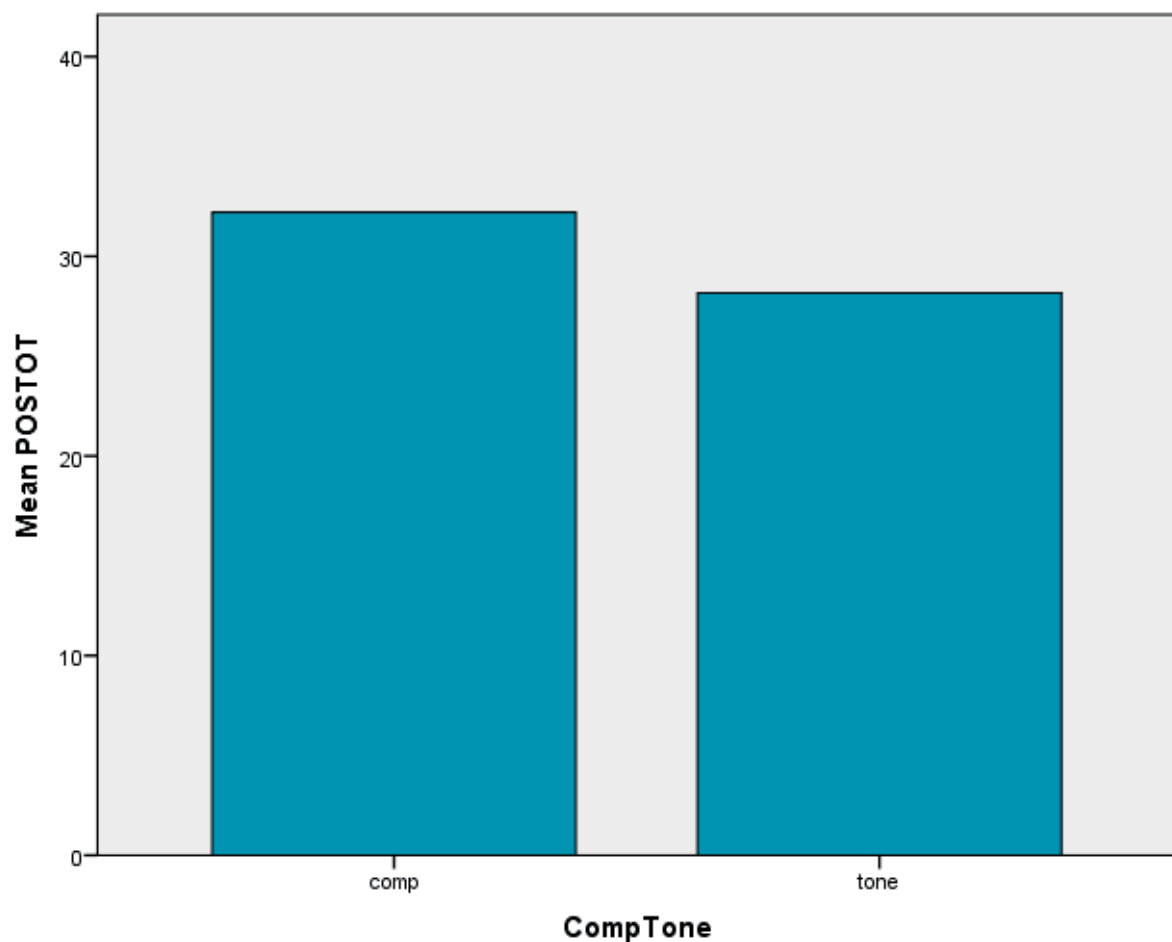
Figure 1 shows Mean EEG (Hz) between the 2 groups



3.3 PANAS (Positive Affect):

To evaluate the psychological outcome on both of the groups, the results from the PANAS were entered into SPSS and totalled by Positive affect (POSTOT) and Negative affect (NEGTOT). The other hypothesis of the current study was to propose that those that listened to the musical composition would score higher in the positive affect than those that listened to the tone. The independent t test found there was not a significant difference in the positive affect scores for COMP group ($M=32.21$, $SD=7.920$) and TONE group ($M=28.17$, $SD=9.713$) conditions; $t(29)=1.27$, $p=.215$. This result failed to satisfy the second hypothesis, though suggested positive affect was increased in both groups.

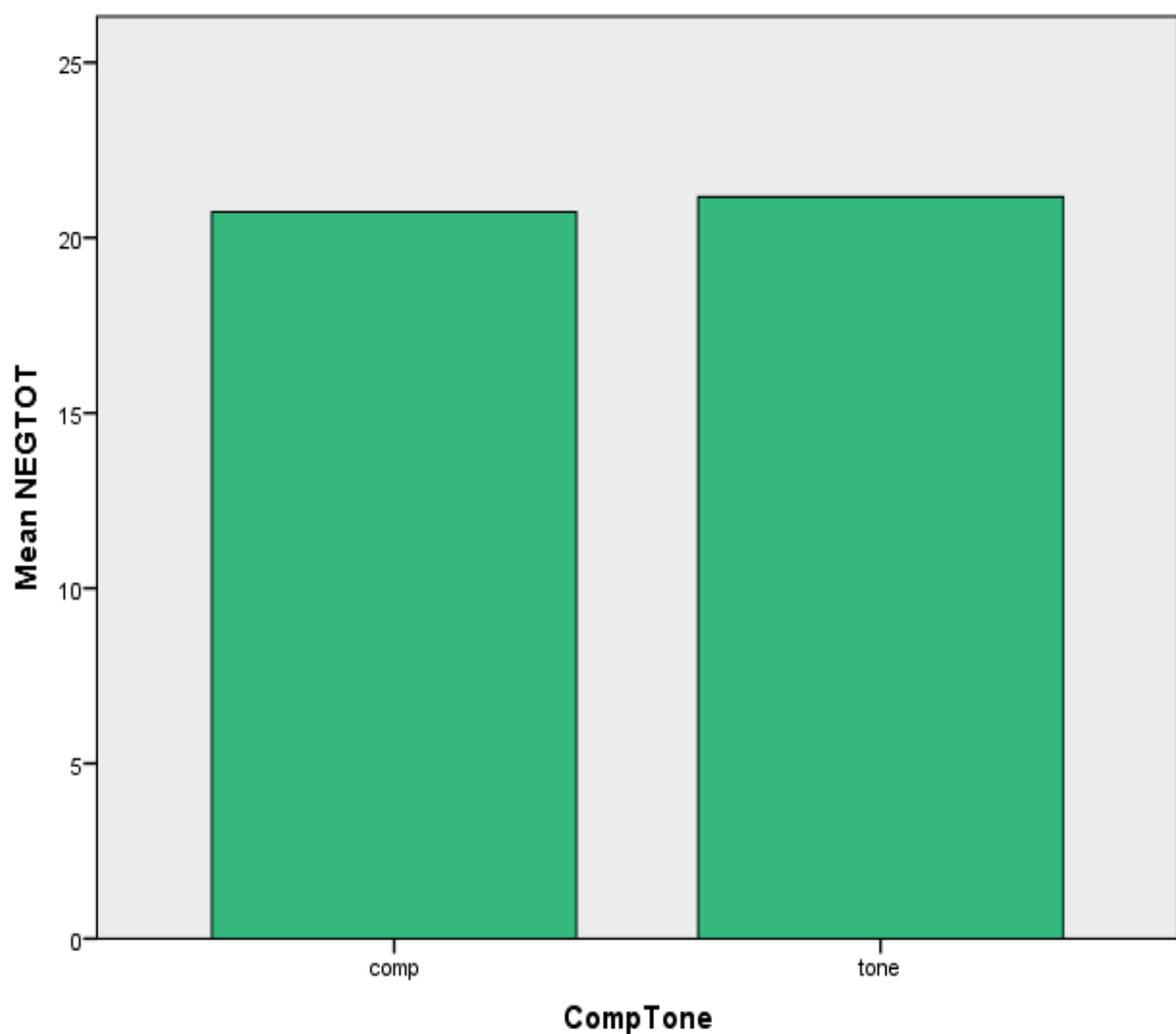
Figure 2 represents positive affects scores between the two groups



3.4 PANAS (Negative Affect):

Levene's equality showed $p=0.03$ on the independent $-t$ test; therefore assumptions needed to be corrected. A Mann-Whitney U was employed and showed that mean rank for negative affect scores in TONE group was higher, though not statistically significant different from negative affect scores for COMP group where $U(29) = 99.50$, $Z=-.592$, $p = >0.05$

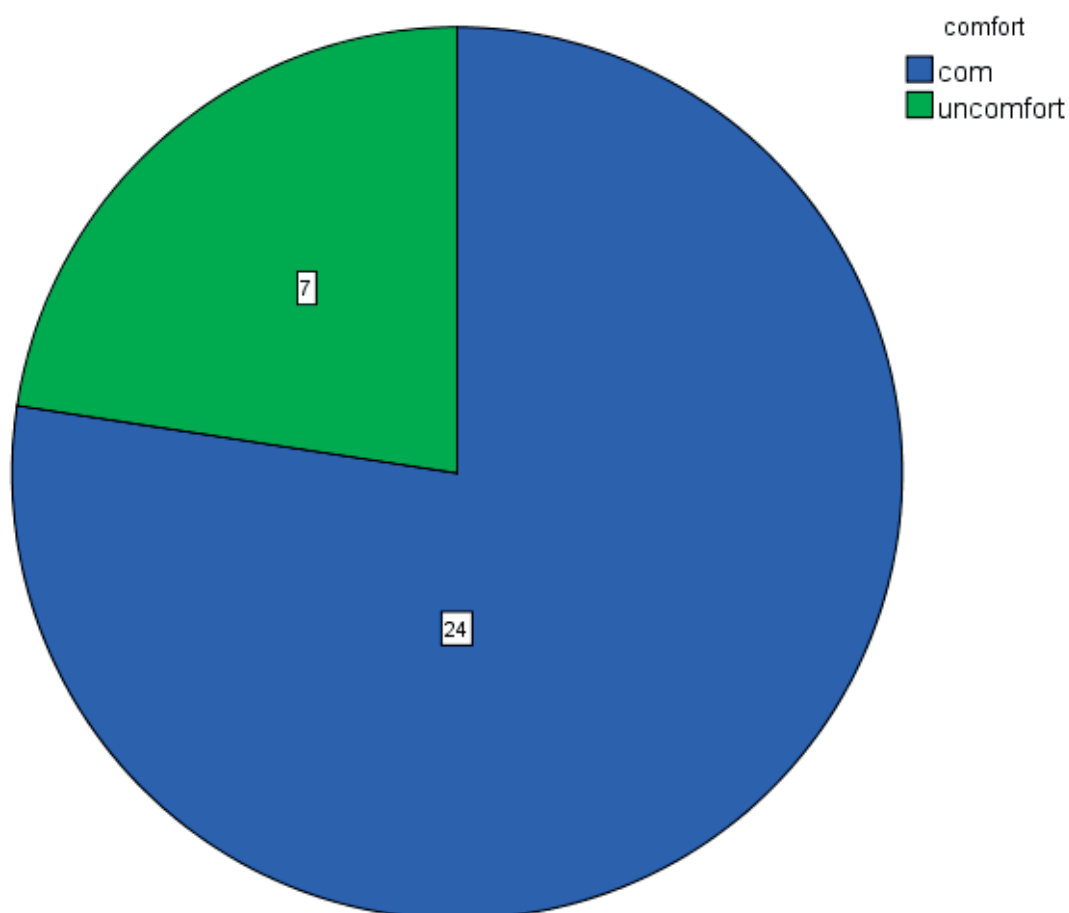
Figure 3 represents negative affect scores from the two groups:



3.5 COMFORT OF AUDIO:

The final hypothesis (1C) in the present study proposed that the test group exposed to the tone with musical accompaniment would rate their audio experience as comfortable in comparison to the group that listened to the tone. A Mann Whitney U test returned a statistically significant difference in how the groups perceived the comfort of the audio they listened to, with the TONE group scoring higher with the “Uncomfortable” rating where $U(29)=63.00$, $z=-2.28$, $p=.039$. This result was thought to have satisfied the third hypothesis.

Figure 3 showing COMP scoring higher for comfort overall



Discussion:

The aim of the present study was to compare alpha brainwave entrainment with and without musical accompaniment. Statistically, BWE with or without musical accompaniment yielded no difference in the two conditions; that alpha wave entrainment was active when the 10 Hz isochronic tone was situated below a musical composition. The data results from the PANAS questionnaire statistically reflected an overall positive affect for both conditions; with and without musical accompaniment. The participant perception of their audio experience suggested that BWE with a musical composition was a comfortable audio experience in contrast to the tone in isolation. This is thought to have built on the questioning from Charyton and Huang (2008) comprehensive review and Le Scourenacs (2001) study with respect to pairing BWE with music, and is thought to be novel to this particular study.

4.1 Comparison with previous research

The present study was seemingly consistent with past research on the entrainment capabilities of isochronic tones and positive affect on mood. Statistically, on the PANAS questionnaire there was no significant difference between positive outcome results in both conditions: Composition with tone (N=31, M=32.21) and tone by itself (N=31, M=28.17), and furthermore positive affect scores were higher than negative affect for both conditions: Composition with tone (negative) (N=31, M=20.74) and tone (negative) (N=31, M=21.17). Comparatively, the present study gravitated toward the single session research on BWE and mood state when drawing reference to resulting data. In Ossebaard's (2000) research on workplace stress and BWE, there was an immediate reduction in anxiety when administering

a 10Hz Binaural beat, and using Spielbergers State trait anxiety scale for measurement. The current studies high ratings on positive affect after a 7 minute exposure to a 10Hz Isochronic tone and isochronic tone with musical composition are thought to be conducive with Ossebaards (2000) observation in the “short term pleasant effects of entrainment”.

Next, Le Scourenacs (2001) research looked at whether a group of 15 mildly anxious people, exposed to a daily binaural beat session, for one month, would show a decrease in anxiety and improvement in mood. The participants were given three tapes containing Theta and Delta BWE beats. Their study noted that music accompanied these tones, though did not specify genre, frequency or potential effect this may have on the participants. With respect to measurement, participants kept a daily journal of how they felt after entrainment, also, the researchers used Becks State-trait anxiety scoring. Listening to the daily 30 minute sessions showed a significant reduction in anxiety by participants self-reporting, with perceived anxiety dropping from 41.1% to 21.2%. Le Scourenacs (2001) conclusion made reference to the choice of music for future studies, that genre or preference should be considered.

With regards Padmanabhan et al’s (2005) study, they used a 30 minute binaural beat session to investigate the potential for stress reduction in pre-operative anxiety. A paired samples, before and after BWE design was employed. The results were typical with Le Scourenacs (2001), in so far as mean results for participant’s anxiety were approximately halved on the State-Trait Anxiety Inventory. Again, their study made use of pairing an audio piece with a binaural beat, though did not comment on the frequency, genre or effect this may have on participants mood, noting “we did not extend the study to examine the impact of

anxiety levels on patient satisfaction, although it would be interesting to conduct such a follow-up study”. (Padmanabhan et al, 2005).

Further research on Isochronic tones, PANAS and musical composition should look to address mood state prior to BWE and compare with after BWE session to identify differences. The current study did not take a baseline mood state, so comparison could not be made prior to BWE. In light of this, the composition used in the present study started with in a major key, and it cannot be ruled out that this contributed to participant’s scores on the PANAS questionnaire; further studies should attempt to establish the mood of the participants before and after entrainment with musical composition. It could be considered necessary for future research to establish if different genres or frequency’s over-ride or excite the BWE experience.

4.2 The importance of a carrier frequency with musical composition

Of the previous studies that have reviewed BWE and isochronic tones, none have made reference to the pitch of the tone when attempting to bind with a musical composition. A moderate understanding of musical theory would be desirable when attempting to create and blend isochronic tones with a musical composition. It was apparent that the pitch chosen to represent the tone, the *carrier* pitch, must be the root note of the composition, or a derivative of the root note, a third or a fifth on the musical scale. A deviation or lack of understanding of this, will result in harmonic dissonance; making an uncomfortable audio experience for the listener. Harmonic dissonance is defined as “notes producing a harsh and inharmonious sound; being at variance or disagreeing”. This can be conceived when we hear

singer or instrument out of key, the saliency of the dissonant pitch is amplified through its difference to the other harmonious instruments or notes.

When creating an isochronic tone, the distance between tone and silent interval creates the desired frequency; 0.05 sec tone, followed by 0.05 silent interval results in a 10Hz isochronic tone. The pitch of this tone however, is how the listener will perceive it; the isochronic tone must be an audible frequency to the listener.

If this was to be adopted into a therapeutic or recreational environment, those administering the tone with a composition would need to know: the key of the musical composition, and then the corresponding frequency of that note to employ an adequate carrier frequency. Due to the composition being an original in the present study, the root note was a known B flat; in turn the isochronic tone was then matched at B flat's frequency, 466.16 Hz. As well as avoiding harmonic dissonance, this further improves on reducing the saliency of the tone itself. Given there is much home software available to create isochronic tones, from companies such as Transcorp Inc, and a large number of user made isochronic tones and binaural beats on popular sites such as Youtube, this point is a critical for making use of these tones with a musical composition. One implication of using these tones on non- original compositions would require, the listener having knowledge of the root note of each song they wished to accompany with the tone, the known frequency of the corresponding root note, the ability to create the tone for each song, and the software to place the tone below the mix of the composition.

4.3 Advantages and Disadvantages of the present research:

The current study set out to examine if BWE was active with an Isochronic tone and composition and compared this to an Isochronic tone in isolation. The data showed that this was effective, and in scope with previous studies with respect to BWE in the alpha range and short term positive effect on participants mood. It is felt the strongest contribution made was the identification of carrier pitch for future studies to consider when attempting to blend with a musical composition.

The disadvantages of this study were felt to be the lack of a baseline for measuring mood. Given the scores on the PANAS questionnaire, it would have been beneficial to compare the results of mood before and after the BWE. Furthermore, with more time and a paired samples t-test, a comparison could have been made using two different genres of music. The idea being, to see to what effect music and BWE complement or detract from each other's capabilities on participant's mood.

4.4 Future therapeutic and recreational possibilities of BWE

Audio downloads for the purposes of BWE are becoming very popular. There are presently upwards of 100 producers of “entraining” audio for relaxation, cognition, sleep, performance, etc. (Siever, 2003). A recent study (Luangboriboon, Tantayanon and Wongsawat, 2013) created a portable binaural entrainment device only 5X6X3 cm in size. This utilises BWE possibilities by allowing the user to set a desired frequency. The device then delivers binaural beats and “a PCM generated Binaural audio” (Luangboriboon, et. al, 2013). It was not noted in that study if the audio was thought to have any effect on the

participant's mood, or what the pitch of the carrier frequencies was. The ability to create a portable device that can deliver BWE frequencies has tremendous potential; therapeutic sessions could be conducted from the comfort of the listener's home, or journey to work.

Following from the current study, it is clear that pitch plays an important role when pairing with BWE frequencies with an audio composition. If there was a way to for a portable device to identify the frequency of the incoming song and then generate the correct isochronic tone and pitch, BWE could become as accessible as listening to music on an IPOD. This is not as radical as it may sound; there is existing software that can identify audio frequency from the incoming signal. The "Quiztones" app was designed to assist sound engineers identify frequencies from incoming audio. If this could be merged with Luangboriboon, et. al's (2013) device, and a portable music device like an IPOD it is conceivable a prototype of this concept could be developed.

The benefits of BWE have shown both short term or temporary change in mood and anxiety (Ossebaard, 2000; Calabreses, Wahbleh and Zwickey, 2007), as well as long term changes (Siever, 2003; Siever and Berg 1999; Le Scourenac, 2001). Furthermore, as research grows, new and novel ways to utilise BWE are becoming more apparent, such as stress reduction in pre-operative anxiety, attention deficit disorder, depression and portable Binaural generating devices. The ease at which these methods of induction can be created or developed, contributes to making BWE an accessible, cost effective alternative to medicinal therapy.

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<http://www.transparentcorp.com/>

<http://www.quiztones.com/>

Appendix A:
Consent Form

I.....agree to participate in Cormac Doherty's research study.

The purpose and nature of the study has been explained to me verbally.

I am participating voluntarily.

I give permission for my EEG reading and questionnaire to be used.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that I can withdraw permission to use the data within two weeks of the interview, in which case the material will be deleted.

I understand that anonymity will be ensured in the write-up by disguising my identity.

I understand that disguised extracts from my participation may be quoted in the thesis and any subsequent publications if I give permission below:

I agree to quotation/publication of extracts from my participation ☐

Signed.....

Date.....

Appendix B:

PANAS Questionnaire

This scale consists of a number of words that describe different feelings and emotions.

Read each item and then list the number from the scale below next to each word.

Indicate to what extent you feel this way right now, that is, at the present moment OR indicate the extent you have felt this way over the past week (circle the instructions you followed when taking this measure)

1	2	3	4	5	6
Very Slightly	Not at All	A Little	Moderately	Quite a Bit	Extremely

_____ 1. Interested	_____ 11. Irritable
_____ 2. Distressed	_____ 12. Alert
_____ 3. Excited	_____ 13. Ashamed
_____ 4. Upset	_____ 14. Inspired
_____ 5. Strong	_____ 15. Nervous
_____ 6. Guilty	_____ 16. Determined
_____ 7. Scared	_____ 17. Attentive
_____ 8. Hostile	_____ 18. Jittery
_____ 9. Enthusiastic	_____ 19. Active
_____ 10. Proud	_____ 20. Afraid

How would you rate the audio you have just listened to?

Comfortable or Uncomfortable