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ALPHA FREQUENCY DISCREPANCY AND TRAIT ANXIETY, ACTIVATION, AND INHIBITION IN STATES OF ANXIETY AND MINDFULNESS

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ABSTRACT

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Meditation techniques are potential tools for wellbeing improving and maintaining and stress reduction. Various neuroscientific studies show immediate results of meditative techniques influencing oscillatory mechanisms in the brain. Meditation has also been shown to have long-term effects that include overall decrease of anxiety and worry.

To form a preliminary framework for developing a brain-computer interface system for sustained attention enhancement, the behaviour of alpha frequency band during states of anxiety, mindfulness and rest was studied, and the differences were juxtaposed with personality traits of anxiety, inhibition and activation.

This study was conducted at the Jyväskylä Centre for Interdisciplinary Brain Research using MEG laboratory and standardised scales measuring personality traits and tendencies (BAI and BIS/BAS). The experiment was conducted on 27 subjects during the second half of 2017.

Results implicate that states of mindfulness and anxiety are distinguishable from each other and from resting control state. Findings also suggest that certain reward responsiveness affiliated personality traits correlate with alpha frequency power in distinct cognitive states. Further the difference between alpha power and these states could be linked to differences in personality traits and tendencies. Results offer insight on the relation of personality traits and alpha frequency band behaviour in different cognitive states.

Keywords: Cognitive neuroscience, anxiety, meditation, mindfulness, brain-computer interface, BCI, alpha, oscillation

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Meditaatiotekniikat tarjovat laajalti mahdollisuuksia hyvinvoinnin ylläpitämiseen ja kehittämiseen sekä stressin lievittämiseen. Useat neurotieteelliset tutkimukset ovat osoittaneet välittömiä tuloksia meditatitiivisten tekniikoiden soveltamisen ja aivojen oskillatoristen mekanismien välisessä suhteessa. Meditaatiolla on osoitettu olevan myös pitkäaikaisia vaikutuksia, joihin sisältyy ahdistuneisuuden ja murheen väheneminen.

Keskittymistä tukevan aivokäyttöliittymän alustavan suunnittelun tueksi tutkittiin alpha-aallonpituuden käyttäytymistä ahdistuneisuuden ja mindfulnessin tiloissa ja niiden välisiä eroja lähestyttiin aktivaatio-/inhibitio -persoonallisuuspiirteiden sekä ahdistuneisuuteen taipuvaisuuden valossa.

Tutkimus toteutettiin Jyväskylän monitieteisessä aivotutkimuskeskuksessa (CIBR) MEG-laboratoriossa persoonallisuuspiirteitä ja taipumuksia mittaavia standardikyselyitä hyödyntäen. Tutkimukseen osallistui 27 koehenkilöä vuoden 2017 toisen puolikkaan aikana.

Tutkimustulokset ehdottavat, että mindfulnessin ja ahdistuneisuuden tilat voidaan erottaa toisistaan. Löydökset antavat myös tukea hypoteesille, että tietyt palkitsemiseen liittyvät persoonallisuuspiirteet korreloivat alpha-aallonpituuden voimakkuuden kanssa eri tavoin erilaisissa kognitiivisissa tiloissa. Tulokset tarjoavat lisätietoa persoonallisuuspiirteiden ja alpha-aallonpituuden käyttäytymisestä erilaisissa tiloissa ja voivat edesauttaa aivokäyttöliittymän suunnittelua.

Asiasanat: Kognitiivinen neurotiede, ahdistuneisuus, meditaatio, mindfulness, aivokäyttöliittymä, alpha, oskillaatio

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GLOSSARY

ADD	Attention-deficit disorder
ADHD	Attention deficit hyperactivity disorder
BAI	Beck's Anxiety Index
BCI	Brain-Computer interface or Brain-computer interaction
BDI	Becks' Depression Index
BIS/BAS	Beck's behavioural inhibition / activation scale
CIBR	Centre for interdisciplinary brain research (in Jyväskylä)
EEG	Electroencephalography
ERP	Event-related potential or evoked response potential
FMRI	Functional magnetic resonance imaging
HCI	Human-computer interaction
HTI	Human-technology interaction
MEG	Magnetoencephalography
NFL	Neuro feedback loop
P100/P200/P300 /N170/N400 etc.	Waveform component or feature of the ERP, often recorded after a delay in milliseconds corresponding the stated number. N is for negative and P is for positive.
PTSD	Post-traumatic stress disorder
SQUID	Superconducting quantum interference device, sensor technology used in MEG devices
VEP	Visual evoked potential

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1 INTRODUCTION

In 2016 the number of mental health or behavioural disorders diagnosed in Finland was 59 171, which is almost twice the amount of year 2006. During 2006 - 2016 the share of those disorders from overall diagnoses has risen from 2.32 % to 3.08 %which means a one third growth of the relative percentage of all diagnoses over ten years as seen in figure 1. This means more than 21 000 more mental health or behavioural disorders were diagnosed in 2016 than in 2006. In the year 2016 patients of psychiatric specialist health care was 177 839, which is roughly 3.2 % of overall Finnish population being roughly 1 in every 30. (THL, 2017.)

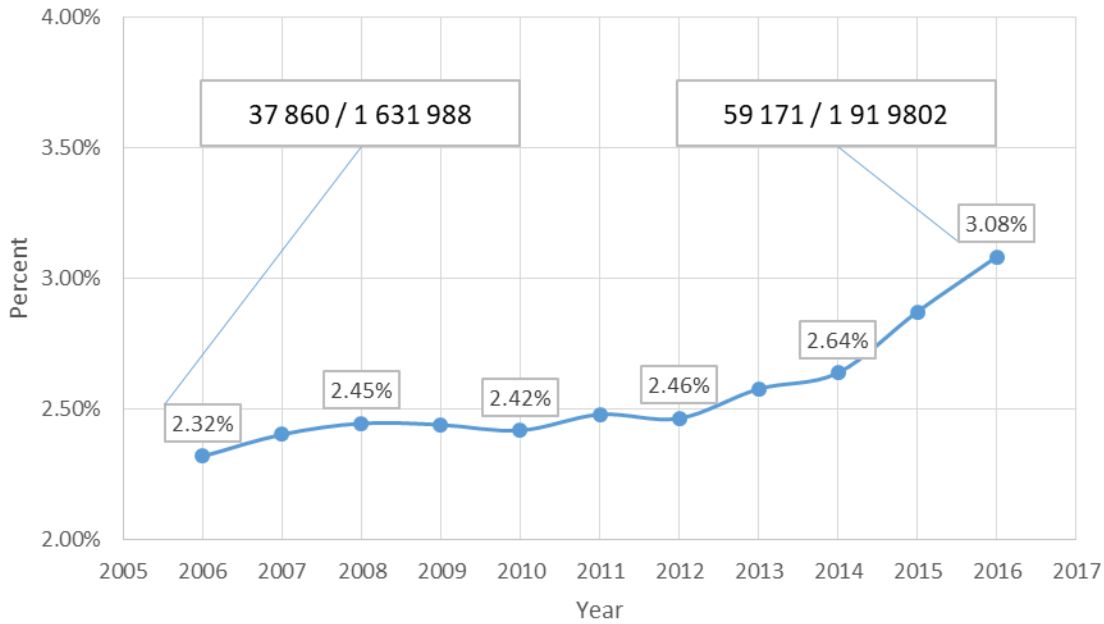


FIGURE 1 Percentage of diagnosed mental and behavioural disturbances of overall diagnoses in specialised healthcare in Finland in years 2006 – 2016

Meditation and relaxation techniques are potential tools for wellbeing improving and maintaining, in addition to stress reduction (Lagopoulos, Xu, Rasmussen et al., 2009). Various neuroscientific studies show immediate results of meditative techniques influencing oscillatory mechanisms in the brain (Takahashi et al., 2004; Dunn, Hartigan and Mikulas, 1999; Aftanas and Golocheikine, 2002). Tomljenovic, Begic and Mastrovic (2005) state that meditation has also long-term effects that include an overall decrease of the inhibitory alpha oscillation. Also state anxiety and cognitive worry were reportedly decreased after meditational training intervention (Tomljenovic et al., 2005).

A brain-computer interface (BCI) is a device that facilitates a human-computer interaction through data that is acquired from the brain (Leuthardt et al. 2004). Various BCI's have been developed through the years (Wolpaw et al. 2002). As Doud et al. (2011) articulates, BCI's are thought to allow control of computer only using thought. Wolpaw et al. (2002) elaborate that essential challenges in contemporary BCI development include limitations set by large quantities and variance of neural activity, physiological complexity of brain, and diversity of results between trials and studies.

To enable more advanced development of brain-computer interface technologies the underlying mechanisms that BCI's rely on must be further elucidated. This can happen through multidisciplinary quality research and keeping various possibilities for practical applications in mind.

Jyväskylä Centre for Interdisciplinary Brain Research (CIBR) is a partner in a research project consortium called NeuroFeed funded by Academy of Finland. The main aim of NeuroFeed is to produce a real-time machine learning neuro feedback system that would enhance long-term attention and mindfulness. This study aims to procure information of possible solutions to function as grounds for preliminary framework for development process of the neuro feedback system. Additionally, this study explores the relationship of anxiety personality trait and the brain oscillatory activities in alpha frequency domain.

The experiment was conducted using CIBR MEG laboratory and standardised scales measuring personality traits and tendencies. Hypotheses of associations are examined using statistical analysis methods. Results implicate that states of mindfulness and anxiety are distinguishable from each other and from resting control state. Findings also suggest that certain reward responsiveness affiliated personality traits correlate with alpha frequency power in distinct cognitive states and that the difference of alpha power between states could be linked with differences in personality traits and tendencies.

Results indicate parallel accomplishments relative to previous studies further supplementing existing research gaps in neuroscientific study of meditation, anxiety, and their relation to personality traits. Study offers usable information in relation to theoretical logics on which attention and mindfulness enhancing BCI neuro feedback system could operate on.

1.1 Thesis structure

This thesis consists of seven main chapters. In the first chapter the theme and subject matter is introduced to the reader and related questions are contemplated. First chapter includes definition of the most essential concepts approached in this thesis and describes problematics behind research problem and questions.

Second chapter includes a brief review into the contemporary nature and theory behind brain computer interface (BCI) development and practical applications. In the beginning of second chapter a general overview of brain computer interface related concepts is given with definitions. Afterwards, technical questions are addressed and several input methods for BCI's are explained. Practical solutions and different types of BCI's are also discussed in the second chapter. Second chapter ends with various examples of brain computer interfaces in the fields of rehabilitation and entertainment.

Third chapter introduces different approaches to meditation, mindfulness and anxiety, which are essential target states in this study. Third chapter starts with introduction of views to anxiety as a psychological trait and state and integrates anxiety related previous neuroscientific studies. Meditation section includes discussion and various philosophies behind different meditation disciplines including mindfulness. Also, previous cognitive neuroscientific studies are addressed accordingly especially in the relation to alpha frequency domain.

In fourth chapter the research setting, methodology and scientific approach are introduced and motivation for the selected research methods and approaches are rationalized. Fourth chapter includes also the introduction and justification of study procedure, research sampling, data acquisition and handling, and used analysis methods. Results are presented in fifth chapter. Results are juxtaposed with research questions and hypotheses and each hypothesis is reflected accordingly in the sixth chapter. In-depth discussion is asserted in chapter six also. Sixth chapter includes extensive contemplation of results and synthesizes the results with pre-existing theories and previous studies.

In 7th chapter the scientific value produced by study is assessed and the essential deductions of results and practical application possibilities are addressed, and research is given an extensive reflection on its validity and reliability. The research methods, measuring techniques and analysis procedures are evaluated and discussed with precision. Before ending chapter seven, possible practical applications are proposed, and future research questions are raised.

2 BRAIN-COMPUTER INTERFACE

In this section common theory behind brain-computer interaction is discussed and contemporary research and practical applications harnessing BCI-technologies are portrayed.

2.1 Electrophysiological activities in brain enabling BCI

Inside the human brain the actors that are thought to be held accountable for our thoughts, experiences, consciousness and decisions are called neurons (Kalat, 2012). One adult human brain can contain 100 billion of these (Houzel-Herculano 2009) highly functional, complex and multi-directionally interconnected cells (Kalat, 2012). The neurons form a network-like highly connected structure that through its internal interactions allows us to have thoughts and experiences (Kalat, 2012). In neural connections specific parts of each neuron play a vital role in making such elaborate and accurate communication possible. For these communicational purposes neurons have in addition to the neuron body (soma) axons and dendrites to convey information into and out from the cell itself of which the former specialises in sending information as impulses and latter in receiving information. (Kalat, 2012.) Neurons vary in size, shape, and connectivity and thus have different contributions and roles in the system they represent as portrayed in figure 2 (Kalat, 2012).

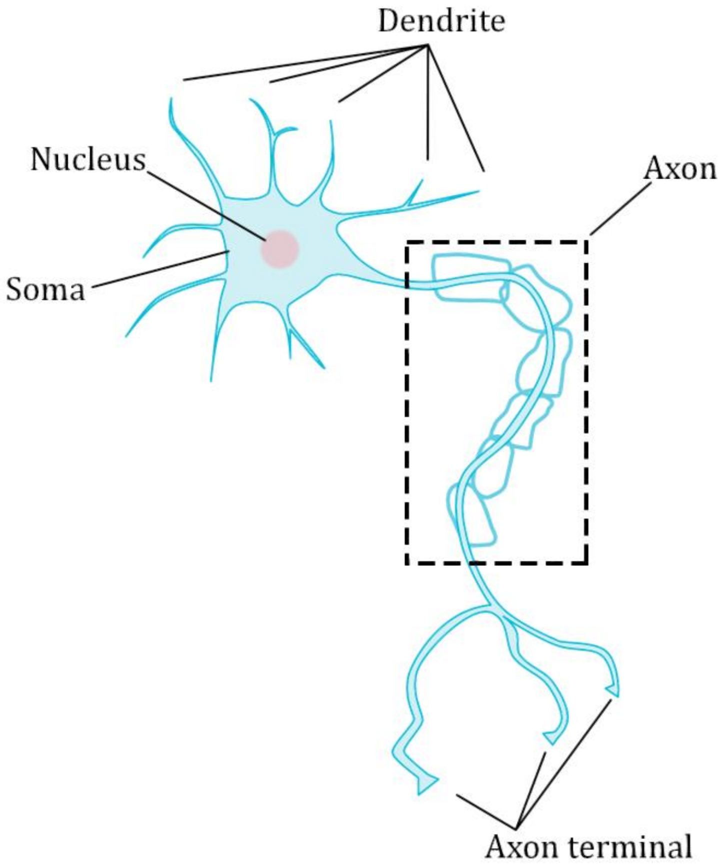


FIGURE 2 Example of a neuron and its main parts

Briefly put information is transferred inside the said networks between neurons through impulses relying on dendrites and axons in the manner explained above. The functionality of these impulses that accumulate into information is based on potentials and their acute local imbalances. (Kalat, 2012.) The mechanisms behind these imbalances that establish the actual inter neural communication is based on polarization levels between insides of a neuron and the surroundings that operate on gradient variance of potassium and sodium ions that causes internal cell polarization and sudden de-polarization when certain thresholds are exceeded (Kalat, 2012). The rapid de-polarization and following normalisation of polarization is called an action potential (Kalat, 2012). These polarization changes are in the core of some brain imaging and measuring techniques, and the most feasible ones for BCIs rely mostly on these electrical activities (EEG) or their corollary magnetic fields (MEG) happening on the outermost layer of brain, the cortex, and are measured from all over the scalp as described in figure 3.

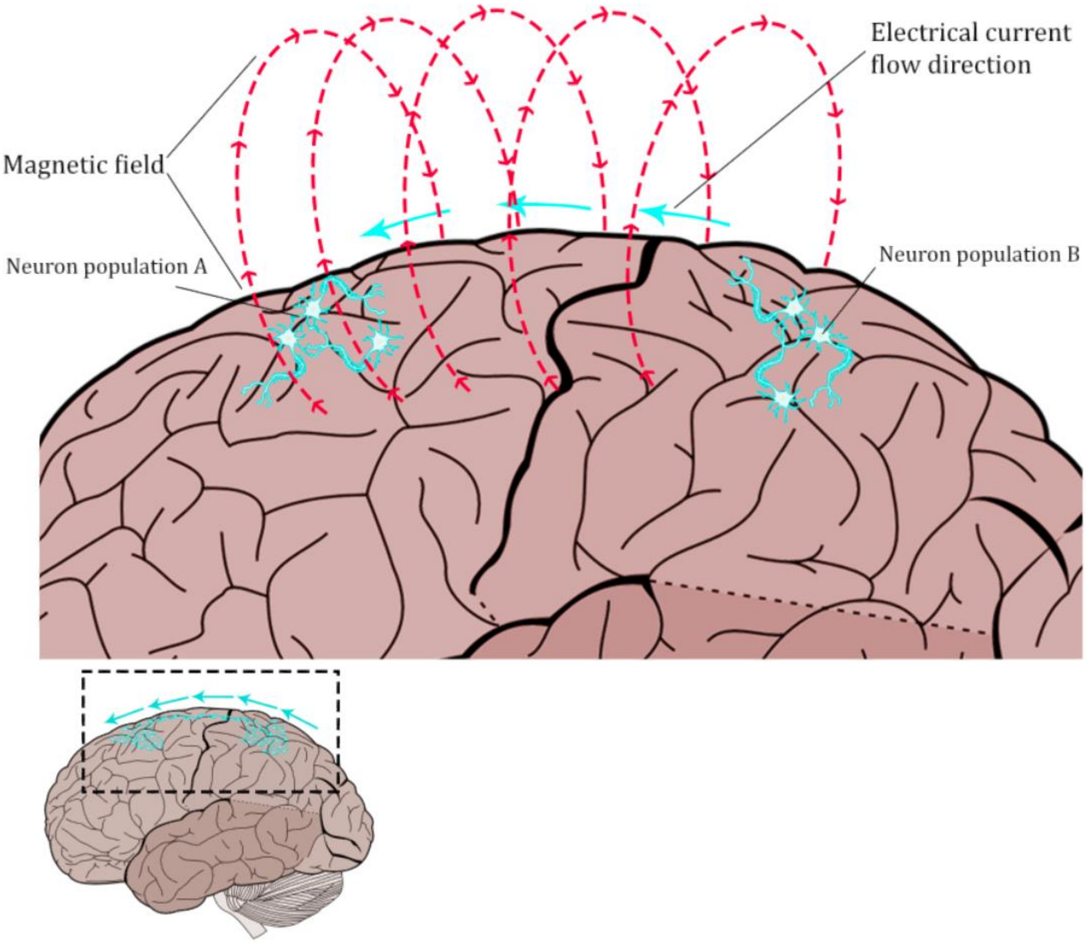


FIGURE 3 Formation of a magnetic field around an electrical current flow between neuron population B and A.

Surely it must be said that information processing in brain between neurons or neuron populations consists of far more factors than just electrical currents, and the firing or not firing of single neurons is in constant interaction with various components including but not limited to neurotransmitters and hormones. In addition to interaction between neurons being electrical it can be described to be chemical also. (Thagard, 2005.)

2.2 What is a BCI and how does it work?

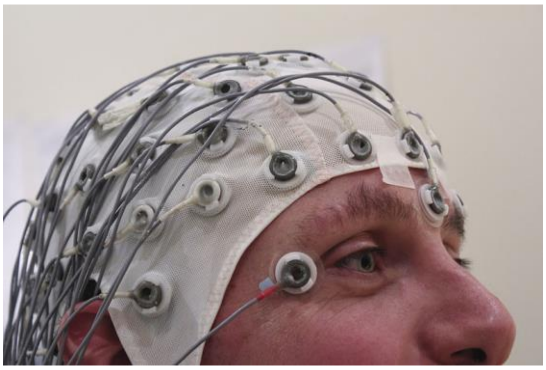
Brain-computer interface (BCI) is used to interact with a computer directly through data acquired from the brain. BCI uses input that is collected from the brain and alters it, so the user's possible intentions are interpreted. (Leuthardt et al., 2004) It has been discussed and thought of for many years already that measuring electrophysiological activities from brain can allow a person to interact with the surrounding world without using words or hand gestures or through haptic means of communication. The possibilities at their wildest are thought to form an outline for a certain advent of new ways of communication especially for instance quadriplegics and people suffering from locked in syndrome and other neuromuscular conditions. To ensure the development and implementation of these applications and platforms and further advance the possibilities in clinical settings it must be noted and acknowledged that proficiency, understanding, and knowledge are needed from multiple fields including but not limiting to behavioural and neuro sciences, engineering, mathematics, and computer sciences. (Wolpaw, Birbaumer, McFarland, Pfurtscheller, Vaughan, 2002) Or as Doud et al. (2011) articulate: "BCIs allow a user to interact with a computer system using thought."

Various operational BCIs have been developed since the seventies and the logics, platform, and frameworks differ from system to system. Some systems make use of visual evoked potentials and their measurements as some use slow rhythmical voltage shifts recorded from different scalp sites which both I explain in a more extensive manner later. Multiple channels for feedback have also been operated on. (Wolpaw et al., 2002.)

2.3 Brain-computer interface technologies

From the range of possibilities in brain imaging and measuring techniques each has its upsides and downsides in properties in temporal and spatial resolution, invasiveness, indirect and preparational requirements, and in physical dimensions of needed equipment and facilities. For instance, positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) that are based on cranial blood circulation would not be able to offer a communication platform in real time due to their rather long throughput times and can therefore be left out for now. Magnetoencephalography (MEG) and electroencephalography (EEG) could both be considered currently as feasible platforms but today EEG is seen as a more potential option for development as the price, mobility and technical requirements beat MEG's features. (Wolpaw et al., 2002.)

In non-invasive EEG (Figures 4 and 5) the signals that are measured from the scalp represent differences and changes in electrical activities on the outermost layers of cerebral cortex. These measured variations and sudden permutations are usually divided in intrinsic rhythmical activity or variation in these rhythms and event-related potentials abbreviated ERP. See figure 6 for example of ERP visualized. (Vidal, 1973.) Rhythmical activities and their variances are often studied as a representation of frequency distribution or frequency spectrum and these oscillatory variations are thought to be affiliated with distinct cognitive states (Vidal, 1973). These rhythmical activities used in BCI communication are also known as spontaneous inputs (Wolpaw et al., 2002). For measuring electrical activities in brain at single neuro level some more invasive methods are applied using electrodes that are installed inside the brain through operations, but these invasive methods are often unsuitable for regular use outside surgeries (Thagard, 2005).



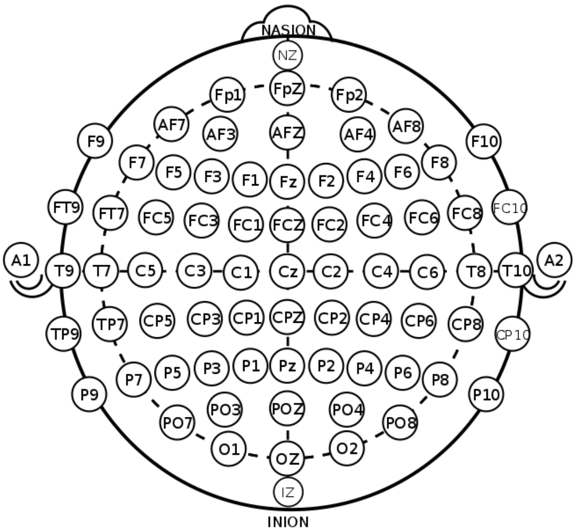


FIGURE 4 and FIGURE 5 photograph of an EEG cap installed on a subjects' head (left) (Hope) and named electrode sites on scalp in the international 10-20 EEG system pictured from above (right).

In figure 3 is described a formation of a magnetic field around an electrical current originating from an interaction between two neuron populations as a corollary. MEG, magnetoencephalography, is based on measuring these small magnetic fields and their fluctuations, that form around electrical events all around cortex. MEG takes advantage of a superconducting quantum interference device (SQUID) technology, which is a sensitive tool for detecting magnetic flux. (Hämäläinen et al., 1993)

EEG and MEG can be said to be related as they both are used to acquire signals that originate from same neural activity in the cortex. Both EEG and MEG can acquire data in high temporal resolution scale of milliseconds. (Hämäläinen et al., 1993.)

ERPs are usually studied as amplitude fluctuations as a function of time, normally in time frames of tens of milliseconds to several hundred (sometimes in some thousands) of milliseconds often induced with external controlled stimuli (Luck, 2014). In the example ERP, figure 6, stimuli happen in point zero on X-axis, and some ERP components are named later in time on Y-axis. Some distinct repeatedly examined ERPs are named after their latencies for example P200 also known as P2 a response that is normally recorded around 200 milliseconds after stimulus trigger (Luck, 2014) and is linked to visual responses and measured at anterior and central scalp sites (Luck, 2014).

Wolpaw et al. (2002) argue that BCIs can theoretically be approached in the same manner as default neuromuscular channels when discussing relationship of intent and action. BCIs are supposed to use the measured signal and translate it into actions that manifest in the world outside the user thus being in a way similar to functionality of nerves and muscles. Bearing this analogy in mind it at least makes sense that to create an operational BCI the constant feedback of activation and result should be taken in consideration and flexibility and adaptation of signal interpretation need to be noted. Wolpaw et al. (2002) further describe that "...BCI operation depends on the interaction of two adaptive controllers: the user's brain … and the BCI itself…" which as a defining notation does not make the development work and framework specification for brain-computer interfaces too simple.

To successfully operate a brain-computer interface the user must in a way be able to control his or her electrophysiological signals which as a skill might cause some to doubt. Some responses are thought to be adequately prevalent and sufficiently generalizable for example ERP named P300 which I discuss more later in the next chapter, 2.4. These intrinsic responses to external stimuli could in some cases be used as is and do not always require rigid training for the user but would most likely require adaptations in the BCI between users to allow functional operation (Wolpaw et al., 2002)

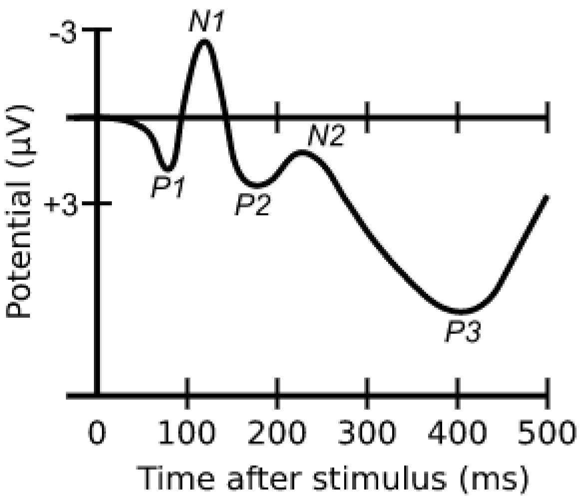


FIGURE 6 ERP visualized, and multiple components marked. Note that positive change in potential (Y-axis) is downward and negative is upward. ERP's can be visualized y-axis represented either way, upwards being negative or positive.

Wolpaw et al. (2002) elaborate that EEG's key challenges in BCI applications consist of limitations set by large quantities and variance of electrical neural activity, ratio of noise and applicable data, physiological complexity of both brain and scalp, and diversity of results between trials. Also, as the number of channels EEG is measured through and sampling rates are increased i.e. overall amount of acquired data grows the requirements for computing and interpretation of data are set higher also which might set limitations in certain applications for the time being (Wolpaw et al., 2002).

2.4 BCIs are operated with various input methods

Generally, BCIs can be divided in two classes depending on in which way the neural signals are made use of by the system. More specifically the principles are split in dependent and independent domains. Noteworthy, is that even though in neither of these classes the normal output pathways for communication in brain are used for data acquisition in dependent BCIs activity in those pathways is used in a way as a proxy. In other words, dependent is used to address a BCI that for instance harnesses a visually evoked potential (VEP) after increased activity in visual cortex due to a straight stare at an object as independent could in such case respectively use for example an evoked response potential called P300 that in some situations is considered to be related to intent. (Wolpaw et al., 2002)

Brain-computer interaction (BCI) is also used to denote the use of applications and devices that aim to affect neural activity for instance through a neurofeedback (NF) loop that uses data on brain activity as input information and modifies neural activity through proxy stimulus being for example visual or auditory stimuli that acts as output for the loop and thus targets to manipulate neural responses accordingly. Such devices are already used in rehabilitation and other settings among for instance paralyzed individuals and treatment of post-traumatic stress disorder (PTSD). (van der Kolk et al., 2016)

Gert Pfurtscheller et al. (2010) state that Hybrid BCI is used to address brain-computer interfaces that use more than just a single BCI input for interaction. A hybrid BCI can consist of two separate BCI systems or can have a BCI system that is supported by another interaction method being for example eye movement tracking or electrophysiological measures. (Pfurtscheller et al., 2010)

Advantages in hybrid BCIs over simple BCIs often include enhanced intent acquisition, overall performance and functionality of the system and increased accuracy in interaction through false positive activation reduction. Parallel functioning input methods in hybrid BCIs can be approached as simultaneous or sequential where the simultaneous functioning actually has two or more systems working at the same time and in sequential system the first method can for instance function as a switch to enable second method. (Pfurtscheller et al., 2010)

One-dimensional EEG based cursor control has been achieved by simply measuring changes in amplitudes of 8-12 Hz or 18-26 Hz sensorimotor cortex rhythm. Increase in amplitude would move cursor upwards and decrease would move cursor down. Even though the extracted SMR spectral features are spontaneous, control is achieved by training. (Sellers, Krusienski, McFarland, Wolpaw, 2007)

2.5 BCI applications in healthcare and rehabilitation

Van der Kolk, et al. (2016) elaborate that positive results could be obtained in PTSD patients with BCI applications used in psychotherapy as they pointed out a declining pattern in multiple trauma scales and measures paired with a BCI NF based intervention in a group of 52 persons suffering from PTSD. Their study shows significant improvement of PTSD symptoms and affect regulation capacities in weekly measurements during a 12-week BCI therapy intervention.

Thomas Fuchs and associates discuss in their comparison study the differences of effects of using neuro feedback system-based treatment and medical treatment on children suffering from ADHD and reported improvements in both groups over a 3-month intervention period (Fuchs, Birbaumer, Lutzenberger, Gruzelier, Kaiser, 2003). 34 children of ages between 8-12 years diagnosed with ADHD without prior treatment were included in the study. Subjects were divided in two groups depending on parents' preference: 22 in neuro feedback training program and 12 to methylphenidate group. Medication treatment dosage was adjusted per subject. EEG neuro feedback training was administered with frequency of three sessions each week over 12-week program using Neurocybernetics EEG Biofeedback System. Each neuro feedback session included from 30 min to 1 hour of visual and auditory feedback with short breaks if needed. (Fuchs et al., 2003.) Various metrics were used to measure behavioural dimension of ADHD manifestation before and after the intervention period. Both groups achieved statistically significant differences in *Test of Variables of Attention (TOVA),* which measures impulsivity, inattention, variability and response times (Fuchs, T. et al., 2003). Significant differences were also found in *Attention Endurance Test* sections of speed, accuracy and combined total times (Fuchs, T. et al., 2003). *IOWA-Conners Behaviour Rating Scale* that was used by parents to rate the subjects, also gave statistically significant results in both groups (Fuchs et al., 2003).

This study supports the plausibility of using neuro feedback system for training attention and as a rehabilitation tool for ADHD as the effects were measured in many perspectives and considered to be significant (Fuchs et al., 2003). Although further studies are needed to conclude, for now it seems that various neurofeedback systems have substantial potential to become broadly used platforms in fields of therapy and rehabilitation. They offer a wide range of possibilities and can be considered relatively cost-efficient applications especially when accompanied with combination of adequate technical, psychological, and neurophysiological knowledge (van der Kolk et al., 2016).

2.6 BCI and entertainment

Various applications and experiments of BCIs have been implemented in field of entertainment also. The methods and techniques developed for entertainment usage could often be applied to other settings also. Before judging still simple and crude game-like experiments, it must be considered that the foundation for BCI development is still evolving and being laid down. Fundamentally high-quality standards, codes of conduct and flexible frameworks are created through trial and error, and before BCI related research is granted more massive funds, the entertaining content will stay narrow due to technical demands. One feasible and very interesting field for BCIs to be applied in entertainment context is obviously gaming.

Doud et al (2011) describe in their article a framework, development process, data acquisition and processing methods and control methods for a EEG based BCI game in which the user controls a virtual helicopter in a three-dimensional environment. In their trial the subjects were trained to utilize their arms, legs and tongue separately and their resting states were measured. These separate control signals were iterated in many stages and after reaching wanted precision level the subjects were allowed to continue to the game. (Doud et al. 2011, p. 2.) Subjects, three of them, were to play the game altogether more than 40 times each, over a three-week period. The goal was to control the helicopter within a three-dimensional domain and to fly through designated loops set in the virtual environment. Succeeding to penetrate a loop without collisions on the way or with the loop structure, a "Hit" was recorded. If the helicopter would hit a building or leave the domain a "Miss" was recorded. Users were to control the helicopter through the mental utilization described above so that imagining moving hands formed the turning to left or right, tongue and foot operated helicopter ascension and descent, and both arms versus rest was used for moving the helicopter backward and forward. (Doud et al., 2011.)

The subjects were able to achieve control over the helicopter in the three-dimensional environment and the control accuracy was described to be high measured in two separate metrics (Doud et al., 2011). Two of the subjects had previous experience in two-dimensional control through BCI and one had none prior to the training included in the test. The fact that the subject with no prior experience in using BCI exceeded accuracy scores of the one of the more experienced BCI user demonstrates learnability of this specific BCI with these specific subjects. (Doud et al., 2011)

Another game-like practical application in BCI field is introduced by Finke, Lenhardt, and Ritter (2009). The application is called The MindGame and it is based on ERP P300 that "…can be elicited reliably in every neurologically healthy human." P300 is an especially feasible component for intentional interaction for it can be applied as a discrete event, whereas other easily detected ERP components could be made use of in a more continuous manner and are less explicit in their nature. (Finke et al., 2009)

MindGame is played on a virtual checkerboard and the player controls a character by choosing target coordinates. The software randomly highlights rows and columns and as a P300 with defined characteristics arise consequentially, selection for the next move has been executed. Relevant variable in P300 that is utilized for selection is the component amplitude in addition to target selection probability. (Finke et al., 2009). Finke et al. further speculate that MindGame or similar applications could function as a neuro feedback system for training attention, as training and concentration is mandatory for the player to be in control.

2.7 Summary

Most brain-computer interface systems rely on neural electrical activities or their corollary magnetic field fluctuations. Advantages using such techniques as a basis for BCI include rapid throughput times, scalability, and various input method possibilities and logics for interaction. BCI's can be operated through slow rhythmical activities, event related potential interpretation, or a combination of these. BCI interaction logic can include multiple levels in in its process so that the interaction technique itself can function as I/O switch for next level functions. Majority of practical BCI applications are based on EEG technology due to costs and technical and physical requirements. Most common challenges in BCI development include high noise to signal ratio, sufficient interference protection, and signal processing optimization that require ample computing capacity. BCI techniques are applied in a multitude of distinct environments and settings including but not being limited to healthcare, rehabilitation, and entertainment.

3 Anxiety, Meditation, and Mindfulness

In this section the basic concepts of meditation, mindfulness, and anxiety are described and their relation to neuro scientific field is discussed. This study approaches mindfulness as a meditation technique. Mindfulness and anxiety are considered cognitive states in the experimental setting.

3.1 Anxiety

In this chapter several anxiety related states are covered and various previous studies that contemplate anxiety in trait and state domains and their relationship to brain oscillatory functions are discussed. The narrow semi-systematic literature review elucidates background theories and previously established correlations to further explain grounds behind research questions and hypotheses. Anxiety can be considered as a cognitive state or at least a state that affects human cognition (Aslanyan et al., 2016; Khemka et al., 2017; Kamaradova et al., 2016).

3.1.1 Literature search method

Search for anxiety and alpha frequency connection covering literature was conducted in a semi-systematic manner. Scopus database was used for literature search. Scopus was selected for search due to its vast indexing, efficient filtration methods, and usability (Burnham, 2006). Used search string was following: "TITLE-ABS-KEY ((anxiety OR anxiousness) AND (alpha AND frequency)) AND (LIMIT-TO (SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA , "PSYC")) AND (LIMIT-TO (LANGUAGE , "English")) AND (EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "PHAR"))" in which the keywords with Boolean operators were "Anxiety OR Anxiousness" AND "Alpha AND frequency".

Results were limited so that the keywords had to be found from the publication title, abstract or supplied keywords. Excluded subject areas were biochemistry and pharmacy assuming they weigh more in biochemical domains. Subjects were limited to neuroscience and psychology. Only English publications were included in the search. With such criteria 179 results were listed. From the result list interesting related topics were manually chosen according to their title. The paper had to include a concept that is related to this thesis framing in title to be chosen for further analysis. 24 documents were selected for inspection of which 19 were available for download to University of Jyväskylä. 3 of the 19 were classified as "Review" and included approaches and conclusions supplied by the other included items. Remaining 16 items' abstracts were read and from this set 12 were chosen to be used as final references. Three were discarded at a later stage as they proved not to focus on previously specified themes.

Focus of the review is research outcomes and its goal is to outline recurring results of studies to produce a generalizable theoretical framework relying on empirical data and to summarize underlying conflicts. Results are attempted to be presented in a neutral manner, and exclusion of individual studies is rationalized. (Cooper, 1988.)

3.1.2 Anxiety and its alpha frequency band correlates

According to the study of E. V. Aslanyan et al. (2016) trait anxiety among other personality factors can affect the effectiveness of voluntary brain activity control (p.916). In their research 17 volunteers were given a bimodal EEG biofeedback training functioning in visual and auditory domains with the aim to affect the noise-sound volume level ratio through EEG in two separate training sets. Set A included alpha frequency power measured on parietal sites and set B included beta power measured on frontal sites. Among other personality traits classifications, the subjects were divided in two groups according to their trait anxiety. Formed anxiety level groups were labelled as high and intermediate (p.918). After running a factor analysis, for further testing, all subjects were divided into two groups of which the first was characterized to have overall higher levels of extraversion and lower levels of trait anxiety than the second group. The second group had lower alpha frequency power in calm waking. Subjects were instructed to think of non-existent objects in order to reduce alpha frequency power in occipital and parietal sites (p.918). Group 2 (Higher anxiety-trait) succeeded better in training scenario A and group 1 (Lower anxiety-trait) acquired results more efficiently in training scenario B. The differences of performance in training settings was statistically significant between groups. Aslanyan et al. (2016) further discuss that voluntary decrease of power in higher beta frequency domains is affiliated with a strategy that is connected to increase in lower frequency bands including alpha. Voluntary decrease of parietal alpha frequency was accompanied with other slow frequencies decrease which is associated with overall cortical activity propagation.

Kamaradova et al. (2016) studied variance of different brain oscillation frequency bands in people suffering from obsessive-compulsive disorder (OCD) executing tasks demanding cognitive encumbrance in groups of 15 healthy control subjects, 20 OCD patients, and OCD patients' subgroups of those with cognitive impairment (n=11) and those with no cognitive impairment (n=9). Cortical EEG was recorded from subjects with 21-channel EEG set at 200 Hz rate. Subjects were divided into two groups, those with no cognitive impairment and those with cognitive impairment. Statistically significant differences were found between groups in delta and theta activity in frontal areas comparing OCD patients to healthy controls. Kamaradova et al. (2016) suggest that in OCD domain, groups suffering from cognitive impairment could possibly be identified from their differing frontal low-frequency functions compared to non-impaired in resting-state EEG.

Khemka and research group (2017) contemplate in their study the manifestation of anxiety affiliated oscillatory functionality in hippocampus especially in spectres of approach and avoidance. 20 subjects were studied in MEG during a game-like task that included a threat of virtual predator and possibility to gain or lose coins. Anxiousness was induced by modulating threat level and approach/avoid-scales were measured from behavioural tendencies during the game. Findings propose a linear correlation between threat probability and oscillatory power increase in right-side mid-hippocampal area. Power shifts manifest mostly in gamma frequencies that is further speculated to be modulated by slower theta bands which also found to fluctuate in a similar manner. Also heightened theta oscillation was present in medial prefrontal cortex.

Another view to relationship of brain oscillations and anxiety is presented in a study by Knott et al. (1997) in which they approached anxiety as a property of panic disorder. Their method included a narrative to be played on tape to patients suffering from panic disorder (n = 36) and healthy non-PD control subjects (n = 20) while recording their cortical electrical activity through 16 channel EEG at 256 Hz. In addition to EEG their physical symptoms related to anxiety were measured and rated. Other audiotape was a neutral story tape as the other was a relaxation tape which included instructions for relaxation. Findings showed that the patients suffering from panic disorder had less beta frequency activity, and that control group tended to have more both alpha and theta frequency bands in relaxation phase. They further speculate that patients at subclinical level might differ to relaxation as opposed to controls, and that relaxation had more effect in electrophysiological response on control group. In their discussion it is also stated that their results might imply that differing electrocortical responses may be affiliated with panic and related anxiety.

Knott and others have studied panic disorder and its EEG correlates also (1996). EEG of 34 panic disorder patients and 34 healthy controls was recorded and results indicated vast discrepancy between groups. Patients suffering from panic disorder had larger amplitude in delta, theta and alpha frequency bands.

Impulsivity and anxiety, and their relation to brain oscillations has also been addressed by Gennady Knyazev et al. (2008). 51 subjects were studied using a 32-channel EEG system. The study results imply that upper alpha frequency band (10-15 Hz) was higher in subjects that scored higher in their inhibitory behaviour scaling. It was further speculated that individuals with higher score in STAI paid more attention to external stimuli and their alpha power was found to be higher than those who were preoccupied by inner thoughts. Knyazev et al. conclude that these mechanisms of alpha frequency activity can be affiliated with inhibition as a preparatory function to allow higher cortical engagement for execution of required actions in a situation. Higher baseline alpha was present in persons with higher scoring in the inhibitory trait and can thus be speculated to be more alerted and more prone to preparation in brain oscillatory functions.

Knyazev et al. (2005) approach anxiety and alpha synchronization in their EEG study. They experimented with hypothesis that higher alpha power might signify higher readiness of alpha system for processing on 30 subjects. Subjects scoring higher in anxiety trait had higher alpha power during reference state, and in responses higher amplitude of phase-locked alpha. STAI questionnaire was used to measure anxiety properties and 32-channel EEG was used at 300 Hz sampling rate for recordings. During word processing tasks it was found that higher bands of alpha was higher in anxious subjects at posterior cortical area. Higher bands of alpha power density before stimulus was higher in anxious subjects also at posterior site. It is speculated that these mechanisms could be affiliated with heightened preparation for information processing. Lower anxiety subjects show increase of attention as they react to surprising stimuli as higher anxiety persons tend to increase overall and unspecific attention, which might show higher overall alertness.

Lackner et al. studied anxiety and aggression predictability in 84 teenagers at ages of 12-15 years (2013). Their EEG was measured at 500 Hz in 128 channels. For anxiety assessment Symptom Checklist (SCL) Anxiety subscale was used and to measure aggression SCL Hostility subscale was used. Results implied that anxiety is associated with alpha oscillation synchrony lock durations on both right and left hemispheres. Findings propose that anxiety related abnormalities might be specific to interconnected phase locking of different sites. This alpha phase locking correlation with higher anxiety trait scoring might be affiliated with mediating anxiety-provoking thought patterns and reducing alpha system flexibility.

Study conducted by Hiroshi and colleagues (2012) imply that alpha power was lowered at left dorsolateral prefrontal cortex (DLPFC) when subjects (N = 15) were exposed to unpleasant pictures. Subjects EEG was measured using 128 channels 2048 Hz system.

Murata, T. et al. (2004) assert that an increase of alpha coherence is increased at frontal areas of the brain during meditation in all their subjects. This change correlated negatively with trait anxiety score measured with Spielberger's State-Trait Anxiety Inventory. It is further suggested that higher anxiety is affiliated with utilizing relaxation dominantly to induce meditation as lower anxiety might be linked to tendency to inward targeted attention in meditation.

Social phobia (SP) and its manifestation in EEG data has been discussed by Gabriele Sachs and colleagues in their study (2004). They used STAI to measure anxiety trait of 25 patients and 25 controls and compared their EEG in resting and vigilance-controlled states. It was found that the ones with higher scoring in STAI had higher dominant alpha frequency but lower slow alpha power, and thus suggested that patients with social phobia show a constant hyperarousal as a factor of anxiety.

Richard T. Ward et al. (2018) approach anxiousness and its relation to alpha frequency and argue that subjects with higher trait anxiety display alpha desynchronization during task execution. They further discuss that less anxious individuals have more stable cognitive resourcing over rest and task, and higher anxiety subjects have more active attentional ongoing resources. They ran EEG measurements on 30 subjects. STAI was used for anxiety assessment. EEG was recorded on 64 channels at 1024 Hz. Alpha activity was greater in subjects with higher anxiety score during task. It is also speculated that more anxious persons are likely to be less ready to function during resting state as individuals with lower STAI scoring. This said highly anxious individuals might be less prepared to engage from resting state than less anxious.

Also, physiological correlates have been studied for anxiety. Cornwell et al. carried out an MEG experiment on the effects of anxiousness on cognition with a comparison of anti- and prosaccade changes in their time-domain, their relation to brain oscillation frequencies, and oscillation frequency amplitudes (Cornwell et al., 2012). Threat-induced anxiety caused the anti-saccades to slow and brought up false pro-saccades in anti-saccade trials. The correct anti-saccade execution was linked with heightened theta-wave. I.e. theta activity may be affiliated with the mechanisms affecting the delay in anti-saccade generating process. (Cornwell et al., 2012)

3.1.3 Summary

Although conflicting results exist, the theories arguing that high anxiety trait property is affiliated with heightened power of alpha frequency band, repeatedly emerges throughout the included studies. Alpha power fluctuation during resting states and task execution, being affiliated with alertness, preparatory mechanisms, and attention targeting recurs in discussions and contemplated possibilities for explanations. In various studies it is further discussed that Individuals with higher anxiety trait measurement scoring might be less prepared to engage from resting state. Maintaining of these states and allowing transition between states are, if not modulated by, at least affiliated with alpha frequency behaviour as inhibitory mechanism. Alpha frequency band is proposed to be linked with attention targeting in stressful conditions and states of anxiousness; increase of alpha power is speculated to be affiliated with enhancing attention to external stimuli and decrease of subjective internal observation.

3.2 Meditation and Mindfulness

Accurate definition of meditation is difficult due to the multitude of approaches and disciplines in practices. Takahashi et al. (2004) assert that "Meditation is the attainment of a restful, yet fully alert physical and mental state practiced by many as a self-regulatory approach to emotion management…"

Dunn, Hartigan and Mikulas (1999) propose that mindfulness can be seen as a subset for meditative practices. Concentration is controlling one's focus and can have a single target. Mindfulness can be thought to be expanding and intensifying awareness and include multiple targets. In a state of mindfulness, one is able to face rising stimuli as new experiences.

Meditation and relaxation techniques are also approached as tools of stress reduction and wellbeing promotion (Lagopoulos, Xu, Rasmussen et al., 2009).

Meditative techniques have been practiced for an extensive period of time in far eastern cultures and have been linked in addition to wellbeing to religious contexts also (Lagopoulos et al. 2009).

Research of meditation in cognitive neuroscientific approach is often approached through studies of oscillatory mechanisms during meditative states and comparing brain activity during these states to control states (Takahashi et al. 2004; Dunn, Hartigan, and Mikulas, 1999; Aftanas and Golocheikine, 2002). Also, the synchrony of these oscillatory activities between distinct areas of brain can be addressed (Marzetti, Lanzo, Zappasodi, Chella, Raffone and Pizzella, 2014; Hebert, Lehmann, Tan, Travis, Arenander, 2005). A vast array of distinct techniques is used to measure and analyse meditation related electrical brain data, and combination of knowledge from multiple fields, including but not limited to, mathematics and signal processing might help understanding underlying mechanisms (Davis, Lin, Gillett, Kozma, 2017). In addition to immediate changes in brain oscillation, meditation has been approached in longitudinal neuroscientific studies (Tomljenovic, Begic, Mastrovic, 2015).

In this chapter meditation related electrical activities in the cortex are discussed and possible affiliations between personality, meditation, and their corollary brain activity are addressed in form of brief introduction of previous studies.

3.2.1 Literature search method

Search for literature elucidating meditation and alpha frequency affiliation was executed in a semi-systematic manner. Scopus database was used for search. Used search string was following: TITLE-ABS-KEY ((meditation OR mindfulness OR meditative) AND alpha AND frequency) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO (SUBJAREA , "COMP")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2007) OR LIMIT-TO (PUBYEAR , 2005) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 1999) OR LIMIT-TO (PUBYEAR , 1996) OR LIMIT-TO (PUBYEAR , 1994) OR LIMIT-TO (PUBYEAR , 1988))

Results were limited so that the keywords had to be found from the publication title, abstract or supplied keywords. Included subject areas were neuroscience, psychology, and computer science. Pharmacology was ruled out assuming results would focus outside this study scope. Arts and humanities were also excluded. Only English publications were included in the search. With such criteria

52 results were listed. From the results list interesting related topics were manually chosen according to their title. The paper had to include a concept that is related to this thesis framing in title to be chosen for further analysis. 17 documents were selected for inspection of which 14 were available to University of Jyväskylä. Only papers published after 1988 were included as during 80's, digital EEG was increasingly utilized, more accurate source modelling methods were developed, and in the beginning of 90's MEG techniques were used more broadly (Swartz & Goldensohn, 1998). 6 papers were excluded after more accurate assessment leaving 8 items for further discussion. Excluded papers were outside the scope of this study.

Focus of the review is research outcomes and its goal is to outline recurring results of studies to produce a generalizable theoretical framework relying on empirical data and to summarize underlying conflicts. Results are attempted to be presented in a neutral manner, and basis for exclusion of individual studies is explained. (Cooper, 1988.)

3.2.2 Meditation, mindfulness, and their relation to alpha frequency band behaviour

Takahashi et al. (2004) approach meditation as a mental state. In their study 20, subjects with no meditation experience were tested. Their EEG was recorded at 500 Hz on six channels and their personality traits were assessed with the Japanese equivalent of Cloninger's Temperament and Character Inventory (TCI). TCI measures of four dimensions of personality were used: novelty seeking (NS), harm avoidance (HA), reward dependence (RD), and persistence (P). Subjects were instructed to practice specific Zen meditation technique during test. Results showed that during meditation slow alpha power (Alpha1, 8-10 Hz) increased at frontal area. A positive correlation was found between percent change of frontal alpha power and the novelty seeking domain scoring. It is further discussed that meditation subsidized inward targeted attention has an effect on sympathetic activity that is inhibitory in its nature and its mechanistic features include increase of slow alpha rhythm power in frontal area of brain.

Concentration and mindfulness meditation can be discussed as separate states of consciousness when it comes to terms of EEG. Dunn, Hartigan and Mikulas (1999) state that in their study a strong difference between mean amplitudes were found between distinct meditative states, mindfulness, concentration, and relaxation. Ten volunteers were studied during a 16-week meditation course. EEG was measured using 20 channels at 60 Hz before and after meditation course. Subjects were also asked to rank the experience of depth of relaxation or meditation during measurements on a scale of one to ten at varying intervals. Increase of alpha was found on posterior sites during concentration compared to relaxation. During mindfulness higher alpha amplitude was present at central and posterior sites than during relaxation. Mindfulness also produced higher alpha amplitudes than concentration at identical sites. Dunn et al. also contemplate that these findings might promote the theory that during mindfulness mind can be quiet but simultaneously aware of stimuli. This is supported by the results: more delta and theta are present which is affiliated with calmness and relaxation, but also more delta and theta activity can be seen which is affiliated with being awake and alertness.

Aftanas and Golocheikine (2002) addressed manifestation of EEG power in different frequency bands in Sahaja Yoga meditation which features internal attention and positive emotional experience emergence. In their study a 128 channel EEG was used to measure 20 experienced meditator volunteers. An increase of alpha1 (8-10 Hz) power was present at anterior midline areas during meditation. Alpha2 power was higher in meditation at posterior and occipital sites. They also assert that these findings could be affiliated with the theory that inhibition of irrelevant stimuli, and maintaining meditative state requires control of attention and this mechanism could be linked to alpha frequency enhancement.

Nondirective meditation has been studied by Lagopoulus et al. (2009). In their study subjects were instructed to apply their normal meditation technique and resulting data was juxtaposed with resting state with eyes closed both being 20 minutes of duration. 18 volunteers participated in the study and all of them had experience in meditation. Significant increase in alpha power was found in meditation compared to resting state. Higher alpha power was situated especially at posterior than at frontal region.

Hinterberger, Schmidt, Kamei and Walach (2014) also argue that meditative state of consciousness differs from general states of focus in addition to sleep and drowsiness especially among experienced meditation practitioners. Fifty subjects with different backgrounds in meditation were measured over distinct meditative tasks and states. Results showed that differences in electrical activities in brain were more significant among subjects with more experience in meditation. Open monitoring state produced an increase in alpha amplitude compared to thoughtless emptiness. Thoughtless emptiness compared to resting state did not produce a significant difference in alpha power.

Kamei, Toriumi, Kimura and Kimura address yogic respiratory exercise in their study (2001). Eight yoga instructors were studied during different exercises. On six out of eight subject's alpha was increased on 9-11 Hz and on one subject alpha increase took place at 7-8 Hz in meditation compared to resting state. Kamei et al. discuss that the results indicate activation of frontal alpha rhythm which may be mechanistically affiliated with increased stimulation of brain areas linked to respiratory functions, and exercise induced changes in breathing patterns that affect blood oxygen levels in brain.

Another study on frequency band behaviours in meditative states was conducted by DeLosAngeles, Williams, Burston, Fitzgibbon, Lewis, Grummett, Clark, Pope and Willoughby (2016) and its results also support alpha activity increase during states of meditation compared to control states. Twelve experienced meditators were studied during various meditation technique sessions as was their matched meditation-naive controls. Their EEG was measured at 2000 Hz sampling rate using a 128-channel system. Alpha power was increased in meditators compared to control subjects especially at frontal midline and temporo-parietal sites. They further contemplate that difference of alpha behaviour between seasoned meditators and controls might be explained through increased arousal and alertness during tasks. It is also speculated that increase of alpha power during meditation might be affiliated with global cortex inhibition, and that alpha power affiliation with meditation might be linked to task performance or subjective difficulty of execution.

Tomljenovic, Begic and Mastrovic (2015) argue that meditation has, in addition to short term effects on brain oscillations, in long term also. In their study 12 students were tested before and after three-month meditation practicing and training. Although the most tangible changes happened in theta band, also a significant difference between before and after measurements was found on alpha band. Overall alpha power was decreased on sites T3, O1, and O2, in international 10-20 EEG system. It was also asserted that trait anxiety did not differ, however state anxiety and cognitive worry decreased significantly after meditational training period.

3.2.3 Summary

Predominant consensus among the introduced studies seems to be that meditation can be affiliated with changes in oscillatory activities in brain including but not limited to alpha frequency. The included studies seem to have procured similar results in behaviour of alpha frequency band during meditation. Although previous studies have used techniques that provide more accurate spatial data and have managed to raise specific cortical areas that alteration of alpha behaviour is present at into discussion, the results combined outline increase of alpha power during meditation compared to control states. Unfortunately, only one of the included studies address longitudinal effects of meditation on brain oscillation and it asserts that practicing meditation might decrease overall alpha power in addition to state anxiety mitigation. Also, there seems to be differences between immediate effects of separate meditation techniques on oscillatory activities. One study showed a positive correlation between alpha power difference and novelty seeking personality trait.

4 METHOD

4.1 Methodology

The main objective for this project was to explore the possibilities of forming a plausible link between behavioural data, distinct cognitive states (Anxiety, mindfulness and rest), and neural correlates and discrepancies for these especially in the domain of anxiety. The main methods for this study include an experiment with live human subjects and a set of background survey questionnaires.

Methodologically this study includes features from human-technology studies, cognitive neurosciences, and neurophenomenology. General motivation for this study is the needed definition of a framework for a brain-computer interface for sustained attention, which to be executed, requires knowledge and proficiency from aforementioned scientific disciplines. To develop a framework of a neuro feedback loop, an in-depth understanding of the phenomena at hand needs to be acquired.

Jokinen (2015) approaches human-technology interaction methodologies through a four-dimensional field as described in figure 7. On the axis of causal explanations and intentionality this study is difficult to explicitly position to any of the distinguished areas. The methodology in this study seems to foster neuroscientific, subjective, and cognitive approaches. Neuroscientific point of view is included as neural correlates for cognitive states are contemplated. Subjectivism and phenomenological implications are observed as measured states vary on subjective level, and experience sampling, that is used as one dimension of data validation, is highly phenomenological in its nature as it accounts the subjective experience of measured phenomenon. Functionalistic approach lies particularly in the theoretical framework. Distinct emotional and cognitive states are addressed and their relation to cognitive functions are contemplated in addition to their neural correlates. Also studying meditation in this perspective has an intentional nuance. Meditative techniques include conscious attention targeting and self-monitoring and can also be approached as tools for attaining better wellbeing. Causal dimension is present. Affiliations for psychophysical conditions and neurophysiological correlates for cognitive states are pursued. Personality features, traits and tendencies are also addressed and their relation to state dependant neural correlates is hypothesized. Theoretical framework and hypotheses rely on previous studies empirical data. However, this research does not reciprocate defined characteristic of behaviourism in full extent as mental states and subjective experience are referred.

		Causal explanations	
		No	Yes
Intentionality	No	Behaviourism (Empiricism)	Neuroscience (Physicalism)
	Yes	Subjectivism (Phenomenology)	Cognitivism (Functionalism)

FIGURE 7 Four-dimensional field of methodological positioning in HTI-research as described by Jokinen (2015, 33)

Consciousness have been described to be something "mysterious" and "impossible to define" and many seem to agree when portraying it to be analogous with being aware or knowing, having perceptions, thoughts and feelings and it seems generally to be also affiliated with self-awareness, seeing oneself and experiencing the surroundings (Frankish et al., 2012). Consciousness is also associated with being "property of spiritual minds and is not open to scientific explanation" but has also been seen as a physical process that takes place in a computational system which can offer a sufficiently complex platform for consciousness to execute on (Thagard, 2005).

In the perspective of naturalistic approaches to cognitive science, the methodological point of view of this study could be theorized to rely somewhere in a cross section of functionalism and (neuro)phenomenology (Varela, 1996). It has functionalistic implications as the research questions and measuring methods include exploration of different cognitive states and consciousness is also slightly addressed although not explicitly named. Neurophenomenological aspect can be thought to be present as experience sampling i.e. subjective experience measuring functions as a method of validation, and study includes research of intricate subjective states that are complex to explicate thoroughly and explicitly, and the corollary neural responses of these states (Figure 8). (Varela, 1996.)

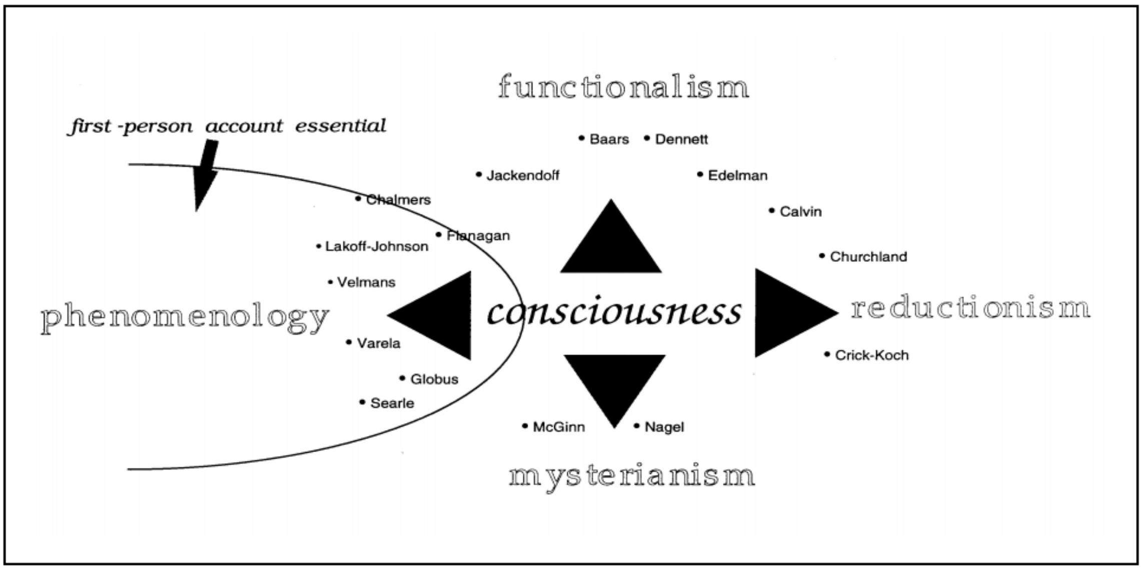


FIGURE 8 Four-way methodological division according to Varela (1996)

Measurements and analysis are positioned in the field of cognitive neuroscience as neural correlates for cognitive functions are studied. Cognitive neuroscience simply put has its aim in finding answers to the question: ”How does the brain facilitate thinking?” in the way that functions of brain in different cognitive states are assumed to have neurophysiological mechanisms, basis or effects. In this question, the word brain points specifically to the physical structures and functions facilitating human thinking. Thinking on the other hand denotes the domain of ”High level, systematic nature of the processes under study”. Theories or approaches could be said to fall under cognitive neuroscience if they affiliate cognitive functions and brain activity together in a mechanistic view. (Standage D. & Trappenberg, T., 2012.)

4.2 Research questions and hypotheses

This study attempts to procure possible solutions to use as grounds for a preliminary framework for a brain-computer interface, and to explore relationship of anxiety personality trait and the brain oscillatory activities in alpha frequency domain. Defined aim for the in-development BCI neuro feedback system is to be able to enhance attention and mindfulness. Van Der Kolk et al. (2016) state that oscillatory activity-based interaction design is a possible approach in BCI. This study concentrates on alpha frequency band because it is known for good signal-to-noise ratio (Pfurtscheller and Neuper, 2006). Previous studies exist concerning alpha frequency behaviour and distinct cognitive states, but there seems to be a gap in alpha fluctuation discrepancy between states of anxiety and mindfulness, and anxiousness personality trait relation to alpha manifestation difference between these states. Research questions were derived as follows:

1. Is there a difference in alpha peak behaviour between states of anxiousness and mindfulness

2. Does anxiety personality trait correlate with alpha peak value in states?

3. Do approach and inhibition personality traits have a correlation with alpha peak value in states?

4. Does anxiety personality trait have a correlation with alpha peak value difference between states?

5. Do the approach and inhibition personality traits have a correlation with alpha peak value difference between states?

Thus, forming hypotheses:

H1 There is a difference in alpha peak behaviour between states of anxiousness and mindfulness.

H2 Anxiety level has a correlation with alpha peak value in states.

H3 Approach and inhibition tendency levels have a correlation with alpha peak value in states.

H4 Anxiety level has a correlation with alpha peak value difference between states.

H5 Approach and inhibition tendency levels have a correlation with alpha peak value difference between states.

4.3 Variable operationalization

To measure these phenomena, multiple variables needed to be formed. The concepts are operationalized to measurable variables using scale values produced with standardized questionnaires.

Beck's anxiety inventory (BAI) is used to assess clinical anxiety. Beck et al. (1988) conclude that BAI is a usable instrument in measuring anxiety due to its discrimination of anxious groups from non-anxious groups, high inner consistency, and eminent test-retest reliability. BAI has been chosen over state trait anxiety index (STAI) due to its higher discrimination validity (Beck et al. 1988). Background questionnaires give standardized insight on behavioural traits and are used to form index score numbers on subjects in traits accordingly. In this study BAI, Beck's anxiety index score functions as a meter for anxiety.

Carver and White (1994) assert that one way to assess behaviour in motivational perspective is through behavioural inhibition system (BIS) and behavioural activation system (BAS) division. BIS dimension predicts level of nervousness when punishment is impending and BAS responding happiness to awaiting reward. It is theorized that BIS/BAS dimensions are affiliated with underlying neurophysiological system that plays a role in emotional and behavioural regulation concerning approaching and avoiding (Carver & White, 1994). BIS/BAS scales are used in this study to elucidate subjects inhibitory and activation tendencies. BIS/BAS scales form multiple scores that indicate subject tendency to approaching or avoiding behaviour. BAS part is divided into Fun seeking, Drive, and Reward responsiveness, which all indicate approaching tendency. Also, a BAS Total is used, which is a sum of all the other BAS factors.

Subjective experience of feeling and level of focus during the tasks is measured through experience sampling on the scale from 0 to 1. Neurophysiological responses include information on topography, frequency, and power. Due to limitations of thesis the only actual neurophysiological variable that is tested in this study is alpha power in a fixed ICA component array. Alpha frequency band behaviour is operationalized into peak power mean and localization.

4.4 Experimental procedure and design

All the experiments were conducted between June 1st and December 20th, 2017. The experiment was carried out in one approximately three-hour session during which the subjects would first sign the disclaimer and read through an information package before testing and filling questionnaire forms. After signing the disclaimer, the subjects were to visit the MEG measurement room and a test measurement was ran to make sure that the subject would not cause interference for the device for any reason.

As the subject was declared interference-free, he/she was ready for the preparation phase, in which a three-dimensional raw model of one's scalp was drawn on the data acquisition computer and head positioning indicator (HPI) coils were placed on designated sites. At this point also, the electrodes for metering saccades and blinks were attached to the lower corner of right eye and upper corner of left eye of subject, as was the earth electrode placed on the collar bone. After the subject preparation was finished, the subject was instructed to choose from two sets of photos, themed under planning and anxiety, 16 in each group to be used in the test. This selection was to ensure effective and personally relatable imagery but also to avoid excessively stressful pictures and interruptions due to for instance uncontrolled phobias in images labelled under anxiety.

MEG was recorded at 1000 Hz rate on 306 channels using Elekta Neuromag Triux MEG system at Jyväskylä Centre for Interdisciplinary Brain Research (CIBR). The MEG measurement phase was divided into three parts and a short break was held between second and third parts as described in figure 9. First measurement session was altogether eight minutes of resting state of which first four minutes the subject had eyes open and rest four minutes eyes closed. Blocks 1 and 2 were identical although different sets of imagery were used over blocks and task cycle was semi randomized for counter balancing of stimuli. Each block would last circa 30 minutes and varied due to individual subject sampling answer durations.

In each block eight separate images for every state was presented with short written instruction phrase. For the anxiety instruction phrase was "Consider yourself or someone close to you to be in the situation" and for planning instructions were phrased as "Plan something related to the image". Mindfulness was instructed as: "Concentrate on the air flowing through your nose. Also, you can implement a method if you have practiced mindfulness or meditation before." Tasks cycled in both blocks in semi randomized order so that each target state was followed by a varied state, i.e. states were never sequentially the same.

Each part in both blocks included the 7 second instruction phase which was followed by a fixation cross that the subject was instructed to look at during the task. After 53 second period of fixation cross display, the experience sampling questions were presented, and the subject answered accordingly. Subjects were asked at this point of cycle two questions: "How focused were you during the task?" and "How were you feeling during the task?". Questions were answered using a tablet-like answering device. Subjects were instructed to answer without a specific scale so that on right-hand side was positive and left-hand side was negative. Subjects were instructed to use the whole scale when answering. Experience sampling answers were logged in on a continuously varying scale from zero to one. After answering, the cycle restarted with a new target state instruction and related image repeating altogether 24 times per block.

After finishing the second block, the HPI coils and electrodes were removed, and the subject was instructed to fill out background questionnaire forms.

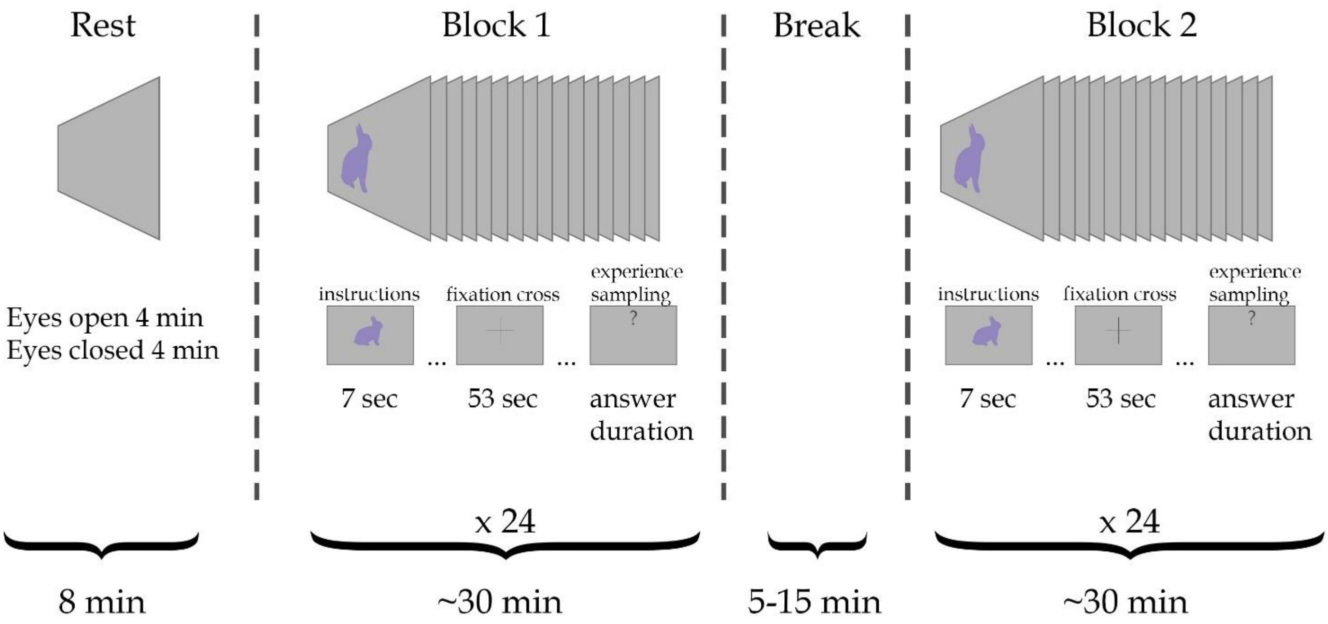


FIGURE 9 Experiment design

Questionnaires were divided into two parts of which the first part was filled on-site right after the measurement. The reason for dividing questionnaires into two was to avoid excessive stress on subjects as total number of questions grew relatively high. Second part was implemented through Webropol, to which a link was supplied to subjects immediately after the test. The first part that included background information, substance usage, lifestyle, meditation experience, MEG related information, BDI, BIS/BAS, and BAI, was digitized directly to Excel, and results from the second part were imported also. The second part consisted of FFMQ, ATQ-77, BCQ, and ERQ questionnaires.

4.5 Data preparation

Before analysis the MEG data was prepared in various steps, the raw data was filtered from bad channels and highpass and lowpass filters were applied at 1 and 80 Hertz. Two subjects were rejected due to bad data leaving 27 observations for analysis of MEG data. Independent components used for analysis were formed applying independent component analysis (ICA) for over group concatenated resting states creating 36 independent components. This ICA matrix was then applied to all the target states i.e. anxiety, mindfulness and planning states were projected into the concatenated rest ICA space for comparison. ICA spectres were formed through 2 to 18 Hz to evaluate the whole spectre profile. From these ICA spectres the top values were dissected in each block to form a comparison value. The peak value is the value for comparison. This whole pipeline formed for analysis 36 components in four states from two experiment blocks delivering altogether 288 figures for each subject.

After averaging over both blocks altogether 144 top figures were formed in three states and 36 independent components for analysis to be set in dialogue with background variables in each observation. ICA analysis was also applied to subject level measurement data to create a per subject reference component array for component selection. For this thesis seven components were selected for a more detailed inspection. Selection was based on the components spectre form, localisation and frequency of overlapping manifestation in both over group level ICA array and in subject level ICA array. Criteria to be selected, a component's spectre had to have an explicit peak, and it had to be focal in its topographical nature. In figure 10 can be seen the selected components and their spectre and topography. Spectre charts comprise of frequency over X-axis in Hertz and power over Y-axis.

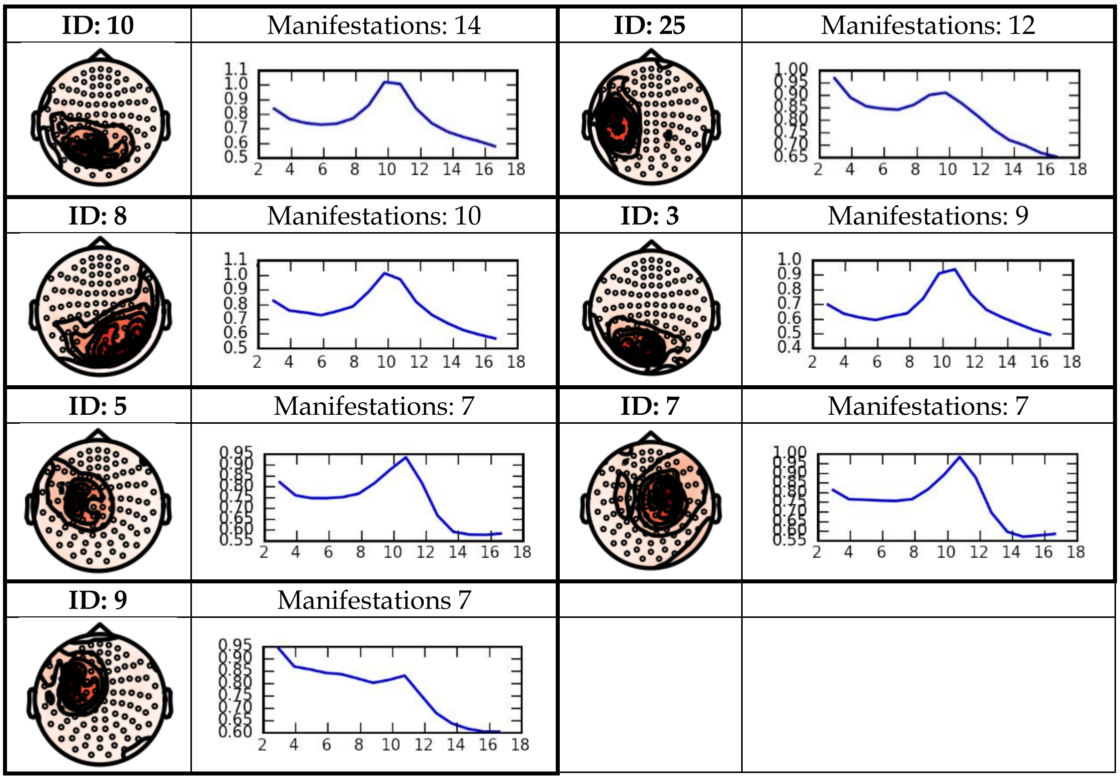


FIGURE 10 Selected components

4.6 Analysis

All statistical testing was executed in SPSS. Before applying statistical tests, all variables were tested for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. Shapiro-Wilk is used additionally due to Kolmogorov-Smirnov weaknesses that include the possibility of false positive result. Normality was tested to decide if applicable analysis methods should be parametric or nonparametric. *T*-tests were applied to discover possible discrepancies between variables introduced. Pearson correlation coefficients were calculated between variables accordingly. (Howell, 2013.) Correlation significance was calculated using online calculator: http://www.socscistatistics.com/pvalues/pearsondistribution.aspx

Sum variables such as personality trait scales are tested for inner consistency using Cronbach's alpha (KvantiMOTV, 2008). Cohen's *d*-value that denotes effect size was calculated using online calculator: https://www.uccs.edu/~lbecker/. Effect size is calculated to further elucidate the magnitude of the tested phenomenon (Howell, 2013).

For a more precise inspection, seven components were chosen. From ICA set of 36 components, numbers 10, 25, 8, 3, 5, 7, and 9 were chosen due to their frequent manifestation in both subject level ICA and group level ICA, explicit spectre form showing peak at alpha frequency band (8-12 Hz), and their focal spatial positioning. Chosen components are displayed in figure 10. Each of these components data that is used in these tests consists of peak value in each state in every component. Variables are named accordingly, number stands for component number of the used ICA space and the letters are abbreviation of denoted state. "Mind" is used to address mindfulness target state. "Anx" stands for anxiety and "Rest" for resting state.

The main aim of this thesis was to find out whether it would be possible to detect differences between states of anxiousness, mindfulness, and rest through MEG acquired data and especially differentiating anxiety as a state from other target states. To test hypothesis H1 "There is a difference in alpha peak behaviour between states of anxiousness and mindfulness." A t-test must be conducted. Before conducting *t*-test to see if there is a statistically significant difference between states the variables must be tested for their normality.

Initially the absolute component peak values were normalised by applying a logarithmic transformation. Variables distribution normality was tested with Kolmogorov-Smirnov and Shapiro-Wilk tests, and criteria for a variable to be interpreted as normal it had to receive significance value more than .05 in both tests, which can be seen in table 1 in columns under "Sig.". All the chosen variables passed the normality test and received a *p*-value of higher than .05, and thus it is justified to apply parametric statistical tests on them. In this normality test the background questionnaire variables were also checked for normality.

TABLE 1 Normality test results of variables. All values are > .05 (column Sig.) with both tests and can be considered normal.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statis-tic	df	Sig.
BAI score	.126	27	.200	.957	27	.308
Bas Total	.167	27	.051	.943	27	.143
Bis Total	.132	27	.200	.952	27	.246
Bas Drive	.158	27	.083	.933	27	.084
Bas Reward Responsiveness	.099	27	.200	.982	27	.903
Bas Fun seeking	.162	27	.066	.929	27	.067
10 Rest	.089	27	.200	.984	27	.939
10 Mind	.131	27	.200	.982	27	.895
10 Anx	.144	27	.157	.966	27	.512
25 Rest	.098	27	.200	.967	27	.523
25 Mind	.076	27	.200	.975	27	.745
25 Anx	.107	27	.200	.948	27	.193
8 Rest	.134	27	.200	.959	27	.360
8 Mind	.113	27	.200	.951	27	.226
8 Anx	.115	27	.200	.960	27	.361
3 Rest	.109	27	.200	.972	27	.643
3 Mind	.091	27	.200	.983	27	.927
3 Anx	.102	27	.200	.980	27	.865
5 Rest	.085	27	.200	.984	27	.940
5 Mind	.103	27	.200	.968	27	.558
5 Anx	.122	27	.200	.976	27	.756
7 Rest	.095	27	.200	.980	27	.872
7 Mind	.096	27	.200	.976	27	.769
7 Anx	.117	27	.200	.972	27	.642
9 Rest	.082	27	.200	.977	27	.782
9 Mind	.094	27	.200	.971	27	.622
9 Anx	.091	27	.200	.974	27	.718

Conducting a paired *t*-test on each possible target state pair in components in the array of selected components, elucidates the possibilities of statistically significant differences of states on component level. The *t*-test tests whether there is a difference in the amount of alpha frequency power in particular component between the tested state pairs.

To test hypotheses H2 ("Anxiety level has a correlation with alpha peak value in states.") and H3 ("Approach and inhibition tendency levels have a correlation with alpha peak value in states."), a correlation test of states alpha peak must be tested against subject scores in according background questionnaires. As stated before, the variables can be considered to be distributed normally, ergo the conducted correlation test can be parametric and thus Pearson's correlation test can be applied to the data. Pearson's correlation coefficient is marked with *r*. Components which passed the paired *t*-tests earlier were selected to be used in testing for correlation to subject scoring of BAI and BIS/BAS questionnaires. BIS/BAS results were divided into distinct classes according to the thematic characteristics: BAS Total, BIS Total, BAS Drive, BAS Reward responsiveness, and BAS Fun seeking. BAS dimension indicates tendencies towards approach behaviour where as i in BIS stands for inhibition and can be described to count in avoiding tendencies.

All the behavioural trait index formation background questionnaire answers were tested for inner consistency using Cronbach's alpha. BAI received a Cronbach's alpha value of .842, BDI .887, BAS Total .826 and BIS Total .800. BAS reward responsiveness's level of inner consistency measured on Cronbach's alpha was .637, BAS Drive received alpha value of .850 and BAS Fun seeking got .630. It can be stated that BAI, BDI, BAS Total, BIS and BAS Drive being over .800 are high and acceptable in inner consistency. BAS Reward responsiveness and BAS Fun seeking received under .700 as their Cronbach's alpha value making them questionable in consistency.

For testing of hypotheses H4 ("Anxiety level has a correlation with alpha peak value difference between states") and H5 ("Approach and inhibition tendency levels have a correlation with alpha peak value difference between states"), a comparable alpha frequency peak value must be formed between states. Comparable value is formed by subtracting states peak alpha values from each other forming a value that is tested for correlation with personality trait scales scoring.

4.7 Subjects sampling

Total of 29 test subjects were recruited for the experiment using the University of Jyvaskylä's volunteer e-mail lists and through researcher's contacts via open online enrolment form. Two were rejected due to bad data leaving 27 subjects. Seventeen of the subjects announced their sex to be male, and 10 answered "female", thus being rounded to 63 % males and 37 % females. The average age of the whole sample was 27.7 years and median 26 years. Most of the subjects were between the ages of 21 and 30 years old. The youngest subject was 21, and oldest 48 years of age. Sample has a standard deviation of 5.8 years in age.

Eighteen of the subjects were single and had never been married, and 11 were in cohabitation, married or in a registered relationship. Nine of the subjects were employed, 14 announced their status to be student and five were either unemployed, on sick leave or reported their status to be "other". Thirteen answered their level of education to be university level (masters or graduate) and nine had received a bachelor's (or undergraduate) degree in university or in university of applied sciences. Five reported none of the above and one subject reported an employment professional course or other professional course of duration over four months as his/her education level.

Total of 16 subjects had experience in meditation as 13 answered to have no experience what so ever. Fourteen subjects had practiced meditation for from half a year to five years, and only two subjects had exercised meditation for more than six years as can be seen in figure 11.

One recognizable challenge in meditation or mindfulness experience classification over subjects is the lack of standardisation of meditation practice. Experience could be approached in domains of practice intensity, frequency or overall extensity of meditation exercising history. Also estimated average duration of each exercise could be addressed. In the demographic sampling introduction, subjects' overall longitudinal history in meditation is used in classification.

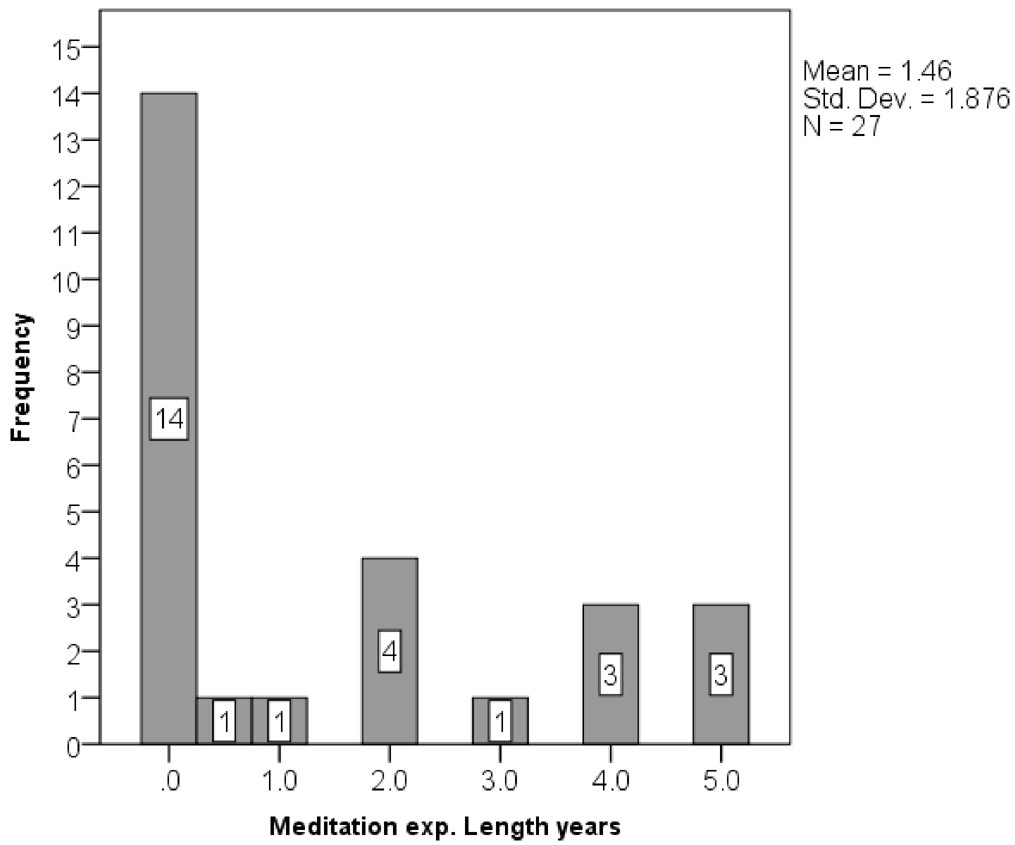


FIGURE 11 Experience in meditation among subjects

Sixteen of the subjects reported that they had been suffering from depression at some point in their life and one subject reported to be depressed at the time of experiment. One subject reported that he had been diagnosed with ADHD. One subject was on sleeping medication that affects the central nervous system and one subject "was not sure" whether he was under medication that affects the central nervous system.

Twenty-two subjects ranked between 0-9 of total score on Beck's depression inventory which indicates minimal depression and five of them summed zero. Three subjects got 10-18 for mild depression and 2 received a score of 19-29 which indicates moderate depression. Beck's anxiety inventory scores were similar in their nature in the sample. Sixteen subjects scored between zero and nine, which indicates normal to minimal anxiety. Nine subjects received 10-18 for mild to moderate anxiety and two subjects landed between 19 and 29 of the score that indicates moderate to severe anxiety.

Differences between genders in BDI and BAI scores were visible in the sample. As females ranked lower in BDI on average (4.8) they did receive higher mean score in BAI (10.3). Male averages were similar in BDI (7.4) and BAI (10.3) although their median figures had a difference of two points (BDI 6.00 and BAI 8.00). Divergences between genders were statistically significant in both BDI ($p = < .05$) and BAI ($p = .02$) when tested with *t*-test.

BAS which indicates the approach tendency trait received an average of 48.6 for males and 51.7 for females. In the means of BAS Fun seeking and BAS Reward responsiveness the only small difference was present between males and females, under one point in each. BIS which points to inhibition or avoidance tendency trait differed between sexes for almost five points in the average score as males received 8.1 average and females 12.9. Overall scoring means are shown in figure 12.

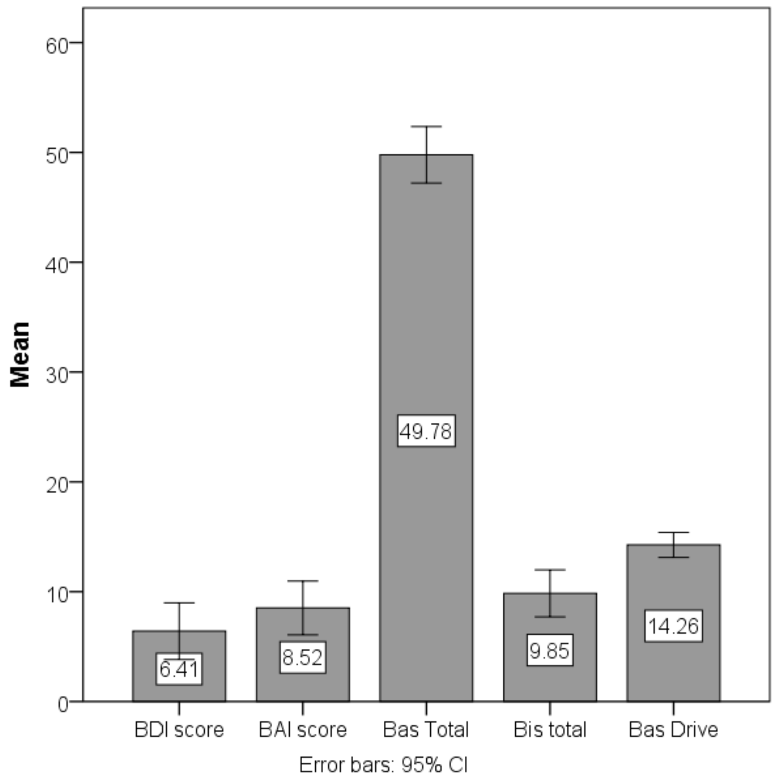


FIGURE 12 Behavioural trait scoring

5 Results

5.1.1 Experience sampling

Figure 13 shows the average and normalised average fluctuation of subjective experience of focus level through the whole experiment including both blocks sequentially. Especially interesting phenomena is how drastically, nonetheless presumably, the average experience of focus deteriorates during the last three tasks due to experiment fatigue (Numbers 9 to 11 on x-axis) in block 1, and peaks right after the break (Numbers 12 and 13 on x-axis). Normalisation was executed by taking the minimum value per array (subject experience sampling values) dividing it by the array's maximum value and subtracting the array's minimum from the quotient.

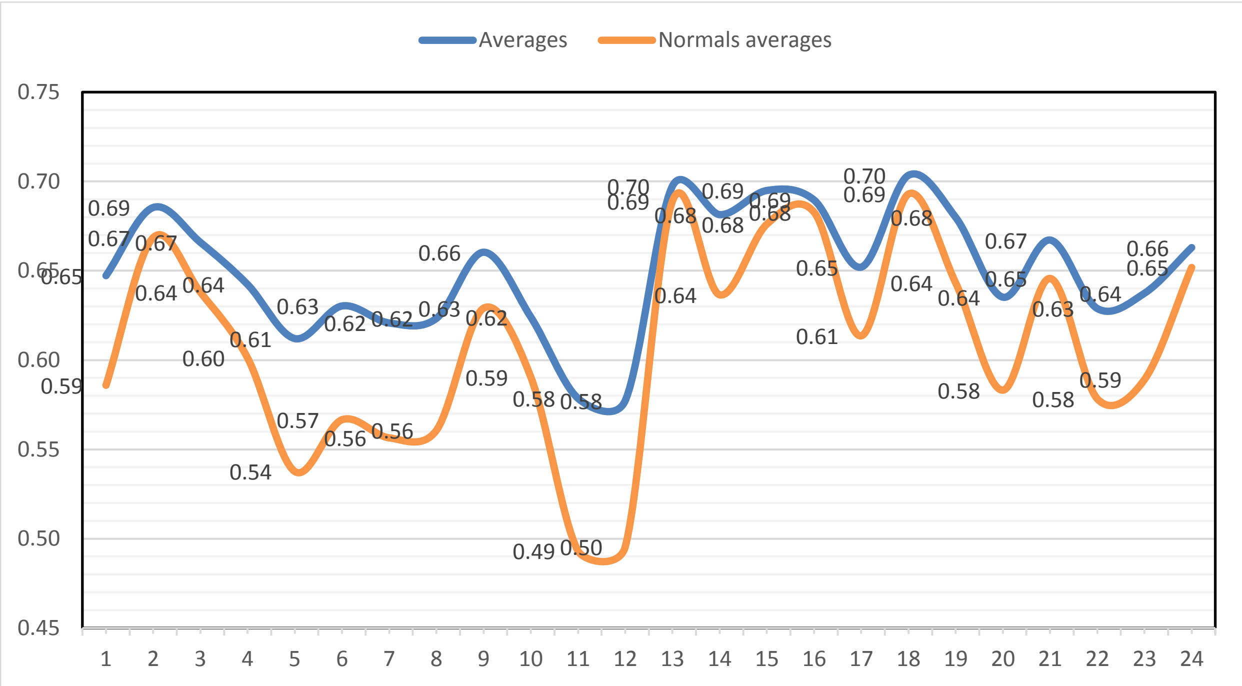


FIGURE 13 Experience sampling focus averages and normal averages over measurements

In addition to focus experience the subjects were asked to rate their feelings during tasks and again data was logged on a scale from zero to one, one meaning feeling very good and zero indicating feeling very bad. Figures 14 and 15 describe the normalised averages of experience of feeling and focus level in each state. Especially noteworthy is the behaviour in experience sampling of anxiety state in both focus and feeling dimensions. As the subject's experience of focus in anxiety state increases, a decrease in feeling rating is visible. Even though this phenomenon does not validate the whole experimental method per se, it does demonstrate a pattern that increases method credibility especially in the anxiety target state domain. Values were normalised in the same manner as in focus sampling.

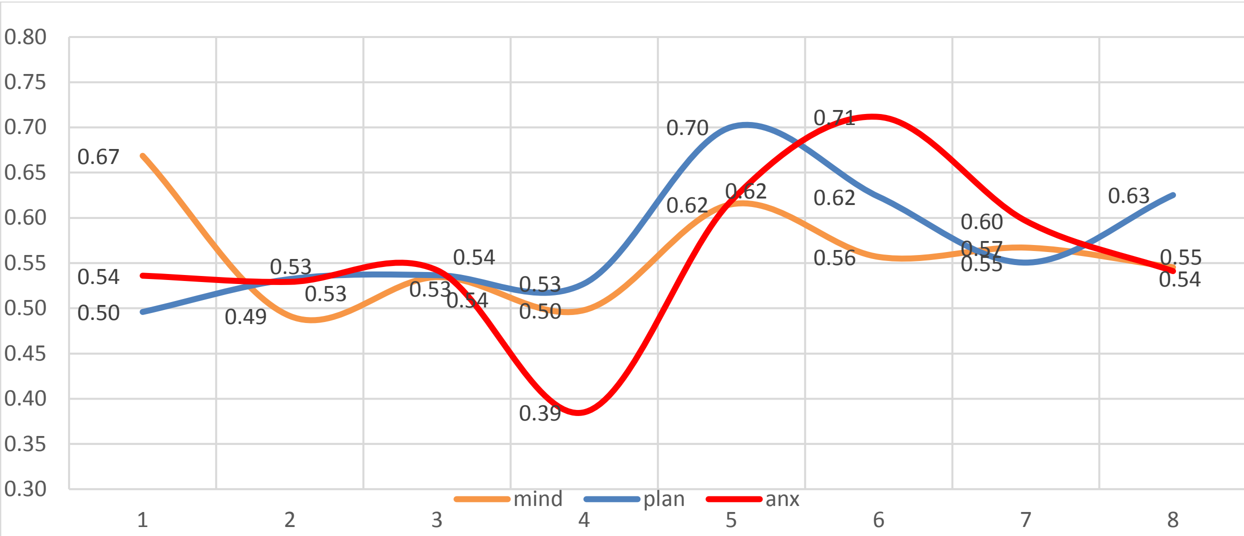


FIGURE 14 States focus averages normalized

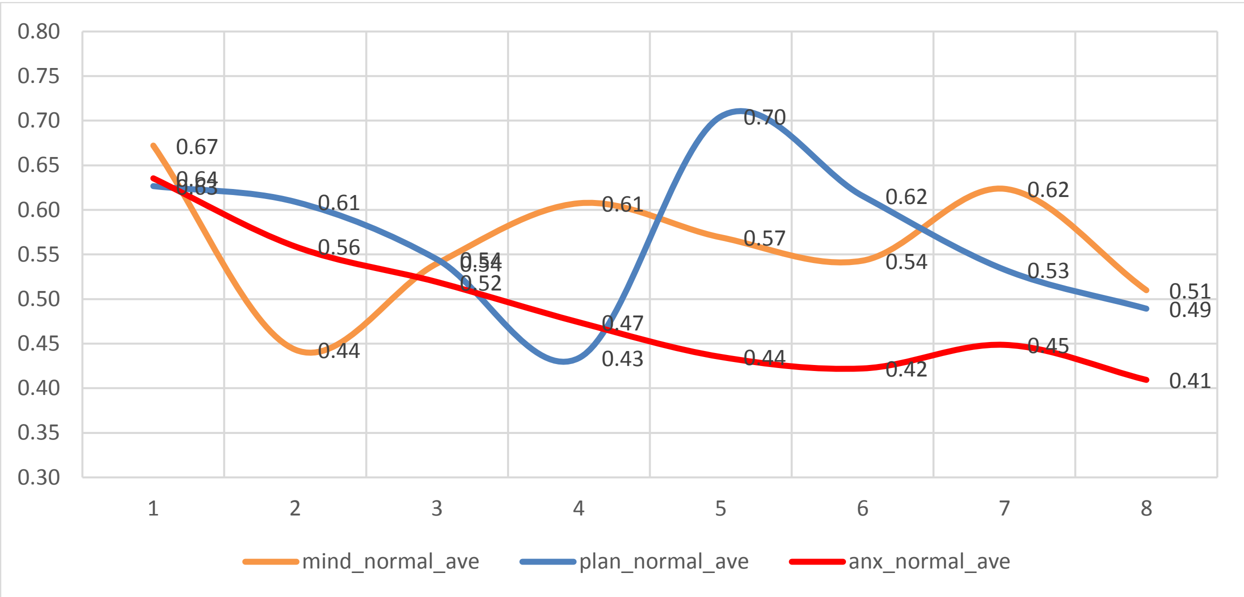


FIGURE 15 States feeling normalised averages

Experience sampling can also be evaluated in raw average form in which the divergency of anxiety from the other two target states is more clearly visible. Experience sampling average score of feeling in mindfulness was 0.68, planning 0.72 and in anxiety 0.46 having standard deviation of 0.18, 0.17 and 0.21 respectfully. Anxiety feeling experience sampling result is statistically significantly different from mindfulness receiving p-value of .04. Also, the difference of anxiety experience sampling to target state planning experience sampling is statistically significant with p-value of .01. Both were differences were tested with t-tests. Differences in non-normalised averages in states over blocks are described in figure 16.

For anxiety, in addition to being statistically significantly different from, the difference effect size can also be considered large receiving Cohen's *d*-values of -1.36 when tested against mindfulness target state and -1.12 when tested against planning.

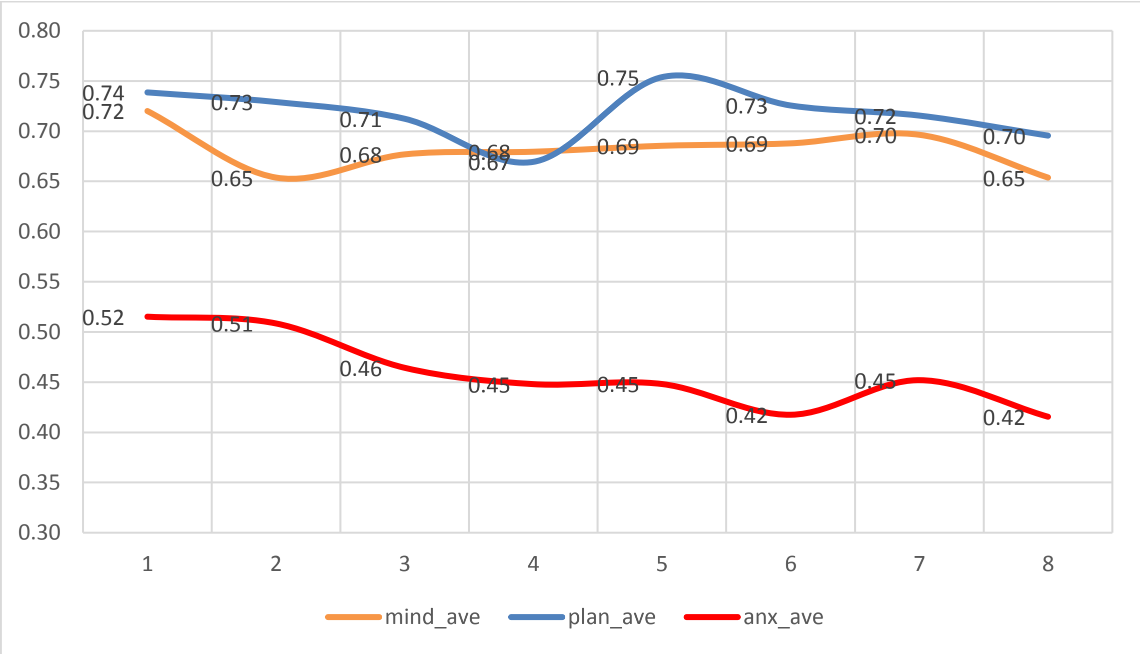


FIGURE 16 States feelings averages

5.1.2 Differences of alpha peak behaviour in target states

As can be seen in table 2, a statistically significant divergency could be found in several components and between multiple pairs. In component number 10 a difference is shown between resting state and mindfulness (t = -3.760, p = < .050) as is between rest and anxiety (t = -2.636, p = .014). A difference was also found in component 25 between states of rest and mindfulness (t = -2.415, p = 0.023). In component 8 differences in pairs of rest and mindfulness, and rest and anxiety were visible (t = -2.779, p = .010, and t = -2.968, p = .006 respectfully) and similar findings were visible in component 3 resulting in t-value of -2.529 and p-value of .018 between rest and mindfulness. For target states rest and anxiety corresponding values in component 3 were and -2.398 (t) and 024 (p). Component 9 differs slightly for its statistically significantly deviant pairs were rest and mindfulness (t = -3.935, p = < .05), and mindfulness and anxiety (t = 2.884, p = .008).

In component 10 the differences are visible at the parieto-occipital lobe weighted on the left hemisphere. In mindfulness target state alpha power is higher than in rest and anxiety is lower. Component 25 is situated on the left-side parietal area and alpha is faintly higher in mindfulness target state than in resting state. In component 8 alpha is vaguely lower in mindfulness than in rest but is higher in anxiety than in resting state. Component 8 takes place on the right-side parieto-occipital area. Situated slightly further behind than component 25 we can see component 3 with both mindfulness and anxiety target states exceeding resting state alpha. Component 9 is focused on parieto-frontal area slightly leaning on left side. See figures 17, 18, 19, 20, and 21 for component state differences and localization.

Cohen's *d*-value, which is an indicator for effect size, reached at maximum .200 in this *t*-test in component 10, when pairing rest and mindfulness. All the other tests received a Cohen's *d*-value of under .200, and thus all the effects can be considered to be small in their size.

TABLE 2 Paired *t*-test for target states in components Bolded and marked with * are statistically significant.

Component pair	*t*	Sig. (2-tailed)	Cohen's *d*
10 Rest - 10 Mind	**-3.760**	**0.001***	**0.200**
10 Rest - 10 Anx	**-2.636**	**0.014***	**0.185**
10 Mind - 10 Anx	0.232	0.818	0.009
25 Rest - 25 Mind	**-2.415**	**0.023***	**0.097**
25 Rest - 25 Anx	-0.987	0.333	0.054
25 Mind - 25 Anx	0.880	0.387	0.041
8 Rest - 8 Mind	**-2.779**	**0.010***	**0.103**
8 Rest - 8 Anx	**-2.968**	**0.006***	**0.124**
8 Mind - 8 Anx	-0.580	0.567	0.022
3 Rest - 3 Mind	**-2.529**	**0.018***	**0.073**
3 Rest - 3 Anx	**-2.398**	**0.024***	**0.079**
3 Mind - 3 Anx	-0.287	0.776	0.006
5 Rest - 5 Mind	-1.372	0.182	0.042
5 Rest - 5 Anx	-0.326	0.747	0.011
5 Mind - 5 Anx	0.724	0.476	0.031
7 Rest - 7 Mind	-0.759	0.455	0.035
7 Rest - 7 Anx	-1.116	0.275	0.048
7 Mind - 7 Anx	-0.251	0.804	0.013
9 Rest - 9 Mind	**-3.935**	**0.001***	**0.100**
9 Rest - 9 Anx	-0.071	0.944	0.002
9 Mind - 9 Anx	**2.884**	**0.008***	**0.097**

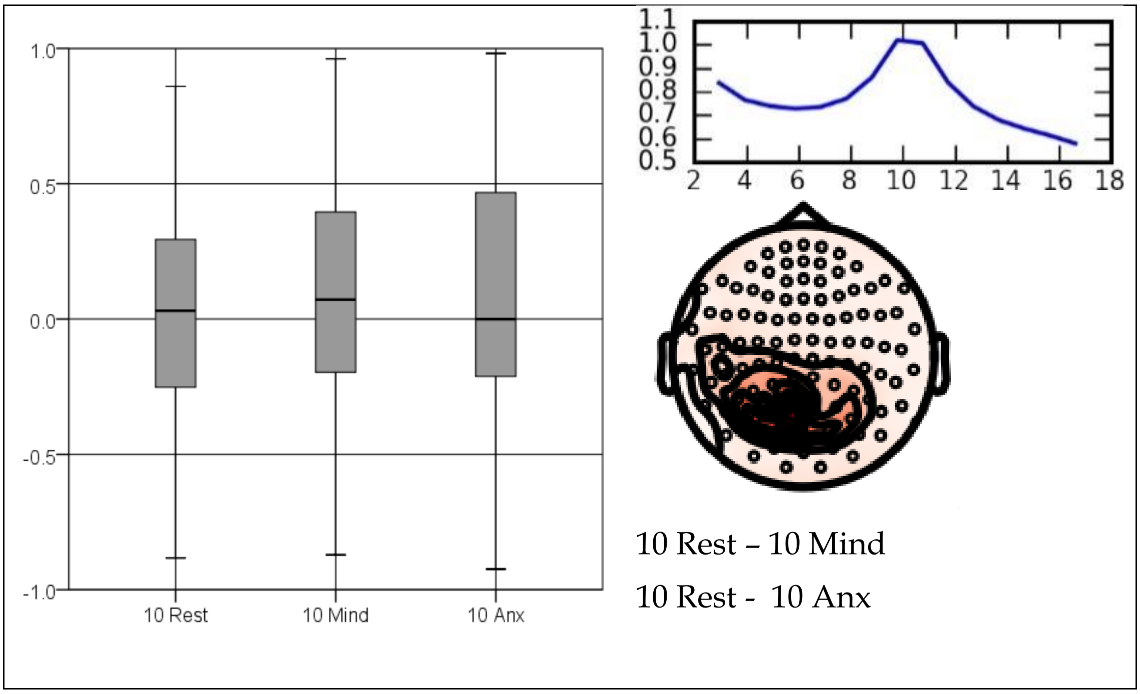


FIGURE 17 Component 10 state differences, spectral form, and localisation

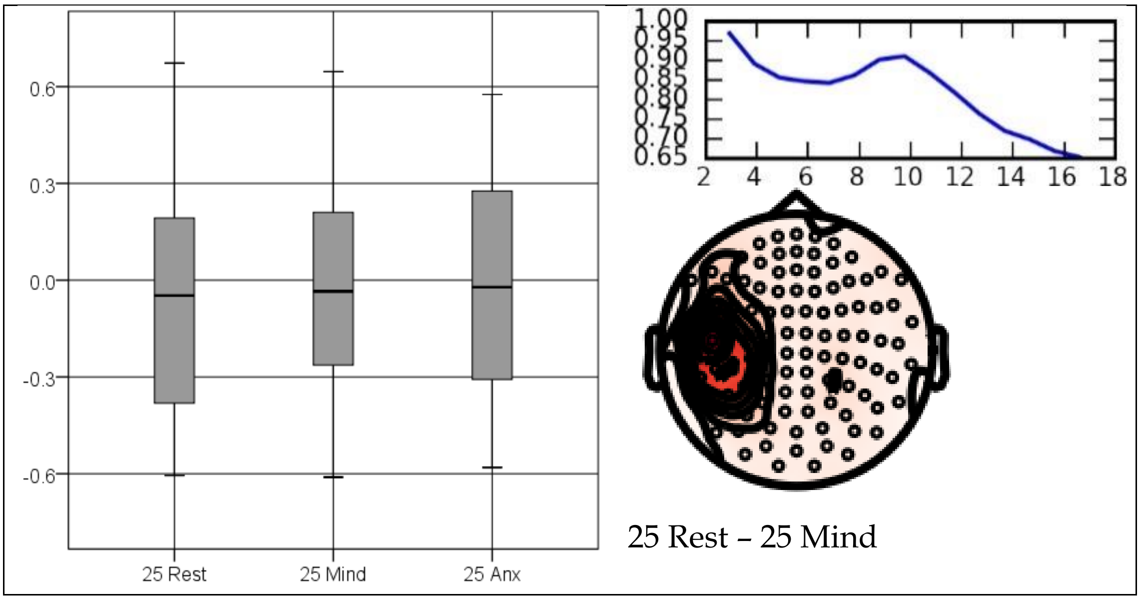


FIGURE 18 Component 25 state differences, spectral form, and localisation

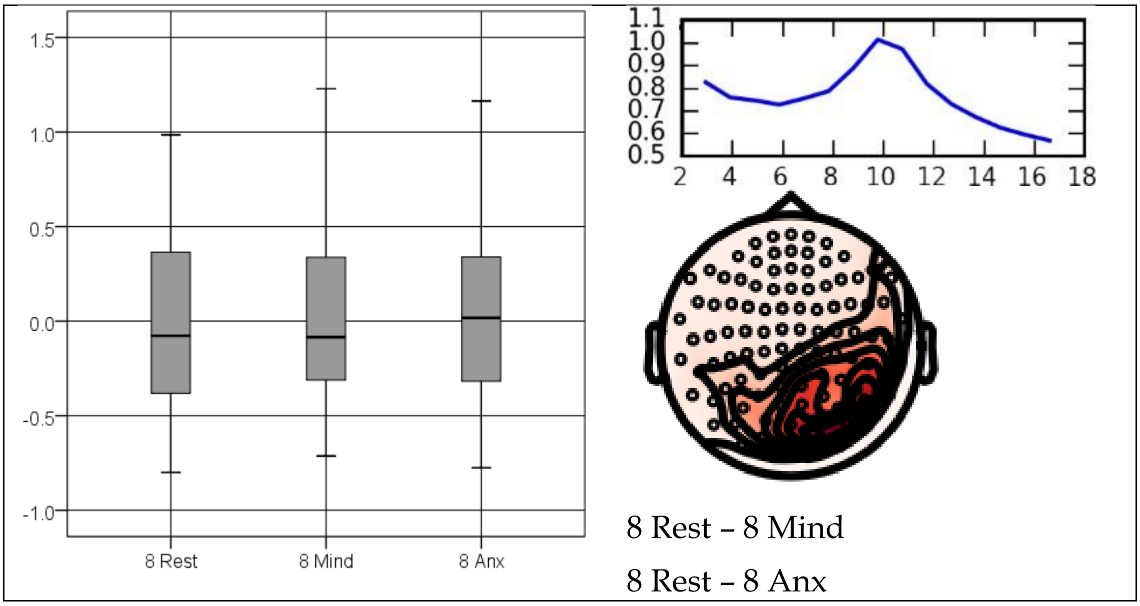


FIGURE 19 Component 8 state differences, spectral form, and localisation

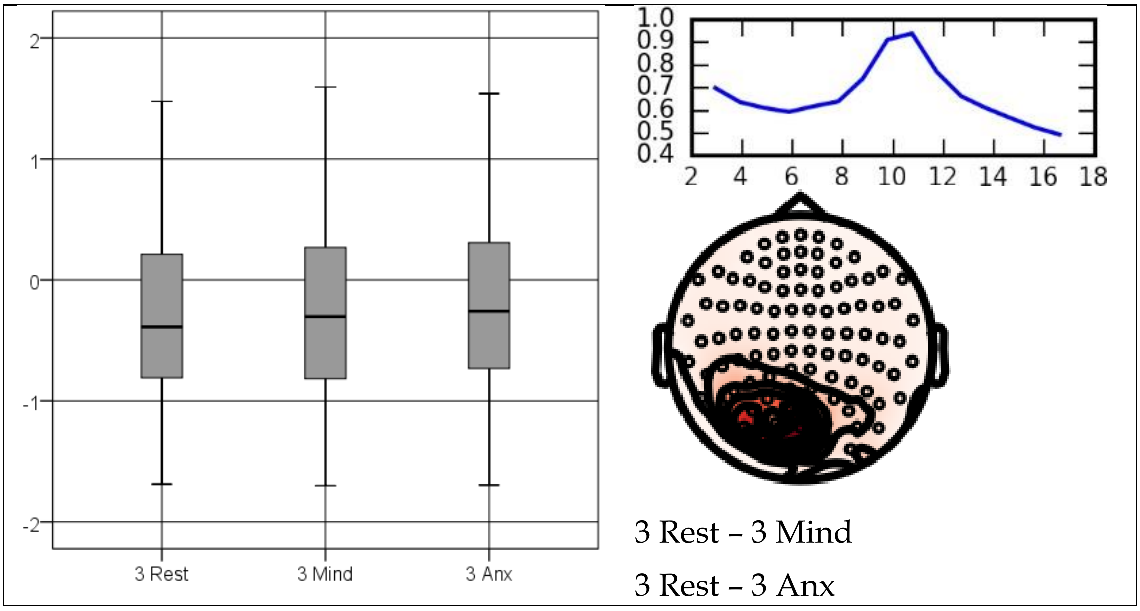


FIGURE 20 Component 3 state differences, spectral form, and localisation

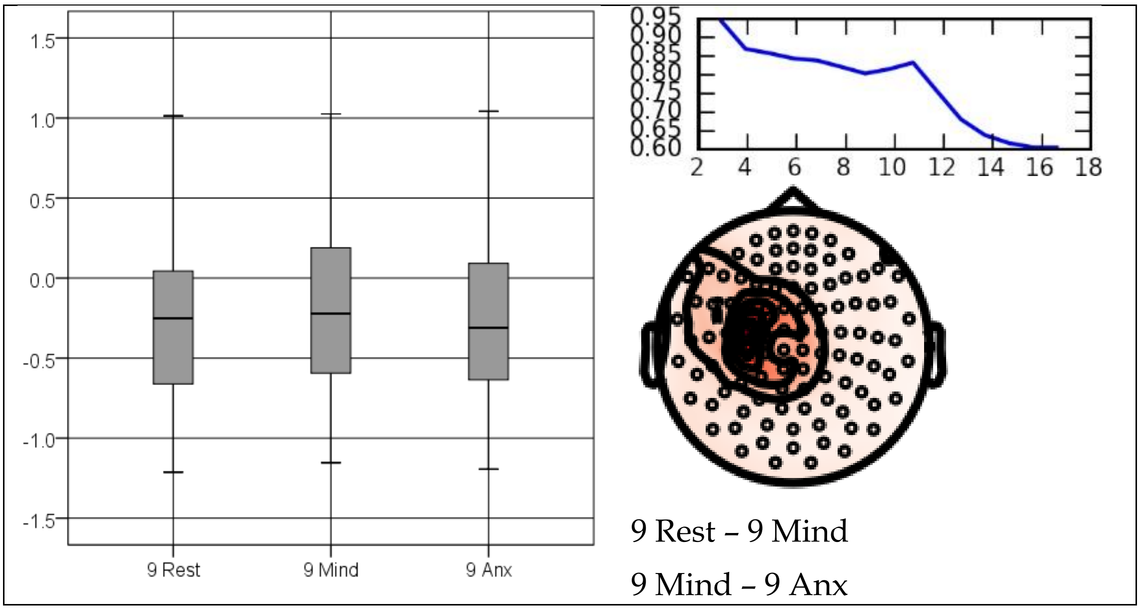


FIGURE 21 Component 9 state differences, spectral form, and localisation

The results of conducting *t*-test on each state in selected components suggests that even though a statistically significant difference between states could not be found in all the selected components, there are various components that the difference could be found in. Results of *t*-tests implicate viability of first hypothesis H1 “There is a difference in alpha peak behaviour between states of anxiousness and mindfulness.” but not thoroughly conclusively. It must also be noted that the statistically significant differences are visible mostly in between a target state and resting state, and only in component 9 a difference between states of anxiety and mindfulness was established. Additionally, size of effect is remarkably small in all the state contrasts. All in all, statistically significant difference was found in components 10, 25, 8, 3, 5, and 9 summing six components.

5.1.3 Relation of alpha peak to behavioural traits

A statistically significant correlation was formed between component 8 anxiety state with BIS Total scoring with Pearson's correlation coefficient value of .391 and *p*-value of .04, meaning that as score in BIS total increased, so did alpha peak power in anxiety target state. Correlation can be considered weak or moderate in its nature.

Also, a correlation formed between component 10 and BAS reward responsiveness in anxiety and mindfulness target states with correlation coefficients value of -.394 (p = .04) and -.411 (p = .03) respectfully. Between component 10 anxiety and mindfulness correlation to BAS reward responsiveness the direction is negative i.e. alpha peak value increased as subjects scoring in BAS Reward responsiveness decreased. This correlation can also be described weak or moderate.

Component 8 states of rest and mindfulness formed a correlation with variable BAS Fun seeking. Resting target state in component 8 and BAS Fun seeking variables received a correlation coefficient of -.370 and *p*-value of .050 as mindfulness correlated with BAS Fun seeking with coefficient of -.401 (p = .040). Component 8 correlations can too be deemed weak to moderate in their size. These correlations were also negative in their course meaning that smaller BAS Fun seeking score meant larger alpha peak value. See Figure 22 for linear relationships of these variables.

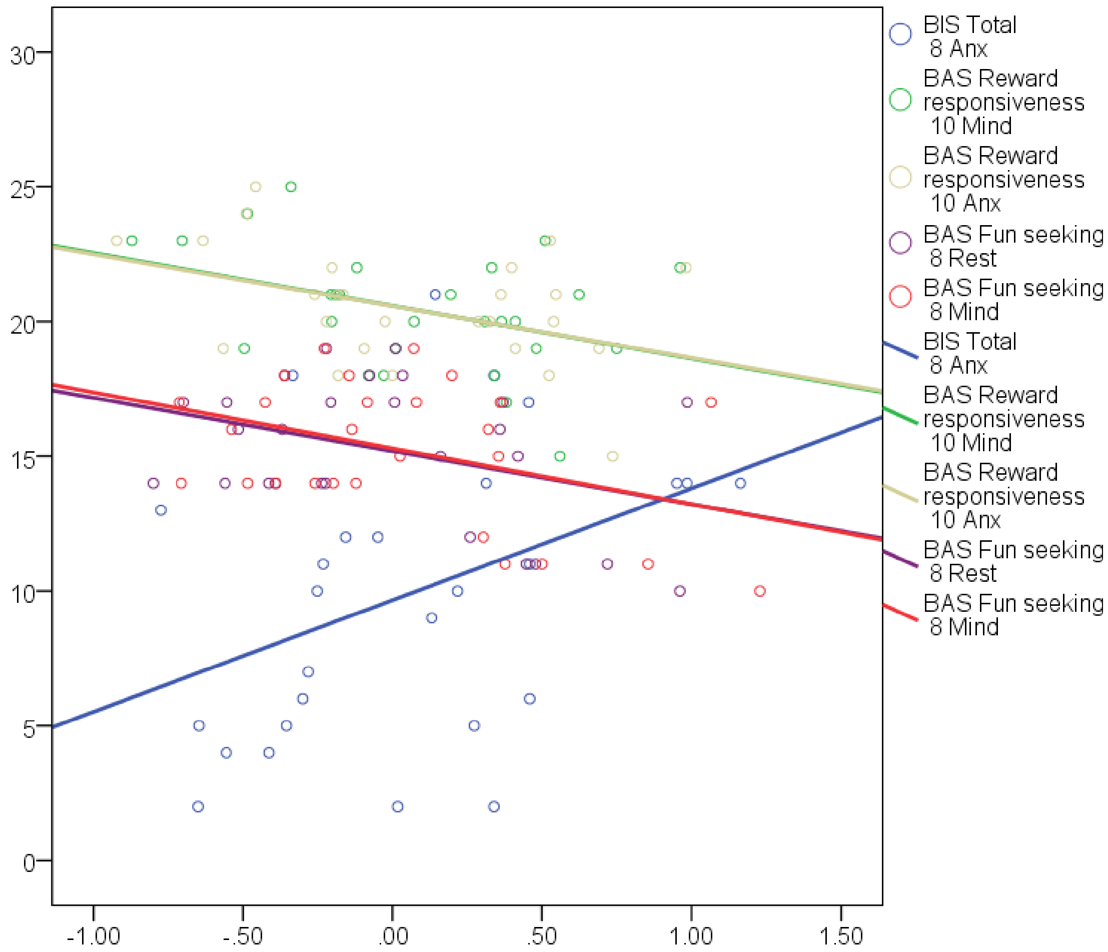


FIGURE 22 Linear correlative relationships of alpha peak to behavioural traits (N = 27)

Results of correlation tests support the rejection of H2 "Anxiety level has a correlation with alpha peak value in states." Correlation test results also point towards supporting the third hypothesis H3, "Approach and inhibition tendency levels have a correlation with alpha peak value in states."

5.1.4 Alpha peak discrepancy in states and traits correlations

Statistically significant correlations of behavioural traits and differences of alpha peak value in states was found in components 10, 8, and 3. In component 10, difference formed between BAS Reward responsiveness and rest and mindfulness (r = .471, p = .013) and rest and anxiety (r = .465, p = .014) having a weak or moderate correlation. This means that as the BAS Reward responsiveness score increased, alpha power increased in resting state compared to mindfulness and to anxiety.

In component 8 the correlation of difference between rest and anxiety was statistically significant to BAS Drive trait (r = .411, p = .033). Meaning that increase in BAS Drive score, amount of alpha in anxiety state decreased in relation to resting state.

Component 3 was similar in its nature. Increase of score in BAS Reward responsiveness alpha power in rest was increased in relation to mindfulness and to anxiety. A correlation of BAS Reward responsiveness score to difference of rest and mindfulness and to difference of rest and anxiety was found in component 3. Difference between rest and mindfulness received a correlation coefficient value of .442 and *p*-value of .021. Rest minus anxiety equivalents were .427 (*r*) and .026 (*p*-value). Each of these correlations were positive in their nature meaning that values fluctuated parallel as can be seen in figure 23.

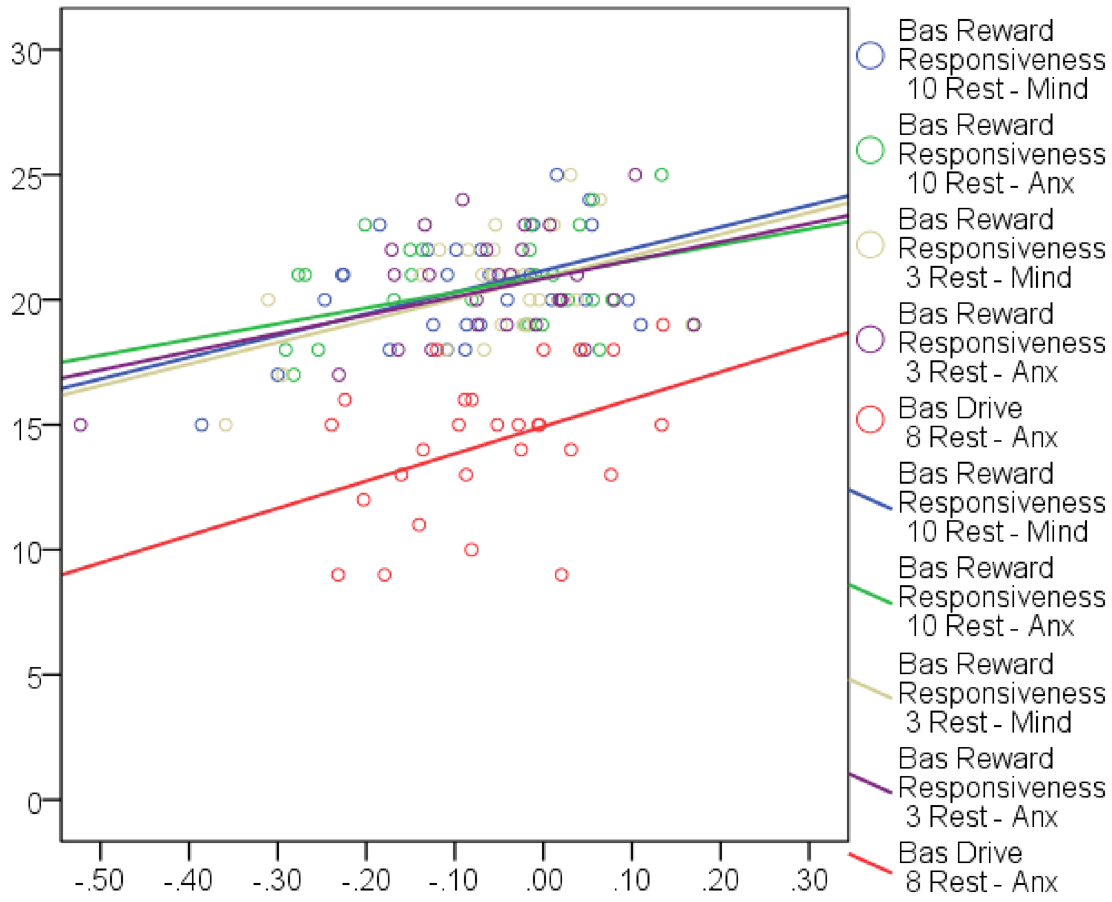


FIGURE 23 Linear correlative relationships of alpha peak differences over states in components to behavioural traits (N = 27)

Correlation test results imply discarding of fourth hypothesis H4, “Anxiety level has a correlation with alpha peak value difference between states.” However, results do suggest approval of fifth hypothesis H5, “Approach and inhibition tendency levels have a correlation with alpha peak value difference between states.”

6 Discussion

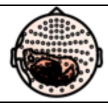
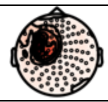
The main aim of this study was to further develop an initial logics framework for an attention sustaining neuro feedback loop system by finding possible measurable correlates and affiliations between distinct personality traits, anxiety, mindfulness, and electrophysiological functions in the brain. Study is limited to alpha frequency oscillation domain. Hypotheses were established on results of several separate previous studies.

The most important result of this study from the brain computer interface development point of view, is the answer to research question two, and the support of validation of corresponding hypothesis H1: "There is a difference in alpha peak behaviour between states of anxiousness and mindfulness." This difference is present in component number 9. Although this phenomenon obviously requires more specific studies it might function as a basis for developing a neuro feedback loop system to enhance alpha power by mindfulness-like practicing, which could have a lot to offer in facilitating rehabilitation therapy in realm of anxiety spectrum.

Although not thoroughly conclusively, this study does elucidate and advocate the possibilities of using behavioural data and data of the incorporated neural correlates when designing and defining frameworks for brain computer interfaces. Interests lie especially in the variety of anxiety rehabilitation, and attention and focus enhancement domains as various statistically significant associations were present between behavioural measures scoring and alpha peak power in distinct cognitive states.

As displayed in table 3 alpha was higher in mindfulness than in rest or anxiety in components 10 and 9 at parietal and left frontoparietal sites. However, alpha was higher in anxiety state than in mindfulness or in rest in components 25, 8, and 3 at left temporoparietal area, right parieto-occipital area, and left parieto-occipital area.

TABLE 3 Highest and lowest alpha manifestations and their localization

Component ID	**Highest alpha**	**2nd. highest alpha**	**Lowest alpha**	**Location**	
10	Mind	Rest	Anx	Parietal	
25	Anx	Mind	Rest	Left temporoparietal	
8	Anx	Mind	Rest	Right parieto-occipital	
3	Anx	Mind	Rest	Left parieto-occipital	
9	Mind	Rest	Anx	Left frontoparietal	

Previous studies show similar results in the direction of alpha changes comparing anxiety state to resting state and mindfulness state to resting state. According to Purves et al. (2012) information concerning motion, spatial orientation of body, and posture is processed eminently by the vestibular system, which plays a pivotal role in perception of body. Vestibular cortex is situated at posterior parietal area. Kalat (2012) summarizes the study of Snyder, Grieve, Brotchie & Andersen (1998) that posterior parietal cortex is activated when movement is planned, and the same area is affiliated with body position tracking. The primary somatic sensory cortex, that is located at frontal region of posterior parietal cortex, is affiliated with bodily sensations and has representational sub areas for distinct parts of body (Kalat, 2012; Purves et al. 2012).

Previously the increase of alpha oscillation in meditative states has been speculated to be affiliated with inward targeted attention which might require alpha induced inhibition of external stimuli focusing through inhibition of somatic sensory mechanisms (Aftanas & Golocheikine, 2002). Clark et al. (2016) assert that meditation related increase of alpha reflects global cortex inhibition.

The findings presented in this study might suggest that during meditation an inhibitory mechanism sets in at sites which are associated with movement and perception of body. This could be affiliated with controlling attention towards internal activities and thus be considered consistent with mentioned previous studies. Inhibition of areas affiliated with motor functions could also be thought to be corollary activity due to voluntary physical stillness in addition to be a result particularly of meditative task. It must be considered that without source modelling the localization of neural correlates is not of absolute accuracy. Component 9 could also reflect inhibition of Broca's area that plays according to

Purves et al. (2012) a key role in language processing, especially producing parlance.

Alpha oscillation power has been asserted by Knyazev et al. (2008) to have a positive correlation with anxiety as a personality trait. Knott et al. (1997) disclose that patients suffering from panic disorder had lower alpha during relaxation than their control peers. Knyazev et al. (2008) speculate that those who paid more attention to external stimuli also received higher STAI scoring and had higher alpha, which could be affiliated with panic and its corollary anxiety. However, Maoeka et al. (2012) reported a decrease of alpha at dorsolateral prefrontal cortex (dlPFC) when subjects were displayed unpleasant imagery.

In this study alpha being higher in states of anxiety than in resting state is analogous with previous studies. However the, previously reported decrease of alpha at dlPFC was not documented. Heightened alpha at left hemisphere during state of anxiety might reflect inhibition of language information processing.

Takahashi et al. (2004) state that a positive correlation was found between alpha power situated at frontal cortex and novelty seeking personality trait during meditation. As this study did not discover frontal alpha component, it is not possible to explicitly juxtapose these results. In this study the opposite phenomena were found in components 3 and 10, which are situated at parietal and left parieto-occipital sites respectfully. Components showed a correlation between BAS reward responsiveness personality trait and difference of alpha frequency power between resting and mindfulness and resting and anxiety. This indicates that alpha power is smaller in mindfulness state than in resting or anxiety on those persons that score higher in Reward responsiveness. This could be affiliated with decreased inhibitory functions due to stimuli expectance or tendency towards preparedness.

7 Conclusions, validity and future research

7.1 Conclusions

Acquired results indicate parallel accomplishments relative to previous studies further supplementing existing research gaps in neuroscientific study of meditation, anxiety, and their relation to personality traits. Although an explicit conclusion in the neurophenomenological approach is limited due to restricted resolution of neural correlates localization and small quota of observation units, the results offer operable insight for preliminary development of a logics framework for attention enhancement neuro feedback system. Results also further converge alpha frequency domain and how its power fluctuation between distinct cognitive states could be modulated by certain personality traits.

7.2 Validity and reliability of research

Altogether three researchers participated in measurements. Even though experiment procedure was thoroughly documented, and all the steps were introduced to every researcher, some minor alteration of for example instructing the subjects on tasks might have occurred, which can cause some variation in the exact techniques used by subjects to reach the targeted states of mindfulness or anxiety. The specific nature of techniques of mental association was not recorded from the subjects and it could have given interesting insight on the possible differences between methods in mindfulness target state related results. Researcher related variation in protocol might be a threat to reliability of the research due it might affect to possible reproduction of similar results.

According to Lazar et al. (2010), the fact that laboratory settings are often used in experimental scientific research may affect the test subjects and they might be prone to abnormal behaviour when studied. The possible effect of tension and laboratory setting induced stress was minimised by giving the subjects time before the measurement and by introducing the measurement equipment during preparations. Researchers experienced that test subjects were not particularly stressed or nervous during tests.

Also, as the measurement session duration proceeded for almost three hours, subject fatigue must be considered. Suffering from fatigue varies subjectively and thus it might have an effect on such an extensive measurement. In addition to fatigue, learning is also often addressed in studies which involve repeatedly executable tasks for subjects. Learning in this experiment could happen as subjects might adopt new techniques producing mental imagery during the experiment or succeed to be more focused due to relaxation. Experience sampling might give insight on both dimensions, fatigue and learning, in the forms of focus and feeling. Presumably fatigue can cause focus to decrease and on the other hand learning can could cause the subjective experience of focus to increase. Secondly fatigue could also cause feeling ranking to decrease. However, the influence of fatigue or learning over results was minimized by semi randomizing tasks during experiments and by averaging alpha peak values over measurement blocks. Not minimizing the factors of learning and fatigue by averaging over blocks might have posed a threat to reliability of the study.

Subject sampling consists largely of students of higher education or people whom had already attained a bachelors or master's degree. Subject sampling cannot be described to be fully randomized even though participator recruitment was open for general public theoretically. Convenience sampling describes sampling more accurately than fully random sampling. As this increases the homogeneity of sample group the results cannot be generalized to major population as is. This decreases the external validity of the study.

Overall great precision and exactitude was exercised during data acquisition. Elekta Triux MEG infrastructure instructions were followed closely. Instruments were inspected before every measurement and recorded signal was monitored at all times during measurements and both digital and physical recorded data was handled with care. Measurement homogeneity was assured by rigid procedure and its exact compliance. These approaches to operation decrease possibility of data corruption in both acquisition and handling phases, and as such increase both reliability and validity of the study.

Formed ICA components were reviewed with different ICA sets on the same data varying in total number of forming components. A total number of 36 ICA components was used due to convention and to fine bad components to good components ratio. The number of components is high enough to differentiate actual independent components but also small enough not to substantially decrease accuracy and generalizability of produced components on sampling.

Because the selected independent components form key variables and are under special attention in analysis, the component selection method should be considered especially. This is due to the fact that it constructs a threat to the fidelity of this study. At all times when selection and cross referencing is executed manually, and is based on single researcher's subjective choice, proneness to error is increased. Although selection has been executed with great regard to accuracy and interpretation of components nature was attempted to accomplish profoundly, susceptibility of faulty selection must be noted. Erroneous selection might cause both type I and type II errors due to possible false statistical relationships based on falsefully named components. Attempts to mitigate possible errors in selection procedure included reviewing of components in both spectral and spatial characteristics and creating a systematic workflow for selection with multiple manual reviews. It must be admitted that many of the components outside this selection are similar in their nature to the selected ones, but differences were nonetheless tangible.

The analysis phase was carefully designed, and all the steps in data handling and analysis have been described in this report in detail. All the conversions of data from linear space to logarithmic space are reported and explicated extensively. Double normality testing of variables was exigent and exclusive. Further analysis in domains of *t*-testing and correlations of states over independent variables is coherent. Further test phases and results are also reported extensively and all the steps for reiteration of study is represented. All the testing steps rejected statistically insignificant elements before continuing to the next phase which could improve both reliability and validity of results due to exclusion of insignificant components.

Even though altogether the questionnaire set was extensive, to focus in-depth to a single target state incorporated relationship with its behavioural trait reciprocal data, a more comprehensive set of questionnaires concerning the particular state related background is necessary. Usage of multiple background questionnaires measuring various areas of backgrounds was a limitation set by larger framework. In future studies concerning anxiety, the diversity of anxiety manifestation forms and mechanics should be noted, and a more inclusive set of independent variables in anxiety domain, measuring distinct characteristics of varying anxiety forms, should be applied. Studying anxiety also in both state and trait dimensions should be noticed and operationalized accordingly. Limiting the subject level trait or state anxiety measurement instruments might compose a threat to validity, however data did have high inner consistency according to its Cronbach's alpha value which supports higher validity of results.

The between-state discrepancy in alpha peak value correlation to behavioural trait scoring was statistically significant in the exact trait score indexes, which were questionable in their inner consistency measured on Cronbach's alpha, which raises the question if the correlation was actually connected to what was presumed to be measured initially. The increase of possible inaccuracy in targeted variable data acquisition and inability to certify actually measured effect could cause the inner validity of the study to decrease.

Spatial dimension of components nature must be approached bearing in mind that without source modelling and actual anatomical models of brain, the topography of components is merely perfunctory and thus precise origin and localisation of each component cannot be established accurately. The used methods can produce only a rough estimate of localisation. Also, subject level variance and inaccuracy of components spatial features might vary due to minor inherent physical movements during and in-between measurements of subjects. Research subject's movement during measurements was minimized by instructing subjects to execute necessary scratching etc. actions during the experience sampling phase or during question display and to hold still whenever the fixation cross was displayed, which increases the validity by enhancing data accuracy. However, possible movement induced error was corrected in data pre-processing.

7.3 Future research

Future studies could approach the dimension of experience sampling variance correlation to power differences in different frequency bands and meditation experience, and practice intensity in relation to alpha and other frequencies differences. The next logical step in development of BCI neuro feedback system would be addressing the manipulation of different frequencies through interaction and other practical applications.

The possible BCI in development could be considered in interaction and interface design domains also. Depending on how explicitly distinct cognitive states could be modelled, interface usability and user experience testing could include a BCI enhanced testing phase, in which valuable data on interface complexity and demanded cognitive effort could be measured.

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APPENDIX 1 BAI QUESTIONNAIRE

Below is a list of common symptoms of anxiety. Please carefully read each item in the list. Indicate how much you have been bothered by that symptom during the past month, including today, by circling the number in the corresponding space in the column next to each symptom.

	Not At All 0	Mildly but it didn't bother me much. 1	Moderately - it wasn't pleasant at times 2	Severely – it bothered me a lot 3
Numbness or tingling				
Feeling hot				
Wobbliness in legs				
Unable to relax				
Fear of worst happening				
Dizzy or lightheaded				
Heart pounding/racing				
Unsteady				
Terrified or afraid				
Nervous				
Feeling of choking				
Hands trembling				
Shaky / unsteady				
Fear of losing control				
Difficulty in breathing				
Fear of dying				
Scared				
Indigestion				
Faint / lightheaded				
Face flushed				
Hot/cold sweats				
Column Sum				

APPENDIX 2 BIS/BAS QUESTIONNAIRE

A person's family is the most important thing in life.
Very false for me 1 2 3 4 5 Very true for me

Even if something bad is about to happen to me, I rarely experience fear or nervousness.
Very false for me 1 2 3 4 5 Very true for me

I go out of my way to get things I want.
Very false for me 1 2 3 4 5 Very true for me

When I'm doing well at something I love to keep at it.
Very false for me 1 2 3 4 5 Very true for me

I'm always willing to try something new if I think it will be fun.
Very false for me 1 2 3 4 5 Very true for me

How I dress is important to me.
Very false for me 1 2 3 4 5 Very true for me

When I get something I want, I feel excited and energized.
Very false for me 1 2 3 4 5 Very true for me

Criticism or scolding hurts me quite a bit.
Very false for me 1 2 3 4 5 Very true for me

When I want something I usually go all-out to get it.
Very false for me 1 2 3 4 5 Very true for me

I will often do things for no other reason than that they might be fun.
Very false for me 1 2 3 4 5 Very true for me

It's hard for me to find the time to do things such as get a haircut.
Very false for me 1 2 3 4 5 Very true for me

If I see a chance to get something I want I move on it right away.
Very false for me 1 2 3 4 5 Very true for me

I feel pretty worried or upset when I think or know somebody is angry at me.
Very false for me 1 2 3 4 5 Very true for me

When I see an opportunity for something I like I get excited right away.
Very false for me 1 2 3 4 5 Very true for me

I often act on the spur of the moment.
Very false for me 1 2 3 4 5 Very true for me

If I think something unpleasant is going to happen I usually get pretty "worked up."
Very false for me 1 2 3 4 5 Very true for me

I often wonder why people act the way they do.
Very false for me 1 2 3 4 5 Very true for me

When good things happen to me, it affects me strongly.
Very false for me 1 2 3 4 5 Very true for me

I feel worried when I think I have done poorly at something important.
Very false for me 1 2 3 4 5 Very true for me

I crave excitement and new sensations.
Very false for me 1 2 3 4 5 Very true for me

When I go after something I use a "no holds barred" approach.
Very false for me 1 2 3 4 5 Very true for me

I have very few fears compared to my friends.
Very false for me 1 2 3 4 5 Very true for me

It would excite me to win a contest.
Very false for me 1 2 3 4 5 Very true for me

I worry about making mistakes.
Very false for me 1 2 3 4 5 Very true for me