Brain-computer interfaces in meditation

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Master's thesis

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Student, Toni Sanio: Using the brain computer user interface in meditation
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The topic of the thesis was to find out the utilization of brain computer user interfaces to assist meditation. In order to find this out, I looked at the history of meditation and its basic methods on which a modern support system should be based. In addition, I examined the effects of meditation in the brain in terms of both physiological changes and electrical activity. Measuring electrical activity would also allow meditation to be examined using a brain computer interface.

I did a review of the options for transforming the state of consciousness with the help of technology. These included transcranial magnetic stimulation, biofeedback, neuroplasticity therapy and brainwave entrainment, which showed promising results. Of these options, I chose to combine neuroplasticity therapy and brainwave entrainment. In this work, an experimental arrangement is presented, which aims to control a meditation session with the help of audio feedback. Among other things, natural sounds such as the lapping of water and the sound of sea waves were used as sound feedback. The system modified the voice feedback based on the person's EEG curve and tried to guide the person to change the state of the brain to be more favorable for meditation. The new system compared to the previous one included, among other things, an amateur-level EEG device and changing soundscapes to prevent boredom.

Finally, I tested the functionality of the system with 16 test subjects with two different types of sessions, and from the results of the test it could be seen that the results of the groups could be separated from each other based on the EEG curve. During the sessions, the subjects experienced relaxation, reduction of anxiety, hypnagogia, recollection of memories, silence of inner dialogue and transformation of thoughts.

Keywords: Brain computer interfaces, a/t neurofeedback, EEG, meditation, neurofeedback

ACM categories (ACM Computing Classification System, 1998 version): D.2.2 User interfaces

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Student, Toni Sanio: Brain-computer interfaces in meditation
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Abstract:
Topic of my thesis was to research possibilities of brain-computer interfaces as meditation aid. To do this I researched meditation history and it's basic methods which provided the basic philosophy and guidelines for building modern tool to aid meditation. Then I studied the phenomenon which are observed or measured during meditation state or as a result of long term meditation practice in brain. The electrical activity of brain related to meditation would provide an possible interface for measuring meditation state or help reaching it with means of brain-computer interface.

I also did list of different ways to alter state of mind externally via technology. These included transcranial magnetic stimulation, biofeedback, neurofeedback and brainwave entrainment which seemed very promising as a result. From these methods I chose to combine neurofeedback and brainwave entrainment. I then constructed a system which guides individual meditation session with audio feedback. The audio consisted mostly of nature sounds for example sounds of ocean waves or fountain. The given audio feedback was altered according person's EEG and it's purpose was to encourage person to change his state of brain into more meditative state. New things in this study was for example non-medical hobbyist EEG-device and changing audio environment to prevent boredom.

In the end I did an experiment to verify the operability of the system with 16 participants with two different sessiontypes. It was possible to conclude that two different groups could be distinguished from each other by their avarage EEG recordings. From the session comments written and given by participants it was noted that they experienced relaxation, decrease of anxiety, hypnagogia, coming up of memories, silencing of inner dialogue and changes in thought patterns.

Keywords: a/t-neurofeedback, Brain-Computer Interfaces, EEG, Meditation, Neurofeedback

CR Categories (ACM Computing Classification System, 1998 version): D.2.2 User interfaces

Preface

When I started working on this topic, the first thing that happened to me was to read the literature on the topic and add the hobby of meditation to my life. I was greatly annoyed by the large gap that had been made between meditation practice and modern life. I felt the need to understand the mechanism of meditation and get a scientific perspective on it. Because meditation is often associated with a large amount of religious or mystical doctrine, which prevents modern people from taking up the hobby, especially considering that in Western countries meditation teaching or hobby is not as readily available as, for example, other subjects or sports. I understood that it is necessary to learn about possible methods that are suitable for modern people. Because, like yoga, meditation techniques have also developed over time, adapting to people's lives.

With the peace that meditation brought to my mind, I felt that meditation could be very necessary for a modern person who lives a busy life. At some point, I also experienced, on the other hand, humility towards the old teachings and the need to join the Buddhist community, because my practice in the field of meditation was always an encounter with myself in a quiet room. I was wondering why, with current technology, it would not be possible to create community sessions between people who practice meditation with the help of the internet.

I went through many twists and turns in assembling the meditation-assisting system, so that the first versions of the system were very loud in their soundscape, downright disturbing, and the device and settings at the time did not seem to be reliable in any way. I sat like this many times, sometimes frustrated and sometimes excited. Also, getting the EEG-SMT device working was very difficult and this could not have been done without the support of Harri Karhu, Prof. Markku Tukiainen, Olimex forum and Tommi Fredriksson and Viet Nguyen. I experienced a moment when I gave up hope of building a fully functional system, after which everything started to work better. For the rest of the time, I sat every night trying out the system and had already changed my traditional meditation to this after noticing its positive and deeply nurturing effect on my life, the improvement of my sleep and the possibilities it brought with it. I really felt that life was trying to cope without this aid when I had to take the system to the University for two weeks for exam sessions. During this time, I was able to take my yoga practice forward, while my time was spent moving and taking care of just running exams.

Here I thank Prof. Markku Tukiai for directing, Harri Karhua for making the device collar and other acquaintances who helped me with what I was doing. Especially my family members and acquaintances, who knew how to leave me alone and, on the other hand, motivate me well while doing this job. In addition, I also thank prof. Tobias Egner, who was still able to advise me a little more than 10 years after working with a/t neurofeedback.

I also thank all the literature and research that has been the basis for this work.

I also thank you www.freesample.org, and the artists there from a wide range of free audio sources that I utilized in the system. I also thank Bob Decker for the recording "Gamma Waves 40Hz-Monaural tones", which inspired me to make the gamma-monaural beat.

I thank all the free programs, tools and libraries and their previous work that made this system possible: Audacity, OpenEEG, Audiere, Allegro, FFTW, CodeBlocks and Boost.

I also thank the test subjects for their patient participation and constructive feedback and their help in verifying the functionality of the system significantly.

Thanks also to Michael Paul Coder, who is working on very interesting projects, looking for ways to increase clarity with, for example, MindWave and EEG-SMT devices http://lucidcode.com/

Thanks to Anton Tsypchenko for letting me publish a picture of the beginning of the session.

I tried to combine something with this thesis that could also help those working in the same area or beginners to easily find the most relevant issues and the previous research base related to them. I hope you can see in my thesis the inspiration that has driven me while doing this work. Enjoyable reading moments!

List of abbreviations

ACM	Association for Computing Machinery; a worldwide scientific association in the field of information technology
FFT	Fast Fourier Transform; converting the signal into spectral data, i.e. Fourier transformation
FFTW	Fastest Fourier Transform in the West; library to perform the Fourier transform
FFR	Frequency Following Response; a phenomenon when the brain's electrical activity begins to repeat or follow a desired frequency
BDNF	Brain-Derived Neurotrophic Factor; a protein involved in the growth of the nervous system
FMRI	Functional Magnetic Resonance Imaging; a method of imaging the brain
EEG	ANDlectroencephalography
PTSD	Post-traumatic stress disorder
PMS	Premenstrual syndrome

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Attachments

Appendix 1: Appendix of results (1 page)

1 Introduction

In this treatise, we create an overview of meditation in general and some methods for assisting it with technological means. At the beginning of the thesis, in the "Fundamentals of meditation" chapter, we go through the history of meditation and its various commonly known forms, on which it is possible to start building the development of meditation aids. In addition, we also create an overview of the health effects of meditation in general.

In the chapter Effects of meditation on the brain, we examine how meditation affects the mind and brain structures. In addition, we examine how the state of meditation appears in the brain and with what means it can be measured with the aim of mapping the interface for detecting the state of meditation.

In the chapter "Technological aids to change the state of consciousness", we look at different ways to try to change the state of consciousness or influence the electrical activity of the brain with external aids.

In the chapter "Building a system to assist meditation" we combine the issues of the previous chapters into a system that takes advantage of the parameters that define meditation and external means to guide the meditator. Thus, we assemble a system to assist meditation using a brain computer interface and examine its functionality in sessions performed on test subjects.

2 The basics of meditation

In order to be able to develop meditation tools, it is worth trying to study where meditation comes from and what is meant by the different general basic forms of meditation. This chapter describes the course of the history of meditation and the principles of meditation in a condensed form. In more detail, section 2.1 describes the origin of meditation, section 2.2 describes what meditation means in general, section 2.3 describes the practice of meditation briefly, section 2.4 describes Vipassana meditation and section 2.5 describes a little about the health effects of meditation.

2.1 Origins of Meditation

Today, meditation has become commonplace in such a way that people generally have some idea of what meditation is. While researching this topic, I discovered that many forms of modern meditation stem from the same source. Finding out the origin of meditation is important to be able to understand the essential core of meditation. Because the new meditation methods can be modified so far from the original context that their basic nature is not necessarily easy to understand. Here I describe a possible origin for meditation.

According to Prisco (2013), meditation has been practiced in different cultures and its origins can be traced back thousands of years. Meditation is very strongly connected to yoga and withto amanism. Because the earliest forms of meditation are believed to have been practiced within amanism and yoga. The word yoga is also known to have been used more than 3000 years ago withamong the amans regarding all types of healing. Among the forms of yoga, Kemetic yoga from the region of Egypt is estimated to be up to 10,000 years old. It was practiced by Nubians and Egyptians. According to Ankh (2011), the Kemet name means black land. Black land refers to the flooded muddy coast of the Nile. The trainees at that time called themselves "kemet" and the name Egyptians only came later.

According to Rauhala (1992), Indian randand yoga would have been born in the valley of the Indus River, where there was a high level of culture with water pipes and baths. The Vedas, which are religious-worldview hymns, also come from here. The oldest of them is the Rig-Veda, which is at least 3500 years old or even 4000 years old. It is considered the oldest written product of Indo-European culture. The Vedas also contain philosophical reflection, such as searching for alternatives to metaphysical problems, criticism and doubt. In other words, they contain genuine philosophical thinking that is foreign to purely religious attitudes. The Upanisads then developed on the basis of the Vedas. It is very difficult to estimate the exact moments of writing these. The Upanisads are even more distinctly philosophical musings, while the Vedas are the creations of poets like our Kalevala.

RandThe instructions for practicing yoga, such as the Yoga Sutras, were collected and organized in written form by Patanjali, who lived ca. 200-150 BC There is some uncertainty about this, too, because according to sources based on legends, Patanjali would have lived around 2000 BC. Of these works of Patanjali, specifically the first, Samadi-pada (*Samadhi-pada*), focuses on teaching meditation. In Samadi-pada, the transformation of consciousness and the whole person is systematically taught. Even when helping people suffering from mental disorders in Western countries, the central goal is precisely the development of a way of experiencing, which is essentially the same as Patanjali'sandin yoga.

It is also noteworthy, according to Counter (2010), that Patanjali was only interested in the meditative aspect of yoga and only three of his 195 sutras deal with asana practice (physical yoga practice). Thus, many modern forms of yoga, which include heavy asana practice, may have no connection with the original system described by Patanjali.

Although randA convincing scientific consensus has not been reached regarding the relation of yoga meditation to the Christian and Islamic meditation traditions, it is possible that they have received stimuli and influences from the Indian randand yoga for meditation. However, according to Rauhala (1992), the vast majority of profane meditation methods that have settled in Western countries are inherited through various stages from the Indian randand yoga. From India, yoga meditation has also

spread to other parts of the Far East, including Tibet, Korea, Thailand, China and Japan, where it is practiced especially under the influence of Zen Buddhism. However, it should be noted that the forms of Zen meditation differ somewhat from the original Indian randstopping.

2.2 What is meditation?

In this section, I will describe in more detail how, according to Patanjali, the core of meditation can be approached at the beginning of the practice, and roughly what samadhi, which is also associated with the ecstatic state of meditation, is.

According to Prisco (2013), according to the people who call themselves the people of Kemet, the purpose of yoga was to connect oneself with universal consciousness. In addition, Ankh (2011) describes the matter in such a way that man consists of a lower and a higher nature and these should be brought together. Thus, the word "yoga", to unite, is related to this. This goal is also described in Kemetic Yoga with the title "Nehast" or the awakened state. This means in Mystic World Fellowship (2000) according to Ledgerwood (1989) that a yogi is a person who consciously integrates body, mind, emotions and spirit so that they work well together. According to Mystic World Fellowship (2000), a yogi strives to open the gift of life and seeks to complete the possibilities it offers. A yogi strives to find a higher consciousness and how the body, mind and nature of feelings can be completed by connecting their purpose.

More detailed instructions have been described for reaching this goal, which can be found, for example, in rājayoga, where many of the current forms of meditation have their roots. According to Rauhala (1992), Patanjali says in the second sutra that rājayoga is about limiting or preventing the operations of consciousness, mainly the multiplicity of experience. Patanjali teaches the importance of correct posture and breathing. In addition, introversion, concentration, calmness, the use of mantras and other deepening are required.

According to Kishe (2002), Patanjali's sutra describes many different concepts such as the concept of true knowledge, false knowledge, imagination, dreams and

memory. Delusions are considered to distort the true nature of things. The process that summarizes yoga is described in Sanskrit: *"Yoga is the source of all the good things in life"* - This means that yoga (the union of the higher and the lower nature) is the gradual stopping (nirodhah) of the vrttis (mental patterns or variations of the mind) of the citta.

According to Rauhala (1992), meditation in the sense of Patanjali's Rājayoga is, in this initial phase, precisely the prevention of the multiplicity inherent in the occurrence of consciousness, i.e. 'emptying' it of all real content. Here, it is good to note that in some religious forms of meditation, instead, you may focus on a thought or idea from the beginning, i.e. on the reflection of the content.

According to Rauhala (1992), in the first stage of rājayoga meditation, the goal is to reach a state of consciousness where no specific content of experience is present. However, this state shaken by separate experiences is not the final goal, but a methodical intermediate step that is necessary for something else to happen. The stage after this state is followed by the teaching of the Samadhi-pada of the second sutra, where the aim is to achieve the state of samadhi. Patanajali distinguishes two stages in it: The first stage, where the pieces of the world are separate, and the second stage, which is referred to as samadhi, when the duality that maintains the separation of the categories of time and place disappears.

In one of these stages, thinking and cognition can only be spoken of in a remotely analogous sense. Thus, there is no longer any separation between the experienced and the experiencer. It cannot be said whether the content in question is in the experiencer's consciousness or whether his consciousness is that content. This state where the ego evaporates is what Patanjali calls purusa. This ecstatic state of consciousness is characterized by boundless happiness, ecstasy and bliss. The Samadhi state is also described in Roma's (2014) translation of Hatha Yoga Pradipika, IV, 5: "Just as salt, when mixed with water, becomes one with it, so the atma (Supreme Self) and the mind unite. This is called samadhi."

According to Roman (2014), the ageless wisdom tradition teaches that in order to enter the state of meditation one must follow these specific steps:

Dharana - mental concentration

Dhyana - meditation

Samadhi - blissful identification

It should also be noted that while there are many differences in many religious forms of meditation, some schools use these same steps. According to Roman (2014), in the Western tradition, such as in Orthodox Christianity, these three steps are called *consideration* (viewing), *contemplation* (contemplation) and *abducted* (rapture). Each step that is mastered leads naturally to the next step.

Although the work defined by Patanjali describes a philosophical system and special attention is paid to meditative exercises, it should also be noted that According to Kish (2002). Patanjali also defines an alternative means of attaining samadhi: ”*Īśvara-Praṇidhāna vā*”. Which means devotion or surrender (*Praṇidhāna*) to God (*Iśvara)*, where a person does not necessarily need to understand the philosophical side to achieve samadhi.

Many forms of meditation aim at the focus-practice meditation shown by Patanjali, but many forms of meditation Dunn & al. (1999), for example in Zen Buddhism and Theravadin Buddhism (Vipassana) additionally distinguish the so-called conscious presence (*mindfulness*) practice. Practicing conscious presence is considered an essential and important part of the development of comprehensive meditation, which I describe in section 2.4.

2.3 The practice of meditation

Regardless of the different theories and philosophies, the different forms of meditation often have a common way of being still in the actual practice at first. In addition, there are similarities in many aids. In this section, I will briefly describe the traditional procedures for meditation practice. I describe modern aids in more detail in chapter 4, which is one of the main goals of this thesis.

According to Rauhala (1992), when meditating, you usually sit either on the floor on a mat, so-called in a lotus position with legs crossed or on a chair with feet on the

ground. The most important thing is that the back is straight and the head is in a natural position as an extension of the body, with the gaze directed straight ahead. Correct breathing is very important. Great attention is paid to its teaching in all systems. You should close your eyes especially if there is a lot of light that cannot be removed. According to Rauhala (1992), good results can also be achieved in a lying position, which may be necessary due to illness, for example. It would be recommended to get guidance in the beginning, but it is not always possible when there is no teaching in every place.

Many forms of meditation use aids that facilitate concentration and calm the stream of consciousness. Such are, for example, tangible objects of observation, to which the eye is directed, such as mandalas. A mandala is usually a circle-shaped pattern that, through the mutual composition of various animal and human figures, symbolically represents the entirety of the universe. Also a candle, various symbols, such as a cross, a ball, geometric patterns, etc. can serve this purpose. Similarly, repetitive sound, music, observing one's own breathing or heartbeat, and tactile stimulation in the form of vibrations have proven to be useful in trying to cut off the stream of consciousness. Mantras are also one such tool. A mantra is usually a word or sound, for example "om". This can be repeated in the mind, recited quietly or loudly so that a vibration is felt in some part of the body.

Mantra is used in meditation throughout the East, such as China, Japan, Tibet and India. Sometimes mantras are associated with magical effects and, according to Indian meditation philosophy, are considered to have a connection with cosmic energy. However, the functions of the mantras remain partially hidden and unclear, and even the lamas of Tibet have not been able to fully explain them.

2.4 Vipassana

In this section, I will describe Vipassana meditation. It contains the generally well-known forms that are essential for meditation, i.e. meditations of concentration and conscious presence, which I will describe in more detail. Understanding these basics can be useful in expanding the understanding of meditation and the development of its aids.

According to Thatcher (2008), Vipassana can be expressed in the words "know thyself". Buddha once realized that suffering can be eliminated when we understand our own true nature. Thus, happiness is found within us rather than by modifying external things. However, we are changing beings after all. Vipassana offers a way to clear the mind of anxiety and suffering. The cause of suffering is often our habits. Thus, the idea is to remove our attachment and habituation to things. Once these are removed, cravings and delusions disappear. The ultimate idea of meditation is to be in the moment.

Miller (1993) and Thatcher (2008) says that Vipassana is more precisely divided into two main categories, which have been studied a lot. The first of these is concentration meditation (*samatha-bhavana*), where a person develops his concentration on an object. The second category is inward meditation, i.e. conscious presence (*vipassana bhavana*), where a person develops his awareness of his inner affairs. According to Miller (1993), a meditator often uses a combination of these during one meditation session or during practice. Vipassana Fellowship Ltd (2014) explains that vipassana meditation is like a tandem bicycle that works with these two meditations of concentration and presence in balance.

According to Vipassana Fellowship Ltd (2014), concentration meditation can be defined as meditation where the mind is focused on one object without interruption. The space is meant to be free of greed, anger and delusion. This is not about, for example, focusing on a feeling of anger that can harm others. The concentration considered in this context is free from corresponding contaminations. This state could be described with a magnifying glass analogue. Sunlight by itself does not burn the paper, but when a magnifying glass is brought in, the focal point of the light rays works more effectively for this purpose. The same goes for the mind in concentration exercises.

According to Miller (1993), in concentration meditation, the mind is taken to one object, such as the breath, a mantra, a prayer, the light of a candle or a visualized color. When the mind begins to wander, the mind is brought back to the intended destination. When the background noise of the mind eventually dissipates, a common experience is that the memories of the past and the pains associated with them rise

up. Sometimes the feeling can be so strong that it is difficult to return to the object of concentration.

According to Miller (1993), Goldstein & al. (1993) have noted that sometimes repressed trauma can be overwhelming for a novice meditator. According to Miller (1993), as the practice continues, the mind becomes stronger and this is usually followed by a state of peace, relaxation and calmness. According to Vipassana Fellowship Ltd (2014), concentration practice is usually practiced in a place with as little distraction as possible. For this reason, it is often practiced, for example, in monasteries.

According to Vipassana Fellowship Ltd (2014), concentration exercise in itself is not yet an effective enough means of treating the mind. Because great concentration is like a powerful tool, for example a knife. Depending on the person, the knife can be used in different ways: to harm others or to serve one's ego otherwise, or it can also be used as a tool for liberation. In order for the things observed in the depths of the mind, which concentration meditation brings out, to bring wisdom, the meditator needs to practice conscious presence.

Bærentsen et al. (2010) mentions that Kabat-Zinn (1994) describes conscious presence as a special orientation towards one's own experiences in this moment, characterized by curiosity, openness and acceptance. According to Vipassana Fellowship Ltd (2014), the practice of mindful presence cannot be done by coercion or force. When practiced violently, it interferes with development. Its skill grows with understanding and insight to just calm down and feel comfortable, no matter what it's experiencing. Of course, this does not mean that conscious presence happens by itself. The awareness skill of conscious presence is developed with gentle effort and effortless effort. It is developed simply by gently reminding oneself to keep one's awareness on what is happening. Persistence and a light touch are keywords or secrets. The skill of conscious presence is developed by taking yourself back again and again to gently become aware of what you experience.

According to Vipassana Fellowship Ltd (2014), mindful presence is in no way selfish. It gives you a mental step back from your own desires and dislikes, so you can see the true perspective of yourself: "Oh, I'm like that!". In the state of conscious

presence, you see yourself as you are. He sees his own selfish nature, his own suffering and sees how he hurts others. In this state, a person sees through the delusions of the mind and this leads to wisdom. Conscious presence is not the achievement of anything. It's just watching. Therefore, there is no craving or aversion involved. According to Miller (1993), Kabat-Zinn (1994) and Levine (1979) describe the practice of mindful presence as a non-judgmental awareness of the material. More about observing the processes of the mind rather than its content.

There is no room for competition and struggle in the process and it aims for nothing. We just see what is already there. During mindful presence, we see our greed, self-centeredness, lust, gluttony, and greed and accept ourselves as such. Because normally we don't want to accept, we want to change, deny or justify. Conscious presence is patient acceptance. According to Miller (1993), Krishnamurti (1973) describes the awareness of conscious presence as the awareness of not making a choice. According to Miller (1993), Thera (1962) describes that this aspect is very comprehensively described in Buddhist literature.

According to Miller (1993), as the meditator's conscious presence deepens, he is freed from reflexive and habitual thoughts and behavior, which usually blur the experience of the moment. This increased direct contact with the present moment tends to reduce stress, fear, anxiety, and discomfort, as these states of mind are usually associated with past experiences that distort the reality of the present moment. According to Thatcher (2008), it is also important to let go of names and memories. There is no need to be afraid that anything will disappear, they will come back. Clinging to the past causes suffering in the present, whether the memory is good or bad.

Of course, mindful presence cannot be fully controlled and practiced at every moment. We have to do everyday things, make plans, use language and think about abstract things. But we can always reserve a certain time or hour of the day when we develop the skill of conscious presence and let go of concepts, thoughts and mental models. When you start seeing things systematically differently, the phenomenon is like looking at a mirror image of what you saw before. Old beliefs may turn out to be only momentary. What we thought we were is just an impersonal component. From

here on, we begin to see things more as they are (*ultimate reality*). This happens with a clear understanding of things and thus we can let go of our attachments and become free from suffering. According to Miller (1993), as the skill of mindful presence develops, the meditator is better equipped to deal with increasingly difficult materials calmly and calmly. In the same way that material suppressed during psychotherapy continues to rise into consciousness.

Vipassana therefore consists of two different forms of meditation: concentration meditation and conscious presence meditation. Concentration holds the object firmly in place and conscious presence brings wisdom to what is being looked at. Thus, according to Vipassana Fellowship Ltd (2014), concentration is like a laser, which goes deep, but does not understand what it sees. Present awareness notices self-centered actions and understands what it sees. Conscious presence solves the mystery and discomfort of suffering. Thus, mindful presence liberates. Of these, it would be good for the person to practice concentration meditation more at first. However, later on, it would be good to practice mindful presence more than concentration meditation. But practicing too much mindful presence brings out an overly sensitive state, which Vipassana Fellowship Ltd (2014) describes as similar to the effect of LSD. On the other hand, practicing too much concentration meditation makes a person calm as a stone.

2.5 Health effects of meditation

In this section, I will briefly describe the physical health effects that meditation is said to bring. In more detail about the health effects, I have reserved a separate section 3.1.

According to Miller (1993), Murphy and Donovan (1988) have shown that concentration meditation brings with it physiological changes such as reduced heart rate, blood pressure, breathing rate and muscle tension. Davidson et al. (2003) has also noticed that as a result of meditating for eight weeks, it has been possible to observe that the concentration of antibodies to influenza increased significantly compared to those who did not meditate.

Because meditation affects the mind, it indirectly affects the health of the body. For example, Moss et al. (2012) has noticed that in elderly people with dementia, 12 minutes of daily meditation during eight weeks has had positive results on mood, anxiety and other neuropsychological variables. Anxiety has also been found to be associated with heart disease Kubzansky and Kawachi (2000). Thus, it is good to note that meditation can indirectly prevent the onset of heart disease by alleviating anxiety, as noted by Tacon et al. (2002) and Davidson et al. (2003). In general, the quality of life can also improve with meditation. Kavita et al. (2011) study showed that 15 minutes once or twice daily is a feasible time for meditation. This four-week study showed improvement in stress, anxiety and quality of life. The levels of different hormones in the body can also become more favorable. For example, Cahn and Polich (2006) noticed an increase in melatonin as a result of meditation.

3 Effects of meditation on the brain

This chapter is devoted to describing the manifestation of meditation in the brain. Section 3.1 describes the effect of meditation on the mind in general, section 3.2 describes how meditation can be seen in the brain with functional magnetic resonance imaging, and section 3.3 describes how the electroencephalogram and meditation are related.

3.1 Meditation's Effect on the Mind

One motivating factor for starting and continuing meditating is the mental health benefits it brings. In this section, I present the effects of meditation practice on the mind.

According to Josefsson (2011), mindful presence meditation has numerous physiological health effects as well as an effect that promotes psychological well-being. According to Cahn and Polich (2006), the psychological effects of meditation can be divided into two categories: those caused by the meditation state (*state*) and long-term effects (*features*).

According to Cahn and Polich (2006), meditative states and religious traditions have been reported to contain a deep sense of peace, a quieting or stopping of the inner dialogue of the mind, a clarification of the senses, a merging of conscious perception with the object of meditation, regardless of whether the object of meditation was a mantra, an image or a manifestation of the experience itself.

Longer-term effects brought about by meditation practice can be considered to include an overall deepened sense of calm, increased well-being, intensified awareness of sensations and a changed relationship with thoughts, feelings and the self (*self*) to experience.

Since meditation has a strong effect on the mind, it is also very natural that it has a lot of potential in the treatment of mental illnesses. According to Ivanovski & Malhi (2007), therapeutic methods practicing conscious presence seem to be effective for

treating depression, anxiety, psychosis, unstable personality and suicidal behavior. Barnhofer et al. (2007) has found that those who practiced mindfulness meditation during eight weeks had significantly more balanced brain functionality related to emotions. Thus, it helps individuals who have a high risk of suicide during depression. In addition, Ivanovski and Malhi (2007) mention that mindfulness meditation has also been found to be an effective tool to reduce substance abuse.

Other experiments also confirm similar results. For example, Zeidan & al. (2013) have found that mindfulness meditation increases the positivity of the mind. Similarly, Jain & al. (2007) found that when subjects who practiced relaxation were compared to those who practiced mindfulness meditation, the meditators had more positive states of mind than those who only practiced relaxation. In the experiment, it was also noticed that the number of disturbing thoughts and clinging to negative thoughts decreased more in those who meditated.

Not only does meditation have a mood-lifting effect, according to Wisner (2013), it also has effects that improve cognition in other ways, such as improving concentration and memory. Wisner (2013) had conducted an experiment for high school students (N=35, boys 19, girls 15), where students practicing mindfulness meditation showed improved stress management, increased self-awareness, increased processing of emotions, increased ability to concentrate and better mood.

Conscious presence meditation also has other effects, among which Zeidan & al (2010) have noticed that, in inexperienced meditators, practicing conscious presence for four days has caused reduced fatigue, reduced anxiety and increased awareness. In addition, mindfulness meditation has been found to significantly increase visual perception ability, working memory and functions related to the frontal lobe (*executive function*).

3.2 Meditation Reflected in the Brain

During the meditation state, differences can be noticed in the state of the brain compared to the state of normal consciousness. Likewise, meditation also leaves its

mark on the brain as a result of long practice. I will describe these changes in the structures of the brain in more detail in this section.

According to Cahn and Polich (2006), a broad and comprehensive account of the neurophysiology of meditation is still unrealistic, because measurable phenomena and mechanisms occurring in the brain as a result of many different forms of meditation have not yet been clarified. Bærentsen et al. (2010), however, classical texts on meditation are somewhat in line with modern understanding when trying to understand brain processes and consciousness. These theories consider consciousness and higher mental processes to be the product of the cooperation of many different brain regions. In this chapter, I go through how meditating affects the brain indirectly through body functions. In addition, I also describe in more detail what has been found out by studying the activation of the brain during meditation, as well as how longer lasting meditation is reflected in the structure of the brain.

According to Xiong and Doraiswamy (2009), the mechanism of meditation affecting the brain can also be viewed through body functions. One of the many effects of meditation is preserving cognitive functions and preventing dementia. Although this mechanism is not yet fully understood, it is possible that meditation can affect brain aging and mental alertness through many other factors. For example, meditation can reduce stress-induced cortisol secretion and thus have a neuron-protective effect by increasing the brain's neuroprotective and growth-accelerating protein (*BDNF)* quantity. On the other hand, meditation may also have a potentially beneficial effect on lipid profiles, reducing oxidative stress. On the other hand, this can reduce diseases related to blood circulation in the brain, as well as the degeneration of the nervous system of the brain.

In addition to the indirect effect, it is now possible to examine the effects brought by the meditation state as well as the longer-lasting effects in more detail with, for example, functional magnetic resonance imaging (*fMRI*). Ilves-Deliperi (2010) has found, when examining with functional magnetic resonance imaging, that the blood circulation of the brain decreases in many areas of the brain when meditating. More specifically, these areas have been the midline cortical structures. According to Northoff and Bermpohl (2004), these areas are associated with a person's developed

self-image or self-experience (*self*). Ilves-Deliperi (2010) noticed even more precisely that reduced activity in the midline cortex occurred in the following areas:

> *Cerebral insula, inner part of the frontal lobe (Bilateral anterior insula)*
> *Left ventral anterior cingulate cortex*
> *Right medial prefrontal cortex*
> *The area between the top of the head and the occiput in the brain (Bilateral precuneus)*

By way of exception on the latter inner part of the brain on the right side *(Right posterior cingulate cortex)* there was an increase in activity. These areas are illustrated in Figure 1.

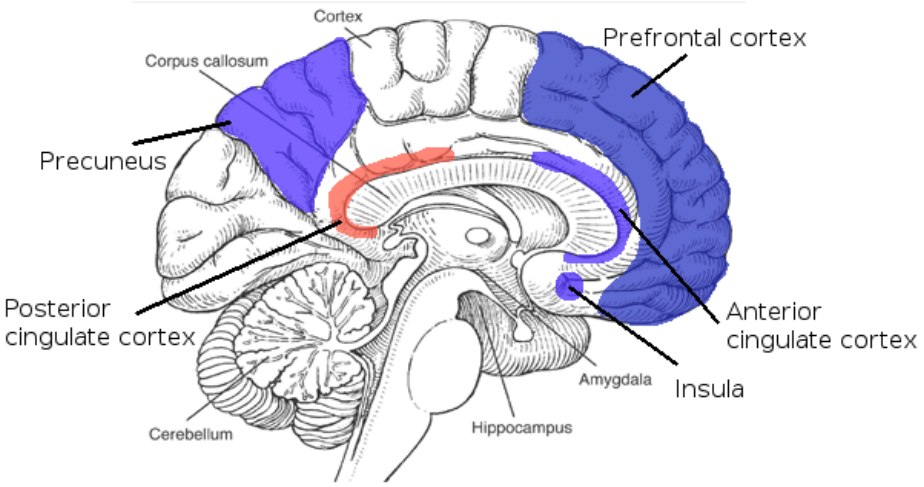

Figure 1. Image of activation of brain areas (red) and reduction of activity (blue) during meditation. (*Tapert et al., 2004/2005 according to Sanio, 2014*).

According to Ilves-Deliperi (2010), these areas of the brain are closely connected to a person's thoughts about himself, and it is indeed possible that a less subjective experience of the moment, i.e. bare attentiveness, follows from the meditation of conscious presence. However, it was notable in this experiment that it did not include a control group that would have, for example, been at rest for a specified period of time.

Farb et al. (2012), an important component in the effects of mindfulness meditation is the improved ability to observe the internal functions of the body. People are able

to examine the internal functions of the body more sensitively with the practice of mindfulness meditation. Farb et al. (2012) included a control group and another group that had just graduated from the mindfulness stress reduction course. Their condition was investigated using functional magnetic resonance imaging. The results of the experiment showed that those who practiced mindfulness meditation had less activation in the frontal cortex (DMPFC, *dorsomedial prefrontal cortex*). Waytz et al. (2012), this brain region has also been found to be associated with altruistic behavior and social cognitive functions.

In addition, Farb & al. (2012) experiment found that the cortex of the frontal lobe of the brain formed an altered connection with the posterior part of the insula (p*the eastern island*) as well as to the hypothesized primary interrupting cortex (*putative primary interceptive cortex*). It is precisely this altered function and connection that is thought to play a decisive role in the rise of the body's internal sensations to be felt during the meditation of conscious presence. This finding is also supported by Raffone et al. (2007) conducted a study with Buddhist monks, where they noticed a decrease in activation in the posterior part of the frontal part of the brain during mindful presence meditation, but an increase in activity, especially in the left frontal part of the brain. Figure 2 shows this point. This area on the left side of the front of the brain is connected to sensing the mental and sensory content arising from the present moment.

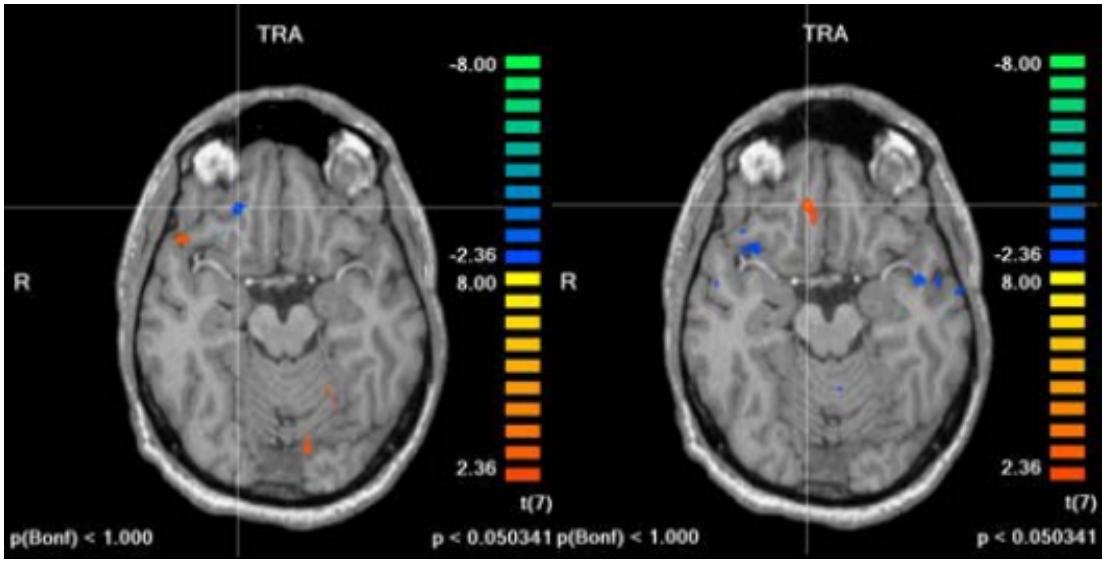

Figure 2. Image of brain activation during different forms of meditation. Concentration meditation on the left and mindfulness meditation on the right. (Raffone et al., 2007).

Differences in brain activity can be observed in different forms of meditation practice. Raffone et al. (2007) in a study found that one who practices concentration meditation can be distinguished from one who practices mindfulness meditation during meditation by observing with functional magnetic resonance imaging. This is also shown in figure 2. The activation of the cortex of the left frontal lobe alone can indicate positive feelings, not judgmental acceptance, which can well be described as a state of conscious presence. Instead, the decrease in activation found in the frontal lobe of the brain in the transverse line during mindfulness meditation would suggest that it is related to a non-selective open acceptance of emerging mental content. This is perhaps because the area is associated with making choices, rewards and values.

The mechanisms that take place in the brain during meditation can therefore be observed based on the activation of different areas. One good method in addition to this is also to study the structural changes of the brain, which is usually used to refer to the plasticity of the brain: its ability to always be molded. Fletcher et al. (2010), the plasticity of the brain is a phenomenon that has only been accepted in recent decades, and recent studies show that, for example, changes occur in the structure of the brain as a result of meditation. This is explained in more detail by Fayed et al. (2013), according to which people who meditate show more gray or white matter in some parts of the brain than people who don't meditate. One of these areas is, for example, the hippocampus, the change of which has been observed with up to eight weeks of meditation practice. This is also well supported by Fletcher et al. (2010) finding that the hippocampus is activated during actual meditation.

Fayed et al. (2013), according to the number of hours spent on meditation practice, usually correlates, for example, with*medial prefrontal cortex*) to the amount of gray matter in the area dealing with emotions, decision-making and risk and fear. Similarly, increased gray matter has been found in the area of the frontal insula and in the right amygdala in people who have recently practiced meditation. This same observation for these two regions had also been made by Murakami et al. (2012).

Murakami et al. (2012) according to Craig AD (2009) says that the right anterior cerebral insula deals with a person's internal sensations about the body and the perception of sensations. Murakami et al. (2012) according to Larsen et al. (2003)

mentions that the activity of this brain region is highly reflective of conscious presence. As Farb & al. (2012) also states that an essential part of mindful presence meditation is increased observation of internal body sensations and events with practice. In addition, Murakami et al. (2012), an increased volume of the right anterior insula may indicate increased awareness of a person's own emotional and stress states and give them cognitive control over their emotions.

In addition to changes in the frontal insula, significant growth occurs in the amygdala in individuals who practice mindfulness meditation. Murakami et al. (2012) according to Gianaros et al. (2008) mentions that the volume of the amygdala is negatively related to its activity and a person's blood pressure in a stress test. In other words, a larger amygdala size in an individual may mean less amygdala activation and thus lower blood pressure. Murakami et al. (2012) according to Hariri et al. (2003) and Thayer et al. (2007) findings suggest that almond kernels are chemically restrained by gamma-aminobutyric acid (*gamma-aminobutyric acid-ergic*). This gamma-aminobutyric acid is secreted from the frontal cortex (*prefrontal cortex*). From this, Murakami et al. (2012) mentions that Rosenkranz (2001) found in animal experiments that the amygdala thus receives inhibitory control from the frontal cortex. The amygdala and the right frontal insula are thus thought to be a somatic circuit. Murakami et al. (2012) according to Naqvi et al. (2006) describes the amygdala as a trigger for emotional states and body sensations, which reacts to the influence of the environment. On the other hand, the anterior cerebral insula on the right side provides a map of the space of the entire body and sensations and gives a sense of intuition.

3.3 What EEG Studies Have Revealed About Meditation

According to Wikipedia (2013a), EEG (*electroencephalography*) is a method for measuring electrical phenomena in the brain.

Why EEG is a good way to observe meditation is because the electrical activity of the brain tells a lot about the state of a person's mind. From the raw data, the intensities of different frequency ranges, i.e. the frequency distribution, can be broken down, for example, with a fast Fourier transformation (*FFT*). These

intensities of different frequency ranges reflect, among other things, the occurrence of different states of mind, which is shown in table 1.

The frequency range of brain waves	Connectable space
Delta range (1-4 Hz)	Deep sleep
Theta-alue (4-8 Hz)	Light sleep, creativity, insight
Alfa-alue (8-12 Hz)	A calm but alert state
Beta-alue (13-21 Hz)	Thinking, a focused state
High beta frequencies (20-32 Hz)	Agitation or restlessness

Table 1. Description of the different frequency ranges of the brain and the states of mind or functions usually associated with them. (Zaini et al., 2011 adapted from Sanio, 2014)

Raffone Antonino and Srinivasan Narayanan (2010) found that many experiments where EEG has been measured during meditation have produced very similar results. Wang et al. (2011), in addition to an increase in the theta and alpha frequency ranges, an overall decrease in other frequencies is usually noticed. Attached are pictures 3 and 4, which reflect what the image of the strength of the frequency areas of the EEG curve can look like during meditation in inexperienced and experienced meditators.

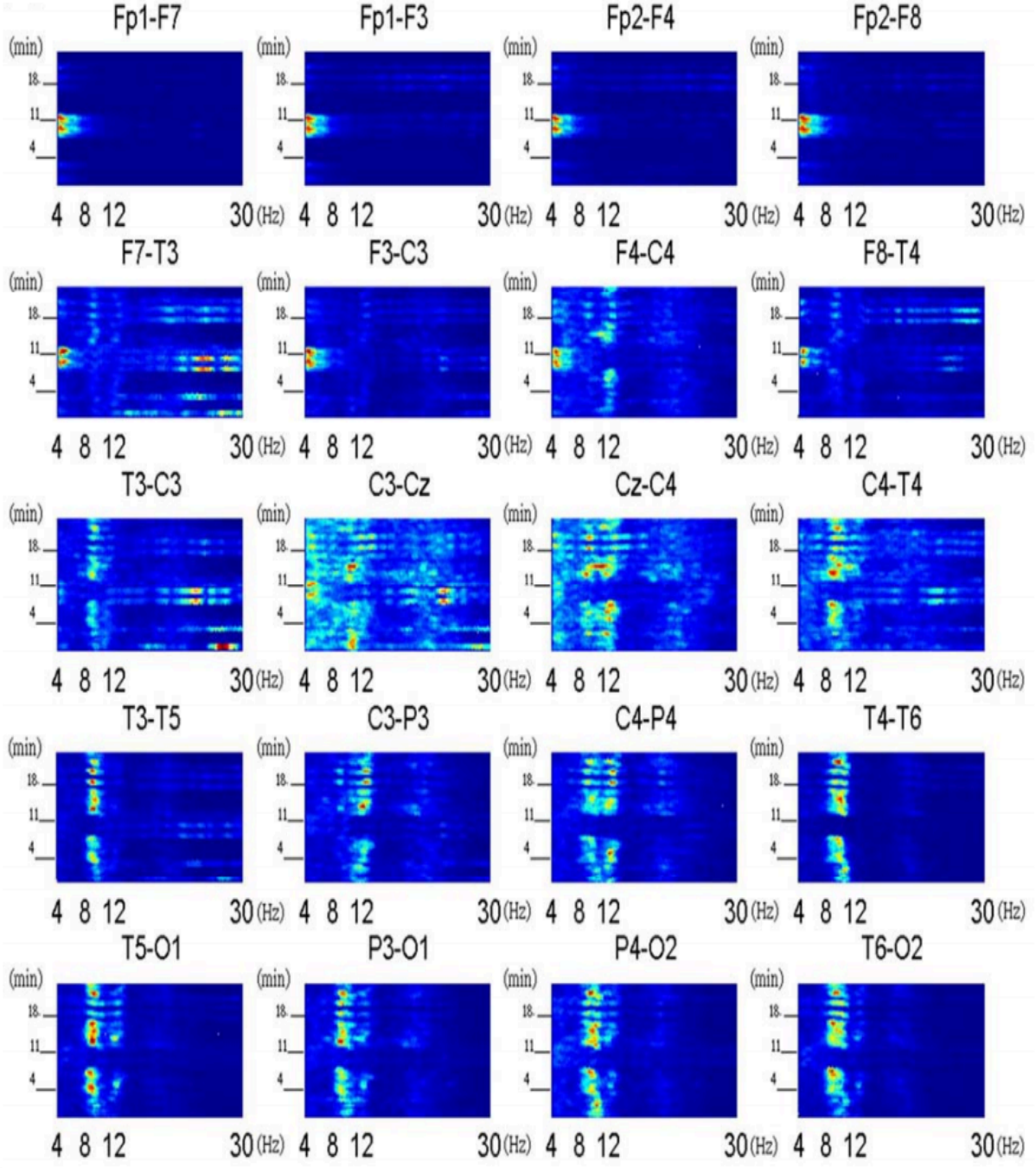

Figure 3. Image of the EEG spectrum of inexperienced meditators from different points on the scalp (Wang et al., 2011)

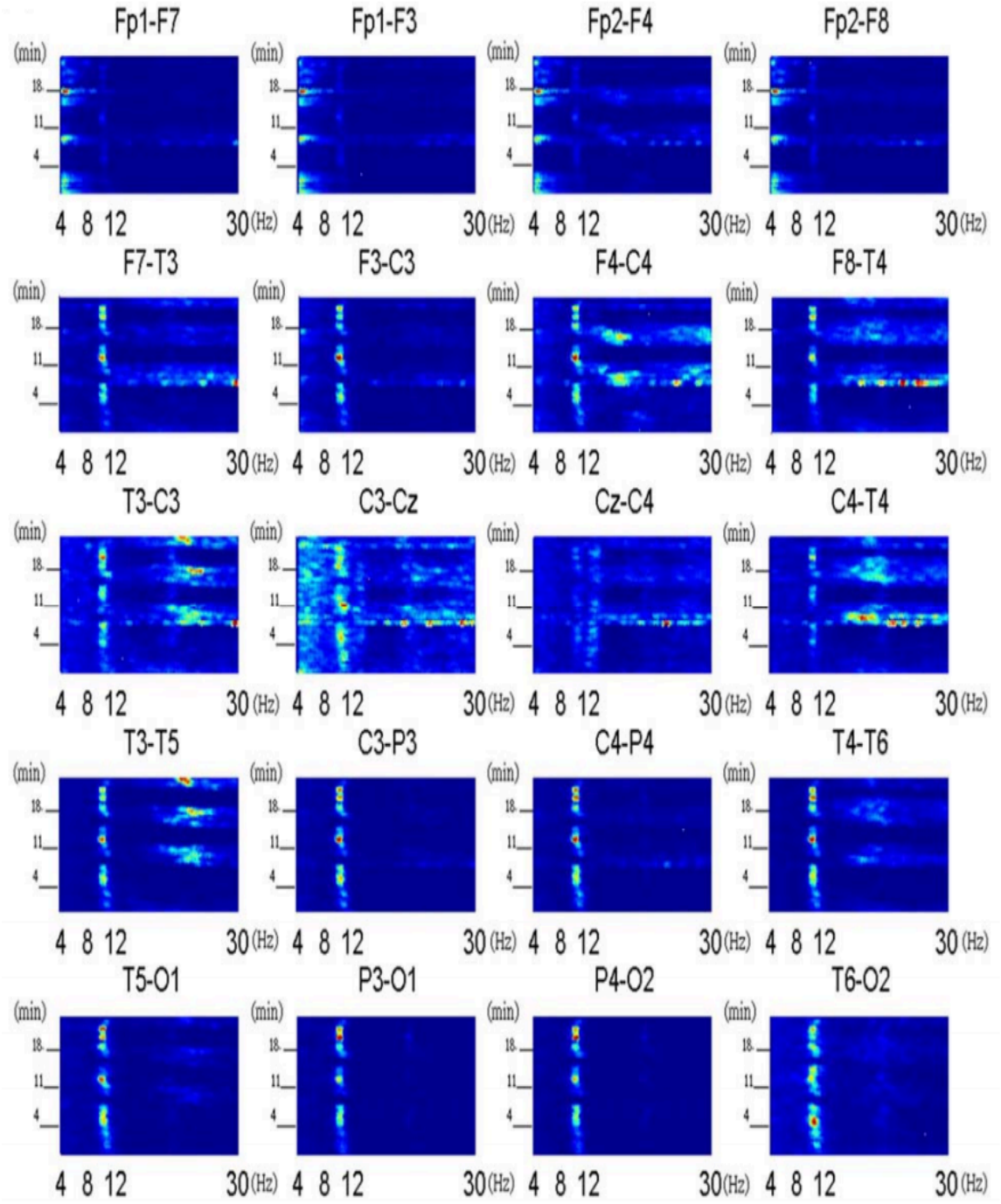

Figure 4. Image of the EEG spectrum of experienced meditators from different points on the scalp (Wang et al., 2011)

Zaini et al. (2011) states that Lutz et al. (2006), the effectiveness of meditation is also thought to have something to do with the synchronization of the cerebral hemispheres. On the other hand, during meditation, a greater activity of the other half is also observed. As we already stated earlier Raffone et al. (2007) have noticed that

functional magnetic resonance imaging has also shown more activation of the left side, and the same is supported by the results obtained with the help of EEG. A greater activation of the left hemisphere, which according to Keith and Cimino (2008) is associated with the processing of positive emotions, can also indicate a positive state of mind during meditation.

Just as we noticed earlier that with functional magnetic resonance imaging it may be possible to distinguish the form of meditation practiced based on images obtained from the brains of two different meditators, EEG can also be used to observe the differences between different forms of meditation. For example, Dunn et al. (1999) have found that mindfulness meditation produces more delta, theta, alpha and beta1 activity than concentration meditation.

In this section, I will highlight what observations have been made in more detail regarding the strengths of different frequency ranges and meditating. In more detail, the subsections examine the following. Subsection 3.3.1 examines delta waves, subsection 3.3.2 examines theta waves, subsection 3.3.3 examines alpha waves, subsection 3.3.4 examines beta waves, and subsection 3.3.5 examines gamma waves.

3.3.1 Delta waves

Delta waves usually occur more during deep sleep than when awake. Regarding meditation, among others, Cahn et al. (2010) have found that delta waves (1-4Hz) are reduced during meditation in the frontal part of the brain. This phenomenon occurred especially in those subjects who did not report fatigue. Similarly, Dunn et al. (1999) have found decreased amplitude of delta waves during meditation.

3.3.2 Theta waves

Amplification of theta waves is a very common finding in the EEG spectrum measured during meditation. This has been found in their studies by, among others, Lagopoulos et al. (2009), Rael and Polich (2006), Cahn et al. (2010), Raffone and Srinivasan (2010) and Cahn and Polich (2006) cite numerous sources where an increase in theta waves during meditation has been observed.

On the other hand, the strength of theta waves also seems to vary and focus on certain points. Lagopoulos et al. (2009), theta waves were measurable on all sides of the scalp, but most strongly in the middle part of the brain (*temporal-central regions*) and from the front of the head (*frontal regions*). An increase in theta wave strength measured from the frontal side of the brain has also been mentioned by Cahn et al. (2010) and Raffone and Srinivasan (2010) according to Baijal and Srinivasan (2010) and Cahn et al. (2006) also cite several sources for the increase in theta wave power measured from the anterior midline of the brain. For example, according to Raffone and Srinivasan (2010), Baijal and Srinivasan (2010) had noticed this increase in intensity during the middle phase of concentration meditation. Instead, exceptionally, they had measured the strength of theta waves that descended from the scalp.

According to Cahn and Polich (2006), the intensification of theta waves depends on the form of meditation and the skills of the practitioner. In particular, Cahn and Polich (2006) mentions that Kasamatsu and Hirai (1966) noticed that in the case of Zen meditation, only more advanced meditators showed an intensification of theta waves. Similarly, the chosen meditation technique affects the measured values. According to Cahn and Polich (2006), Dunn et al. (1999) had found that mindfulness meditation produces more theta waves than concentration meditation. Here, however, it was noticed that the resting group had the highest theta wave intensity, which was thought to be due to drowsiness.

Cahn and Polich (2006) also mention that Gevins et al. (1997) and Mizuki et al. (1980) describe the activation of theta waves as related to tasks requiring concentration. In addition, according to Cahn and Polich (2006), Inanaga (1998) would have found individuals with more theta waves to have less immediate and longer-term anxiety. In addition Hebert et al. (2005), Aftanas and Golocheikine (2001) have found theta waves to be connected to positive feelings.

As one explanation for the increase in theta waves, Cahn and Polich (2006) tells Elson et al. (1977), the location of the meditation state between the waking state and the dream state. For this reason, meditation is similar to sleep stage I, where the theta waves are high in intensity, as is also the case with experienced meditators when meditating. However, different features have been observed between the meditation

state and the actual sleep stage I, of which, for example, according to Cahn and Polich (2006), Lou et al. (1999) had found that in meditation, in addition to the intensification of theta waves, the strength of alpha waves increases by about 50%. Similarly, during sleep stage I, Cahn and Polich (2006) reports that Rechtschaffen and Kales (1968) found a 50% decrease in the strength of alpha waves.

3.3.3 Alpha waves

In addition to the increase in theta waves, Cahn and Polich (2006) and Wang et al. (2011), the strengthening of alpha waves, which also distinguishes the meditation state from sleep stage I, as we stated at the end of the previous paragraph. However, it should be noted here that the intensification of alpha waves depends on the form of meditation and the skills of the practitioner. Not all forms of meditation cause an increase in alpha waves. For example, according to Cahn and Polich (2006), Corby et al. (1978), Hebert and Lehmann (1977), Jacobs and Lubar (1989), Lehrer et al. (1980), Lehrer et al. (1983), Lou et al. (1999), Pagano and Warrenburg (1983), Tebecis (1975) and Travis and Wallace (1999) have found that TM- (*Transcendental Meditation*) and in yoga meditations the increase in alpha waves is absent or even reduced. However, this too has different results. For example, according to Raffone and Srinivasa (2010), TM is very similar to concentration meditation, where a mantra is given on what to focus on. Furthermore, here according to them, Travis et al. (2010) found an enhancement of alpha waves in the frontal lobe of the brain. Particularly high intensities of alpha waves have been observed in kundalini yoga practitioners, according to Cahn and Polich (2006), Arambula et al. (2001) would have found up to a fivefold increase in strength compared to baseline.

Lagopoulos et al. (2009) had found in their experiment that meditating alpha waves were stronger in the back of the brain (*posterior regions*) than in the front parts (*prefrontal and frontal lobes*). Likewise also Want eg al. (2011) found that alpha waves occurred in meditating subjects only in the back of the head and not in the front. The length of the session can also affect how alpha waves appear. Tsai et al. (2013) have also noticed that alpha1 waves are positively associated with concentration and brain metabolic rate. Instead, they found that the strength of occipital alpha2 waves is negatively associated with the aforementioned phenomena.

The alpha1 frequency range is 8–10 Hz and more precisely the alpha2 frequency range is 10–12 Hz.

Tsai et al. (2013) also noticed in relation to meditation that alpha waves become stronger only when the meditation deepens. According to them, for example, the strength of the theta waves increases continuously, but the strength of the alpha waves only when the person is relaxed and the meditation reaches a so-called deeper stage. Cahn et al. (2006), according to Aftanas and Golocheikine (2001), Benson et al. (1990), Drennen and O'Reilly (1986), Hebert and Lehmann (1977), Jacobs et al. (1996), Kwon et al. (1996), Pagano and Warrenburg (1983), Schuman (1980) and Travis and Wallace (1999) have noticed that as a result of practicing meditation, the strengthening of alpha waves is also visible outside the sessions, which is the effect brought by the long-term practice of meditation (*trait effect*). However, it should be noted here that this effect is only observed if the exercise has been continued according to the instructions.

3.3.4 Beta waves

According to Cahn and Polich (2006), Jacobs et al. (1996) had found a reduced strength of beta waves in the frontal part of the brain in those doing mantra-based exercise. More specifically, according to Cahn and Polich (2006), Anand et al. (1961), Banquet (1973), Das and Gastaut (1955), Elson (1979), Elson et al. (1977) and Lo et al. (2003) have found that alpha waves desynchronized and high beta waves (beta2) increased. On the other hand, according to Raffone and Srinivasan (2010), Baijal and Srinivasan (2010) had found reduced beta1 area strengths in the frontal lobe of the brain in meditators. According to Wikipedia (2014a), the beta1 range is 12.5-16 Hz, the beta range is 16.5-20 Hz and the beta2 range is 20.5-28 Hz.

3.3.5 Gamma waves

According to Raffone and Srinivasan (2010), Baijal and Srinivasan (2010) had found reduced gamma wave intensity in the frontal lobe of the brain during meditation. Instead, Cahn et al. (2010) had also noticed increased gamma waves in the temporal lobe and occipital lobe during meditation. In this case, this increase in gamma waves (35–45 Hz) was most clearly seen after more than ten years of meditation.

According to Cahn and Polich (2006), Lutz et al. (2004) and Lutz et al. (2003) state that gamma waves (40Hz) have been found in large amounts compared to meditation and normal rest. This observation has been made in both Tibetan Buddhist meditators and novices who have only been practicing meditation for a week.

According to Cahn and Polich (2006), increased gamma waves have been more precisely found to be associated with a certain area of the brain during so-called "self-dissolution" meditation. This area is the right frontal cortex (*right superior frontal gyrus*), which is related to the transformed state of oneself. Depersonalization, cognitive detachment from the suffering created by the disease, and the effect of cannabinoids are also associated with this area.

Rubik (2011) has also conducted an experiment where it was noticed that people associate the strengthening of gamma waves (40Hz) in the frontal cortex with spiritual experiences and various positive feelings such as joy, love and gratitude. Figure 5 shows these findings.

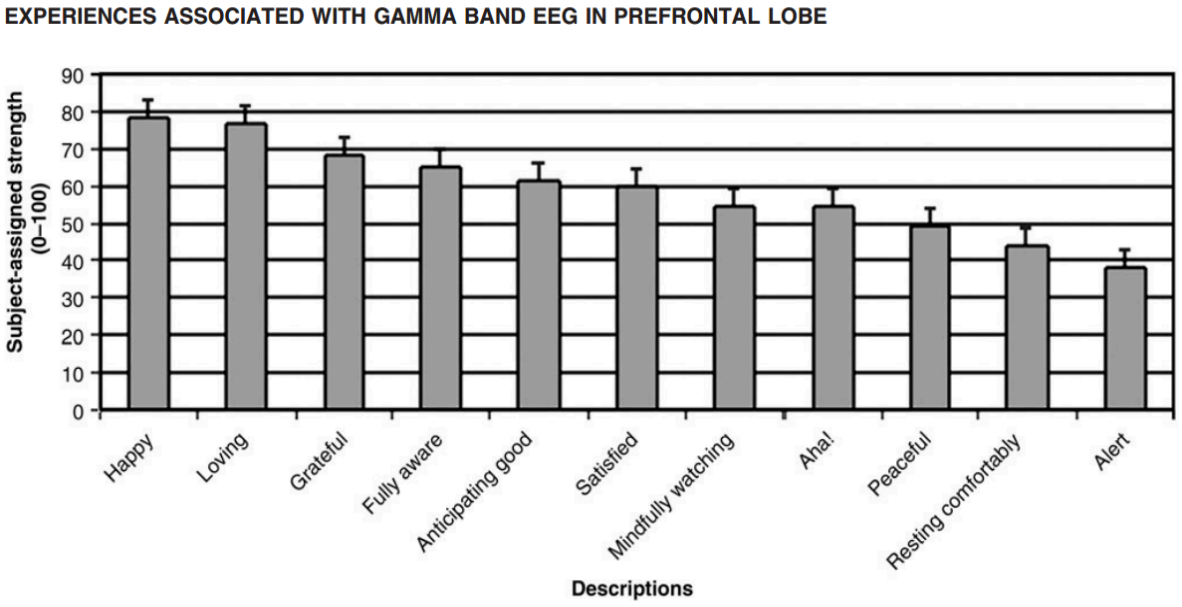

Figure 5. Combining different descriptions of gamma wave intensification (Rubik, 2011)

4 Technological Tools for Altered States of Consciousness

Pickert (2014), who had participated in Kabat-Zinn's mindful stress management program (MBSR), says that technology has made it easy for modern people to break their focus into smaller and smaller chunks. In this way, a person imagines that he increases efficiency by dividing his focus on several things at the same time. For example, a person can pay bills and watch TV at the same time or order groceries while driving. According to Pickert (2014), such behavior can lead to overall less productivity.

According to Pickert (2014), Steve Jobs would have said that his meditation practice helped him focus on his work and push away distractions. Steve Jobs is one of the people responsible for the success of the iPad app market. Although many computer programs can be disruptive, according to Pickert (2014) there are also programs that are actually intended to assist meditation. There are hundreds of training programs for mindfulness and other forms of meditation, one example of which is Headspace. According to Pickert (2014), the developer of Headspace was a former Buddhist monk, Andy Puddicombe. Andy Puddicombe offers the program for free, but offers paid video series sold as a "gym card for the mind".

It is difficult to make a comprehensive report about all these different programs and aids that can be connected to the computer for meditation practice, because many tools are an area that has not been studied either. On the other hand, the area is also very wide. There are many programs that function, for example, as meditation timers, calendars, sound environments or, for example, spoken recordings, or try to change the electrical activity of the brain using some method. All of these have some principle of how they should support meditation. In this chapter, I have categorized various techniques and provided more detailed information about them.

Section 4.1 describes very briefly the tools that guide meditation, section 4.2 describes brainwave entrainment and its subsections in more detail about its different forms, section 4.3 describes transcranial magnetic stimulation and section 4.4

describes biofeedback, and subsections of section 4.4 describe biofeedback from the two monitored organs, lungs and brain.

4.1 Tools That Guide Meditation

Tools that guide meditation are, for example, calendars that schedule meditation, which also record the length of meditation sessions. The programs can also act as timers and make an alarm sound when the session is over. The programs can also contain guided meditations suitable for different situations with a recorded voice. According to Buddhify (2014), one such program is, for example, Buddhify.

On the other hand, sometimes the program can be intended to guide some technique, such as breathing control. Such a program is, for example, Pranayama Free according to Pranayama (2014), which is shown in figure 6.

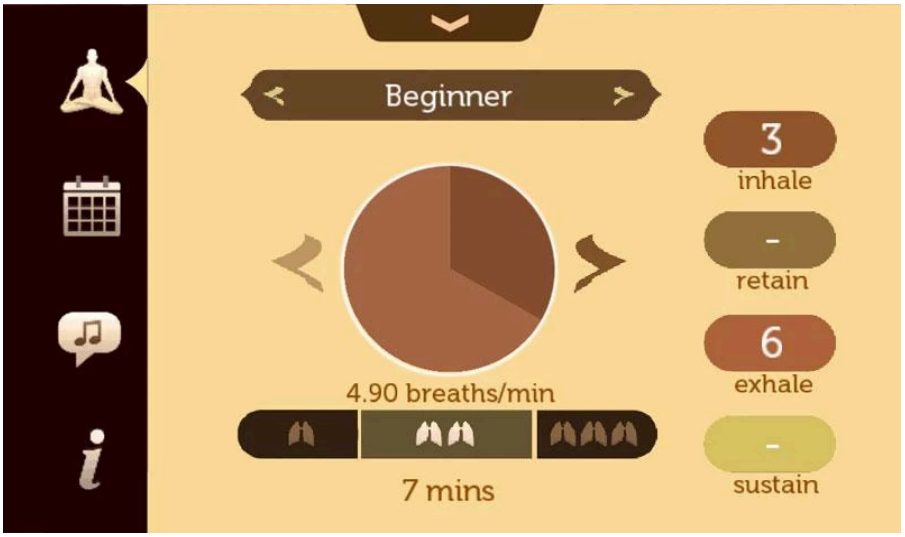

Figure 6. Screenshot of the Pranayama Free program that practices breathing carefully (Pranayama, 2014)

Many programs would fit into this category, but since this is not the main topic of this thesis, I will not continue their review here.

4.2 Brainwave entrainment

Huang and Charyton (2008) defines that brainwave entrainment refers to rhythmic stimulation, the purpose of which is to make the brain repeat or follow the frequency

(FFR) chosen as the stimulus. The stimulus is usually either a visual source, a sound source or even both (AVS i.e. audiovisual, which also goes by the name mindmachine). the industry also uses the names "brain entrainment", "audiovisual entrainment (AVE)", "audiovisual stimulation (AVS)", "auditory entrainment" or "photic stimulation".

Huang and Charyton (2008) have made a comprehensive report about different forms of brainwave entrainment and related experiments. As a solution, they discovered that brainwave entrainment is a functional therapy tool. People with cognitive deficits, pain, headaches, migraines, PMS or behavioral problems have found relief in their symptoms from brainwave entrainment. However, more controlled studies would be needed. In this section, I will describe the different forms of brainwave entrainment and the results of research conducted on them. Subsection 4.2.1 tells about visual stimulation, subsection 4.2.2 tells about sound-based stimulation and subsection 4.2.3 tells about combinations of these.

4.2.1 Visual stimulation

According to Huang and Charyto (2008), visual stimulation (*photic stimulation*) are the first forms of brainwave entrainment to be discovered. This discovery was made by Pierre Janet, a French psychologist in the late 19th century. Janet found that her patients were calmer when they were exposed to a device made of a flickering oil lamp. He used this method as a form of therapy whenever necessary.

According to Huang and Charyto (2008), nowadays visual stimulation is often created with, for example, glasses where there is a flashing light. The person wearing the glasses should keep their eyes closed while the flashing lights are presented, for example, as different waveforms or colors. The light can also be brought to only one eye, if you want to create an effect only on the other hemisphere of the brain.

After Berger discovered in 1929 that EEG activity could be recorded, according to Huang and Charyton (2008), Adrian and Mathews (1934) showed that Berger's waves (alpha waves) could be visually amplified by stimulating the same frequency. Cahn and Polich (2006) also says that measurable changes in brain electrical activity have been obtained with this method. Huang and Charyton (2008) mention that

Williams and West (1975) have noticed that a visual stimulus could also help meditation.

4.2.2 Audio-Based Stimulation

Sound-based stimulation also tends to affect the brain's electrical activity like visual stimulation by providing a precise frequency that repeats itself in the brain. Sound stimulation in brainwave entrainments is divided into three different categories: binaural beat, monaural beat and isochronic tone. According to Huang and Charyto (2008), a binaural beat consists of two sound waves that create the desired frequency when entering different ears. monaural beat does not need two sound sources, but the sound it creates is very similar to binaural beat. Isochronic tone is more than a short tone that goes off and on. I talk more about binaural beats in this song.

According to Oster (1973), binaural beat was invented by the German (experimenter) scientist Dove H. W. in 1839. Puzi et al. (2013), the idea of binaural beat is that two sound sources of the same sound with different frequencies are brought to different ears. For example, the sound frequency is 400 Hz for the left ear and 410 Hz for the right ear. The difference between these two frequencies is 10 Hz and the listener can also hear the rhythms of this. The listener's brain produces a rhythmic sound due to the separation of this sound. The frequency of this rhythm is so essential that the brain is assumed to follow this frequency to some extent. The English name for this phenomenon is Frequency Following Response (FFR). According to Oster (1973), these do not occur very much in nature, but, for example, to tune musical instruments, this is used like tuning a piano. To keep the sounds at the same frequency, the tempo of this rhythmic sound slows down until it disappears.

Zaini et al. (2011) says that many studies have shown the functionality of binaural beats in such a way that by observing the EEG, the frequency of the brain given by the next binaural beat has been noticed. I found many studies to support the functionality of these, but I couldn't get hold of most of them due to their cost. However, I will take examples from some studies here. One similar study has been done by, among others, On et al. (2013), where they found that binaural beats can influence theta and delta waves. In their experiment, 33 subjects went through the same procedure. The EEG was recorded so that the subjects were five minutes

without stimulation, one minute off, then 20 minutes listening to the binaural beat, one minute off again, and then finally five more minutes of EEG recording. It should be noted that there was no control group in this experiment, which could have also confirmed that simply resting still does not produce equivalent amounts of theta and delta waves.

Puzi et al. (2013) had created a 10Hz binaural beat recording with the BrainWave Generator program made by a Finn and verified in the laboratory that the sound was indeed 10Hz. There were 33 people in their experiment, many of whom were stressed. Listening to binaural beats for 20 minutes relaxed subjects and increased the strength of alpha waves in both hemispheres of the brain. On the other hand, a decrease in the strength of beta waves was noticed in both hemispheres of the brain, which indicates a decrease in a stressed state of mind. From the average of subjects, the strength of alpha waves increased and the strength of beta waves decreased. But 39% of subjects did not experience an increase in the strength of alpha waves, however. To this Puzi et al. (2013) think the reason was that the binaural beat should be listened to several times for the effect to be effective. Their study also had no control group, but normal brain activity was recorded for five minutes before listening to the binaural beat.

Some studies have also looked for results with alternative methods instead of EEG. Karino et al. (2006) have done a very enlightening study regarding binaural beats. They recorded neuromagnetic activity from the brain while listening to the binaural beat and noticed that the cerebral cortex of the head and front of the brain, and more specifically the temporal lobe area, including the areas of the cerebral cortex related to sound processing, responded to the binaural beat and repeated it. They did an experiment with 4.00 Hz and 6.66 Hz and thus concluded that the slow binaural beat synchronizes the human cortex.

There are also studies that have produced a negative result about the functionality of binaural beats. For example, Good et al. (2012) conducted an experiment where 31 subjects listened to binaural beats Theta (7Hz) and Beta (16Hz) for two minutes. From the experiment, it could be concluded that a two-minute long Binraual Beat

with theta frequency or beta frequency is not enough to produce a visible effect on the EEG spectrum. Here it is good to note that two minutes is a short time.

Zaini et al. (2011) says that many people are looking for a tool that gives an effect similar to the difficult-to-learn meditation, and listening to binaural beats is such a choice for many. Experiments related to meditation practice and binaural beats have also been carried out. Lavallee et al. (2009) conducted a study with four novices with eight months of meditation practice experience and four experts with 18 years of meditation practice behind them. The experiment had three different stages: Meditation alone without stimulation, a disturbing binaural beat (15 Hz) and a meditation-supportive binaural beat (7 Hz). Brain imaging revealed that novices' theta waves were less powerful when a distracting binaural beat was added to the meditation. In the case of experts, theta strength increased instead. Thus, it could be assumed that the experts had developed a resistance against disturbing external factors. This is shown in figure 7. The experts who listened to binaural beats supporting meditation practice also described their experiences as different from a normal meditation session. These descriptions included sensations of waves of energy, an ecstatic experience, or a connection to the universe.

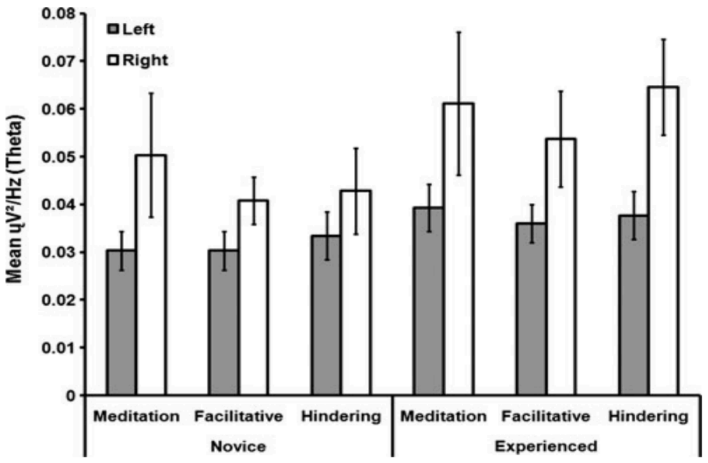

Figure 7. During the hindering binaural beat, the strength of the theta waves of experienced meditators did not decrease like that of novices. (Lavallee et al., 2009)

4.2.3 Combinations

By combining different forms of brainwave entrainment, you get audiovisual stimulation (AVS), which consists of sound and visual stimulation. In practice, this means that, for example, a binaural beat is played at 7 Hz, and at the same frequency,

the person is given a flash of light or other similar stimulation via vision. These devices are also called mindmachines.

Tepla et al. (2006) conducted an experiment where, during two months (25 sessions repeated per person), 20 minutes of audiovisual stimulation 2-18 Hz was performed on six subjects. The results were measured at six points on the head. Their results confirmed that repeated AVS causes significant changes in the electrical activity of the cerebral cortex. Long-term AVS significantly increased, among other things, the intensity in the theta-1, theta-2 and alpha-1 frequency ranges in the frontal and midbrain cortex areas. A large increase in intensity was found on the right side of the head. Their results show that regular AVS produces changes in cortical function that generally closely match the reported features of relaxation or altered states of consciousness. In this experiment, it is also significant to note that the results were compared to two subjects who only listened to music. Listening to music did not have the same effects. So it would seem that a long-term 20-minute AVS works better than a single 20-minute listening to music. In addition, Tepla et al. (2011) have noticed that audiovisual stimulation has also caused clear hemispheric synchronization during these two months and 25 sessions.

4.3 Transcranial Magnetic Stimulation

You can also try to influence the functioning of the brain either by conducting electricity there directly or with the help of magnetic fields. I will briefly describe these methods in this section.

According to Wikipedia (2013b), transcranial magnetic stimulation (TMS) is the activation of neurons in the brain from outside the skull using a magnetic field. A copper coil is placed on top of the patient's head, to which an electric current is fed pulse by pulse. The generated magnetic field affects the neurons of the cerebral cortex through the skin, skull and cerebrospinal fluid. The change in the electrical charge on the cell surface affects neighboring cells, and the resulting effect eventually extends to the activity of brain cells and their mutual communication. In this way, by generating nerve impulses to different areas in the brain and monitoring

their progress, the tasks of different brain areas and, for example, the extent of possible damage can be mapped.

Leong et al. (2013), repeated transcranial magnetic stimulation is a safe and effective treatment for depression. They have done research on depressed people. In the trial, 32 patients received 10 Hz stimulation for four seconds at 26 second intervals *motor cortex*to. The length of the session was 37.5 minutes. Their assumption was that repeated transcranial magnetic stimulation placed on the forehead area (Dorsolateral prefrontal cortex, DLPFC), which area changes are connected to mindfulness, could have the same effect as mindfulness meditation. The results suggested that repetitive transcranial magnetic stimulation could be associated with some improved variables of mindfulness.

Another transcranial method called transcranial direct-current stimulation (*TDCS*) does not take advantage of magnetism so much, but according to Wikipedia (2014c) this method is based on a weak direct current, which is placed in the desired area with electrodes. This method has also received a lot of attention, for example Cohen et al. (2008), it is a safe and promising treatment for brain function disorders. For example, Ferrucci et al. (2014) have also noticed that the cerebellum (*cerebellum*) placed in the area, TDCS accelerates learning.

4.4 Biofeedback

According to Psychotherapy.com (2014), biofeedback is a treatment technique where a person is trained to improve health by using signals received from their own body. For example, psychologists use it to teach tense and anxious individuals to relax. Some specialized cases even use biofeedback to make being with pain easier. A biofeedback device can be, for example, a thermometer or a scale. Thus, a person can learn, for example, about their own weight by monitoring how to eat appropriately. In subsection 4.4.1, I describe in more detail how brain imaging can be used as input to a biofeedback system, and in subsection 4.4.2 in more detail, how breathing can be used as input in connection with meditation. I'm talking about input in this context, although often the input given to the biofeedback system also comes as feedback.

This is because, for example, the data of breathing or brain waves is nevertheless the primary source to which the system apparently reacts.

4.4.1 Brain Imaging as Input

Brandmeyer and Delorme (2013) describes neuroplasticity therapy (*neurofeedback*) method for real-time feedback from EEG that teaches self-control. In this way, it can also be a potential aid to support meditation. Brandmeyer and Delorme (2013) says that Lazar et al. (2005) and Pagnoni and Cekic (2007) have found that many other exercises and skills that cause plastic changes in the brain are not fundamentally different from meditation. Brandmeyer and Delorme (2013) also explain as one hypothesis for the effectiveness of meditation and neuroplasticity therapy that both techniques develop concentration and emotional control. Cognitive control is necessary to manage emotions. When a person intends to change the control of concentration, he must learn to manipulate the amount of concentration, which is naturally reserved for stimuli related to the processing of emotions.

Brandmeyer and Delorme (2013) says that Zoefel et al. (2011) have noticed that the alpha and theta frequencies practiced in many cognitive-enhancing neuroplasticity therapy protocols are shared by Brandmeyer and Delorme (2013) in Braboszcz and Delorme (2011) and Cahn et al. (2013) have the same characteristics as EEG frequencies, which show significant changes in the early stages of meditation practice.

According to Brandmeyer and Delorme (2013), neuroplasticity therapy is already on the market in popular culture. Many companies sell "enlightenment" programs. However, these programs are not based on scientific research on meditation and neuroplasticity therapy, and thus the accuracy and perception of their signals remains a matter of conjecture.

Brandmeyer and Delorme (2013) describes that Thornton and Carmody (2009) have found that some clinical neuroplasticity therapy protocols aim to compare the patient's EEG with a large sample of the average healthy person's EEG and try to make the patient's EEG as similar as possible. Using the same method, it could be possible to train people to meditate in such a way that the sample would be taken

from meditating people. However, Brandmeyer and Delorme (2013) point out that, according to Cahn and Polich (2006), the problem here is that different meditation techniques cause very different neurophysiological activity.

According to Brandmeyer and Delorme (2013), one way to help meditating would be, for example, based on the research of Braboszcz and Delorme (2011), based on the finding that in alpha and theta waves you can notice an increase in concentration. Thus, the program could give feedback about the loss of concentration, for example an alarm sound. This could also be used as a meditation aid in such a way that, for example, the background noise is amplified as a result of the mind wandering.

The Mind and Life Institute (2004) has cited the Dalai Lama as being among the first to be interested in utilizing such a technique to aid in Buddhist practice. According to the Mind and Life Institute (2004), Szu et al. (2013) sees potential in such applications even for the smartphone market. Some EEG-based systems are already compatible with wearable and smartphone technologies and it won't be long before we see neurofeedback-based programs for smartphones. Communities that would be built on top of social media using cloud computing (*cloud computing*) would support each other and their meditation practice. Similarly, the programs could also notice the changes that take place over weeks or years that the person is not even aware of and thus encourage and help in the exercise.

According to Jeremy (2014), the neuroplasticity system has been studied and found to be functional. In the system he describes, the person stares at the feedback of the strength of the alpha waves measured from the brain on the screen. Ros et al. (2013) had conducted an experiment with a similar system on people and noticed that the use of the system resulted in a reduction in mind wandering. In the system, people were rewarded when their alpha frequency strength decreased. In this experiment, the control group received fake data on the screen instead of real feedback from the EEG. Finally, the ability to concentrate was measured with a test and it was noticed that those who received neuroplasticity therapy performed better.

Jeremy (2014) describes systems like this as having many other uses. According to Jeremy (2014), Papageorgiou et al. (2013) had found that training with such a system cleaned the brain waves so that they produced a cleaner signal and less interference.

Ros et al. (2009) also tested this system on surgeons and found that the surgeons were able to work more precisely and 26% faster. In addition, according to Jeremy (2014), neuroplasticity therapy was found to alter the cognitions underlying post-traumatic stress disorder (PTSD). According to Jeremy (2014), Kleutsch et al. (2013) have noticed that neuroplasticity therapy has found help, for example, for those who were abused in childhood. According to Jeremy (2014), NASA has also trained astronauts with this system. Furthermore, he says that Raymond et al. (2005) have also found that neuroplasticity therapy given to dancers before dancing helped considerably. There was also a control group here and the judges didn't know which was which. According to Jeremy (2014), a similar system could also be considered a form of meditation.

Rubik (2011) had conducted a study where subjects tried to increase the intensity of gamma waves with the help of neuroplasticity therapy. In the experiment, it was noticed that people who practiced meditation and people who did not practice meditation were able to produce gamma waves from the frontal lobe area with neuroplasticity therapy. In the experiment organized by Rubik (2011), there were 12 test subjects, half of whom were advanced practitioners of Transcendental Meditation and the other half served as a control group without an advanced background in meditation practice. The experiment used Neureka! -program, which was able to filter out the distractions made by muscles such as the eyes and facial muscles from the gamma waves. This has often been a problem when recording gamma waves, that the interference signals from the muscles, which are also located at the frequency of the gamma waves, are the distractions.

In Rubik's (2011) experiment, subjects received gamma wave intensity feedback in the form of various graphic or audio representations, such as a varying sound frequency or a rising graphic bar, which responds to the gamma wave intensity. Subjects were asked to use feedback to increase the intensity of the gamma waves. The test subjects were also asked what kind of experiences the increased gamma waves could be connected to and all the answers were positive feelings and some also described the experience as spiritual. This is also shown in more detail in Figure 6 in subsection 3.3.5. In the experiment, it was also noticed that those who advanced in meditation were able to increase gamma waves five times more than subjects who

did not practice meditation. Because an increase in the intensity of gamma waves can be associated with a meditative state such as Cahn and Polich (2006) preceded Lutz et al. (2004) while Lutz et al. (2003) had mentioned, this is quite a useful discovery.

Egner et al. (2002) had conducted an experiment to test the a/t - neuroplasticity therapy method. The A/t method comes from the words alpha/theta- neuroplasticity therapy method. This method is described as relaxation therapy, which aims to strengthen the strength of the alpha and theta frequency ranges. Egner et al. (2002), according to Peniston and Kulkosky (1989, 1990) and Saxby and Peniston (1998), the method in question has been clinically useful in the treatment of alcoholism. In addition, Egner et al. (2002) also according to Peniston and Kulkosky (1991) and Peniston et al. (1993) have also found it helpful in treating post-traumatic stress disorder.

Egner et al. (2002), the idea of the technique stems from the association of alpha waves with, among other things, relaxation, the intensification of alpha waves after consuming alcohol, and the association of theta waves with meditative states. Since the name of the technique is a/t, it inevitably brings to mind that alpha waves are added more than theta waves, but in this experiment the aim was specifically to increase the theta cycle to alpha and thus the experiment talks about the t/a ratio. The more specific purpose of this exercise is to train the person to increase the intensity of the theta waves more than the intensity of the alpha waves without causing the person to fall asleep. The aim is to produce a state similar to meditation or apparently hypnagogia. Wikipedia (2014b), hypnagogia is a state where the state of mind is transitioning from a waking state to a sleep state. This condition is also associated with hallucinations, lucid dreams and sleep paralysis. Egner et al. (2002), when striving for this state using the a/t method, the person closes his eyes at the beginning of the session and the brain shows high-frequency alpha waves in the imaging. Later, when the person begins to fall asleep, the activity of alpha waves decreases and the activity of theta waves (and delta waves) becomes more significant. This point, where theta waves become stronger than alpha waves, is usually associated with the loss of consciousness and the onset of stage I sleep. Thus, this a/t feedback exercise sought to train a person to consciously enter a state of mind that would normally be a fileless state. Thus, successful training in that a/t session means an actual increase in

the theta/alpha (t/a) ratio. Similarly, repeated training is supposed to increase this t/a ratio outside of training and also to facilitate the flow of training.

Because in many cases similar EEG states can be described in people who are falling asleep, and thus the resting group was not a good comparison target. Thus, here Egner et al. (2002) took as a solution a comparison group that received EEG data from a previously recorded session instead of real feedback, and thus the actual rest group was not used for comparison. There were 18 subjects in the experiment, six of whom were women and 12 men. Their age was 23.1 years on average. The area to be measured for the EEG was the area between the top of the head and the occipital lobe (PZ). For comparison (*baseline*) the EEG data was initially recorded with the subjects' eyes closed for two minutes without neuroplasticity therapy feedback.

The feedback of the neuroplasticity therapy itself consisted of background sounds linked to alpha and theta frequency intensities and reward sounds. More specifically, the relative increase in the alpha channel produced the sound of a babbling brook, and when it exceeded the reward threshold, a high-pitched gong sound was played. The relative increase of the theta channel was presented as the sound of ocean waves in the background, and by the time the reward threshold was exceeded, a low gong sound was played. According to Egner (2014), the increase in relative channel strength here means that only one channel can be playing at once and not both at the same time. The channel with the higher relative strength is always on. So this comes from the t/a ratio. In addition, during each session, the supervisor of the experiment tried to set identical threshold values for the rewards so that the values of the channels were at least 30% and at most 65% of the time above the threshold value. The volume of the headphones was adjusted according to the preferences of the individuals. In the experiment, subjects were asked to relax deeply, but to avoid falling asleep. The experiment was repeated for five sessions and two to three times per week. The test was almost at the same time for the same subject and the session duration was 15 minutes.

Questions were collected before and after the test, for example regarding relaxation or tension. In the analysis, the trend of theta/alpha waves strength of fake data and real data was compared. From the results, it could be seen that the t/a ratio of those

who received correct data was higher than those who received false data. This is shown in figure 8. Moreover, after each session, this figure improved compared to the previous session.

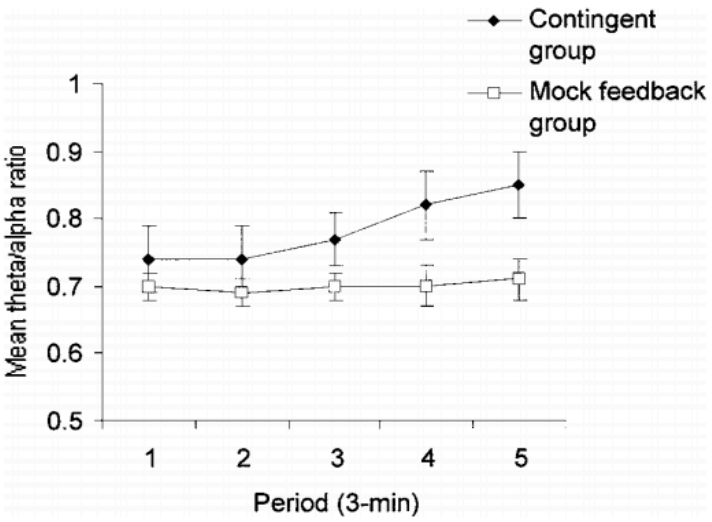

Figure 8. A clear increase in the ratio describing the strength of the theta/alpha frequency compared to those who received sham data in the neuroplasticity therapy trial (Egner et al., 2002).

Neuroplasticity therapy can also be combined with other techniques, such as brainwave entrainment. Such an implementation has been done by Transparent Corporation (2014) in the Neuro Programmer 3 program, among others. The program plays, for example, a binaural beat to the listener, and at the same time, the frequencies to which the person reacts most effectively are observed from the EEG read. Transparent Corporation (2014) describes this as bio-optimization (*BioOptimization*). This supports many devices.

4.4.2 Breathing as Input

Breathing is very essential for meditation, as we already stated in the first chapter that early texts related to meditation also teach a certain kind of breathing. In this subsection, I describe how the breathing measuring device is connected to the sound feedback and in this way a system has been created, which aims to bring the first-time user an experience similar to the state of mindfulness.

Vidyarthi and Riecke (2014) had made a device called Sonic Cradle. Biofeedback sensors were connected to the device, which gave feedback to the person about how their breathing shapes the sound coming from the speakers.

Advanced mindfulness meditators have the ability to restore lost focus without judgment. We tried to bring the same to the first-timer with this device. Even if the person's concentration goes astray, the device creates a soundscape according to autonomous breathing, and the person's concentration is thus restored again and again from the feedback of the environment. In this way, the person's interest returns to how breathing shapes the soundscape. The purpose of the system is also to teach how to restore concentration in everyday life. This cycle is illustrated in figure 9.

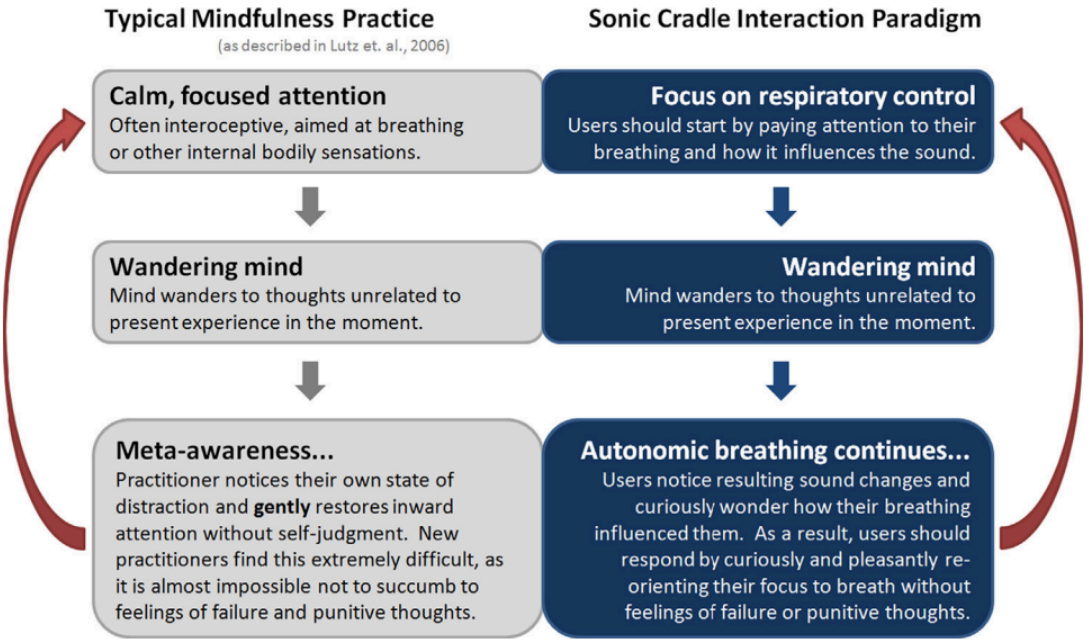

Figure 9. Comparing the mind wandering cycle of a normal mindfulness exercise with the assumed cycle of the Sonic Cradle system (Vidyarthi and Riecke, 2014)

The sounds of the system ranged from the human voice to the sounds of musical instruments and nature. No binaural beat or other form of brainwave entrainment was used. The system sought to model what has evolved into mindfulness. In this test, you weren't even asked to concentrate away from stray thoughts, but naturally the concentration is in the voice. The system had an activation time for the award vote. A humming sound is heard during exhalation and when a certain time limit is reached, a bell sound is played and the next sound is played from the next speaker (4.1 sound

system). Each successful threshold achievement increases the breath time required to reach the next reward threshold. The system also had special rules. If you take four 2.5-second breaths, the sound will be silenced and you will return to the previous point. This is a minus point. Every three steps forward shortens the entry of the minus point by one repetition, e.g. the next three times 2.5 seconds would be enough. A maximum long inhalation changes the last selected sound to a frequency of about 50 Hz, and a maximum long exhalation changes this sound to a frequency of about 1950 Hz. A longer total breath, i.e. the combined time of inhaling and exhaling, makes the sound feel wider. The room thus feels larger. Belly breathing creates a higher volume of sound. The experiment ends and there is silence at 15 minutes.

As a result of this experiment, Vidyarthi and Riecke (2014) noticed that the system was very relaxing and at the same time energizing. People compared the experience to, for example, stargazing, cycling, hallucinogens, a sensory neutralization tank and a massage. One person told about their experiences that it felt like being in a sound pool, where you can control the surrounding water mass. Many experienced an egoless state where there was no need to think or strive for anything. Some experienced hallucinations and almost synesthesia. People got attached to the device and wanted one at home. For many, body sensations also changed. They felt floating, rocking, etc. Many experienced a silencing or disappearance of their inner narrator as well. Many also described a changed sense of time, a dream-like state and positive sensations. Those who had meditated before described the experience as meditating. Some who had not meditated before described the experience as withfor a morning journey, where unpleasant things became past and afterwards a calm and serene state. Vidyarthi and Riecke (2014) state that the sounds should perhaps have had more aggressive sounds to remind us of the Buddhist tradition, where we also try to fight overrelaxation (*dullnes*) against.

5 Building a Meditation-Supporting System

In this chapter, I describe one possible system that can be used to assist meditation. I chose neuroplasticity therapy as technology. Thus, the system reacts to the person's EEG and guides the session with voice feedback with a very low delay. I am trying to use this experimental system to test whether it is possible to build a working neuroplasticity therapy system from a hobbyist-level device. In addition, I try to find out experimentally whether during the session there are also changes in the parameters associated with meditation, such as the quieting of the inner dialogue and the feeling of calmness. Section 5.1 describes the device selection in more detail, section 5.2 describes the operating principles of the system, and section 5.3 contains information about the test I did for the system.

5.1 Choosing an EEG Device

There are many solutions for getting EEG data to a computer. The most accurate and very expensive devices were excluded in this case, but despite this, my selection has accumulated a number of potential devices available. In this section, I describe these different devices that I have become familiar with. In addition, I describe why my choice has focused on a specific device for this purpose of use. This is not really a Device Comparison, but more of a description of the device selection for the project.

Olimex EEG-SMT is based on the OpenEEG open source code project, which is intended as an alternative for hobbyist-oriented EEG data utilization. Five wires are attached to the Olimex device. Four of these form two channels with active electrodes and the last wire is for the passive electrode. The passive electrode is placed in the ear as a reference and the other electrodes can be freely placed on the examined objects. On the website of the OpenEEG project, you can choose some ready-made programs that support the device. These programs include various neuroplasticity therapy and data recording programs. Some of these are paid and some are free.

Installation and commissioning of Olimex's EEG-SMT was successful by following Olimex's instructions. However, the device does not work on all computers. One problem also with EEG-SMT is sometimes the interference signals of high frequencies. This can be observed, for example, when the data was imported with the catEEG program from the EEG-SMT device and transferred to the BWView program for display. Figure 10 shows this situation.

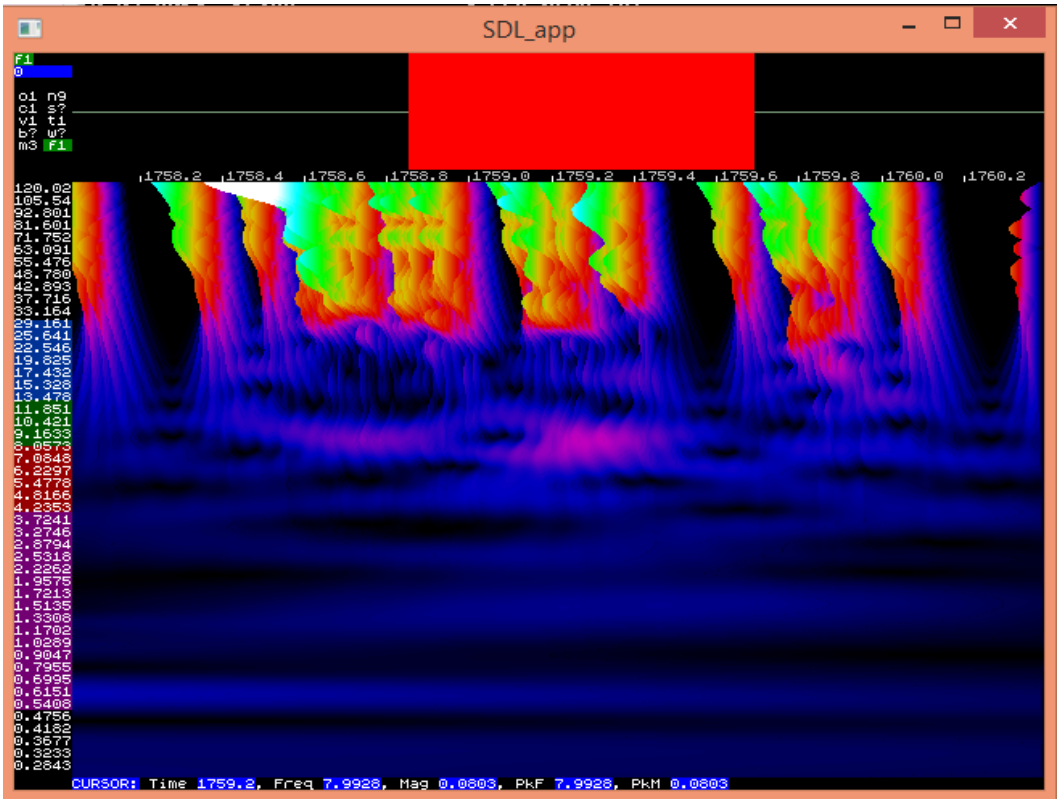

Figure 10. Output of the BWView program from the EEG-SMT device (Sanio, 2014)

However, the data obtained from the signal of the EEG-SMT device can be used, because the frequencies considered for meditation are below 50 Hz. I chose this device for this project. I will describe in more detail algorithms and software solutions for analyzing and utilizing data later in subsection 5.2.2.

Another device I looked at for the purpose of this project is the Emotiv Epoc. This is shown in figure 11. Emotiv Epoc is a wirelessly functioning entity. According to Emotiv.com (2014), it uses a series of sensors that interpret electrical signals from the user's brain, which are used, for example, to interpret a person's thoughts, feelings and expressions. Duvinage et al. (2013) had compared Emotiv Epoc in the P300 system and found it to be satisfactory in terms of its functionality, for example for gaming and less critical applications. Instead, for example, for controlling or

rehabilitating prostheses, its accuracy is not Duvinage et al. (2013) is enough. When looking at the manual for the development of Emotiv Epoc, I noticed that the developer can get the raw data of all channels to be recorded from the interface relatively easily in theory. But setting up the device is a bit of a chore. The sensors are not so-called dry sensors, instead a saline solution should be placed in each sensor. Also, the location of the sensors cannot be freely controlled, although they cover very wide areas from the head.

Kuva 11. Emotiv Epoc (Emotiv.com, 2014)

The Neuro Sky MindWave is also one of the devices I'm reviewing here now. I have already used the MindWave device in a few previous projects, so the device is familiar to me. As well as its introduction to development. The device has only one sensor, which is supposed to receive data from the frontal lobe area (*FP1*) and a reference bracket to be placed in the ear. MindWave's development tools include an interface for acquiring filtered and processed data. The interface includes, for example, raw data and strengths of different frequency ranges. According to Neuro Sky Inc (2009), the accuracy of their device is very close to that of medical devices, as shown in Figure 12 and Figure 13.

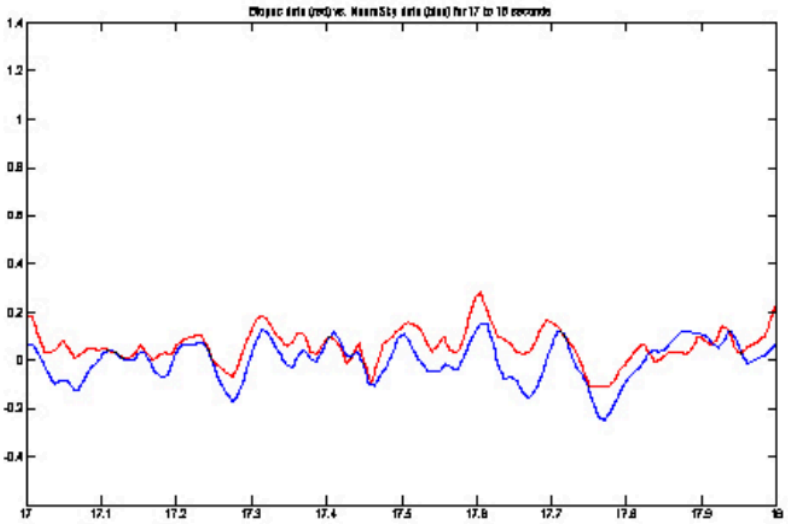

Figure 12. Comparison of the signal given by the Biopac system with the signal of the NeuroSky device (NeuroSky, 2009)

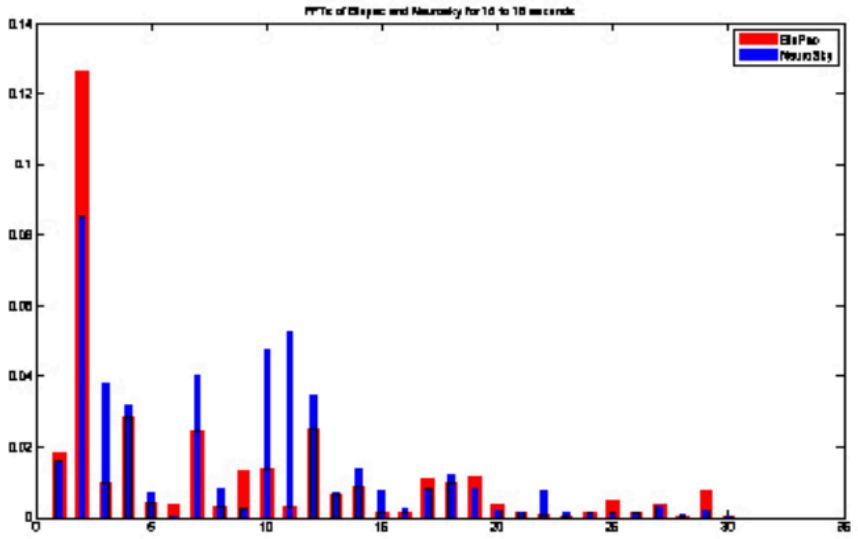

Figure 13. Comparison of the spectral strengths of the signal given by the Biopac system with the equivalent of the NeuroSky device (NeuroSky, 2009)

The advantages of MindWave include its affordability and easy implementation. Thus, a functional system built on this tool would also be feasible for a larger group of people interested in meditation. I chose to leave the interface of this device also available for this program, but I'm not actually using this device for testing the system this time.

5.2 System description

This section describes in more detail what kind of system I built to assist meditation and the tools and sources I used for it. subsection 5.2.1 describes the operating principles of the system, subsection 5.2.2 describes the introduction of the EEG device and data collection, subsection 5.2.3 describes the algorithms used by the system, subsection 5.2.4 describes the design of the system's sounds, and subsection 5.2.5 briefly describes the introduction of the system.

5.2.1 Operating Principles of the System

My purpose was to build a system based on the topic of this thesis. The purpose of the system is therefore to assist meditation mainly based on the electroencephalogram. The system therefore gives real-time feedback on the person's EEG and reacts to this with voice feedback. This is therefore a neuroplasticity therapy system.

The main programming language for system development was C++. The actual program gives the possibility to choose the session type, duration and many other additional settings if the user so wishes. After starting, it adapts to the data received from the person's EEG device and controls the session with voice feedback and saves the results.

The basic principle of the system is the same as in many other systems that utilize the principles of neuroplasticity therapy, where desired brain activity gives the user positive feedback and thus guides in the right direction. These include, for example, the experimental setup organized by Rubik (2011), where subjects increase the intensity of gamma waves by means of feedback that increases or changes the pitch of the sound, or Egner et al. (2002) the operation of the a/t neuroplasticity therapy system, where the person is played an increasing background sound in relation to the strength of the alpha or theta frequency received from the brain. Thus, the feedback that the person receives from the electroencephalogram should be relative real-time feedback from certain frequency ranges of the spectrum of the electroencephalogram.

I decided to implement two operating principles in this system, one of which is similar to the test layout described by Rubik (2011). This operating principle amplifies the sound feedback when the intensity of the person's gamma waves increases proportionally. This is therefore gamma-wave enhancing neuroplasticity therapy. This decision was supported by the good results of Rubik (2011) and the connection of the enhancement of gamma waves to the state of meditation, as well as the fact that the enhancement of gamma waves occurs specifically According to Cahn and Polich (2006), in the right frontal lobe region when meditating. Thus, the location of the sensors can be placed on the forehead, where the hair is not in the way. On the other hand, the system implemented here is different from the Rubik (2011) setup in that this system lacks the corresponding filtering caused by muscle disturbance signals. I believe this to be minor in this setting, where the persons are meditating with their eyes closed in place and thus the distractions caused by the muscles are presumably minimal. The actual sound feedback consists of natural sounds such as sea waves, a water source and others, which I describe in more detail in the subsection 5.2.4. I also added to this operating principle a monaural beat with a gamma frequency, which reacts like a background sound, changing the volume level of the sound according to the intensity of the person's gamma waves, which is also explained in more detail in the subsection 5.2.4. In addition, the person also receives sound rewards for favorable brain activity and variation in the soundscape, which I describe in more detail in subsection 5.2.3 together with a description of the system's algorithms.

Another operating principle, which I decided to implement in the system, is the a/t- or more precisely t/a- neuroplasticity therapy operating principle, which has been used by, among others, Egner et al. (2002). This technique works by playing one sound at a time. For example, either sea waves or the sound of a stream. One of these sounds is associated with the amplification of theta waves and the other with the amplification of alpha waves. The sound of the channel with a relatively stronger value is amplified for the person to hear. This principle aims to create a hypnagogic state with numerous beneficial effects Egner et al. (2002) according to. In addition, the method focuses on giving the person feedback from the alpha1 frequency range, which is more precisely connected to concentration. Likewise, the person is given feedback and the opportunity to become aware of the activity of alpha waves, which

is often associated with the state of meditation Wang et al. (2011) and Cahn and Polich (2006). Likewise, the intensification of theta waves can be connected to the state of meditation, for example Cahn and Polich (2006) and Lagopoulos et al. (2009) according to. In this operating principle, the intensification of theta waves over alpha waves is favorable. Especially at the end of the session, theta waves should intensify as the person approaches falling asleep or a deeper state of meditation. I also added changing soundscapes, sound rewards and the theta frequency (7 Hz) binaural beat to this operating principle, more detailed in the subsection 5.2.3 and 5.2.4. Audio awards also included Egner et al. (2002) to use a similar setup.

The system not only directs the person to brain electrical activity that supports the state of meditation, it also, on the other hand, aims to restore the person's mind from wandering by giving feedback on unfavorable brain activity. This is also somewhat comparable Vidyarthi and Riecke (2014) to the Sonic Cradle system, where the person's mind wandering causes changes in the body, i.e. in breathing, and from this the person receives sound feedback, which restores concentration to the situation. Similarly, the feedback received from the electrical activity of the brain can restore a person's concentration and arouse interest. Thus, with this feedback that arouses the person's interest, the aim is to avoid a judgmental attitude towards mind wandering and thus to increase mindfulness.

Reward sounds and changing soundscapes have also been added to the system, which, on the one hand, aim to combat over-relaxation or boredom mentioned by Vidyarthi and Riecke (2014) (*dullness*) against. Actually aggressive sounds have not been added to this system.

5.2.2 Implementing the EEG Device and Data Collection

The data coming from the device must be separated from the packets coming from the virtual serial port. In addition, the data must be processed to obtain a real-time table showing the strength of the frequency ranges for use by the program. In order for the device to be able to give some readings, it also had to be placed on the person's head well, and thus some kind of headgear had to be made for it. I describe these measures in more detail in this subsection.

The data from the device is collected in two integer tables, which describe the recording of the raw data of two different channels. This raw data comes to about 256 packets per second, but this usually leaves a few packets missing. The structure of the package is as follows:

```
uint8_t sync0; // Synchronization byte
uint8_t sync1; // Always 90
uint8_t version;
uint8_t count; // Package number
uint16_t data[6]; // Channels data.
uint8_t switches;
```

The data table itself only contains the data of two channels, although more is reserved for it. The total number of the channel is also divided into lower and upper bytes in such a way that the actual useful information is obtained by the formula, where the lower and upper bytes are combined:

```
int chanval = chanhigh * 256 + chanlow;
```

In addition, after each second, the Fourier transform formed by the packets that arrived during the previous second is calculated to obtain spectrum data. For this I used an existing one FFTW -library as follows:

```
fftw_plan p; // Plan initialization
p = fftw_plan_r2r_1d(rawSampleSize, in, out,
FFTW_R2HC, FFTW_ESTIMATE);
..
fftw_execute(p); // This is executed every second
```

The in table contains a table created from raw data, and the out table is always the result of the spectrum created by FFTW. `RawSampleSize` is in this case the number 256, which describes the size of the sample received during each second. The same also describes the sampling frequency (*samplerate*). In order to obtain from the spectrum even more precisely the intensity of the frequency range of the EEG spectrum in question, the average of the intensities remaining within the

frequency range is calculated for that frequency range. Since the indices usually do not directly correspond to the hertz reading on the board, they must be calculated using a special formula for this:

```
Int index = (int) (freq / (sampleRate / n));
```

For example, when searching for the alpha frequency range, the index readings are entered into the function as frequency (`freq`) 8.0 – 15.0 Hz. Using the sampling size (`sampleRate`) 256 and board size (`n`) 256. In this case, however, the requested frequency is always the same as the table's index as an integer. Because the function returns the value of the frequency (*`freq`*) with sampling size and array size of 256 because *freq*/(256/256)=*freq*/1 and *freq*/1 = *freq*. Thus, for example, the table's indices for the alpha frequency range are 8 to 15. Thus, for example, the average strength of the alpha frequency is recorded as the average of the items in the out table between indices 7 to 16. Finally, the obtained intensity is divided by the assumed maximum amplitude of 2000 and the absolute value is taken from it. Thus, the end result is a floating-point value between 0-1 for the channel strength, which can be used smoothly later in the program's operation. In addition, since these channels form two spectrums from two separate channels, they are later combined into one spectrum when using the program. More on this in the subsection 5.2.3.

For the functionality of the calculation, I also did testing with sine waves in such a way that I entered *in*-table a sine wave at different frequencies or many different sine waves that appeared in the spectrum values as desired. However, the spectrum from the device itself often contains a disturbance signal in the 50 Hz range, which is probably caused by the alternating current generated by the mains current. However, this is not essentially a disadvantage in this system, because the frequency range of gamma waves, which is the highest frequency range read, is 32 to 44 Hz.

The data obtained from the device is stored in such a way that the raw data is stored in vectors, which are stored in a file stored together with other data. In addition, the spectra calculated from the device's data for every second are saved together with other data so that they can be browsed or processed later.

In order for the data from the device to reliably represent the values measured on the person's scalp, the device must be placed firmly on the person's head. For this purpose, a headgear was made for the EEG-SMT device, which allows placing the four electrodes in the forehead area relatively freely, as well as the attachment to the ear for the reference electrode. The placement of the electrodes must be symmetrical for this device so that the - and + electrodes come to the left and right of the head symmetrically. The headgear itself is a thick flexible rubber band, where there is an area on the inside where the electrodes are attached with stickers. The electrodes have adhesive fabric counterparts so they can be placed on desired patches. The reference electrode and the part that regulates the tightness of the rubber band are made by three-dimensional printing. Figure 14 shows this whole.

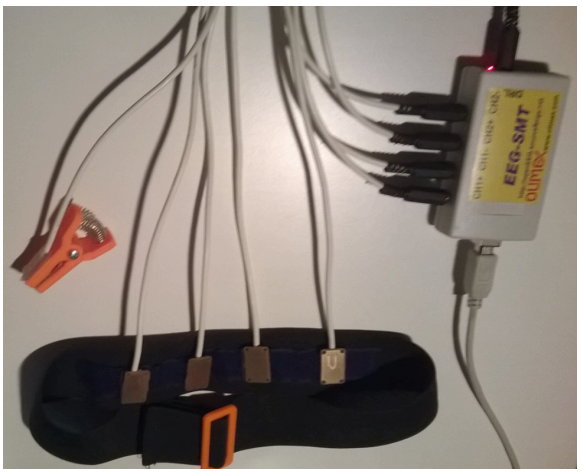

Figure 14. Image of the collar made for the EEG-SMT device and the holder to be placed on the ear of the reference electrode. Designed and made by Harri Karhu (Karhu and Sanio, 2014)

5.2.3 Algorithms Behind the System

In order for the system to be able to play the feedback sound with the correct intensity and to determine the threshold of the reward sounds, it must adapt to the

person's individual EEG intensity. Likewise, the presentation of the strength of the channels themselves must be done slowly in response to changes, because their values vary and jump a lot. If this were not done, it would be impossible to play sounds softly or to get a value suitable for this purpose from the average intensity of each channel.

The intensities of the frequency ranges given by the EEG reading device are brought into the system, converted to values 0 - 1. In addition, in the case of the Open-EEG, or more precisely, the EEG-SMT device, the readings of the two channels are combined and their average is taken, to which the system reacts. This data import happens every second. This is mentioned in more detail in the subsection 5.2.2. After that, every channel are changed to bars with a floating-point value from 0 to 100, which react slowly to the imported values. This has been implemented in such a way that each beam has its own current value, which is moved towards the desired value as the distance between these values determines the speed.

```
currentValue += (desiredValue-currentValue) * 0.1d
* deltaTime
```

`Current Value` reflects the current value. `DesiredValue` here is the value that is the most recent value between 0 and 100 imported from the channel. `DeltaTime` reflects the update speed and thus binds this change to time and equally fast, regardless of the computer's update speed. Standard multiplier `0.1` had been found suitable.

Each session starts with a calibration, the duration of which can be determined in the settings. Before the actual EEG calibration, however, there is a sound calibration, which plays a sound, according to which the appropriate sound volume can be set for the person. After this, the EEG-focused calibration begins, which searches for a suitable average for each channel as a starting value (*baseline*). The calibration average is the average of all read floating point values from 0 to 100 over the calibration period. The average value is also moved using the same formula as the current value of the bar so that it moves slowly to the set location. Based on the average value, the system determines the minimum and maximum. The minimum

and maximum reflect how strong the minimum and maximum value of the respective frequency range of the person can be. The minimum and maximum are by default 10% less and 10% more than the average, compared to the maximum total length of the bars (100). This can also be changed in the settings. The average, minima and maxima given by the calibration are shown in the figure 15.

The value between the minimum and maximum is described in the system by a floating point number 0 – 1, where a small value reflects a small relative intensity during the session in the frequency range in question, for example the theta or alpha frequency range. Thus again, a larger number close to 1 reflects a strong amplitude of the frequency range. I call this number the relative number of the frequency range bar. Because during meditation, an increase or decrease in the strength of many frequency ranges is observed, among other things Wang et al. (2011), the system must also be able to adapt to this, especially when the session is of shorter duration. Thus, the system continues calibration in the background and reacts to a situation where the average of the monitored channel has gone below the minimum or above the maximum. In this situation, the average is slowly moved between the new average and the previous average. The minimum and maximum also move to a more favorable position. The slow movement of the average is essential because the volume of the sounds played is determined by these readings. Thus, a quick movement would cause a strong change in the volume level of the sound and potentially disrupt the session. The background calibration time is the same as the initial calibration time. In addition, it is possible to change the calibration time, minimum and maximum during the session, but the need for this is very unlikely.

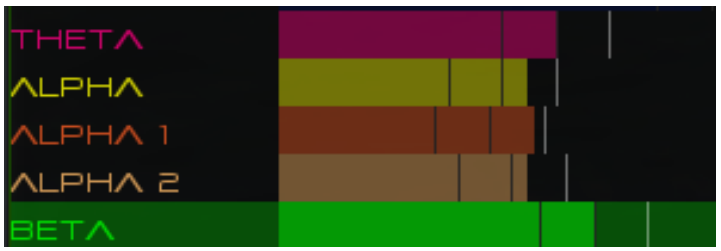

Figure 15. Illustration of determining the relative value of the channel. Minimum, average and maximum. (Sanio, 2014)

The session type of the system, which exercises the strength of the gamma frequency ranges (32 – 44 Hz), responds to the relative reading of the bar modeling the slow

gamma frequency range. It aims to adjust the intensity of background sounds according to the intensity of the person's gamma frequency range. In addition, the system has an adjustable threshold value for the reward, which is, for example, a standard 75% of the relative value of the frequency range bar. Thus, the program plays a reward sound for the person when this value has been exceeded, and in addition, the condition for the reward being played is that a suitable time has passed since the last reward. A suitable interval between rewards can also be adjusted in the settings. It defaults to 25 seconds. This type of session thus aims to direct the user to amplify gamma waves. The session also reacts to the situation when a certain number of awards have been received and it is time to change the soundscape. This number of awards for each soundscape can also be changed in the settings. It is standard seven. I will use the name Gamma session for this exercise that strengthens gamma waves later.

Another type of session, which exercises the t/a ratio, i.e. the intensities of the theta and alpha frequency ranges (more precisely, theta 4.5 – 8 Hz and alpha1 8 – 11 Hz) works Egner et. al (2002) and Egner (2014) so that only one channel is active at a time. Of these, the channel with the higher relative value is in sound. Thus, I have calculated the own volume levels for the channels as follows:

```
alphaVol = 0.0d; // Volume of alpha channel sound
thetaVol = 0.0d; // Volume of the theta channel sound
if (thetaValue>alphaValue)
     thetaVol = thetaValue-alphaValue;
if (alphaValue>thetaValue)
     alphaVol = alphaValue-thetaValue;
```

Here, alphaVol and thetaVol refer to the volume levels of the channel sounds. ThetaValue and alphaValue mean the values of the relative bars modeling the theta and alpha frequency ranges from 0 to 1. Thus, the sound has the channel with the stronger relative value, and similarly this value is calculated from the difference between these values. The sound intensities are thus imported as floating-point values 0 – 1 for use by the sound system. This session type also uses reward sounds that are separate for the alpha and theta channels. More about these votes in the

subsection 5.2.4. Likewise, this session type changes the soundscape when a certain amount of rewards have been accumulated. I will use the name Theta/Alpha session for this session type later.

After the session ends, the program has saved the session data from the initial setting (*baseline*) and from the actual session. From the recordings, you can see the changes in the intensities of all frequency ranges as a function of time. The averages of the channels and, for example, raw data can also be retrieved from the recordings later. In addition, the session makes a text file from the recording, from which you can see the change in the values of the channels as well as the change in the t/a ratio in sections. Currently, there are supposed to be three parts: beginning, middle and end.

5.2.4 Designing the System Sounds

The system had to select sounds for the background to adapt to the intensities of different frequency ranges. When choosing sounds, you had to listen to them and arrange them in such a way that they are pleasant and calm. I found all the audio files on freesample.org. The soundscape was made up of, for example, the sound of the river, the sound of the sea, the sound of Tibetan singing bells, the sound of rain, wind chimes, a water fountain, throat singing, and the sounds of birds. Most of the sounds remained in mp3 format, but I had to leave some of the sounds in wav format due to the graininess of the sound. A more detailed listing of the sources of background sounds is attached according to the program.

Since I chose sounds containing brainwave entrainment for the system, I had to pay special attention when choosing and making them as well. This was due, for example, to the fact that when the gamma frequency is 40 Hz, a binaural beat cannot be made above 30 Hz, which results in a cocktail party effect and the brain separates the sounds into two different sources. The solution was to use isochronous sound or monaural beat:ia, where I chose the monaural beat. I made the monaural beat as a sine wave in Audacity, which is shown in figure 16, and I verified this functionality by recording the program playing this sound, which is shown in figure 17.

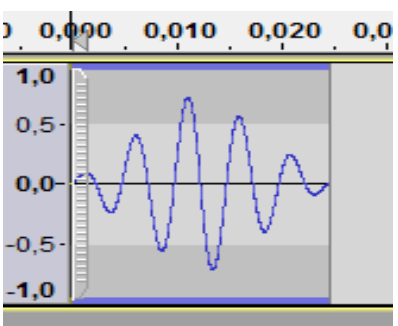

Figure 16. Creating a monaural beat in Audacity. Screenshot from the program (Sanio, 2014)

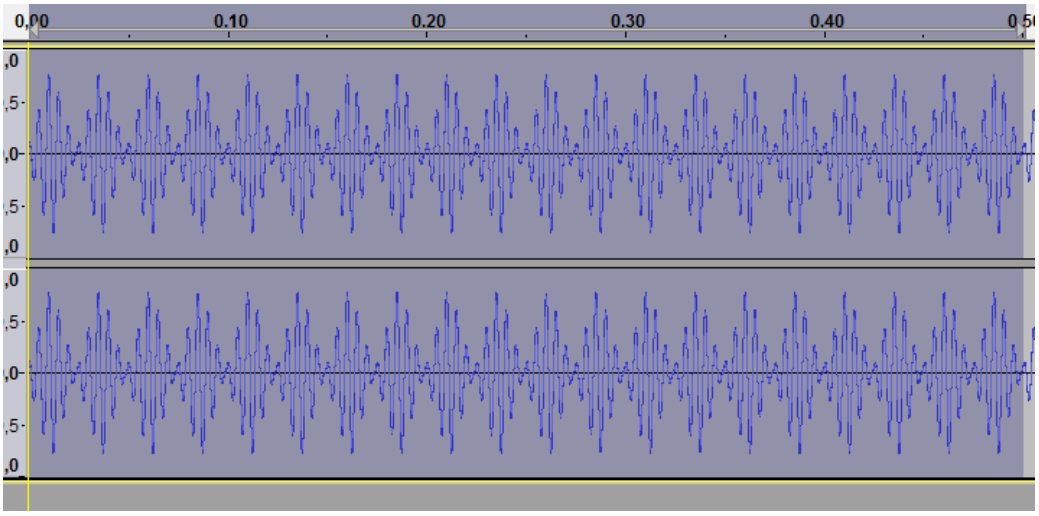

Figure 17. Verification of monaural beat (Sanio, 2014)

I made the binaural beat inside the program in such a way that you can specify the carrier frequency of the binaural beat and the frequency of the binaural beat for the channel. In this case, the frequency of the binaural beat remained at seven hertz. I verified this functionality by recording the sound played by the program in Audacity and mixing it into one track. Figure 18 shows this.

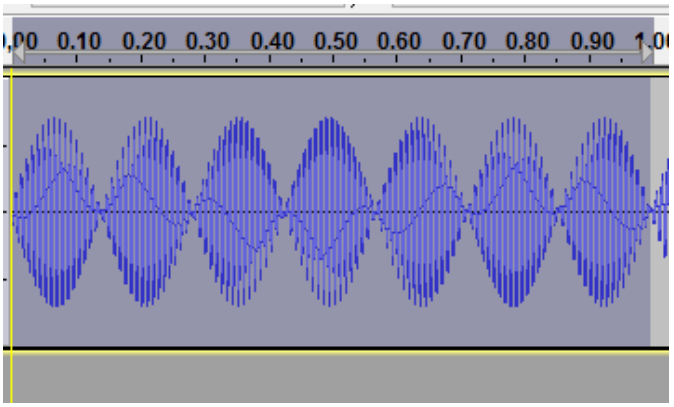

Figure 18. Binaural beat verification (Sanio, 2014)

5.2.5 Running the system

Different things must be taken into account when running the system. The most important thing is the computer itself and the platform. The program works on Windows platforms, but all libraries should also be possible to work on Linux platforms. The system has only been tested on the Windows platform. Another thing to check is the device, installing it on a person and checking the operation. In addition, you must select settings and start the session.

When running the program, it's important to ensure the functionality of the EEG-SMT or other EEG device After starting the program, check if the EEG-SMT port is set correctly. If not, it should be set to the right and then you can try to connect to the EEG device again. After this, an EEG image should be displayed in the upper right corner, which is updated approximately once per second. This can be seen in the screenshot of the program, which is shown in figure 19.

Once the EEG device is set up, the session type is selected. Currently, the program is tuned to support two sessions, which can be selected with the F2 or F3 keys. Or alternatively, you can adjust the settings particularly precisely. The program saves the previous settings when it closes and loads them when it starts.

After selecting the settings, the session is started by pressing the icon, which resembles the play button on a player. A button to stop the session appears instead of the same button. If the session is interrupted, for example, due to a device failure or something similar, the program makes automatic recordings, which allow you to continue the same session as soon as the problem is fixed. Session results and temporary results can be found in the file session.dat and in the brainwaves/ directory. More detailed instructions and documentation can be found with the program.

Figure 19. Screenshot of the program (Sanio, 2014)

5.3 Experimental Testing of the System

There are two different session types in the system, which should be functional in their basic principle, as we noticed in Rubik's (2011) experiment on the amplification of gamma waves and Egner et al. (2002) on experimental testing of t/a-session. However, this system has a new hobbyist-level EEG-reading device mentioned above, the exhaustion of filtering to some extent, and the combination of brainwave entrainment with techniques. Likewise, in this case, it is different that the system should assist meditation. Thus, it is interesting to find out whether a session that strengthens theta, alpha and gamma waves made with this system can really be seen in the EEG spectrum and whether it can also be seen in subjective experiences. For this reason, the persons are also made to sit instead of, for example, resting in a therapy chair. Similarly, the session duration is set to a reasonably long 30 minutes in total, which reflects the duration of the meditation session.

There is also no dummy data group in the experiment, but we are directly trying to distinguish two groups that do a different type of session. This also makes it possible to compare the functionality of different session types.

5.3.1 Materials and subjects

16 people served as test subjects, of which seven were women and nine were men. The average age was 26.75 years with a standard deviation of 4.5 years. Five of them were considered to have a clear background in meditation or yoga.

For the experiment, the program was set to save the results and make average calculations from them for the baseline recording and the duration of the session. The result of the session was also divided into three parts as a function of time. The program also made frequent backups. The actual ready-made settings for different session types were set in the program and these are shown in the table 1.

Table 1. Default settings for sessions.

The session type	**Minimum time for the next prize**	**EEG calibration time**	**Session length**	**Number of awards per soundscape**	**Award Threshold**
Gamma	25s	2 min	28 min	10kpl	40%
Theta/Alpha	25s	2 min	28 min	15kpl	25%

The session consists of calibration and the actual neuroplasticity therapy section. The EEG recording of both sections is recorded. The variables to be monitored are the relative strength of the theta and alpha regions compared to other channels and the relative strength of the gamma region compared to others. These can be used to assess how much the individual monitored channel has possibly strengthened during the session and whether there are differences between the groups.

Before the session, the questions are the nature and duration of the meditation background, as well as the person's current calmness on a decimal scale of 0-10 and anxiety 0-10. Likewise, after the session, we ask about the person's calmness and anxiety. In addition, after the session, we ask how pleasant the person felt the session was, whether they experienced a quieting of the internal dialogue, whether they felt their thoughts change during the session in particular, whether they associated the

reward sounds with certain feelings or conditions, whether they experienced hypnagogia and whether they could imagine using the system in question again.

5.3.2 Conducting the Experiment

At the beginning of the experiment, the subjects were instructed and oriented to fill in the first questions. The questions consisted of questions about the previous meditation background and the current state of being, such as calmness or anxiety. After this, the subjects were instructed on the use of the system that assists meditation and the possibility of interrupting the experiment if they so desired. Falling asleep was not supposed to be a problem here, as the subjects were sitting and not lying on their backs. The test subjects sat on the floor either in a cross-legged position, in a kneeling position, in a lotus position, or in another comfortable position. Figure 20 illustrates this.

One half of the subjects practiced the gamma wave strengthening session and the other half practiced the t/a technique. After the experiment started, the lights were dimmed, the person was assigned a suitable sound volume and a baseline EEG recording. Finally, the session data was saved for later processing. Finally, the test subjects filled out a questionnaire after the test, where they were asked about parameters related to meditation, such as changes in thoughts or quieting of the inner dialogue.

Figure 20. In the session, the persons sat on the floor in the position they chose. (Sanio and Tsypchenko, 2014)

5.3.3 Results

The time of the sessions was divided into three parts, from which the averages of the intensities of the different EEG spectrum channels were taken. Similarly, the average of the sessions was compared to the initial values of the calibration. The t-test of two independent samples and the one-way ANOVA test were taken from the results. The results showed that the average of the theta and alpha amplitudes of the Theta/Alpha exercise group was almost statistically significantly higher in the last phase of the session compared to the Gamma exercise group $p = 0.067$ and $p = 0.030$ (ANOVA). Similarly, the group doing gamma exercise had a higher gamma amplitude in the last phase of the session compared to those doing theta/alpha exercise, almost statistically significant $p = 0.030$ and 0.049 (ANOVA). This is shown in table 2. More details on the comparison of the results can also be found in appendix 1.

Table 2. ANOVA – Comparing the theta and alpha strengths of the final phase of the session with the theta and alpha strengths of the gamma group.

	Sum of Squares	df	Mean Square	F	Say.
Between Groups	,401	1	,401	5,844	,030
Within Groups	,961	14	,069		
Total	1,362	15			

From the results, the amplitude between the average of the session and the starting level as well as the difference between the amplitudes of the first and third phase of the session were also separated. Of these, close to statistically significant p-values were also found as a result of the tests. k21 and 22.

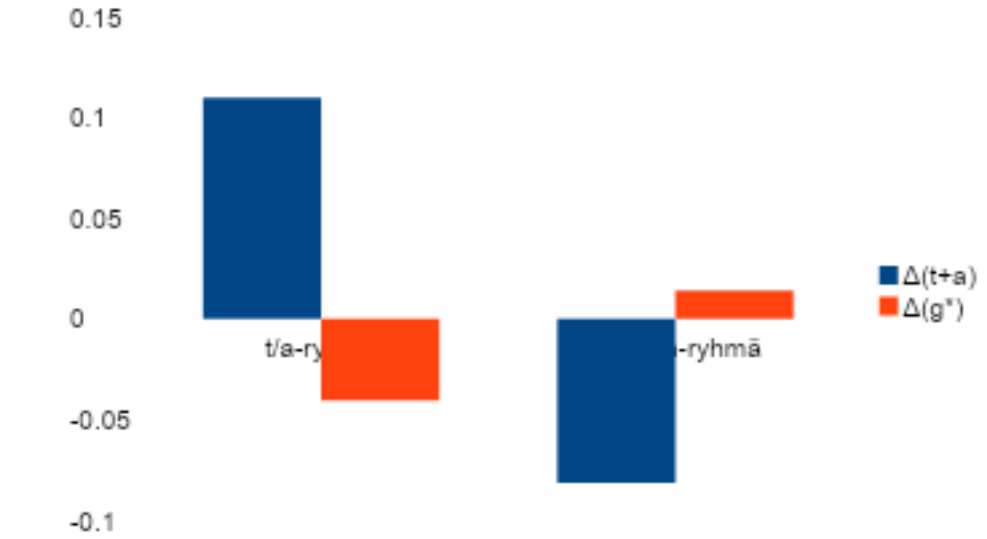

Figure 21. Comparing the baseline mean to the session mean between groups (Sanio, 2014)

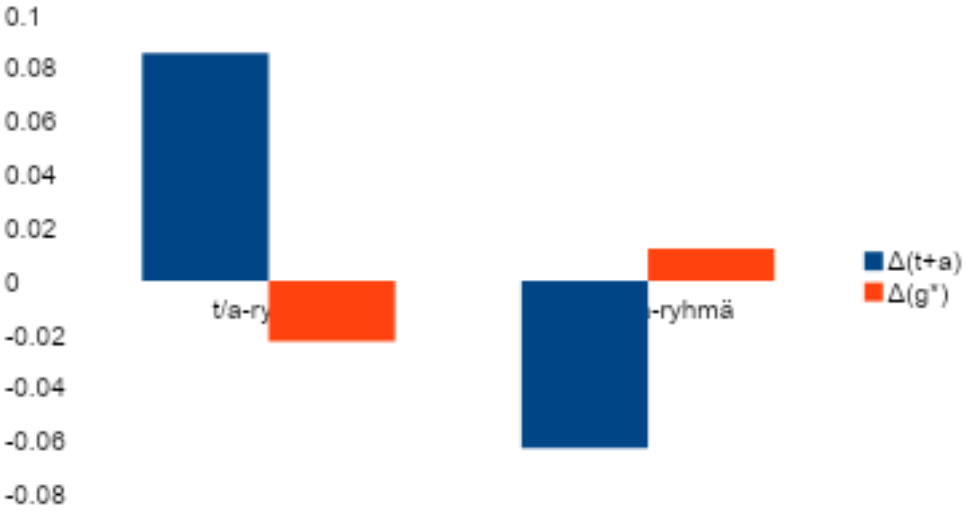

Figure 22. Comparing the averages of the first and third phase of the session (Sanio, 2014)

It was difficult to distinguish between those who practiced yoga or meditation before and those who did not have a background in meditation or yoga due to the small sample size. However, on average, those who had previously meditated or practiced yoga had a higher theta and alpha amplitude in both session types. On the other hand,

the gamma amplitude was higher in non-meditators in both session types compared to those who practiced meditation or yoga. Table 3 shows this.

Table 3. Comparison of the last phase of the session of meditation and yoga enthusiasts with the corresponding values of non-meditators.

The session type	**Meditation background**	**Theta+Alpha -amplitude**	**Gamma amplitude**
Gamma	Yes	1.56	0,67
Gamma	No	1.38	0,73
Theta/Alpha	Yes	1.83	0,60
Theta/Alpha	No	1.74	0,61

The people's sense of calmness increased based on the initial response to the questionnaires in both types of sessions. Similarly, subjects experienced reduced anxiety after the session. Figure 23 shows this.

Figure 23. Calmness and anxiety based on surveys. Before and after the session and change during the session (Sanio, 2014

Gamma-istunto

	Ennen istuntoa		Jälkeen istunnon		Muutos	
	Rauhallisuus	Ahdistuneisuus	Rauhallisuus	Ahdistuneisuus	**Δrauhallisuus**	**Δahdistuneisuus**
	8	1	9	1	1	0
	5	3	6	3	1	0
	6	3	8	1	2	-2
	6	4	8	0	2	-4
	7	1	10	0	3	-1
	8	0	9	0	1	0
	3	7	5	5	2	-2
	2	8	7	4	5	-4
ka	5,625	3,375	7,75	1,75	2,125	-1,625

Theta/Alfa-istunto

	Ennen istuntoa		Jälkeen istunnon		Muutos	
	Rauhallisuus	Ahdistuneisuus	Rauhallisuus	Ahdistuneisuus	**Δrauhallisuus**	**Δahdistuneisuus**
	6	4	5	5	-1	1
	4	7	6	6	2	-1
	7	2	9	1	2	-1
	3,5	5	8,5	1,5	5	-3,5
	4	5	8	5	4	0
	4	3	10	0	6	-3
	4	2	4	5	0	3
	8	4	9	3	1	-1
ka	5,0625	4	7,4375	3,3125	2,375	-0,6875

)

Hypnagogia was experienced by subjects in both sessions, but more by subjects in the Gamma session. This was almost described as twice the average for the theta/alpha session participants. Subjects also felt that their thoughts changed in a special way during the session. This happened more in the subjects of the Theta/Alpha session than in the Gamma group, although this had also happened in the Gamma group. An essential parameter for meditation, the silencing of the inner dialogue was a typical observation for the subjects of both sessions, but the subjects of the Theta/Alpha group described experiencing more of this. Both groups also described associating the reward sounds with specific sensations or states, but this was described as occurring more in the Theta/Alpha group. The subjects also described the meaningfulness of the experience in both sessions on a 0-10 scale of approximately 7 grades. Figure 24 shows these values.

Gamma-istunto

	Kokemuksen mielekkyys	Sisäisen dialogin hiljeneminen	Ajatuksien muuntuminen	Palkintoäänien yhdistäminen tiettyihin asioihin	Hypnagogia
	7	7	4	8	8
	5	6	0	0	10
	5	8	9	2	8
	9	4,5	0	5	3
	6	6	8	7	7
	9	5	2	0	7
	6	3	1	1	4
	9	4	5	7	2
ka	7	5,4375	3,625	3,75	6,125

Theta/Alfa-istunto

	Kokemuksen mielekkyys	Sisäisen dialogin hiljeneminen	Ajatuksien muuntuminen	Palkintoäänien yhdistäminen tiettyihin asioihin	Hypnagogia
	8	6	7	8	7
	7	6	7	0	3
	8	7	6	4	0
	5,5	8	6	9	1
	8	7	7	2	1
	9	10	10	10	8
	8	8	4	3	3
	3	7	5	9	3
ka	7,0625	7,375	6,5	5,625	3,25

Figure 24. Different parameters as a result of queries from different session types (Sanio, 2014)

Subjects reached a maximum of four soundscapes in the Gamma session and three soundscapes in the Theta/Alpha session. No subject interrupted the session.

5.3.4 Analysis and Commentary

Although no statistically significant differences were observed between the amplitudes, statistically almost significant differences were observed there. This would indicate that practitioners of different session types were able to strengthen the frequency range in question: theta and alpha or only the gamma range, depending on the type of session. This is also supported by the comparison of the averages, where the strengthening of a certain frequency range can be seen especially during the session. In these averages, specifically the strength of the theta and alpha frequency ranges of the Theta/Alpha group had increased compared to the baseline, while the strength of the gamma frequency range had decreased. Instead, the intensity of the gamma frequency range of the Gamma group had increased compared to the baseline

level, and the intensity of the theta and alpha frequency ranges had decreased compared to the baseline level.

In the experiment, many things influenced the success of individual sessions. Some people were so tired that they fell asleep for a short while in the middle of the session, which should be avoided in this kind of session, according to Egner (2014). In the case of some test subjects, the instructions also failed and the test subjects had misunderstood the task a little. For example, in the instructions for the Theta/Alfa session, it was unclear whether it was only necessary to be able to focus on the second sound channel or on both, and this was only noticed after the session. One session was also instructed for Theta/Alpha exercise, but an incorrect selection of the session type was noticed about 10 minutes into the session and the subject was informed about this and the session continued as a Gamma session.

Many subjects also experienced pain in their legs or back. Similarly, the collar was left too tight or it ran out of room to loosen it, thus causing pain during the session. These could also be reflected in the results. These can be changed and here, exceptionally, they tried to sit instead of lying down. Comments from test subjects:

-"The sitting position was not that pleasant. I had to change it twice. The rest of the time I just focused on my aching legs."

-"Panta squeezed like a tax collector's wallet."

One thing that explains the somewhat imprecise results is that there is no sham control group to compare to. Another thing concerns the state of meditation so that in the state of meditation Wang et al. (2011), an increase in the theta and alpha frequency ranges is usually observed, as well as an overall decrease in other frequencies. This in itself can increase the amplification of theta and alpha frequencies also during the gamma session, when the person is in a meditative state. Likewise, the overall decrease in frequency ranges can be one of the reasons why it is difficult to strengthen a certain range over a long period of time in meditation. However, an effort was made to take this into account to some extent and to compare only relative readings in each period of time. Similarly, the system itself tried to constantly calibrate to the amplitudes of the persons' EEG.

It would also have been possible to look at the t/a ratio from the results, but I considered it sufficient here to look at the amplification of the theta and alpha frequencies of both channels compared to the amplification of the corresponding channels of the other group, because the purpose of this experiment was to verify the functionality of the device and system. It is also noteworthy here that, for example, Egner et al. (2002), the effectiveness of the t/a method can be seen more clearly in repeatable sessions, so that the person's brain performs better each time and produces a higher t/a ratio. In this experiment, there was only one session, but we still got indicative results.

The results of the surveys showed that both types of sessions calmed and reduced anxiety. Phenomena relevant to meditation also occurred, such as the quieting of the inner dialogue and the transformation of thoughts in particular. Hypnagogia was also experienced by subjects of both session types.

However, judging by the results, the gamma session was more effective in reducing anxiety and manifesting hypnagogia. This in itself is a significant new discovery, as the Theta/Alpha session type was originally developed for practicing the hypnagogia state. Attached are examples of test subjects' feedback from the Gamma session:

-"The sounds are soothing. The ability to feel as if you have been taken somewhere else inside the mind."

-"I saw some cool patterns :) Interesting."

-"Time passed quickly."

-"The system could be good to help you fall asleep."

On the other hand, the Theta/Alpha session was described as more relaxing, and parameters relevant to meditation, such as the quieting of the inner dialogue and the transformation of thoughts, were reported to be felt more strongly in this type of session. Hypnagogia was also reported to occur in this session type to some extent during sessions, although not as much as in gamma sessions. Comments from subjects on Theta/Alpha sessions:

-"It felt like I was half asleep, but I felt like I was somewhere other than this room anymore."

-"It was a nice experience. Relaxing!"

-"It was nice. It helped me understand some of the differences between the facilities."

-"A high sound field was produced by focusing on the left brain lobe, breathing and the voice. A low sound field, on the other hand, was produced by focusing on the right brain lobe and the body and mantras."

As feedback from the Theta/Alpha session, some subjects reported resurfacing of memories. This is a very typical phenomenon in meditation. According to Miller (1993), when the background noise of the mind eventually dissipates, a common experience is that the memories of the past and the pain associated with them rise up. Sometimes the feeling can be so strong that it is difficult to return to the object of concentration. Comments like these were:

-"So many memories in mind.."

-"Brings back memories of my homeland. Memories related to my family."

The sound design of the system was generally perceived as pleasant. The soundscape of both sessions was very similar: One was just exhausted by another channel and a different brainwave entrainment in the background. However, when analyzing the results, it was noticeable that the subjects were able to reach the maximum of the soundscape in three Theta/Alpha sessions, which would indicate that the soundscape may have remained boring. Thus, it would have been good to reduce the number of rewards in Theta/Alfa session per soundscape change.

The test subjects also felt that the reward sounds were related to some state of being or feeling sometimes. This was on average more noticeable in the Theta/Alpha session. However, some subjects did not associate the reward sounds with any state. On the other hand, it was also sometimes difficult for the test subject to figure out whether to focus on the sound or meditate when the instructions were not so clear. Some comments about the soundscape and award sounds:

-"It's hard to know whether to relax or listen to voices."

-"Kongi's voice occasionally drifted into another state."

-"The sounds are soothing."

-"The sound of the water was soothing. Birds not so."

It is difficult to evaluate the effectiveness of brainwave entrainment from the duration of the sessions, but it can at least be noted that they did not completely prevent the functioning of the neuroplasticity therapy and none of the test subjects commented that they were disturbing.

Overall, the system was perceived as pleasant. Everyone answered affirmatively that they would like to use a similar system in the future, except for two test subjects, one of whom added the option Maybe in addition to the options Yes and No to the questionnaire and selected it. In the case of the second subject, the instructions had remained unclear and this could be seen in the results and also in the feedback.

5.4 Further development of the system

The system has a lot to improve and develop in terms of the continuation. In the system, the first threshold is the device, which you can always strive to make more user-friendly. Currently, based on the results, some subjects found it difficult to hold the device on their head for a long time. This was largely due to the tightness of the collar, so this can also be compensated for by reserving a long enough tightenable collar for the EEG device. Similarly, it will also be interesting to try the system on another device.

Only two different types of sessions were tried in the system, but this still leaves a lot of possible avenues open in terms of developing meditation tools. These include, among others Wang et al. (2011) according to calculating the average strength of all channels or, for example, calculating the strength of beta frequency ranges, which is usually observed in meditation Cahn and Polich (2006) preceded Jacobs et al. (1996).

One thing also, which can be observed during meditation, for example Raffone et al. (2007), there is greater activation of the left brain hemisphere, which, according to Cimino (2008), is related to positive moods. This could be good to connect as system feedback or session type. However, testing this should be done carefully, especially if the device is not replaced. Because the instructions for the EEG-SMT device mention the symmetrical placement of the sensors so that they should be on different sides of the head - and + so that they measure the EEG through the head. This almost excludes the possibility of placing the sensors on the same side of the head, in which case it would be possible to read the activation of different sides of the brain. This could still be a potential experiment. In addition, in this experiment we only observed the changes occurring in the frontal lobe area due to its easy placement on the sensors. This leaves the possibility in the future to look at many measurable changes during meditation, which also take place, for example, in the area of the head.

In this experiment, the system's raw data was not actually filtered. After importing the raw data, it could also be good to try different filters, which could improve the accuracy of the data obtained from the signal and eliminate, for example, interference caused by muscle movements.

Testing the system also with repeated sessions can be a very interesting subject of review, because the effect of neuroplasticity therapy will then start to be seen more clearly. Therefore, only profiles should be created in the system, which would enable the recording of several repeated sessions for several people. Thus, the long-term variables of a person's meditation or targeted form of therapy could also be observed.

The system is now made to give voice feedback only. You can modify the voice feedback itself and search for suitable sounds as background sounds, as well as the different options of brainwave entrainment or you can try to change the frequencies that change during the session to suit different sessions. On the other hand, voice feedback can also be replaced or added to, for example, by transcranial magnetic stimulation or light stimulation.

6 Summary

By looking at the basics of meditation and its history, we noticed that the initial steps of meditation are related to the gradual stopping of the mind's functions, the practice of concentration and the development of a state of mindfulness. In addition, we noticed that since ancient times, aids such as mantras or mandalas have been used to help with concentration or to otherwise make meditation more effective. Understanding the basics of meditation appeared to be essential in the development of the meditation aid. To shed light on this, we looked at the concentration and mindfulness techniques of the Vipassana style, which are an essential part of meditation. Of these, the ability to gently restore concentration without judging the wandering of the mind is essential for the development of mindfulness. In addition, we looked at the health effects of meditation from both a physiological and a mental health point of view.

Since our purpose was to approach the development of meditation aids with the brain's electrical activity in mind, we also looked at the effects of meditation on the brain in general. Here, in more detail, how the state of meditation and the long-term effects are seen as changes in the structure of the brain and in electrical activity. We noticed that as a result of long-term meditation, the amount of gray matter in the front part of the brain that deals with emotions, decision-making and risk and fear, among other things, correlates with the number of hours of meditation. We also noticed that the anterior insula and the right amygdala can grow as a result of meditation. From the electrical activity of the brain, we noticed that in the long-term effects of meditation and during the meditation state itself, stronger amplitudes of the theta, alpha, and gamma frequency ranges can be measured compared to non-meditators, usually in the frontal lobe or crown of the head. We also noticed that different meditation techniques cause different measured results and that, in general, the amplitude of all frequency ranges can weaken slightly during meditation.

We looked at various technological aids to transform the state of consciousness with the aim of mapping and finding combinations and a functional tool to support meditation. These included breathing control programs, brainwave entrainment,

transcranial stimulation and biofeedback. Among these, we noticed that, among other things, the Sonic Cradle system had been aimed at making it easier for first-timers to experience a state of mindfulness. This was implemented as biofeedback, where the person receives feedback from breathing. When the breathing changes due to the distraction of the concentration, the system gives feedback to the person with the help of sound and the concentration is restored and thus the person does not remain in a state of self-judgment so easily, but the concentration returns to the sounds of the environment.

From these different techniques and information, we combined a system that guides a person into a meditative state by reading brain electrical activity and responding to it with audio feedback. The voice feedback intensified and gave reward sounds when the person's brain electrical activity was towards favorable activity. As favorable electrical activity of the brain, we chose the amplified amplitude of the gamma frequency range and the theta/alpha neuroplasticity therapy method, where the aim was to amplify the amplitudes of the theta or alpha waves. These were meant to act as directions for the meditative state. The system also tried to take into account things like getting bored by changing the soundscape.

Testing of the meditation assisting system was performed with 16 people and the session was 30 minutes long. The results showed that in some sessions the strap of the device was left too tight and sitting on the floor was also found to be painful for some. Experiencing pain during the session may have taken away concentration from many subjects. Likewise, we noticed that it is particularly important to instruct people precisely, because misunderstood instructions cause an unpleasant session and different results. As a summary of the results of the experiment, it could be stated that the subjects had succeeded in increasing the amplitudes typical of the sessions and this difference could be noted between the two types of sessions, although the statistical significance remained almost statistical significance. The people also liked the session and were interested in using a similar method in the future.

From the results of the system, an overview of the parameters related to meditation could be made, which we found out with surveys. We noticed that both types of sessions reduced anxiety, calmed down, silenced the inner dialogue, changed

thoughts and brought out hypnagogic experiences. Among the types of sessions, the Theta/Alpha exercise seemed to bring the test subjects a greater sense of calmness, a quieting of the inner dialogue and a transformation of thoughts. In connection with the gamma session, we noticed that it alleviated the anxiety a lot. We also made a surprising observation that during the type of session that boosted Gamma waves, subjects reported experiencing a greater amount of hypnagogia. This was therefore new, because the Alpha/Theta exercise was originally designed to approach the state of hypnagogia.

Since the practice of neuroplasticity therapy produces results during repeated sessions and many of the test subjects had not even practiced meditation before, testing the system with one session per person produced very promising results. Likewise, the primary purpose of the testing was to verify the functionality of the hobbyist-level EEG device, the EEG-SMT. And as we found out, this goal was more or less achieved. These findings and the programming work I did also open new doors in terms of continuation and possibly expand the experimental possibilities of neuroplasticity therapy to places where it is not possible to purchase expensive systems.

We also stated that there are points to be developed in the system, the first of which are related to refining the person's sitting position and the usability of the device itself. In addition, we noticed that there are still many different types of sessions to be tried, as well as electrode placement locations in the head area, which may have potential in supporting meditation. In addition, we also noticed that in addition to audio feedback, the system could provide other types of feedback such as transcranial stimulation or light stimulation.

All in all, this is how we mapped out one route to assist meditation with a brain-computer interface and built a system that includes two session types utilizing hobbyist-grade EEG equipment. With the help of the system, most of the test subjects experienced a pleasant session and some of them felt that it supported the meditation practice. None of the subjects had ecstatic experiences, but some people experienced hypnagogia. In addition, a typical observation was a reduction of

anxiety, an increase in calmness, an understanding of different states of mind and the emergence of memories.

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Appendix 1: Appendix of results

Session baseline to session avg

#Theta/alfa-Group

baselineAvg(t-	baselineAVg((	sessionAvg(t+	sessionAvg(g*	**Δ(t+a)**	**Δ(g*)**
1,977	0,505	2,088	0,474	0,111	-0,031
1,562	0,649	1,514	0,668	-0,048	0,019
1,676	0,609	1,684	0,612	0,008	0,003
1,963	0,488	2,048	0,493	0,085	0,005
1,241	0,811	1,506	0,684	0,265	-0,127
1,682	0,598	1,511	0,648	-0,171	0,05
1,52	0,687	2,005	0,508	0,485	-0,179
1,345	0,813	1,487	0,748	0,142	-0,065
		avg->		0,109625	-0,040625

#Gamma-Group

baselineAvg(t-	baselineAVg((	sessionAvg(t+	sessionAvg(g*	**Δ(t+a)**	**Δ(g*)**
1,618	0,616	1,824	0,547	0,206	-0,069
1,721	0,623	1,526	0,708	-0,195	0,085
1,311	0,734	1,315	0,741	0,004	0,007
1,838	0,579	1,755	0,602	-0,083	0,023
1,582	0,608	1,153	0,791	-0,429	0,183
0,864	1,054	1,134	0,833	0,27	-0,221
1,673	0,629	1,525	0,664	-0,148	0,035
1,852	0,619	1,576	0,689	-0,276	0,07
		avg->		-0,081375	0,014125

Session 1. to 3. phase

#Theta/alfa-Group

1. (t+a)	1. (g*)	3. (t+a)	3. (g*)	**Δ(t+a)**	**Δ(g*)**
2,001	0,494	2,084	0,475	0,083	-0,019
1,446	0,72	1,616	0,603	0,17	-0,117
1,671	0,615	1,726	0,603	0,055	-0,012
2,006	0,517	2,08	0,476	0,074	-0,041
1,456	0,689	1,461	0,72	0,005	0,031
1,489	0,634	1,571	0,643	0,082	0,009
1,798	0,563	2,111	0,486	0,313	-0,077
1,54	0,727	1,442	0,771	-0,098	0,044
			avg->	0,0855	-0,02275

#Gamma-Group

1. (t+a)	1. (g*)	3. (t+a)	3. (g*)	**Δ(t+a)**	**Δ(g*)**
1,915	0,521	1,598	0,635	-0,317	0,114
1,498	0,724	1,584	0,673	0,086	-0,051
1,279	0,765	1,376	0,701	0,097	-0,064
1,751	0,604	1,788	0,593	0,037	-0,011
1,345	0,703	1,096	0,822	-0,249	0,119
1,018	0,902	1,145	0,83	0,127	-0,072
1,542	0,673	1,456	0,668	-0,086	-0,005
1,712	0,646	1,515	0,714	-0,197	0,068
			avg->	-0,06275	0,01225