HOW LONG-TERM MINDFULNESS MEDITATION PRACTICE AFFECTS THE BRAIN MECHANISMS OF ATTENTION?

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Abstract:

In the last few decades, the beneficial effects of meditation and mindfulness have been broadly researched. Because attention plays a key role in mindfulness, it has been assumed that long-term practice of mindfulness meditation also has an impact on attention on neurophysiological level. In the current study, we explored how the long-term practice of mindfulness meditation affects the brain mechanisms of attention. We compared two groups, long-term meditation practisers and meditation novices. EEG-scanning was conducted during an attention task of dichotic listening, where two stories were listened simultaneously, and participants were asked to concentrate in only one of the stories at a time. We did not find a difference between meditators and novices in their neural correlations of attention or inhibition. We, however, found out that the long-term meditation practitioners differ from the meditation novices in the hemispheric ditribution of activation during the listening task.

Keywords: meditation, mindfulness, EEG, attention

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1. INTRODUCTION

In the last few decades, the beneficial effetcs of mindfulness meditation have been broadly researched, and the mindfulness-based interventions have been reported to be efficient in treatment of a wide variety of clinical disorders and medical conditions (e. g. Grossman et al., 2004). Additionally, benefits of mindfulness have also been established with healthy patients as improvements in their overall psychological well-being and cognitive skills (e. g. Sedlmeier et al., 2012) and even in the functioning of the immune system (Davidson et al., 2003). Due to these positive results, mindfulness based methods have become a widely used part of treatment in therapy and healthcare, as well as sustaining our well-being in everyday life. Although it's established benefits, there is still little knowledge on why mindfulness meditation works, and, especially, what are the neurophysiological effects of long-term practice.

1.1. Origin of mindfulness meditation

In mindfulness meditation, the attention is focused on experiencing thoughts, emotions and bodily sensations as they appear and pass, simply observing them. Mindfulness is usually seen to be cultivated throught meditation, and meditation as a framework of learning to be ”mindful” (e.g. Chiesa & Malinowski, 2011). Mindfulness originates from the 2000-year-old Buddhist meditation tradition, and Jon Kabat-Zinn, the developer of Mindfulness-based stress reduction –program (MBSR), is perhaps the best-known converter of this Buddhist meditation tradition to the Western consciousness. According to his definition, mindfulness is ”—*paying attention in a particular way: on purpose, in the present moment, and non-judgmentally*” (Kabat-Zinn, 1994).

Based on Kabat-Zinn's definition of mindfulness, other clinical interventions have been developed, including Dialectical Behavior Therapy (DBT) (Linehan, 1993), Mindfulness-Based Cognitive Therapy (MCBT) (Segal et al., 2002), and Acceptance and Commitment Therapy (ACT) (Hayes et al., 2006). Research on the benefits of mindfulness has largely focused on its clinical use, in which it has been witnessed as being a succesful method. Studying experienced long-term meditator practisers, who have chosen to consume mindfulness meditation as a part of their everyday lives, may however provide a possible route to understanding the mechanisms and effects of mindfulness meditation outside of intervetional purposes.

1.2. Theories and definitions of mindfulness meditation

One much-discussed problem in the scientific study of mindfulness meditation is the lack of consensus about the clear operational definition for the concept. The term *meditation* has been used to refer to an expandum of traditions and techniques, from simple relaxation excercising to far more complex practices, and with differing goals (Lutz et al., 2008). Meditation is conceptualized by Lutz et al. as ”a family of complex emotional and attentional regulatory strategies developed for various ends, including the cultivation of well-being and emotional balance”.

Indeed, the practitioners of meditation do not form a homogenous group, and their reasons to meditate as well as the intensity of training vary. For example, while others devote a certain amount of time in a day or a week for meditation training, other practisers describe meditation more as a way of life, practised during the everyday chores.

Mindfulness, on the other hand, is sometimes treated as a method or a technique or a set of techniques, sometimes as a psychological process that can have outcomes, sometimes as an outcome in and of itself (Hayes & Wilson, 2003). However, mindfulness may still be by far the most studied and thus scientifically best-defined component of meditation. Most definitions of mindfulness also include two essential components: awareness or paying attention (conducting behavior) and acceptance (the way in which behavior is conducted). In attempting to build a scientific theoretical framework for understanding the working mechanisms of mindfulness, it has generally been connected to the concepts of attention and self-regulation.

Attention refers to selecting substantive information from the constant stream of sensory stimuli, a process which is highly automatic. Instead of talking about attention as a clear-cut cognitive function itself, it is more accurate to refer to it as a superordinate term in referring to several cognitive capacities, such as ”orienting”, ”detecting” and ”alerting” (Posner & Petersen, 1990). Sustained attention or alertness is the attention focused and then maintained on a certain objective, whereas shifting attention or orienting is needed when changing the target of attention. Selective attention then refers to the skill of choosing amongst multiple competing stimuli, classical example being a noisy party where one particular conversation must be followed. Inhibition, on the other hand, is needed to filter out the interfering stimuli. Executive attention or detecting refers to higher forms of cognitive functions, which control attention orienting.

While the capability of using attention is easy to take for granted in everyday living, it often is damaged in brain-related traumas, and disorders including attention deficit hyperactiviy disorder (ADHD) and schizophrenia. Attention-related biases and impairments of selective attention are also common in anxiety disordes, especially depression (e. g. Schlosser et al., 2011).

Vago and Silversweig (2012) pay regard to the 2000-year-old historical perspective of mindfulness meditation as well as the modern adaptations in their S-ART -framework, which aims to explain the mechanisms by which mindfulness reduces biases in self-processing and improves psychological health. According to them, and based on the Beck's original definition of cognitive therapy, both psychopathology and everyday psychological suffering are largerly caused by cognitive biases, including attention biases, which mindfulness helps to correct. They describe mindfulness as a mental training that develops three other cognitive skills: meta-awareness of self (self-awareness), an ability to effectively modulate or alter one’s behavior (self-regulation), and a positive relationship between self and other that transcends self-focused needs and increases prosocial characteristics (self-transcendence).

According to Shapiro et al. (2006), and based on the Kabat-Zinn's original definition, mindfulness is a moment-to-moment process, which includes three simultaneously occurring, interwoven axioms: 1) Intention, 2) Attention, and 3) Attitude. Bishop et al. (2004), quite similarly to Shapiro et al., have proposed a two-component model of mindfulness. These are 1) self-regulation of attention, so that it is maintained on the immeditate experience, and 2) orientation to experience, meaning curiosity and acceptance.

The role of attention is also emphasized, but differently, in Hölzel's four-component model to describe the mechanism through which mindfulness works and produces it's beneficial effects (Hölzel et al., 2011). The components of this model are: 1) Attention regulation, 2) Body awareness, 3) Emotion regulation, and 4) Change in perspective on the self. Attention in this model is seen as a base upon which the other mechanishms of mindfulness are ”built”, and according to them, attention regulation develops early in mindfulness-meditation training.

Lutz et al. (2008) distinguish two categories of Buddhist meditation: focused attention meditation (FA) and nonreactive monitoring (OM), pointing out that even if attention seems to have a central role in meditation practice, the usage of it varies among different traditions and techniques of meditation.

During the FA-meditation, attention is supposed to be focused on a single object (e. g. breathing), and the attention must be sustained on it. If the focus wanders away from the chosen object (e. g. to surrounding noises or disturbing thoughts), one is recommended to detect these wanderings and then gently shift the attention back to the original object. As for OM-meditation, there is no explicit focus on objects, and thus no selection or nonselection between competitive stimuli. Instead, one is aiming to stay in the monitoring state, and only observe, moment-by-moment. The two styles are often combined, and this also concerns practising mindfulness meditation. However, the investigation of attention's role in meditation seems to be somewhat more focused on FA -style of meditation. FA-meditation training can also be understood as an ”early phase” of learning other, more complex forms of meditation (e. g. Hölzel et al., 2011).

The very basis of linking mindfulness and meditation together has also been questioned – it has been pointed out that meditation may only be one of the many contexts in which mindfulness can be practised and that mindful activity can happen outside of the meditation paradigm as well. Bishop et al. (2004), for example, see mindfulness as a psychological process and as a skill that can be developed with practice, emphasizing attention-regulating as a requirement for it. Mindfulness, according to them, can be learned through practising meditation techniques, but is not limited to meditation. Instead, it can be learned and then used succesfully in different situations. According to Hayes & Shenk (2004), mindfulness-related skills can be achieved even entirely without framework of meditation and with radically different approaches, for example in therapy situations.

However, in this thesis, a conscious decision was made to use the concept 'mindfulness meditation', because subjects of our study were meditation practitioners specifically. Mindfulness is here treated as a skill developed during meditation and possibly adaptive to other situations as well, similarly with Bishop's et al. view. Meditation thus is seen as a form of mental training.

1.3. Behavioral studies of the effects of mindfulness

Because attention is a key element in mindfulness, it has been assumed for a long time that regular training of mindfulness meditation also has effects on attention. Behavioral studies have been made, with somewhat mixed results.

Moore & Malinowski (2008) have studied how long-term meditation practice affects cognitive flexibility, and they have found out that experienced meditators perform better in the Stroop task and the d2-test of attention, which both measure ability to suppress interfering information and direct and focus attention. The second study, where the Stroop task was conducted after a 8-week MBSR -training, did not produce same kind of effects (Anderson et al., 2007). On the other hand, in the study of Tang et al. (2007) the participants showed improvements in Attentional Network Test, a test specifically designed to measure executive attention, after only a five-days long integrative meditation training.

The problem of behavioral studies of meditation is that behavioral tests used in these studies are often developed for limited clinical purposes, and neurophysical implications are difficult to make based solely on them. Therefore, the neuroimaging studies are needed to better understand these phenomena.

1.4. Neuroimaging studies of the effects of mindfulness

The importance of neuroimaging studies of meditation and attention is that they can help in understanding the effects that mindfulness meditation has on brain and which regions of the brain it involves, and thus, test validity of psychological theories. In the best-case scenario, neuroimaging studies may even broaden the understanding of attention-related disorders and other impairments.

During the last few decades, various kinds of functional neuroimaging techniques have also been used to study the role of attetion in meditation. In electroencephalography (EEG), electrical activity of the brain is measured on the scalp. Magnetoenchephalography (MEG) instead measures brain activity by recording magnetic fields produced by the brain's electrical currents. Stuctural magnetic resonance imaging (MRI) is an imaging technique to examine brain- and body anatomy. Functional magnetic resonance imaging (fMRI) measures brain activity by cerebral blood flow changes.

1.4.1. Structural imaging studies of the effects of mindfulness

Generally, neuroimaging studies have shown that meditation practice is linked with anatomical alterations in brain, including increased grey matter (Hölzel et al., 2010) and more cortical thickness (Lazar et al., 2005). Many of these structural findings have been found only in one hemisphere, alluding that meditation might shifts brain asymmetry. Structure of corpus callosum, which connects the two hemispheres, has also been linked with meditational practice: Luders et al. (2012) used Diffusion tensor imaging (DTI) combined with MRI to study callosal area of 30 long-term meditators and matched controls. Their findings suggest that the area of corpus callosum is larger for meditators than novices and that this may indicate greater brain connectivity and increased hemisphere integration.

Current neuroimaging studies have also shown that some of the same brain regions which are associated with attention can be linked with meditation as well: for example, anterior cinculate cortex (Hölzel et al., 2011) and prefrontal cortex (Chiesa & Sherretti, 2010), have both been found to be thicker and more active for experienced meditators than novices. In Lazar's study, 20 long-term meditators were compared with a control group of novices to map differences in cortical thickness (Lazar et al., 2005). It was found that long-term meditation practice may be associated to structural changes in regions related to somatosensory, auditory, visual and interoceptive processing.

However, same areas in the brain are involved in many different processes, and certain brain areas cannot be straghtforwardly linked to changes caused by meditation only because there is earlier evidence of these areas' role in attention. Attention-related tasks should be performed during the imaging to make further interpretations of how meditation affects attention.

1.4.2. Neuroimaging studies during attention-related tasks

There are also studies where meditators have been imaged during attention-related tasks. Majority of these studies have focused on visual tasks. For example, Kozasa et al. (2011) used fMRI scanning to study how experienced meditators perform in Stroop task compared to novices. Behaviorally, meditators performed better in the test than meditation novices, and fMRI showed non-meditators having more brain activity in the right medial frontal, middle temporal, pre-central and post-central gyri and in the lentiform nucleus during the task, thus needing more brain regions to be active under the same task than experienced meditators. This could indicate that the long-term meditation experience improves attentional efficiency. Teper & Inzlicht (2013) conducted an error-related negativity -study (ERN) on the effects of meditation on executive control, especially through the anterior cinculate cortex (ACC). In this study, 20 meditator experts were compared to a control group of meditation novices, and they completed the Stroop task during an EEG measurement. Meditators were found out to have higher ampilutde of ERN than non-meditators and make fewer mistakes in the behavioral task.

Less studies have been focused on the auditory attention. MMN (missmatch negativity) study was conducted by Shrinivasan and Baijal (2007), where 10 meditators were compared to 10 non-meditators. They found that the meditators had larger MMN amplitude than nonmeditators, particularly those for the deviant tone, and suggested that meditation practice may have an impact on preattentive processing. Lutz et al. (2009) studied whether 3-months long intensive FA -meditation training can improve attentional stability and promote more efficient processing, by conducting the dichotic listening task during an EEG-measurement. Frequent standard and rare deviant tones were presented to both ears, and participants had to detect the deviant tone in the attented ear channel. It was found that meditation training increased phase consistency of theta-band oscillatory neural responses over anterior scalp regions to target stimuli and reduced ERD to target tones in the beta (13-30 Hz) frequency band, which indicates less cortical engagement. Meditation training was also associated with enhanced phase consistency of the brain responses to any deviant tone. These findings support the idea that meditation training could affect both target and distractor processing of attention.

1.5. The present study

In the present study, we were interested in how the long-term practice of mindfulness meditation affects the attention mechanisms of the brain. Based on the earlier studies and theory, we asked if the long-term meditation practice would have some overall altering impact on the brain mechanisms of attention. We also asked if long-term meditators would differ from novices in their brain responses to attentional demand, while they had to to sustain attention or inhibit competing auditory stimuli while listening continuous speech. Listening human speech is difficult to study in a realistic manner due to its complexity, but at the same time, it is the most important form of human communication (Ding & Simon, 2012). We used a dichotic listening situation, where two stories were listened simultaneously, and participants were asked to concentrate in only one of the stories at a time – a simulation of the well-known cocktail party situation. During the task, EEG-scanning was conducted to measure the electrical activity of the brain. We assumed that meditators would show a stronger correlation between auditory stimuli and attented story, that they would inhibit competing stimuli better and that there would be some kind of overall difference in their functioning of the brain attentional mechanisms.

2. METHODS

2.1. Participants

28 right-handed adults (ages between 21 and 59, M=36,5) volunteered to the study, 16 of them men, 14 women. Two equal-sized (N=14) groups were compared: The experienced meditators, with experience of 2 years or more and a regular basis of training, and the control group of meditation novices with no

experience of meditation. The subjects in the control group were collected to match the participants in the meditation group for gender (8 males and 7 females in both groups), age (meditators: M=36 years, controls: M=38 years), and their educational level (all participants having a degree of secondary level at least).

In the meditation group, all participants reported having a background of at least 2 years of regular meditation training, average being 8,3 years, and variation being between 2-20 years. All participants reported that they practised meditation daily or several times in a week. Most common method or technique of meditation mentioned was *breathing meditation*, and the next most commonly mentioned were *visualization* and *observing bodily states or thoughts*. 7 participants told that they followed specifically Buddhist traditions in their meditation training, while 8 participants reported basing their meditation practice either in several traditions or not in any particular tradition or philosophy.

We also collected information of subjects' general health, medication, neurological diseases and problems of hearing. Due to small number of subjects in this study, we decided not to leave out participants who were taking medications, had dyslexia or mild hearing problems. However, the statistical analyses were made both including and excluding these subjects to ensure that these conditions didn't impact the results of the study. Three subjects were excluded due to the bad quality of the EEG-data.

2.2. Behavioral tests

In order to estimate and control the level of linguistic and non-linguistic reasoning of subjects, Similarities sub-test of the WAIS-III (Wechsler Adult Intelligence Scale - Third Edition, 1997) and Raven Advanced progressive matrix set 1 were conducted after the EEG-measurements. In WAIS-III Similarities sub-test, participants in the both groups scored above average levels, meditators scoring slightly lower on average than control group (meditators: M=11sp, control group: M=13sp). In Raven Advanced progressive matrix set, both groups got average level scores and above (M=95per in both groups).

2.3. Questionnaires

Before their coming to the experiment, a questionnaire form was sent to all participants, including questions of their background information and medical conditions. Participants in the meditation group also answered to open and closed questions concerning their meditation background.

After the EEG-measurements, participants also filled in five self-report questionnaires concerning their psychological well-being and different facets of mindfulness. Five Facet Mindfulness Questionnaire (Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L., 2006) is a 39-item instrument developed to measure five different factors of mindfulness: observing, describing, acting with awareness, non-judging of inner experiences or accepting and non-reactivity to inner experiences. Acceptance & Action Questionnaire (AAQ-2A, Hayes et al., 2004) measures psychological flexibility and consists of 10 items. Depression Anxiety and Stress Scale (DASS, Lovibond & Lovibond, 1995) is a three-scale, 42-item questionnaire designed to measure negative emotional symptoms over the last two weeks. Overall psychological well-being was measured with 18-item version of Psychological Well-being questionnaire (Ryff, 1989). Participants's current satisfaction to different aspects in their lives was also surveyed with 7-item Life satisfaction questionnaire (Pulkkinen et al., 2005).

2.4. Procedure

EEG-data in this study was collected as a part of a larger study about the brain effects of mindfulness meditation in the University of Jyväskylä. The actual experiment consisted of three different measurements, Meditation (Part 1), MMN during Meditation (Part 2) and Dichotic listening (Part 3). In the beginning of the session, all participants were instructed to do a simple, mindfulness-based breathing rehearsal**,** which they were asked to continue through the study (parts 1 and 2). This was done to ensure that every participant practised the same kind of meditation during the measurements. After the two parts of mindfulness meditation, the dichotic listening task (part 3) was conducted. In this thesis, I only focus on the third part of the study, the dichotic listening task, but the other two are also shortly summarized here.

Part 1: Meditation (10 minutes):

Participants were asked to continue the breathing meditation they were introduced to earlier. When participants noticed that their attention was wandering, they pushed the button (used as a trigger in EEG analysis), and directed their awareness back to the breathing excercise.

Part 2: Mismatch listening task during meditation (17 minutes):

Participants were asked to continue the same meditation during 17 minutes long MMN-design task. Standard and deviant sine-wave tones were played to the subjects through headphones. Participants were adviced to pay no attention to the tones and simply continue following their breathing.

Part 3: Dichotic listening task:

Dichotic listening task is a classical simulation of a cocktail-party situation, where auditory attention is sustained in one particular stimulus (e. g. conversation) among many competing stimuli. In this study, participants were asked to listen to one-minute long segments of story ”Harpo Puhuu”[1] and the same task was conducted both dichotically (simultaneously to both ears at a time) and monoaurally (only to one ear at time). *3a. Dichotic listening:* Two different one-minute segments of the story were presented dichotically, i. e. simultaneously to each ear, to the subjects using headphones. The subjects were asked to focus on only one ear at a time, left and right in turns. The same segments were repeated six times. The ear that was listened to first was counterbalanced over subjects. After every repetition, subjects were also asked to estimate how well they were able to concentrate on the attented segment of the story on a scale from one to five (one = couldn’t focus at all, five = could focus very well). This was done in order to make participants more motivated to the task. *3b. Monoaural listening***:** After the dichotic listening, the same stories were also repeated monoaurally, i. e. one story at a time, taking turns between the left and the right ear. This was also repeated six times, three times to each ear.

[1] Written by Harpo Marx and Roeland Barber, translated to Finnish by Heikki Salojärvi and read by a male speaker, Pekka Savolainen. The read biography was found on the web page of Yle, a public Finnish TV channel.

2.5. EEG-measurement

The EEG-data was recorded with 128-channel Electrical Geodesic Inc (EGI) system. Sampling frequency was set at 1000Hz. The EEG signals were band-pass filtered between 0.1 Hz and 400 Hz.

During the EEG-measurement, the dichotic listening task was conducted. The speech signals of the two story segments were amplitude modulated at 38 Hz and 42 Hz. This was done to distinguish the attented stories from another in further analysis: in other words, different modulation frequencies worked as 'tags' for different inputs. To the right ear, the segment of the acoustic signal of the story was always modulated with a frequency of 42 Hz, whereas to the left ear the story was modulated with a frequency of 38 Hz. Amplitude modulation does not interfere with the understandability of speech but only makes it possible to focus to the activation evoked by different speech signals in the EEG-data. The protocol is adopted from Ding and Simon (Ding & Simon, 2012) when they studied the neural coding of continous speech.

3. DATA-ANALYSIS

3.1. Preprocessing

First, the measurement files were converted from EGI to EDF to FIF-format, trigger-files from EGI to FIF-format and the channel map from SFP to FIF to LOUT-format, using functions provided by Python and MNE-Python -packages. Reference was changed to the mean reference. Next, bad channels were marked and removed by hand, and segments with muscle-, heart- and other artefacts (EOG) were removed using signal space projection -method (SSP, http://link.springer.com/article/10.1007%2FBF02534144). To focus to the signal of interest, a band pass filter was set to 33 - 47 Hz.

Because the same auditory stimulus was always repeated three times during the listening task, we calculated the mean of all repetitions of the same stimuli. Finally, we chose the channels from the right and left hempisphere for further analysis, using the Matlab-program.

3.2. Canonical Correlation Analysis

Canonical correlation analysis (CCA) is a classical method for finding linear relationships between two multivariate datasets, and was first introduced by Hotelling (Hotelling, 1936). In this study, canonical correlation analysis was conducted to find the high 'peaks' from the correlation martix between audio signal and neural activity, utilizing the fact that the audio signal was always presented moduladed to certain frequencies (38 Hz to the left and 42 Hz to the right ear), and therefore it was possible to identify these modulation frequencies from the data. These peak values in the canonical correlation matrix, which represent strenght of correlation between audio signal and EEG activation, were later utilized in the statistical analysis.

3.3. Statistical Analysis of the emotional questionnaires

Results of the emotional questionnaires were statistically analyzed using within-subjects t-tests, a version of the basic t-test that is suitable for the matched pairs experiment setting.

3.4. Statistical Analysis of the CCA-Values

CCA-Values of the meditation group and the novice (control) group are presented as box-plot figures in Fig. 1 – Fig. 4.

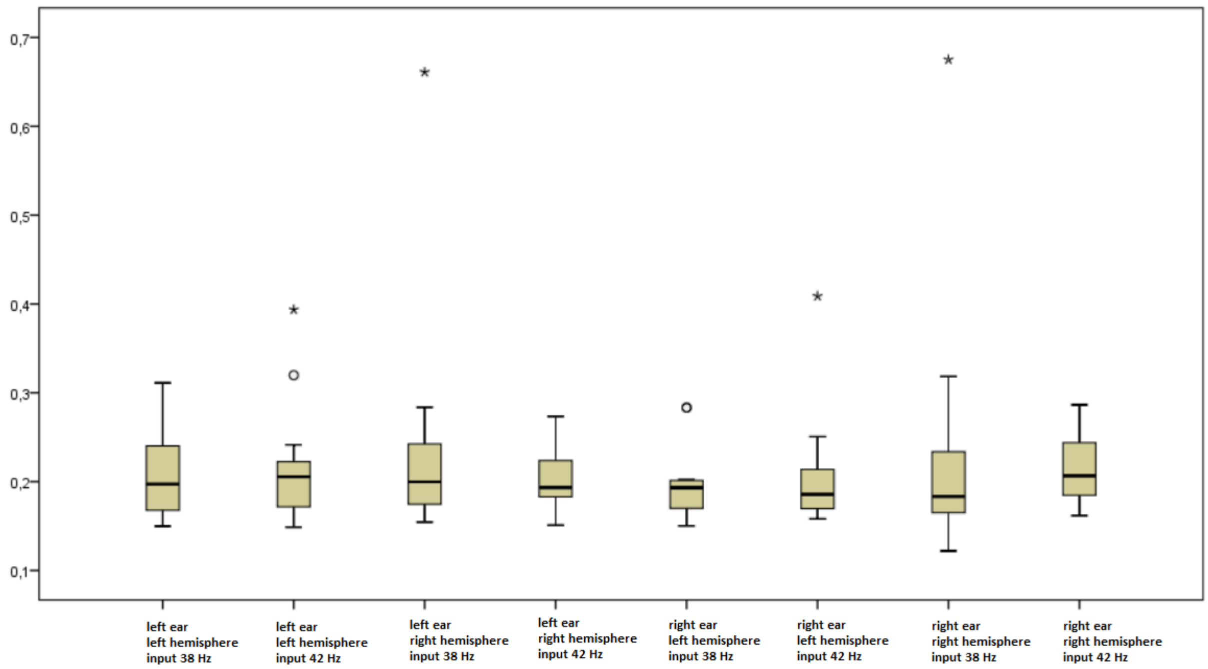

Figure 1: *The cca values of the meditation group in dichotic listening situation.*

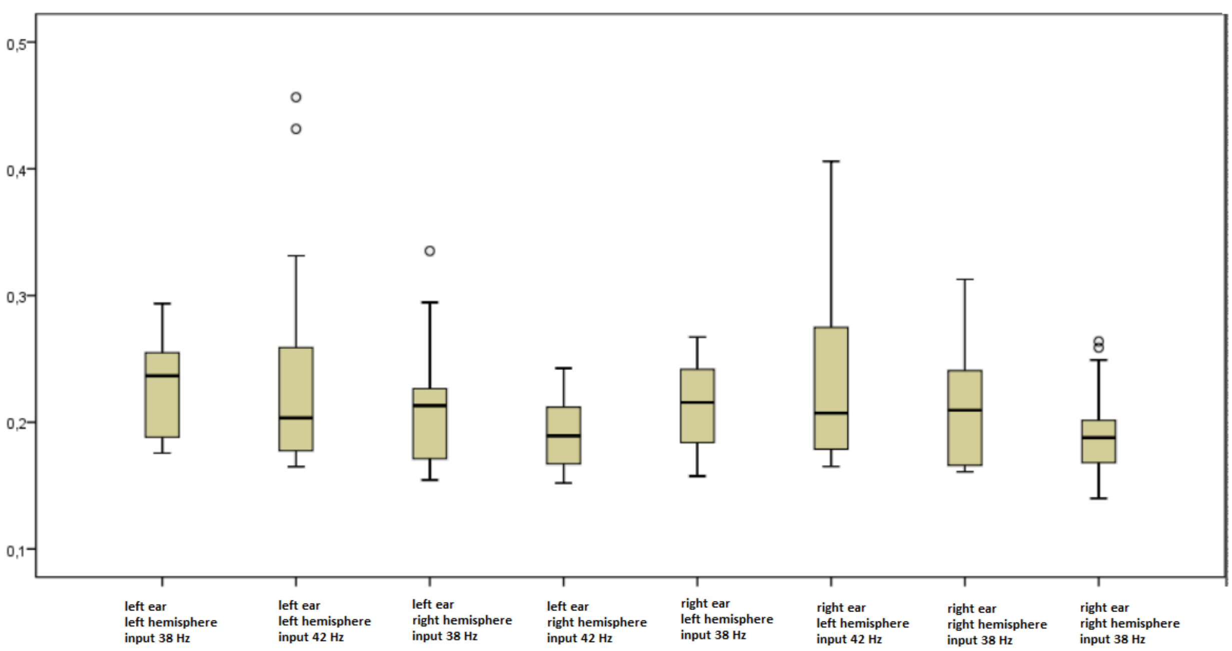

Figure 2: *The cca values of the novice (control) group in dichotic listening situation*

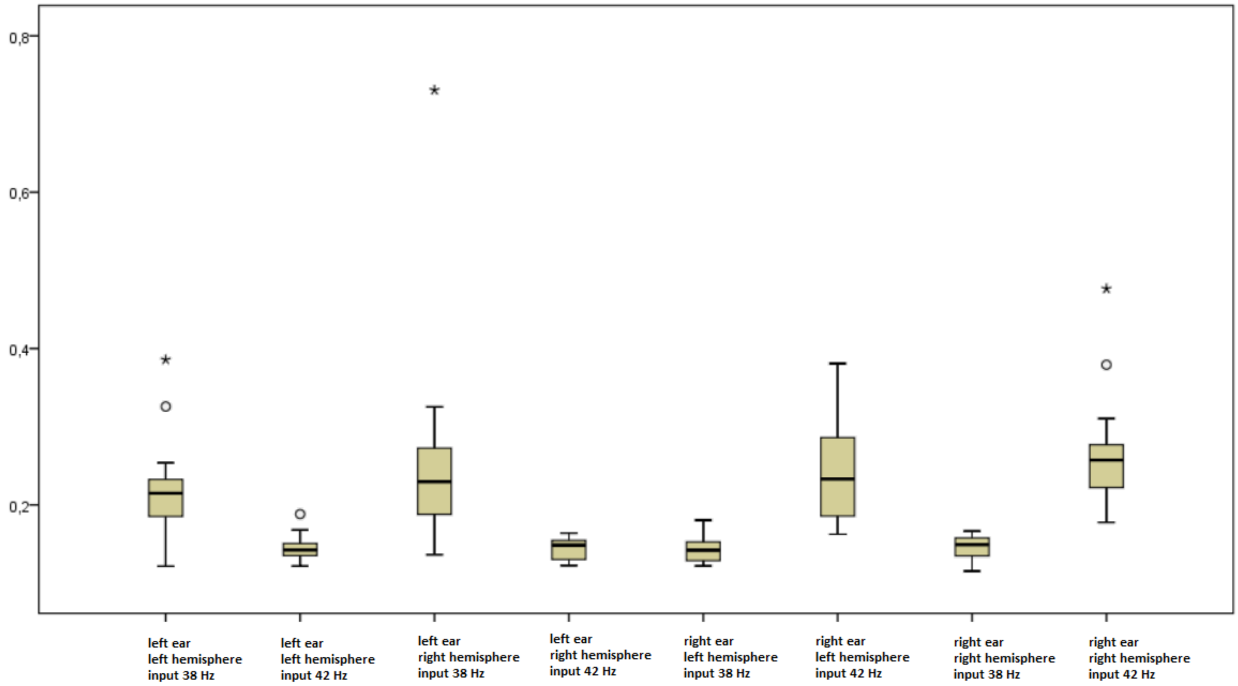

Figure 3: *The cca values of the meditation group in monoaural situation*

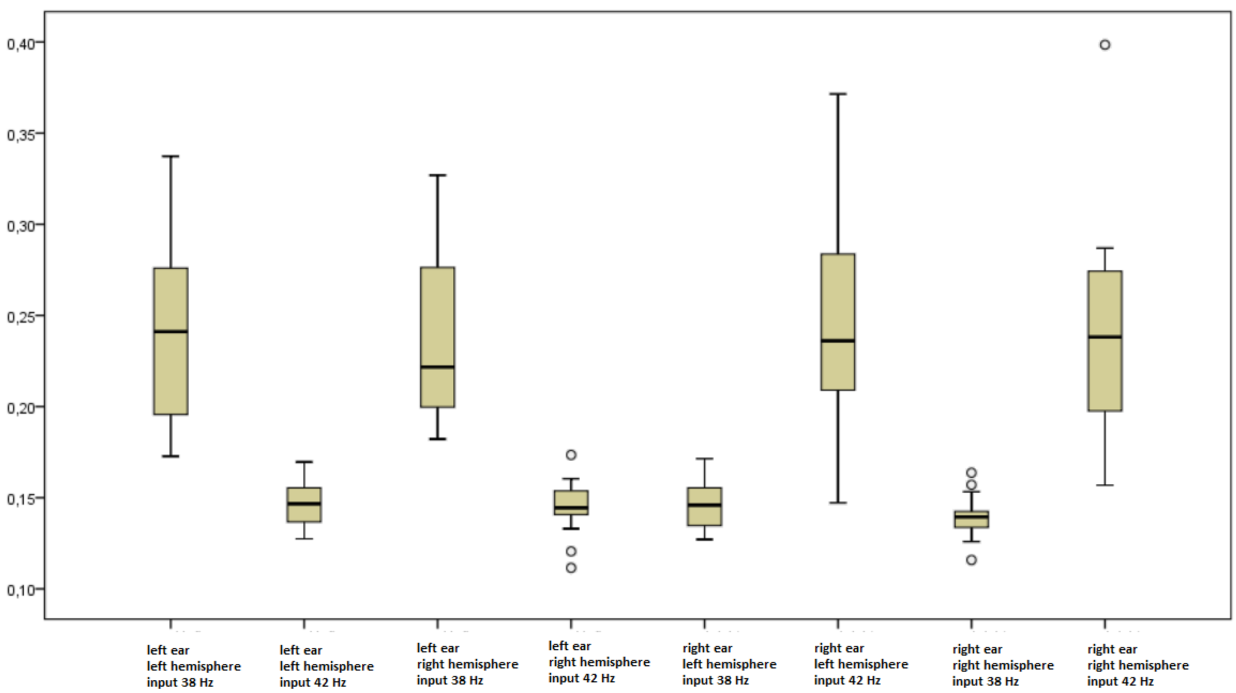

Figure 4: *The cca values of the novice (control) group in monoaural situation*

In order to statistically test the correlation values from canonical correlation analysis, we conducted three different sets of within-subjects ANOVAs:

3.4.1. Differences during dichotic listening situation

First, we wanted to know how long-term meditation practisers differ from novices in how their brain attentional mechanisms function in general during the attention-demanding situations. We conducted two 3x2 ANOVAs, one for the dichotic and one for the monoaural situation.

The multi-factorial ANOVA was used for statistical analysis of the overall difference, because we had multiple within-subjects factors (independent variables), each with two levels, and only one dependent variable. The test of within-subjects was chosen instead of the between-subjects ANOVA, because our subjects in the two groups were matched and thus the situation was comparable to one with repeated measures. The within-subjects factors of the 3x2 ANOVA were: direction of attention (left - right) x hemisphere (left – right) x input (left – right).

Direction of the attention (left – right) here refers to the ear which was being attented – left and right ear were listened to in turns.

Hemisphere (left – right) here refers to the sensor from which the signal is correlated with the auditory input in CCA analysis.

Input (left –right) refers to the actually focused frequencies from the EEG-data. Because in the dichotic listening situation both stories were listened to at the same time, we needed to ’tag’ the different stories to be able to identify them in the following analysis. Thus, stories in each ear were amplitude modulated with different frequencies, the passages to the left ear were always modulated at 38 Hz, whereas the passages to the right ear was modulated at 42 Hz. When the subject's attention was directed to the left side, the right ear's input with 42 Hz modulation was a competing stimulus and the left ear's input with 38 Hz modulation was the stimulus the subjects were trying to attent. When the subject directed his attention to the right ear, the left ear's input with 38 Hz modulation was a competing stimulus, and the right ear's imput with 42 Hz modulation was attented.

The experiment group worked in these ANOVAs as a between-subjects factor. We wanted to compare attention related neural activation in meditators vs meditation novices.

Within-subjects factors and their levels for the dichotic listening situation are also presented in Fig. 5.

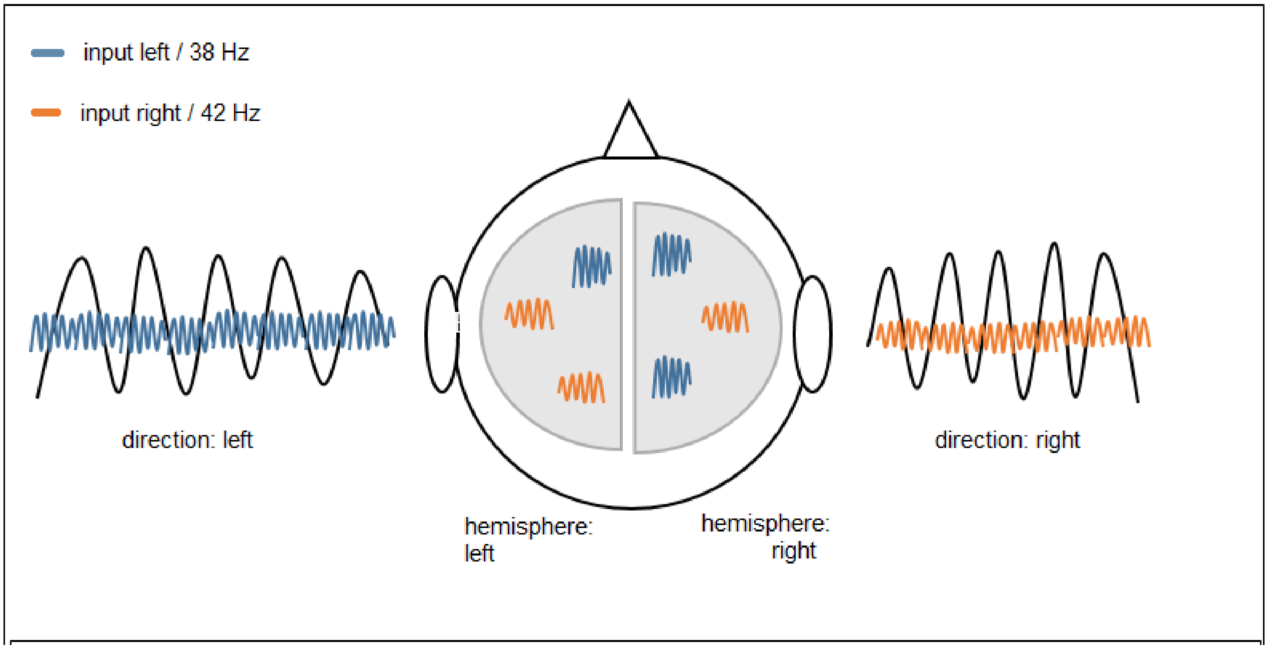

Figure 5: *Factors and levels of the 3x2 ANOVA in the dichotic listening situation. In the dichotic listening, different passages of the story were presented simultaneously through the headphones. Subjects were asked to direct their attention either to the story presented from left or the story presented from right (Direction of the attention: left/right). To be able to differentiate between the two passages in the following analysis, we "tagged" them with different frequencies, the "left" passage with 38 Hz and*

the "right" passage with 42 Hz (Input: left/right). The correlations between input frequencies and neural acticity were examined in both hemispheres separately (Hemisphere: left/right).

Our main interest was in the dichotic listening situation, where one passage had to be attented at the same time while the another had to be inhibited. In the monoaural listening situation, only one story was presented at a time. Therefore, there was no competing stimulus during the listening. However, the same 3x2 ANOVA was conducted for monoaural situation also, mainly to ensure that our presumptions concerning the study arrangements were right.

3.4.2. Attention: dichotic vs. monaural situation

To further elucidate the role of attention in meditation, we asked if the meditators were more capable than novices to direct their attention in the dichotic listening situation, compared to the easier monoaural listening task. We compared the situations where the segment of the story was attented in the dichotic listening situation to the situations where the same segment of the story was attented in the monoaural listening condition.

Since the audio signal was, for experimental reasons, amplitude modulated to two different frequencies, 38 Hz and 42 Hz, and these frequencies were un-comparable with one another due to 1/f artefact, they had to be separately analyzed. Therefore, two different 2x2 within-subjects ANOVAs were conducted: one for 38 Hz and another for 42 Hz. We tested whether there were differences between dichotic and monoraual listening conditions in either hemisphere. Within-subjects factors in these 2x2 ANOVAs were: condition (dichotic - monoaural) x hemisphere (right - left).

Condition (dichotic – monoaural) in this case refers simply to the listening situation in which the measurement was made. The dichotic situation was more demanding than the monoaural situation, where only one story is listened to at a time and there was no competing stimuli.

Hemisphere (left – right) here refers to the sensor from which the signal is correlated with the auditory input in CCA analysis.

Eminently we wanted to know if there was a difference between meditators and their novice controls in their attentional skills. Therefore, there was also one between-subjects factor in the analysis, **the experiment group.**

3.4.3. Inhibiton: the dichotic vs. monaural situation

Thirdly, we wanted to find out if the long-term meditators suppressed the distracting stimuli better than their novice controls. We compared the situations where the segment of the story was unattented (asked to be inhibited while listening to the other story) in the dichotic listening situation to the situations where the same segment of the story was attented in the monoaural listening condition.

Similarly to the attention-part of the study, two 2x2 ANOVAs were conducted. Two un-comparable frequencies had to be separately analyzed. Therefore, one within-subjects 2x2 ANOVA conducted for 38 Hz and another for 42 Hz. The within-subjects factors were: **condition** (dichotic - monoaural) x **hemispere** (right - left). Again, we wanted to find out if there was a difference between meditators and their novice controls in their inhibition, and therefore there was also one between-subjects factor in the analysis, **the experiment group.**

These two comparisons thus revealed the possible difference between groups in their brain responses to attentional demand, both for the attended signal and for the inhibited signal.

4. RESULTS

4.1. Emotional questionnaires

5-Facet Mindfulness Questionnaire:

The mean score of the subjects in the meditation group in the *accepting*-factor of the 5-facet mindfulness questionnaire (M = 34,79 , SD = 3,965) was higher than the mean of the control group (M = 29,29, SD = 6,305), resulting in a difference between groups in how participants self-reported the judging of their inner experiences (M = 5,5, SD = 8,197). This difference was also statistically significant, t (13) = 2,511, $p < .05$, two-tailed.

In the *observing*-factor of the 5-facet mindfulness questionnaire, the mean score of the subjects in the meditation group (M = 32,14 , SD = 3,739) was higher than the mean for the control group (M = 27,64, SD = 4,325). This mean difference between meditators and novices in how they made observations of their surroundings. (M= 4,5, SD = 5,140) was statistically significant, t (13) = 3,276, $p < .05$, two-tailed.

Differences in the other three factors of the 5-facet questionnaire, *describing* (M = 0,786, SD = 6,796), *acting with awareness* (M = 0,643 , SD = 5,555) and *non-reactivity to inner experiences* (M =

0,923 , SD = 5,423), were non-significant, p > .05.

AAQ, RYFF & Life-satisfactory Questionnaire:

In the AAQ, the mean score of the long-time meditators (M = 58,46, SD = 6,54) was approximately at the same level with the novices (M = 58,69, SD = 5,36), indicating that there was no difference between the meditators and the novices in their psychological flexibility (M = -0.231 , SD = 8,992), p > .05.

In the psychological well-being questionnaire RYFF, meditators (M = 62,54, SD = 5,174) scored slightly higher than novices (M = 57,85, SD = 7,347), but the difference between groups was not significant (M = 4,692, SD = 8,645), p = .074.

In the life-satisfactory questionnaire, meditators (M = 24,36, SD = 2,872) and novices (M = 22,00 , SD = 3,374) got scores of the same level, and no significant differences could be found (M = 2,357, SD = 5,227), p > .05.

DASS:

The difference in the scores of the DASS-questionnaire was non-significant (meditators: M =11,57 , SD = 7,920, novices: M = 12,29, SD = 10,936 , difference: M =-0.714 , SD = 16,150), p > .05). Negative emotional symptoms experienced by the participants was at the same level in both groups.

4.3.1. Brain activation - Overall differences in dichotic listening task

A three-factor within-subjects ANOVA for the dichotic listening situation showed that the main effects for *hemisphere* or *input* were not significant. The effect of *direction of attention* was only approaching significant (($F (1,26) = 3,325$, $p < .10$, $\eta 2 = .113$).

The interaction between *hemisphere* and *group* was significant ($F (1,26) = 12,379$, $p < .01$, $\eta 2 = .323$). When groups were analyzed in separate ANOVAs, there was a significant effect of hemisphere only for novices ($F (1,13) = 13,065$, $p < .01$, $\eta 2 = .501$). As presented in Fig. 6, the left hemisphere was more active than the right hemipshere for novices. For meditators, there was no significant hemisphere-effect, but based on the fugure 6 there is a rather tendency towards right stronger than left correlation for mediators. Other effects and interactions were not significant when groups were separately analyzed. According to these results, the long-term meditation practitioners differ from the meditation novices in the hemispheric ditribution of activation during the dichotic listening task.

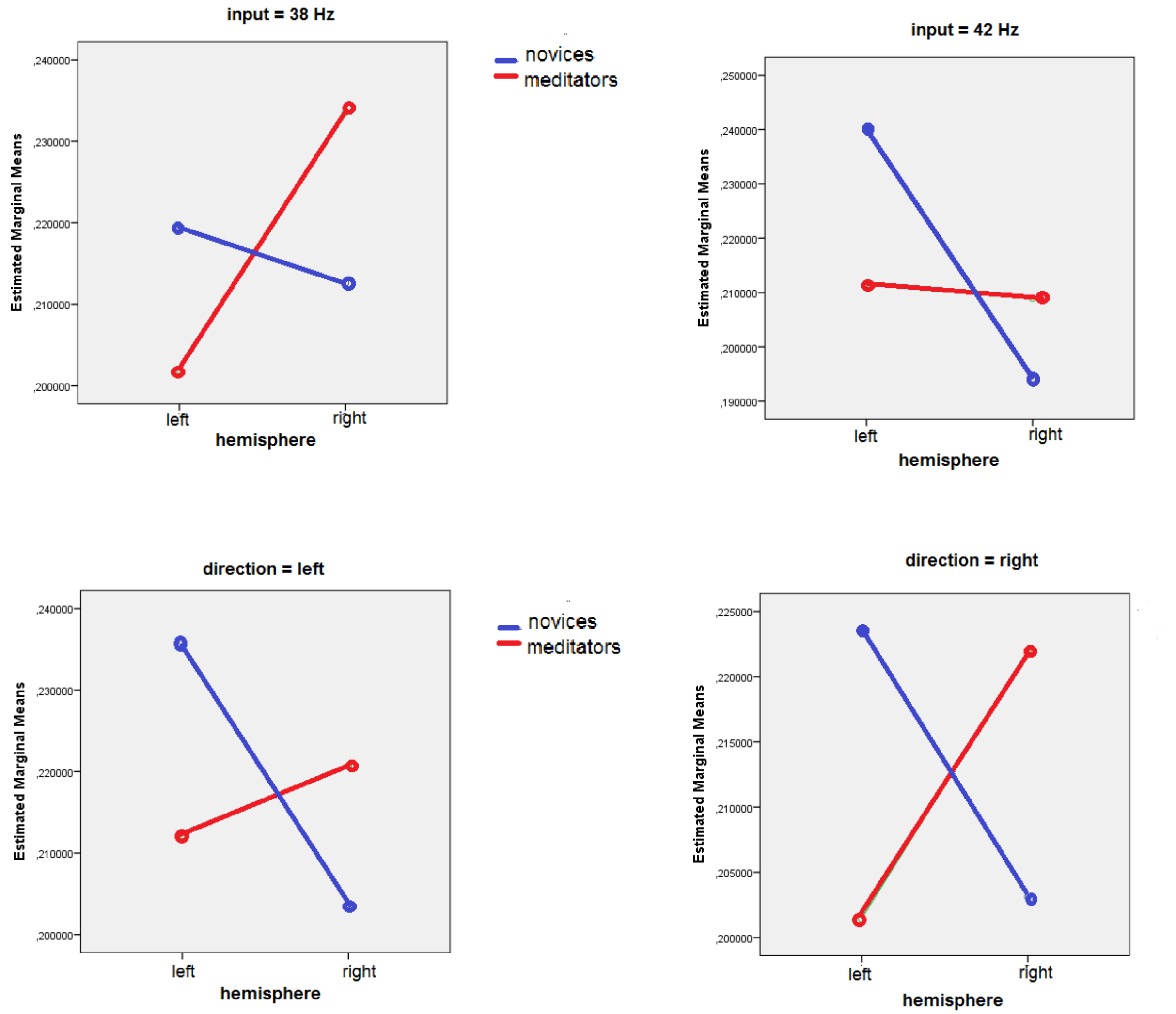

Figure 6: *The interaction between hemisphere and group in the dichotic listening. For novices, the left hemisphere was more active than right hemisphere, both when attending left ear and right ear, and for input of 38 Hz and 42 Hz similarly.*

The interaction between *direction of attention* and *hemisphere* ($F(1,26) = 4{,}535$, $p < .05$., $\eta 2 = .149$) was also significant. To analyze this interaction further, two different ANOVAs were made, for each hemisphere separately. The effect of direction of attention could only be found in the left hemisphere

(F (1,13) = 7,515, p <.05 , η2 = .224). As seen in the Figure 7, in the left hemisphere the attention to left ear story evoked stronger correlation (both with left and right ear input?) than attention to the right ear story. In addition, in figure 7, the input to the right ear (42 Hz) seems to be more strongly correlated with EEG in the left hemisphere and the input to the left ear (38 Hz) seems to be more strongly correlated with EEG in the right hemisphere. This contralaterality effect was however not statistically significant.

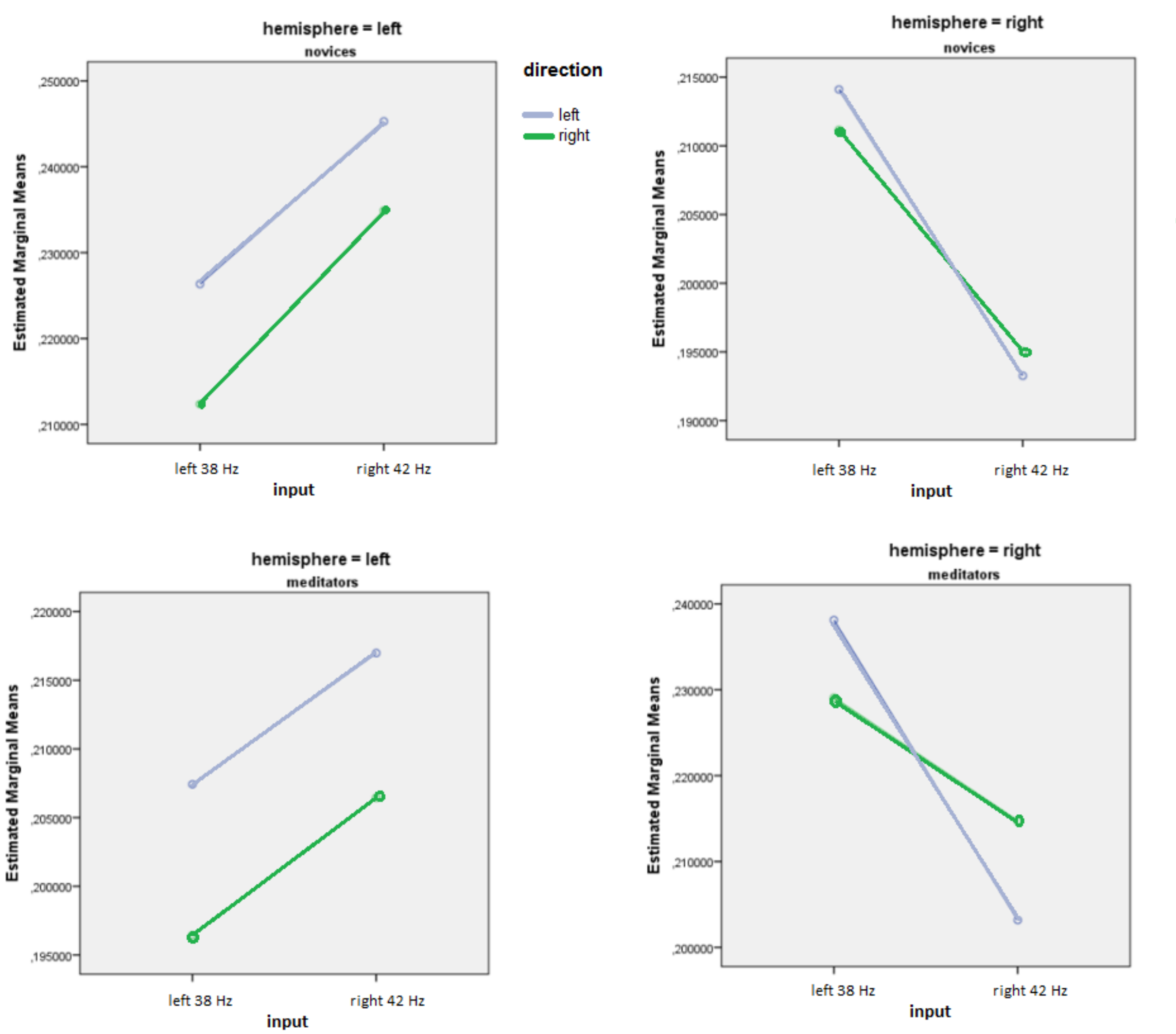

Figure 7: *The interaction between hemisphere and direction of attention in the dichotic listening task. The significant effect of direction could only be found in the left hemisphere.*

Means and standard deviations for all of the interactions are presented in table 1.

4.3.2. Brain Activaiton - Overall differences in monoaural listening task

The three-factor within-subjects ANOVA for monoaural listening situation showed that the main effects for *hemisphere*, *direction of attention* or *input* were not significant. The interaction between *hemisphere* and *group* was significant ($F\ (1,26) = 5{,}866$, $p < .05.$, $\eta 2 = .184$).

These results indicate that also during the monoaural listening task, the long-term meditation practisers differ from novices in the hemisphere which is more active. The interaction between group and hemisphere was analyzed further for both groups separately. For novices, there was a nearly-significant hemisphere-effect ($F\ (1,13) = 3{,}209$, $p < .010$, $\eta 2 = .198$), and by scrutinizing the means it became clear that the correlation was stronger in the left hemisphere. For the long-term meditation practisers, correlation was stronger in the right hemisphere, but again there was only a nearly-significant effect ($F\ (1,13) = 3{,}687$, $p <.010$, $\eta 2 = .221$). This tendency towards right hemisphere for meditators and left hemisphere for meditation novices was similar with the dichotic listening situation.

There also was a significant interaction between *direction of attention* and *input* ($F\ (1,26) = 59{,}751$, $p <.001.$, $\eta 2 = .697$). This interaction between direction of attention and input was similar in both groups. This was to be expected, because there was no competing stimuli in the monoaural situation, and only one story was listened at a time. In the other words, the correlation was higher with the modulation frequency that was used for given situation: 42 Hz in the case of right ear stimulation and 38 Hz in the case of left ear stimulation.

Means and standard deviations for the interactions are presented in table 2.

4.3.3. Brain activation – Comparison between monoaural and dichotic situation tasks for attended signals

In comparison between attended signals in dichotic listening situation and the easier monoaural listening task, no general group difference between meditators and novices could be found. Since the audio signal was amplitude modulated to two different frequencies, two different analyses were made: one for 42 Hz and one for 38 Hz.

For 42 Hz, the two-factor within subjects ANOVA of attention showed that there was no general group differenxe. However, the interaction for *hemisphere* and *group* was significant for 42 Hz (F (1,26) = 6,002, $p < .05$, $\eta 2 = .188$) as well as the interaction for *hemisphere* and *condition* (F (1,26) = 4,995, p = < .05, $\eta 2 = .160$). The main effect for *condition* was significant (F (1,26) = 16,998, $p < .05$, $\eta 2 = .395$). The main effect for *hemisphere* was not significant

The interaction between hemisphere and group was examined further by examining the effect of condition and hemisphere for the two groups separately. For novices, condition had a significant effect to which hemisphere was more active (F (1,13) = 12,251, p = < .01, $\eta 2 = .485$). By scrutinizing the means it came clear that for the novices, correlation were higher in the left hemisphere, but only in the dichotic condition. For the meditators alone, the effect of condition was significant (F (1,13) = 15,619, $p < .01$, $\eta 2 = .546$) the effect of hemisphere was nearly significant (F (1,13) = 4,375, $p < .10$, $\eta 2 = .252$), but the interaction between condition and hemisphere was unsignificant.

For 38 Hz, the two-factor within-subjects ANOVA showed that the main effect of *condition* was significant (F (1,26) = 8,586, p = < .01, η2 = .248) , but not any of the interactions.

The scrutinizing of the means of 42 Hz and 38 Hz ANOVAs also gives evidence that the correlations between neural activity and audio signal were generally higher in the monoaural than in the dichotic situation. This was to be expected, because the dichotic listening situation is more attention-demanding than the simple monoaural listening. Means and standard devitations for the interactions are presented in tables 3a (42 Hz) and 3b (38 Hz).

4.3.4. Brain activation – Comparison between monoaural and dichotic situation tasks for inhibited signals

No general group difference between meditators and novices could be found in how they suppressed the disctracting stimuli.

For 42 Hz, a two-factor within subjects ANOVA of inhibition showed that main effect for *condition* was significant (F (1,26) = 15,047, p < .05, η2 = .367). The interaction for *condition* and *hemisphere* was also significant (F (1,26) = 11,680, p < .05, η2 = .310). Left hemisphere was more prevalent in dichotic situation and right hemisphere in monoaural situation, but without any difference between groups, when analyzed separately.

For 38 Hz, the main effect for *condition* was significant (F (1,26) = 21,916, p <.05, η2 = .457), but there were no interactions.

Correlations between audio signal and neural activity were higher in monoaural task than the more demanding dichotic condition. Means and standard devitations for the interactions are presented in tables 4a (42 Hz) and 4b (38 Hz).

5. DISCUSSION

Mindfulness has been integrated in Western therapy and health care due to positive clinical findings. High expectations have also been set for mindfulness for reducing stress and promoting well-being in everyday life. Neurophysiological mechanisms, through which mindfulness works, are still highly unknown – we already know that mindfulness works, but we still do not really understand why. Mindfulness' relation to attention has been assumed to be an important link between mindfulness meditation and well-being, because attention plays such an important role both in everyday functioning and psychopathology.

In the present study, we asked if the long-term training of mindfulness meditation affects the brain mechanisms of attention. We were interested in how the long-term meditation practitioners differ from novices in the terms of how they can sustain attention and inhibit disctrating stimuli, and, especially, if there was an overall neurophysiological difference in how their brain's attetional mechanisms function. We compared two groups, one of long-term meditation practitioners and other of matched novices, and conducted an EEG-measurement during a task of listening continuous speech which demanded selective attention.

5.1. Impact of long-term mindfulness meditation on psychological well-being

Our subjects filled a set of questionnaires concerning their well-being, emotional symptoms, mindfulness-skills and psychological flexibility. Generally, subjects in the meditation group got the same or slightly higher scores compared to their controls in the tests measuring emotional well-being, mindfulness skills and psychological flexibility, and lower scores in the tests concerning emotional symptoms of depression or anxiety. However, these differences were minor, and statistically significant differences could only be found in two categories of Five Facet Mindfulness Questionnaire: accepting or nonjudging the inner experiences and observing.

This may indicate that the long-time meditation practice has no special impact in pychological well-being or flexibility, but when making interpretations from these results, it is noteworthy to take in account that the subjects in this study were from a healthy population, and that practising mindfulness can still have positive emotional effects, but maybe only to a certain limit. Various intervention studies have shown that mindfulness as a part of intervention has an positive impact on psychologival health and well-being (e. g. Grossman et al., 2004). In our study, the level of emotional symptoms, measured by DASS, was already at a low level both for meditators and novices, and according to AAQ-questionnaire, psychological flexibility of participants in both groups was high.

In the open-end questions, concerning their meditation practice, half of the long-term meditators described that their trigger to start meditating was a difficult life situation. All long-term meditation practitioners self-reported having experienced significant improvements in their well-being and ability to concentrate as a result of their meditation practice. Even if differences could not be found in this study, it is still possible that the subjects in the meditation group initially would have scored lower in these questionnaires, and practising mindfulness has improved their scores to the same level with the healthy controls.

5.2. Impact of long-term mindfulness meditation on attention

Earlier, attention has been considered to be such a highly automatic brain mechanism that is impossible to train, especially on adult age. When the understanding of brain plasticity has grown, the earlier view has also been questioned and it has become quite a stable consensus that these kinds of automatic cognitive functions can be trained. Thus, attentional skills can also be improved within certain limits.

Neuroimaging studies conducted during attention-related tasks have indicated that continuous practice of meditation affects attention at the neurobiological level (e. g. Lutz et al., 2008; Shrinivasan & Baijal, 2007). These studies indicate that meditation training has an impact on preattentive processing and it enhances both processing of targets and distractors during attention task. Studies also indicate that long-term meditation causes alterations in attention-related brain structures (Hölzel et al., 2011; Chiesa & Sherretti, 2010; Lazar et al., 2005).

Compared the earlier studies, our study was quite unique in how we conducted an EEG-measurement during a well-controlled auditory attention -demanding listening task. Due to the fact that we frequency-tagged the different speech signals, attended and inhibited stories were identifiable, and utilizing the correlation values representing strenght of correlation between audio signal and EEG activation, comparisons could be made between different kinds of attentive-demanding situations on neurobiological level. We were also able to examine passive, un-voluntary concentration. Additionally, we aimed to study neural processes of attention related to listening meaningful human speech in a realistical manner.

In our results experienced meditators did not to have higher levels of correlation between audio signal and EEG than novices, while listening continuous speech. The result may indicate that long-term meditators do not use their neural resources of attention more efficiently than meditation novices, at least when it comes to suppressing distracting stimuli or focusing one of the many competing stimuli in a demanding dichotic task.

The fact that we did not find any difference between groups in their neural basis of attention in more demanding dichotic listening and easier monoaural situation is in odds with several earlier studies, and may be partially due to the limited number of subjects and therefore a low statistical power of the study. Some reservations should also be made about our results as the mediation background of our subjects was not homogenious: some of them may have focused on straightforward attention-training more than others, and their experience in years was also very varying. Along with this, our study only concerned auditory attention.

It is also possible that effects could not be detected in this study because the neural signal of which the correlations were measured reflects relatively early processing of auditory information and attention’s role on it. It is possible that long-term practising of mindfulness meditation impacts attention more on higher levels of stimulus processing, and the differences still could be found in the subsequent top-down processing, which required further researching. Earlier studies of mindfulness meditation’s impact on attention indicate that meditation practice improves attention and especially early stimulus processing (e. g. Malinowski, 2013). Interestingly, however, there is not as much clear evidence that mindfulness meditation directly improves inhibition. The study of Moore et al. (2012) rather suggests that meditation-related improvements in inhibition are achieved by more focused attentional resources and efficient conflict resolution processes.

What, then, possibly makes mindfulness meditation different from other forms of mental excercising, such as computer-based working memory training programs? Attention training has been rarely studied by neuroimaging, but the answer may partially lie on the fact that mindfulness consists of at least two essential components: *awareness or paying attention* and certain *attitude towards inner experiences*, often referred as *acceptance* (e. g. Bishop et al., 2004; Hölzel el al., 2011; Shapiro et al.; 2006). Even if the different models emphasize these two core component differently, this non-jugemental attitude cannot be separated from mindfulness as attention training, but forms the very basis of how and where attention is directed in mindfulness meditation, especially during the moments of distraction. Mindfulness meditation therefore is not only paying attention, but also doing the latter in a certain, unique way which makes it different from other forms of cognitive training.

5.3. Impact of long-term mindfulness meditation on brain lateralization

Instead of finding a difference in the levels of correlation, we found difference in how the long-term meditation practitioners use their attentional resources: they seem to use more their right hemisphere or both, when novices use more the left hemisphere. The same effect could be found both in the dichotic and in the monoaural listening situation.

Many stuctural changes found in brain imaging studies of meditation have been found only on one paticular hemisphere (e. g. Davidson et al., 2003; Hölzel et al., 2010; Moyer et al, 2011; Tang et al., 2007,), which suggests that practicing mindfulness meditation could change lateralization of brain. Interestingly, these changes were usually found in the left hemisphere, whereas we found out that long-term meditators' right hemisphere or both were more active during the attention-demanding task, and meditation novices lean more on their left hemisphere.

It is tempting to speculate that the difference in hemispheric balance between meditators and non-meditators may indicate that long-term meditation training increases the integration of hemispheres.

Long-term meditators, thus, may be more adaptive and holistic in how their attentional mechanisms of the brain works. This view is also supported by earlier studies, which indicate that mindfulness meditation enhances brain connectivity (e. g. Luders et al., 2011). Kozasa et al. (2011) found out in their fMRI-study that meditation experience may improve attention efficiency, because the long-term meditators need less brain-regions to conduct an attention-related task than their novice controls. In any case some reservations should be made about our results as they are obtained by using the EEG-scanning, which is not a very accurate method for differentiating between the brain areas.

Mindfulness' impact on brain lateralization and connectivity could be one possible explanation of the processes through which mindfulness improves emotional health and well-being. Increasing understanding of attention's role in mindfulness can, for it’s part, be helpful when developing and refining mindfulness-based interventions and targeting them more precisely for certain conditions and groups.

5.4. Conclusion

In this study, we conducted an attention –demanding dichotic listening task during an EEG-scanning. Compared to earlier studies of attention’s role in mindfulness, our study was unique in how we examined auditory attention using continuous speech and meaningful segments of stories. Our subjects were long-term meditation practitioners who have chosen to consume meditation as a part of their everyday life – not monks but ’commonplace’ meditators with an amount of practice that is potentially accessible for everyone. We compared their neural correlates with a matched group of inexperienced meditation novices, therefore making it possible to establish effects of long term mindfulness meditation practice on the brain attention mechanims.

Our results support the earlier body of research that practising mindfulness meditation has an impact on attention mechanisms of brain, and possibly enchantes attentional flexibility by altering the brain lateralization. It is unlikely that our results of hemisphere difference could be explained by, for example, a fact that long-term meditation practice was chosen by people who already have these kinds of differences in their neural mechanisms of attention. This was ensured by using the matched pair -setting and forming the both groups with subjects with similar background information: age, gender, IQ, handedness and education.

In any case some reservations should be made about the results as they are obtained by using the EEG-scanning, which is not a very accurate tool for differentiating between the brain areas. The most important limitation of this study was the relatively small number of participants (N=14 both in meditation and control group). This was mainly due to the limited amount of long-term meditation practitioners in the area. Because of the limited number of experienced meditators, we also couldn't restrict this study to only certain forms or traditions of meditation, but our participants were from different meditational backgrounds, and their amount of experience in years varied greatly, from only two to even ten years and more.

An interesting topic of future research would then be to repeat the similar study using for example more regionally accurate MEG -technique and with larger number of subjects with more difinite history of meditation practice. More research is still needed to understand mindfulness meditation’s impacts on the brain lateralization and how these changes are possibly linked to emotional well-being and psychological flexibility.

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Table 1: Means for interactions, dichotic listening

Table 1: Means for interactions

	tutkimusryhmä	Mean	Std. Deviation	N
dichotic - left - left hemisphere - 38 Hz	novices	,22635143	,038999932	14
	meditation	,20742429	,048409474	14
	Total	,21688786	,044198957	28
dichotic - left - left hemisphere - 42 Hz	novices	,24528214	,095306213	14
	meditation	,21697000	,066567626	14
	Total	,23112607	,081943938	28
dichotic - left - right hemisphere - 38 Hz	novices	,21410000	,049931498	14
	meditation	,23811429	,127834428	14
	Total	,22610714	,096011022	28
dichotic - left - right hemisphere - 42 Hz	novices	,19326643	,029615821	14
	meditation	,20318643	,035831771	14
	Total	,19822643	,032649660	28
dichotic - right - left hemisphere - 38 Hz	novices	,21237000	,035960401	14
	meditation	,19645071	,040944562	14
	Total	,20441036	,038671870	28
dichotic - right - left hemisphere - 42 Hz	novices	,23490143	,075795038	14
	meditation	,20645286	,064859039	14
	Total	,22067714	,070720060	28
dichotic - right - right hemisphere - 38 Hz	novices	,21115214	,050241828	14
	meditation	,22905500	,138125824	14
	Total	,22010357	,102394008	28
dichotic - right - right hemisphere - 42 Hz	novices	,19505214	,037768313	14
	meditation	,21472571	,037308662	14
	Total	,20488893	,038175185	28

Table 2: Means for interactions, monoaural listening

Table 2: Means for interactions

	tutkimusryhmä	Mean	Std. Deviation	N
monoaural - left - left hemisphere - 38 Hz	novices	,24501571	,057397242	14
	meditation	,22486857	,065126393	14
	Total	,23494214	,061103412	28
monoaural - left - left hemisphere - 42 Hz	novices	,14651571	,012814961	14
	meditation	,14594786	,017575420	14
	Total	,14623179	,015095743	28
monoaural - left - right hemisphere - 38 Hz	novices	,23924643	,050503267	14
	meditation	,26357286	,143383051	14
	Total	,25140964	,106207877	28
monoaural - left - right hemisphere - 42 Hz	novices	,14410429	,015572481	14
	meditation	,14495929	,014142341	14
	Total	,14453179	,014603045	28
monoaural - right - left hemisphere - 38 Hz	novices	,14727357	,012618448	14
	meditation	,14340643	,016332657	14
	Total	,14534000	,014456109	28
monoaural - right - left hemisphere - 42 Hz	novices	,24825071	,059874513	14
	meditation	,24458357	,067527866	14
	Total	,24641714	,062650928	28
monoaural - right - right hemisphere - 38 Hz	novices	,13961071	,012312972	14
	meditation	,14584929	,016176118	14
	Total	,14273000	,014459429	28
monoaural - right - right hemisphere - 42 Hz	novices	,24123857	,061206007	14
	meditation	,27074929	,077086073	14
	Total	,25599393	,069932737	28

Table 3a: Means for interactions, attention 42 Hz

Table 3a: Means for interactions

	tutkimusryhmä	Mean	Std. Deviation	N
dichotic right hemisphere 42 Hz	novices	,19505214	,037768313	14
	meditation	,21472571	,037308662	14
	Total	,20488893	,038175185	28
dichotic left hemisphere 42 Hz	novices	,23490143	,075795038	14
	meditation	,20645286	,064859039	14
	Total	,22067714	,070720060	28
monoaural right hemisphere 42 Hz	novices	,24123857	,061206007	14
	meditation	,27074929	,077086073	14
	Total	,25599393	,069932737	28
monoaural left hemisphere 42 Hz	novices	,24825071	,059874513	14
	meditation	,24458357	,067527866	14
	Total	,24641714	,062650928	28

Table 3b: Means for interactions, attention 38 Hz

Table 3b: Means for interactions

	tutkimusryhmä	Mean	Std. Deviation	N
dichotic right hemisphere 38 Hz	novices	,21410000	,049931498	14
	meditation	,23811429	,127834428	14
	Total	,22610714	,096011022	28
dichotic left hemisphere 38 Hz	novices	,22635143	,038999932	14
	meditation	,20742429	,048409474	14

	Total	,21688786	,044198957	28
monoaural right hemisphere 38 Hz	novices	,23924643	,050503267	14
	meditation	,26357286	,143383051	14
	Total	,25140964	,106207877	28
monoaural left hemisphere 38 Hz	novices	,24501571	,057397242	14
	meditation	,22486857	,065126393	14
	Total	,23494214	,061103412	28

Table 4a: Means for interactions, inhibition 42 Hz

Table 4a: Means for interactions

	tutkimusryhmä	Mean	Std. Deviation	N
dichotic right hemisphere 42 Hz	novices	,19326643	,029615821	14
	meditation	,20318643	,035831771	14
	Total	,19822643	,032649660	28
dichotic left hemisphere 42 Hz	novices	,24528214	,095306213	14
	meditation	,21697000	,066567626	14
	Total	,23112607	,081943938	28
monoaural right hemisphere 42 Hz	novices	,24123857	,061206007	14
	meditation	,27074929	,077086073	14
	Total	,25599393	,069932737	28
monoaural left hemisphere 42 Hz	novices	,24825071	,059874513	14
	meditation	,24458357	,067527866	14
	Total	,24641714	,062650928	28

Table 4b: Means for interactions, inhibition 38 Hz

Table 4b: Means for interactions

	tutkimusryhmä	Mean	Std. Deviation	N
dichotic right hemisphere 38 Hz	novices	,21115214	,050241828	14
	meditation	,22905500	,138125824	14
	Total	,22010357	,102394008	28
dichotic left hemisphere 38 Hz	novices	,21237000	,035960401	14
	meditation	,19645071	,040944562	14
	Total	,20441036	,038671870	28
monoaural right hemisphere 38 Hz	novices	,23924643	,050503267	14
	meditation	,26357286	,143383051	14
	Total	,25140964	,106207877	28
monoaural left hemisphere 38 Hz	novices	,24501571	,057397242	14
	meditation	,22486857	,065126393	14
	Total	,23494214	,061103412	28