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Neural and cardiac signaling during two contemplative practices: experiment design and a four-week data collection

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1 Project Description

Comparative Analysis of Mindfulness Meditation and Cyclic Sighing: Investigating Modes of Attention and Physiological Responses

This project aims to conduct an extensive literature review and complete data collection to compare the effects of Mindfulness Meditation and Cyclic Sighing on modes of attention and physiological markers. The focus is to deepen understanding of how these distinct contemplative practices influence mental states and categorize them by their sympathetic and parasympathetic responses, contributing to the growing field of contemplative research.

Key Components

1. **Literature Review:** A thorough examination of existing studies and publications on Mindfulness Meditation, Cyclic Sighing, and contemplative practices, focusing on their impact on stress reduction, mood enhancement, attentional states, and physiological changes. The review will synthesize findings from various sources, highlighting similarities, differences, and gaps in current knowledge.

2. **Data Collection:** Building on the groundwork laid by Balban 2022, this project will involve the data collection for a follow-up study comparing Mindfulness Meditation and Cyclic Sighing. It will expand upon previous research by gathering EEG and ECG data to objectively measure brain activity and heart rate variability, alongside self-reported questionnaires to assess subjective experiences during these practices.

3. **No Data Analysis:** This project phase will not include an analysis of the newly collected data. The comprehensive analysis is planned for a subsequent Master's Thesis project.

4. **Attentional Modes:** A primary objective for the subsequent Master's Thesis is to determine whether Mindfulness Meditation and Cyclic Sighing engage different types of attention, namely effortful or effortless. This aspect of the study will explore how each practice potentially activates distinct neural circuits and their sympathetic and parasympathetic responses, contributing to either a more contracted or flowlike state of mind.

5. **Physiological Markers:** The subsequent Master's Thesis project will examine the impact of Mindfulness Meditation and Cyclic Sighing on key physiological parameters like heart rate, heart rate variability, and brain wave patterns. These objective measures will offer insights into the autonomic changes induced by each practice, providing a more nuanced understanding of their health benefits.

The outcome of this project will lay the groundwork for a comprehensive Master's Thesis, providing valuable insights for tailoring specific contemplative practices to individual needs, enhancing their efficacy in mental health and wellness applications, and increasing scientific knowledge in the field.

2 Introduction and Background Literature

Contemplative practices are time-honored methodologies that entail disciplined body and mind training, fostering self-awareness, self-inquiry, and self-regulation (Davidson and Cortland J. Dahl 2017). They facilitate focused, non-judgmental attention and introspection and offer a tranquil anchor amidst the hustle of daily life — this calm-centeredness aids in the exploration of meaning, purpose, and values. Examples of contemplative practices are meditation, focused attention, yoga, breathwork, prayer, meditative strolls, and many others (Bruce et al. 2018).

Historically, these practices have been preserved and taught by spiritual leaders such as priests and yogis. Yet, in recent decades, they have captured the attention of a wider audience' (Brandmeyer and Delorme 2021). According to Clarke et al. 2018, approximately 14.3% of US adults were practicing yoga, with a similar percentage engaging in meditation. Similar estimates of 17.5% of US adults with no functional limitation using some form of mind-body therapies were found by Okoro et al. 2012. Similar numbers have also been found in Norway by Kristoffersen et al. 2022, with nearly a quarter of respondents relying on self-help practices like yoga and meditation during the first wave of the COVID-19 pandemic. This surge is likely linked to mindfulness practices offering a wide array of promising results, from benefits for mental and physical health by cultivating positive thoughts (Alexander et al. 2021) to mitigating age-related cognitive decline as well as enhancing brain function among young and middle-aged individuals (Gard et al. 2014).

A surge in scientific inquiry has paralleled the rising public interest in these practices (Brandmeyer and Delorme 2021). This growing body of research has primarily focused on how these practices reshape the brain's structure and function and improve behavior, medical outcomes, and professional performance (Brandmeyer and Delorme 2021). Techniques like Mindfulness-Based Stress Reduction (MBSR) (Chen et al. 2020) and various forms of yogic breathing (Brown and Gerbarg 2009) have been shown to alleviate symptoms ranging from anxiety and depression to post-traumatic stress disorder. Yet, the research landscape is marked by variability in design and rigor. Small sample sizes, differing methodologies, and short-term focus make it difficult to draw broad, generalizable conclusions (Chen et al. 2020).

Many studies rely heavily on self-reported questionnaires to measure outcomes as found by C. J. Dahl et al. 2015, saying:

> "Though preliminary findings suggest that meditation and other forms of mental training may produce demonstrable changes in subjective experience, behavior, patterns of neural activity, and peripheral biology, rigorous studies are still needed to uncover the precise mechanisms that underlie these changes. In particular, randomized trials, active control groups, longitudinal studies that examine within- and across-subject changes over time, and across-practice comparisons will be significant in determining the efficacy of meditation training paradigms."

While valuable, these subjective measures are not bolstered by objective physiological markers, such as hormone levels, neural activity, or other biochemical indicators. This would provide a more comprehensive understanding of the mechanisms at work, especially for across-practice comparisons.

One recent across-practice comparison study, relying primarily on self-reported data, was a study by Balban 2022 comparing, amongst others, the effects of Cyclic Sighing, a type of structured breathing exercise, with Mindfulness Meditation on mood and relaxation. When practiced for five minutes daily, the researchers found that Cyclic Sighing was more effective in enhancing mood and reducing breathing rate than Mindfulness Meditation. This suggests that certain breathing practices might be more immediately beneficial for mood improvement and show promise for effective stress reduction.

Though improvements in behavior, medical outcomes, and professional performance are all positive side effects, the purpose of mindfulness practices is usually aimed at cultivating a dispositional quality marked by present-moment focus, imbued with curiosity, openness, and acceptance (C. J.

Dahl et al. 2015). The study of contemplative practices and this present-moment focus is, thus, the study of attention at its core.

Studies dating from the 1970s have suggested that effort can be equated with attention and that effort/attention is a special case of sympathetic dominance of the autonomic nervous system and is associated with an increase in metabolic activity in the brain (Kahneman 1973). However, growing behavioral, physiological, and neuroscience research evidence indicates that effort cannot be equated with attention (Bruya and Y.-Y. Tang 2018). For example, attention can also occur under parasympathetic dominance and is likely to be experienced as effortless (Y.-Y. Tang, R. Tang and Gross 2019). From an effort perspective, then, there are two types of attention: one associated with sympathetic dominance (e.g., control, tonic alertness) that handles the demands of cognitive tasks and is experienced as effortful, whereas the other is related to parasympathetic dominance (e.g., monitoring, phasic alertness) and effortlessness (Y. Y. Tang et al. 2015)(Y.-Y. Tang, R. Tang, Posner et al. 2022).

These two different types of attention operate via distinct neural mechanisms (Y.-Y. Tang, R. Tang, Posner et al. 2022). As reported by Y. Y. Tang et al. 2015, the most active brain regions during the meditative state are:

> "The caudate, which is thought (together with the putamen) to have a role in attentional disengagement from irrelevant information, allowing a meditative state to be achieved and maintained; the entorhinal cortex (parahippocampus), which is thought to control the mental stream of thoughts and possibly stop mind wandering; and the medial prefrontal cortex, which is thought to support the enhanced self-awareness during meditation."

Effortful and effortless training are distinct approaches that engage different neural circuits and autonomic responses. Effortful training primarily activates the frontoparietal regions of the brain and is associated with sympathetic dominance, which may lead to a more rigid and fixated mode of attention. It requires a continuous effort to maintain focus on the chosen object(s) of attention. In contrast, effortless training promotes parasympathetic dominance and involves the anterior cingulate cortex (ACC), posterior cingulate cortex (PCC), and striatum. This leads to an open, soft, and flexible attention mode, where the subject can rest as an innate awareness that emerges effortlessly. Understanding these divergent mechanisms, as well as what types of contemplative practices lead to what kind of attention, is crucial for choosing the appropriate practices based on the desired outcomes and individual predispositions(Y. Y. Tang et al. 2015)(Y.-Y. Tang, R. Tang, Posner et al. 2022)

Effortless training involving the ACC, PCC, and striatum also facilitates parasympathetic responses such as reduced heart rate and increased high-frequency heart rate variability (HF-HRV). HF-HRV is beneficial in a variety of medical and psychopathological conditions such as asthma, cardiovascular disease, depression, and PTSD (Singer et al. 2016). On the other hand, low-frequency HRV has been associated with increased all-cause and cardiovascular mortality (Fyfe-Johnson et al. 2016). Such training, exemplified by nature exposure, also promotes relaxation, attention restoration, and cognitive benefits(Y. Y. Tang et al. 2015)(Y.-Y. Tang, R. Tang, Posner et al. 2022).

As ECG can measure HRV, it can be used to categorize the different contemplative practices by their sympathetic and parasympathetic responses, as parasympathetic dominance is associated with HF-HRV and effortless attention, while effortful attention is not. However, this is unlikely to be a clean separation, as some research opposes that low frequency (LF) is necessarily indicative of sympathetic cardiac control (Reyes del Paso et al. 2013)(Valenza et al. 2016). Thus, other measurements, like EEG data, are likely needed for a conclusive classification.

3 Knowledge gaps and Motivation

The increasing interest in contemplative practices like meditation and breathing techniques, once rooted in spiritual contexts, now captures widespread attention due to their mental and physical health benefits. This shift in societal interest has prompted a surge in scientific research examining the impact of these practices on brain function and overall well-being. However, challenges such as variability in research methodologies highlight the need for more rigorous studies, particularly those incorporating objective physiological markers alongside subjective self-reports comparing different practices. This approach would not only strengthen the validity of the findings but also aid in understanding the mechanisms underlying these practices.

Crucial to this research is exploring different types of attention, effortful and effortless, and their distinct neural mechanisms. This knowledge is vital in selecting specific practices for desired health and wellness outcomes, potentially leading to improved quality of life and benefits in healthcare and personal development. For instance, practices leading to parasympathetic responses, such as reduced heart rate and increased heart rate variability, can be strategically used for relaxation, heart health, and cognitive benefits. Such research advances scientific understanding and has practical implications for addressing modern life's stressors and mental health challenges. This is an exciting possibility for development towards the UN Sustainable Development Goal 3 (United Nations Department of Economic and Social Affairs 2023).

Figure 1: UN Sustainable Development Goal 3: Ensure healthy lives and promote well-being for all at all ages.

Given recent findings and the gaps in current knowledge, we will focus on two contemplative practices, Mindfulness Meditation and Cyclic Sighing, in this study. The study will use rigorous data collection methods, namely EEG and ECG and subjective measurement questionnaires. The study will explore what modes of attention the different practices have and do a follow-up to Balban 2022 with physiological markers. The leading hypothesis of the study is that Mindfulness Meditation, the passive observation of one's breathing, is characterized by a monitoring state, is related to parasympathetic dominance, and can consequently be categorized as effortless attention. Cyclic Sighing, on the other hand, is a breathing technique using intentional control of the breath to follow a pre-defined pattern, which requires sustained effort and can be characterized as effortful.

4 Methodology

4.1 Introduction to Methodology

This section describes the structured approach employed in investigating the physiological and psychological effects of Mindfulness Meditation and Cyclic Sighing. The methodological design integrates both quantitative and qualitative data collection, aiming to capture a nuanced understanding of these contemplative practices. Emphasis is placed on detailed, reproducible procedures to ensure the reliability of the findings and to facilitate a comprehensive analysis of the intervention effects on attentional and autonomic processes.

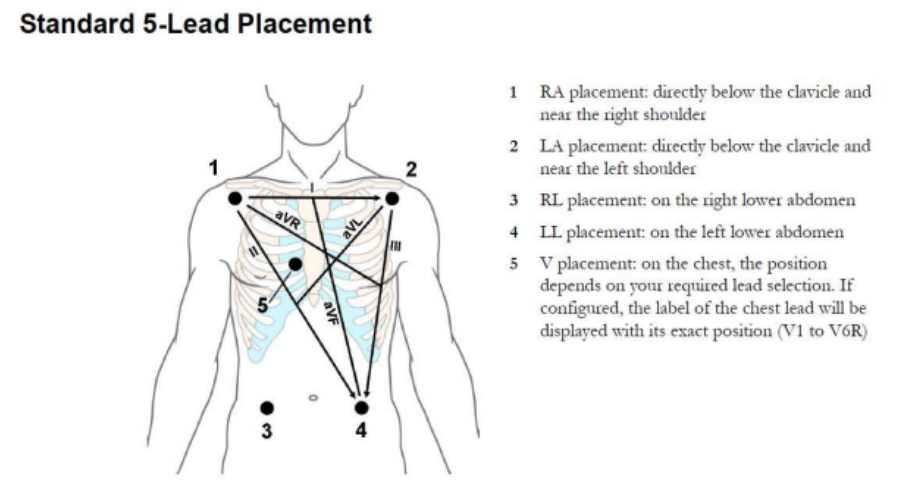

Figure 2: Electrode setup of ECG.

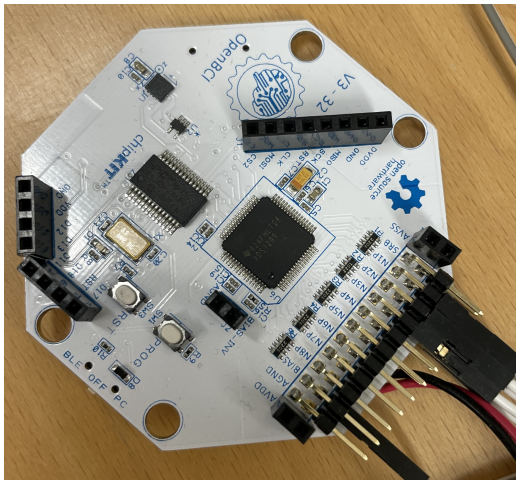

Figure 3: OpenBCI Cyton board used for ECG.

Figure 4: ECG electrodes.

4.2 Equipment

4.2.1 ECG

For the ECG measurements, the OpenBCI Cyton board was utilized (see Figure 3). This board is mainly chosen for its high-resolution data-capturing capabilities, essential for accurate ECG analysis. The setup followed the Standard 5-Lead Placement, as illustrated in Figure 2, due to its superior signal quality compared to the more noise-prone 3-Lead setup. The electrodes used can be seen in Figure 4. The OpenBCI software was employed for data streaming via LSL, offering an efficient and user-friendly interface for real-time data handling. Detailed guidelines and specifications for this setup can be found in the OpenBCI ECG Setup documentation OpenBCI 2023.

4.2.2 EEG

For EEG recordings, two cap sizes, medium and small, were chosen, each fitted with pre-positioned electrodes shown in Figure 5). This ensures an optimal fit for varied head sizes, which is crucial for consistent signal acquisition. The 32 wet electrodes provide comprehensive brain activity coverage, conforming to a modified 10-10 system (Figure 7). The earlobe fitting reference is displayed in Figure 10, while the gel used is shown in Figure 6. The Mentalab Explore+ amplifier, depicted in Figure 9, was selected for its accuracy and reliability in signal amplification. The accompanying Metalab Explore Desktop app was used for efficient data streaming over LSL.

Figure 5: EEG caps and electrodes.

Figure 6: EEG electrode gel.

4.2.3 Digitization

The digitization process employed the Polhemus Fastrack Digitizer displayed in Figure 11. It accommodates up to four sensors for versatile and precise digitization tasks. The sensors used were the stylus and custom-fitted 3D-printed glasses shown in Figure 12, as well as the standard cube.

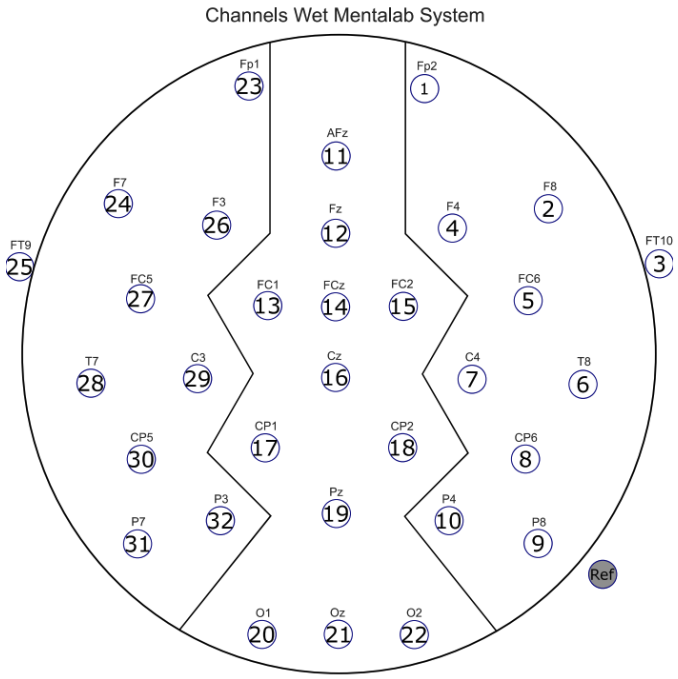

Figure 7: Electrode setup of EEG used in the study. Variation of 10-10 system.

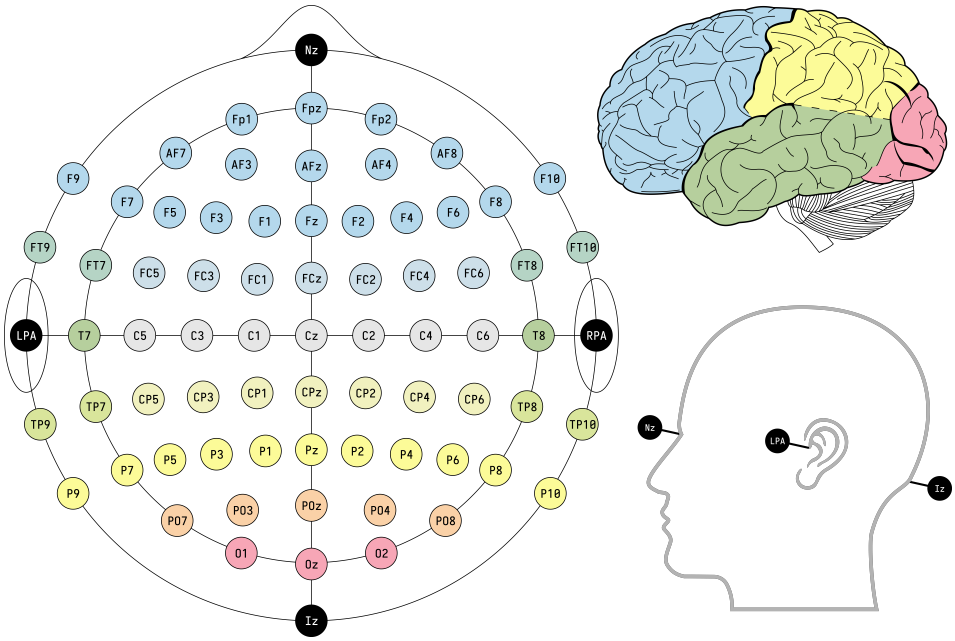

Figure 8: EEG 10-10 System. Picture from Wikipedia 2023.

Figure 9: Mentalab Explore+ EEG amplifier.

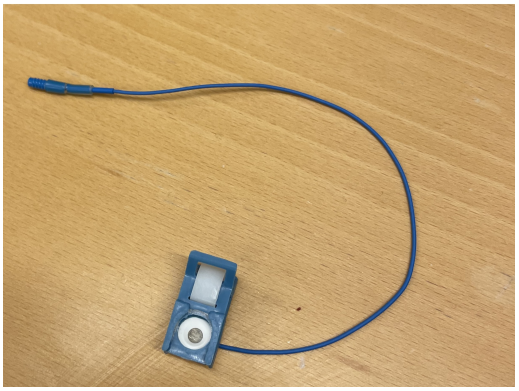

Figure 10: EEG earlobe reference electrode.

Figure 11: Polhemus Fastrack Digitizer.

Figure 12: Stylus and custom-fitted glasses.

4.3 Study Design Overview

The study is structured as a controlled experiment with two intervention groups, one for each contemplative practice. Participants were assigned to either the Mindfulness Meditation or Cyclic Sighing group, each undergoing a standardized set of measurements. The design includes pre- and post-practice measurements to evaluate each session's immediate effects and observe changes over time. The study design overview is given in Figure 13.

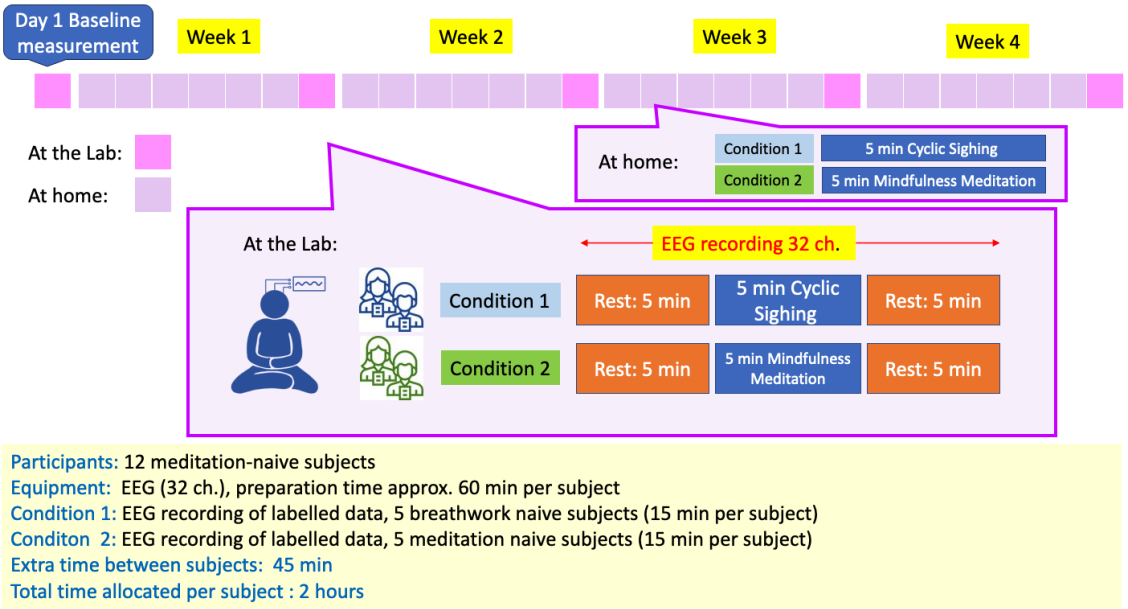

Figure 13: Study overview.

4.4 Participant Selection

Several considerations went into selecting the participants of the study. The considerations and reasonings are discussed here in order of importance. All potential participants applied through the application form found in Appendix C.

4.4.1 Schedule Considerations

The most important consideration was scheduling participants in timeslots where they could be physically at the lab for five consecutive weeks. As physiological measurements were core to the study design, this was paramount. This was the most challenging criterion, with only 36 applicants and 12 two-hour timeslots divided over Tuesday, Wednesday, and Thursday to fill. This setup was selected to fit the data collectors' other class schedules. Keeping timeslots consistent was chosen to ensure reliable comparisons, considering the number of practice days and participants' circadian rhythm. Data collection during the weekend was also considered, but the idea was abandoned as finding willing participants was deemed unlikely.

The time slots of the study are given in the table below:

4.4.2 Health Considerations

The exclusion of individuals with specific medical interventions or diagnoses, such as pacemakers, neurodegenerative disorders, mental disorders, diagnosed diseases, and those regularly using medications, was based on several considerations. These conditions can significantly influence heart

	Tuesday	Wednesday	Thursday
08:00-10:00	Participant 1	Participant 6	Participant 8
10:00-12:00	Participant 2	Participant 7	Participant 9
12:00-14:00	Participant 3		Participant 10
14:00-16:00	Participant 4		Participant 11
16:00-18:00	Participant 5		Participant 12

Table 1: Participant Timeslot Schedule.

rate and brain activity, potentially affecting the data collected. Furthermore, medications, particularly those involving the nervous system, could alter the physiological responses the study aimed to measure. Subjects with pacemakers could also be put at risk due to the setup of electrodes such as the ECG. Setting these exclusion criteria, therefore, improves the study's validity while keeping subjects safe.

4.4.3 Sex Balance

The sex balance of six males and six females in our study was chosen to allow for the exploration of any potential sex-related variations in response to Mindfulness Meditation and Cyclic Sighing. This approach was not based on a presumption of significant sex differences but rather as a precautionary measure to ensure they could be appropriately identified and analyzed if such differences emerged.

To maintain methodological rigor, we equally distributed participants across the two practices, with three males and three females in each group. This setup allows for a balanced comparison, ensuring that any findings related to sex differences (or the lack thereof) are not skewed by disproportionate representation in either group. Such an approach is crucial in preliminary explorations where the impact of sex on responses to specific contemplative practices is not fully known, potentially informing future research directions.

4.4.4 Practice Experience

The study specifically sought participants with little to no experience in the contemplative practices of Mindfulness Meditation and Cyclic Sighing. The criterion was defined as not having previously engaged in the practice for more than a short duration, preferably with their last experience being a year or more. The criterion was chosen for several reasons. Firstly, focusing on novices allowed us to observe the initial reactions and learning processes, which are often more pronounced in those new to such practices and more relevant to the population. Secondly, this criterion aligns our study with previous research in the field, which often focuses on novice practitioners to gauge the baseline effects of these practices, Balban 2022 included, ensuring consistency and comparability with these studies. Finally, recruiting beginners was feasible and practical, as it matched the background of the majority of applicants, providing a homogeneous study group in terms of prior exposure to the practices.

4.4.5 Automated Scheduler

An automated scheduler was created to facilitate efficient participant selection. This system was critical in managing the logistical aspects of participant selection and allocation. Utilizing responses from the online application form, saved in CSV format, the scheduler automatically applied predefined exclusion criteria. This initial screening helped to quickly identify applicants meeting our study's specific requirements, such as health status and availability.

The scheduler's primary function was to allocate time slots to participants based on their indicated availability. It was programmed to ensure a sex balance. The system also had flexibility, proposing

a list of substitutes for all timeslots to simplify the manual fine-tuning and in case of possible drops.

4.5 Intervention Groups

4.5.1 Group Formation

As all selected participants had little to no experience with both practices, group formation was based on the sex balance discussed in section 4.4.3. Three males and three females were thus divided into both the mindfulness and breathing exercise groups.

4.5.2 Activities Description

On their first day at the lab, each of the two groups was given instructions on how to practice. They were allowed to ask questions about the instructions until they felt satisfied with their understanding. The instructions were given on a laminated piece of paper as step-by-step instructions on the front, with a short version visual guide on the back. Participants were given the instructions to keep it for home practice. An identical set of instructions was also present in the lab in case subjects did not bring their own. These instructions were taken directly from Balban 2022 for a fair comparison and can be seen in Appendix A.

The Mindfulness Meditation group was instructed to focus on their breath and then move their focus to the forehead region between their eyes. When they noticed a thought distracting them from this focus, they were instructed to shift their focus back to the breath and then again to their forehead region. On the back, the four-stage process was described visually as a circle of: Focus on the practice → A thought arises → Notice the thought → Re-focus attention → Focus on the practice. They were instructed to do this practice for five minutes.

The Cyclic Sighing group was instructed to follow a breathing pattern of one big in-breath, followed by a second in-breath to fill the lungs completely. It was explained that the second in-breath was often briefer and of smaller volume than the first. They were then instructed to breathe out slowly, more slowly than the combined time of both in-breaths. On the back, the three-stage process was described visually as a circle of: Breath in until lungs are expanded → Take another short breath → Breath out slowly → Breath in until lungs are expanded. They were instructed to follow this breathing pattern for five minutes.

4.6 Duration and Measurement Protocol

The study consisted of 29 days of practice for each participant, with data collection lasting 31 days (starting on a Tuesday and ending on a Thursday). The four-week (28 days) practice period was selected to follow up on the study done by Balban 2022, with one extra day for the last measurements. The team led by Balban found statistically significant changes in mood improvement and respiratory rate reduction in the short timeframe, with only 5 minutes of practice. To follow up on these results, this study also had participants practice for 5 minutes.

4.6.1 Procedure Rationale

Participants were measured for baseline on their first day of the study and once a week for the next four weeks (a total of five times) on the same weekday at the same time. This was done to have consistent measurements over time while negating circadian effects. Between lab sessions, participants were asked to practice at home and complete two sets of questionnaires before and after the practice. This was primarily done to measure the subjective effect of the practices as a followup to Balban 2022 and serve as an objective measure of participant adherence.

4.6.2 Questionnaires

The questionnaires used in the study were the State Anxiety Inventory (SAI), Positive and Negative Affect Schedule (PANAS), Trait Anxiety Inventory (TAI), and Patient-Reported Outcomes Measurement Information System (PROMIS). The TAI and PROMIS questionnaires were administered only during the first and last lab sessions to capture a month-long perspective. In contrast, SAI and PANAS were filled out daily before and after the practice sessions, both at the lab and at home, thus doubling as an adherence measurement. This questionnaire setup closely matches that of Balban 2022. All questionnaires used can be found in Appendix C.

4.6.3 Data Collection

Practice in the lab always consisted of establishing a baseline by measuring for five minutes with the participants' eyes open, looking at a black screen, breathing, thinking, and feeling as usual. This was followed by a five-minute practice session with eyes closed, with the practice depending on the participant given one. The session concluded with another five minutes of measurement with eyes open, thinking and feeling like usual. This was explicitly done to observe changes in blink rate and other changes from the baseline.

The data collectors were always in the room to ensure the measurements went as expected but remained still and quiet during the 15 minutes of pre-, during, and post-practice measurements. A small wall was set up between participants and the computer displaying the data to hide distracting elements. Outside disturbances were noted down if present, like slamming doors, drilling, or other loud sounds.

4.7 Lab Procedures

4.7.1 Preparatory Activities

For all lab sessions, the equipment needed to be dry and clean. The EEG electrodes were cleaned between sessions to remove the EEG gel and any microbes. The cap was also washed between sessions, and if two participants needed the same size cap right after each other, the cap was also dried using a hairdryer. The EEG electrodes were fitted to the cap in anticipation of the next participant. The ECG was also fitted with new electrodes between each participant, and the syringes used for administering EEG gel were cleaned and put in alcohol.

4.7.2 EEG and ECG Setup

The EEG setup started with measuring the distance between the left preauricular point (LPA) and right preauricular point (RPA), marking the midpoint. Similarly, marking the midpoint between the nasion (Nz) and inion (Iz) and placing the Cz electrode in the cross-section. The placements of LPA, RPA, Nz, Iz, and Cz can be seen in Figure 7 and Figure 8. After fitting the cap correctly, the electrodes were digitized to determine the relative position of each electrode. The EEG electrode setup followed the system described in Figure 7. The EEG electrodes were then filled with gel, and impedances were measured and adjusted to reach satisfactory levels. A participant with good impedance measurements can be seen in Figure 14.

Participants were asked to fit the ECG electrodes on themselves according to a standard five-lead system between digitization and gel administration.

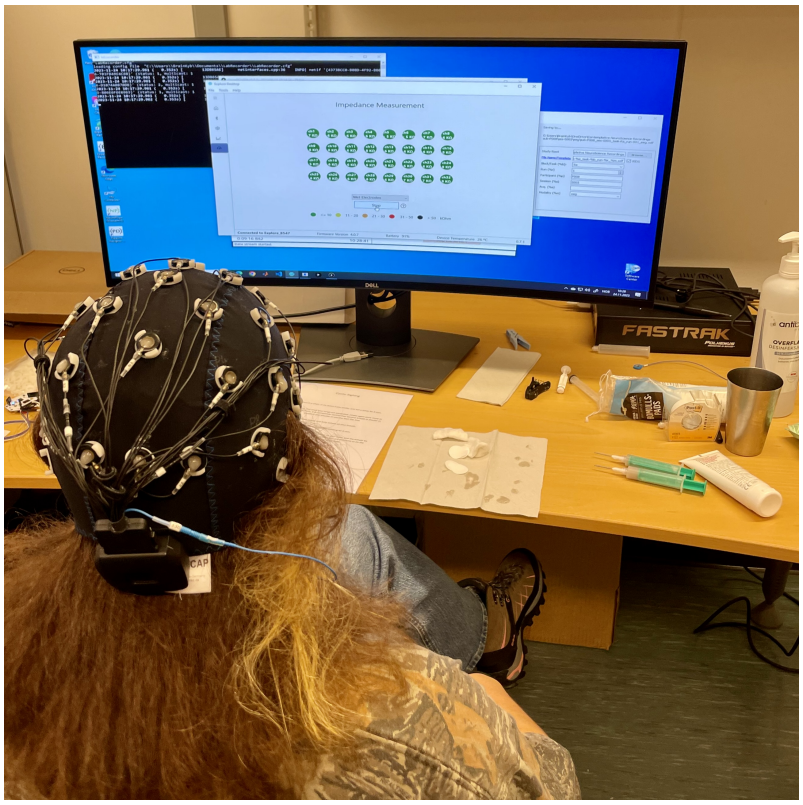

Figure 14: A participant with satisfactory impedance measurements after gel administration.

4.8 Laboratory Workflow

4.8.1 Sequential Laboratory Procedures

1. **Preparation:** Ensure all equipment is clean and properly functioning. Fit EEG electrodes to the cap according to the participant's size. Prepare ECG electrodes and the participants' practice instructions. Verify the operation of all software. This can all be done before the participant's arrival.
2. **EEG Cap Placement:** Measure the distance between the LPA and RPA, marking the midpoint. Similarly, mark the midpoint between the Nz and Iz. Align the Cz electrode at the intersection of these midpoints.
3. **Digitization:** Switch all devices to flight mode to reduce noise, as the digitizer is sensitive to electromagnetic interference. Mark the Nz, LPA, and RPA twice for spatial reference, then mark all electrodes for complete digitization.
4. **ECG Setup:** Allow the participant to self-fit the ECG electrodes for comfort and accuracy following the system described in Figure 2.
5. **EEG Electrode Gel Application:** Apply conductive gel to the EEG electrodes until satisfactory impedances are achieved. Also, apply gel to the reference electrode and attach it to the participant's earlobe.
6. **Data Streaming Verification:** Confirm that all data is streamed to the computer system accurately and continuously.
7. **Questionnaire Administration:** Have the participant complete the SAI (Subjective Anxiety Inventory) and PROMIS (Patient-Reported Outcomes Measurement Information System) questionnaires.
8. **Data Collection:** Conduct three 5-minute sessions of data recording: pre-practice, during, and post-practice.

9. **Post-Experiment Questionnaire:** Administer the SAI and PROMIS questionnaires again post-experiment.
10. **Cleanup:** Provide the participant shampoo and towels for gel removal. Thoroughly clean all equipment in preparation for future use.

4.8.2 Modified Procedures for First and Last Lab Sessions

At the outset of the initial laboratory session, participants were required to read and sign a consent form described in Section 4.10. This session also involved the administration of the TAI (Trait Anxiety Inventory) and PROMIS (Patient-Reported Outcomes Measurement Information System) questionnaires, as detailed in Section 4.6.2. Participants were assisted in selecting the appropriate EEG cap to ensure a comfortable and accurate fit. Participants were also allowed to familiarize themselves with the practice procedures and ask any questions regarding the study. The TAI and PROMIS questionnaires were subsequently readministered during the final lab session to assess changes and gather comparative data.

4.9 Communication Strategy

In the study, communication played a crucial role in coordinating participants. This subsection details the communication approaches and methods utilized throughout the research period.

4.9.1 Initial Contact and Recruitment

All potential participants were initially contacted via email. This was the primary mode of communication used to extend invitations to individuals who had expressed interest in the study. The email provided details about the research and asked recipients to confirm their willingness to participate.

4.9.2 Ongoing Communication and Engagement

Weekly emails were sent to maintain ongoing communication with the participants. These emails served multiple purposes: they acted as reminders for upcoming sessions, provided updates about the study, and kept participants engaged and informed. The use of blind carbon copy (BCC) in these emails ensured the confidentiality of participants' identities.

A typical weekly email included updates about the study's progress and reminders about best practices for the upcoming measurement sessions. For instance, participants were reminded to wash their hair the day before measurements for optimal electrode connections, avoid hair gels on the day of measurements, refrain from consuming coffee and other stimulants two hours before the sessions, and adhere to the same scheduled time and place as the previous weeks. These communications also clarified that questionnaires and practice sessions would occur in the lab, thus not requiring home practice on measurement days.

4.9.3 SMS Reminders

In addition to email, an optional automated SMS reminder system was implemented. This system was designed to remind participants of their practice routines and was sent out 15 minutes before their individually scheduled practice time, enhancing adherence to the study protocol. These SMS reminders were a supplementary tool, primarily focusing on facilitating time-consistent practice habits among participants. Though the SMS reminders were optional, all participants opted in.

4.9.4 Communication with Non-Selected Applicants

Individuals not selected for involvement received thank-you emails acknowledging their interest and expressing gratitude for their willingness to be involved in the study. This approach was chosen to convey respect for their time and interest and foster positive relations and potential future engagement with our research initiatives.

4.10 Ethical Considerations

All participants were given a consent form to read through and sign before the first session. All data collected is to be anonymized so it cannot be traced back to the involved participants.

Participants were asked if anything was painful or uncomfortable during all setup phases: pre-, during, and post-practice. This, combined with waiting for participants to be ready, ensured the participants' comfort.

The consent form emphasizes that participation is entirely voluntary, with participants being able to withdraw at any time without consequences. The study's goals, procedures, and participant commitments were thoroughly explained to ensure informed consent. The study team maintains strict confidentiality and data privacy, with personal data slated for deletion post-study and anonymized data potentially used for future research. Comfort and safety were paramount, with procedures in place for addressing any discomfort or adverse effects. Participants were reminded of their commitment through agreed-upon methods and were offered a gift card as a token of appreciation. Contact details for the research team were provided for any questions or concerns. The data collection and processing were in accordance with the declaration of Helsinki for research on human subjects. The SIKT assessment is given in Appendix B.

4.11 Potential Limitations

The study's design, with specific time slots for practice, as given in Table 1, could have influenced participants' adherence and stress levels. While efforts were made to allocate convenient time slots, variations in personal schedules meant that some participants found it challenging to practice consistently outside the lab, potentially affecting the uniformity of the practice experience. Additionally, the small sample size and the exclusion of individuals with certain medical conditions might limit the generalizability of the findings.

To address the potential adherence issues, the study incorporated voluntary SMS reminders to encourage consistent practice. These reminders, sent 15 minutes before scheduled practice, were intended to help participants adhere to the practice, especially on non-lab days.

4.12 Summary of Methodology

Our research methodology was designed with precision and careful consideration at every stage, as outlined in the preceding sections. The selection of participants, as discussed in Section 4.4, was guided by stringent criteria, including scheduling availability, health considerations, and a balanced representation of sexes. These measures were essential to ensure the integrity and representativeness of our data.

The employment of research-grade ECG and EEG equipment, detailed in Section 4.2, allowed for the capture of detailed physiological data, critical in assessing the impact of the contemplative practices under study. The specificities of these technologies, such as the OpenBCI Cyton board for ECG and the Mentalab Explore+ for EEG, provided high-resolution data crucial for accurate analysis.

Our intervention groups were formed to ensure comparability as described in Section 4.5. The practices were standardized based on the established protocols from Balban 2022, and participants

were given comprehensive instructions to ensure consistency in practice, both at home and in the lab.

Furthermore, the data collection protocol, explained in Section 4.6, was structured to include pre-, during, and post-practice measurements to enable observation of changes over time and to assess the immediate effects of each session.

To ensure data reliability, the entire step-by-step procedure was detailed in Section 4.8, which, combined with Section 4.2, should make reproducing the results straightforward.

5 Conclusion

This study represents a significant step in unraveling the intricate effects of Mindfulness Meditation and Cyclic Sighing on attention and physiological markers. The objective, as stated in the Project Description (Section 1), was to comprehensively compare these two practices using rigorous methods for data collection, including research-grade EEG and ECG, although without conducting data analysis at this stage. The Introduction and Background Literature (Section 2) contextualizes the historical and current significance of such contemplative practices, highlighting the void in research regarding objective physiological markers focusing on attention. Thus, the focus elaborated in the Knowledge Gaps and Motivation section (Section 3) was to delve into the types of attention and their neural mechanisms, aiming to enhance our understanding of these practices in health and wellness. The methodology (Section 4) incorporated careful participant selection and data gathering methods, with detailed practice instructions for the intervention groups. While this paper lays the critical groundwork, the subsequent Master's Thesis promises a detailed analysis and deeper insights. This preliminary study thus sets a strong foundation for future explorations, potentially impacting mental health and stress management practices significantly.

6 Acknowledgements

I express my deepest gratitude to my supervisor, Marta Molinas, and co-supervisors, Andres Soler and Amandeep Cheema, for their invaluable guidance, insights, and support throughout this research project. Their expertise and encouragement were instrumental in shaping this study's direction and success.

Special thanks are also extended to Shiva Sri Hari Alagu Uthaya Kumar for his comprehensive and diligent work in data gathering. His dedication and meticulous approach to data collection was crucial in laying a solid foundation for the research.

This project could not have been accomplished without their collective efforts and unwavering support. I am immensely thankful for their contributions and am honored to have had the opportunity to work under their mentorship.

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A Appendix

A.1 Mindfulness Meditation Instructions

These instructions were given to the Mindfulness Meditation group on a laminated piece of paper for them to take home. The steps were printed on the front, and the visual guide was on the back.

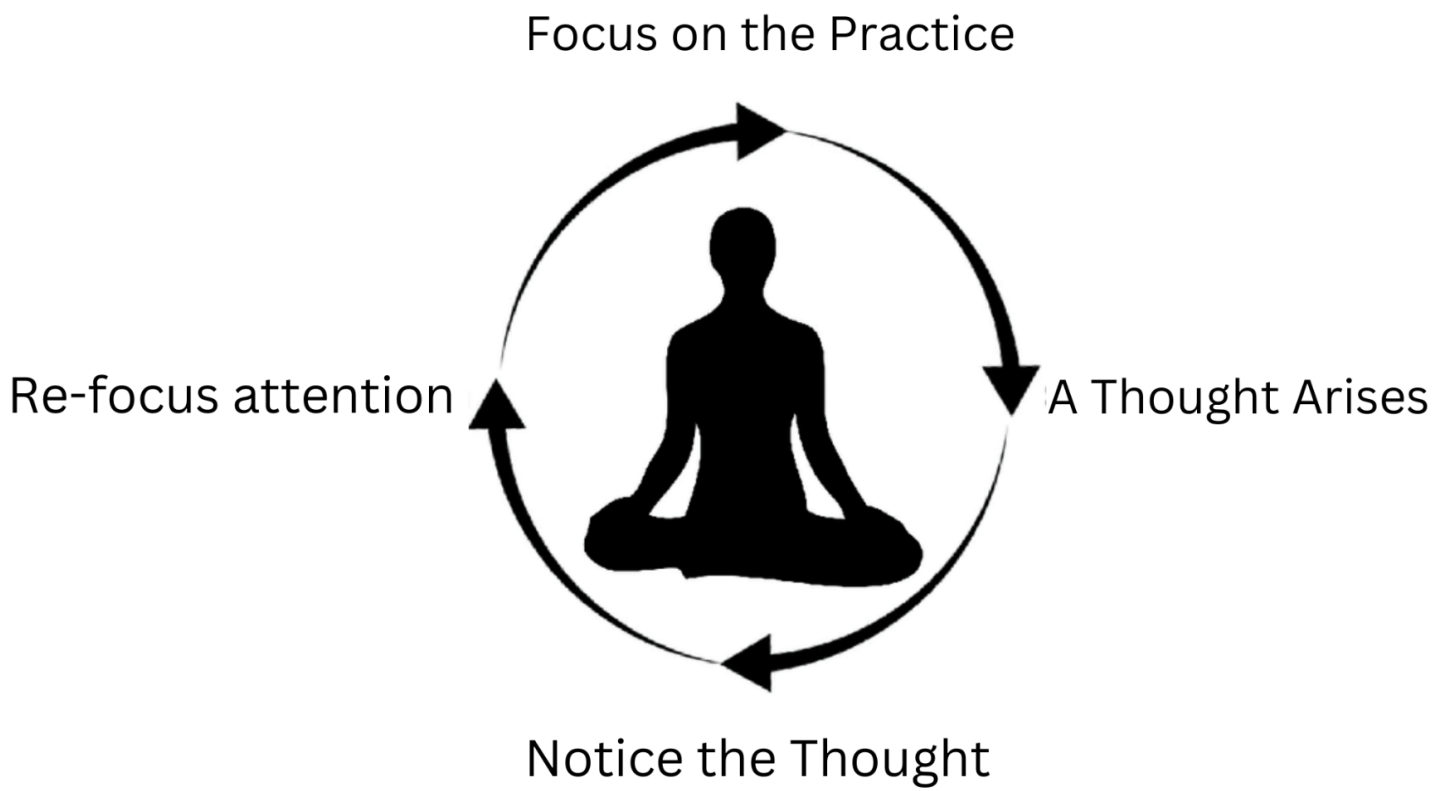
Mindful Meditation

Sit down in a chair or lie down if you prefer, and set a timer for 5 min.

Close your eyes and start to breath while focusing your mental attention on your forehead region between your eyes.

If your focus drifts from this location re-recenter your attention by first focusing back on your breath, and then on the forehead region between your eyes.

When thoughts arise, recognize this as normal, and refocus your attention back to your forehead region and to continue the practice.


Focus on the Practice
Re-focus attention
A Thought Arises
Notice the Thought

A.2 Cyclic Sighing Instructions

These instructions were given to the Cyclic Sighing group on a laminated piece of paper for them to take home. The steps were printed on the front, and the visual guide was on the back.

Cyclic Sighing

Sit down in a chair, or lie down if you prefer, and set a timer for 5 min.

Inhale slowly, and once your lungs are expanded, inhale again once more to maximally fill them. It is completely normal that second breath is shorter in duration and smaller in volume than the first.

Then slowly and fully exhale all your breath.

Repeat this pattern of breathing for 5 min.

Ideally both inhales should be performed via your nose, and the exhale be performed via your mouth, but if you prefer, you are welcome to do the breathing entirely through your nose.

Breath in until lung are expanded

Breath out slowly

Take another short breath

B Appendix

B.0.1 SIKT

Sikt

Assessment of processing of personal data

Reference number	Assessment type	Date
968653	Standard	10.11.2023

Title
David and Goliath: single-channel EEG unravels its power through adaptive signal analysis

Institution responsible for the project
Norges teknisk-naturvitenskapelige universitet / Fakultet for informasjonsteknologi og elektroteknikk (IE) / Institutt for teknisk kyberteknikk

Project leader
Marta Molinas

Project period
19.11.2018 - 31.12.2024

Categories of personal data
General
Special

Legal basis
Consent (General Data Protection Regulation art. 6 nr. 1 a)
Explicit consent (General Data Protection Regulation art. 9 nr. 2 a)

The processing of personal data is lawful, so long as it is carried out as stated in the notification form. The legal basis is valid until 31.12.2024.

Notification Form

Comment
Data Protection Services has assessed the change registered on 11.10.2023.

Sample 6 have been added.

We find that the processing of personal data in this project is lawful and complies with data protection legislation, so long as it is carried out as described in the Notification Form with dialogue and attachments.

TYPE OF DATA
The project will be processing special categories of personal data about health, and general categories of personal data.

FOLLOW-UP OF THE PROJECT
We will follow up the progress of the project underway (every other year) and at the planned end date in order to determine whether the processing of personal data has been concluded/is being carried out in accordance with what is documented.

Good luck with the project!

C Appendix

C.0.1 Application Form

The application form was answered online, and participants were gathered using posters with QR codes to the application form.

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Participant application form: Contemplative Neuroscience

Contemplative Neuroscience a Brainwave Meditation Study

We are currently setting up a study to figure out in more scientific terms what kind of contemplative practice is most effective. There have been many studies with varying degrees of scientific rigor in this field, and thousands of years of contemplatives sharing experience in non-scientific ways. Most findings have found incredible results for stress reduction, regulation of moods, increases in concentration and many other interesting findings.

One recent study in particular by researchers at Stanford led by famous neuroscientist and podcaster Andrew Huberman caught our eyes. It compared different forms of breathing patterns with meditation to find the most effective practice for regulation of stress and mood. The drawback of the study was that most of the results were based on questionnaires.
Link to original study: https://doi.org/10.1016/j.xcrm.2022.100895

We intend to continue this study with more rigorous methods of data collection, namely EEG and ECG, collecting both brainwave and heart rhythm data on all participants. The participants will be split into two different groups, one doing a meditation practice, and the other doing a cyclic sighing breathwork exercise.

All participants will be put on a one-month-long program of meditation or breath work practice, every day, for 5 minutes. A short questionnaire will need to be filled out before and after each practice. We seek people with little to no prior experience with meditation or breathwork practice. A video explaining the practice will be given to guide you through the exercises. EEG and ECG data will be collected ones a week every Tuesday, Wednesday, or Thursday (5 days in total) depending on group placement at the same time every week. If you, for example, would get the Tuesday at 11.00 slot, this would be your time every week for the duration of the study. The study aims to start on October 10th, and will need you to be available for lab experiments every Tuesday or Thursday for the following 4 weeks (29 days). If this schedule is not possible, the study may be postponed by one or two weeks.

All participants will also receive a 300kr gift card.

Data Collection and Consent:

- All data collected will be confidential and stored to the data storage standard set by NTNU, UIO and NSD/SIKT.
- A Consent Form with further information will be issued to participants that are chosen to take part in the study.
- Consent can be withdrawn at any time for any reason.

What we need from you:

- 5 minutes of practice every day for one month.
- Some minutes to answer a questionnaire before and after practice every day.
- 45-min lab sessions (30 min set up, 5 min warm up, 5 min practice, and 5 min wind down) at the same time each week, either on Tuesday or Thursday for all 4 weeks. The lab is on Campus

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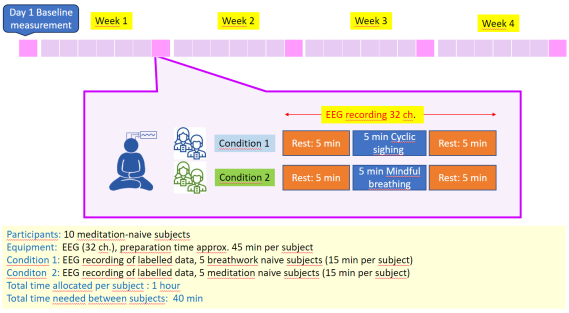
Gløshaugen in the Electro building.
- Little to no experience with meditation and breathwork practice

What you can gain from participating:

- A structured environment to gain a new habit with lots of scientifically backed positive effects. Habit building usually takes 20-something days.
- Opportunity for self-exploration and increased self-awareness.
- See your own brainwaves!

If you are interested in joining the study, we need to know some personal information about our schedule and how to reach you, so please fill out this form! (If you are on mobile, we advise filling in the form in landscape mode).

By filling out this form, you consent to the research team contacting you in the following weeks.



Name:

Email address:

Phone number:

Sex:

What is your biological sex?

- Male
- Female

Do you have any of the following medical interventions or diagnoses?

- A pacemaker, neurodegenerative disorders, mental disorders, diagnosed diseases
- Any recent or regular use of medication
- None of the above

Do you have any experience with meditation?

- No experience
- Little experience (i.e. tried a few times long ago)
- Some experience (i.e. used to practice but not anymore)
- More (i.e. have had for some time and currently have a meditation practice)

Do you have any experience with breathwork?

No experience

Little experience (i.e. tried a few times long ago)

Some experience (i.e. used to practice but not anymore)

More (i.e. have had for some time and currently have a meditation practice)

What 5 consecutive week streak are you available in the coming weeks?

As the studies starting time is not set, three different options for all days are defined. You will only be selected to join one.

Tuesdays (10th Oct., 17th Oct., 24th Oct., 31st Oct., 7th Nov.)

Tuesdays (17th Oct., 24th Oct., 31st Oct., 7th Nov., 14th Nov.)

Tuesdays (24th Oct., 31st Oct., 7th Nov., 14th Nov., 21st Nov.)

Wednesdays (11th Oct., 18th Oct., 25th Oct., 1st Nov., 8th Nov.)

Wednesdays (18th Oct., 25th Oct., 1st Nov., 8th Nov., 15th Nov.)

Wednesdays (25th Oct., 1st Nov., 8th Nov., 15th Nov., 22nd Nov.)

Thursdays (12th Oct., 19th Oct., 26th Oct., 2nd Nov., 9th Nov.)

Thursdays (19th Oct., 26th Oct., 2nd Nov., 9th Nov., 16th Nov.)

Thursdays (26th Oct., 2nd Nov., 9th Nov., 16th Nov., 23rd Nov.)

What days are you available in the coming weeks?

Please fill out the same information as above, as well as specific days. This will help us figure out spare days if you cannot join for 5 consecutive weeks.

Tuesday

Week 41 (Starts Mon. 9th Oct.)

Week 42 (Starts Mon. 16th Oct.)

Week 43 (Starts Mon. 23rd Oct.)

Week 44 (Starts Mon. 30th Oct.)

Week 45 (Starts Mon. 6th Nov.)

Week 46 (Starts Mon. 13th Nov.)

Week 47 (Starts Mon. 20th Nov.)

None

Wednesday

Week 41 (Starts Mon. 9th Oct.)

Week 42 (Starts Mon. 16th Oct.)

Week 43 (Starts Mon. 23rd Oct.)

Week 44 (Starts Mon. 30th Oct.)

Week 45 (Starts Mon. 6th Nov.)

Week 46 (Starts Mon. 13th Nov.)

Week 47 (Starts Mon. 20th Nov.)

None

Thursday

Week 41 (Starts Mon. 9th Oct.)

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Week 42 (Starts Mon. 16th Oct.)
Week 43 (Starts Mon. 23rd Oct.)
Week 44 (Starts Mon. 30th Oct.)
Week 45 (Starts Mon. 6th Nov.)
Week 46 (Starts Mon. 13th Nov.)
Week 47 (Starts Mon. 20th Nov.)
None

What times are you available during the chosen days?

This will be used to slot you in a time that works with your schedule, so you do not miss any classes or other activities-

Tuesdays

08.00-09.00
10.00-11.00
12.00-13.00
14.00-15.00
16.00-17.00
None

Wednesdays

08.00-09.00
10.00-11.00
12.00-13.00
14.00-15.00
16.00-17.00
None

Thursdays

08.00-09.00
10.00-11.00
12.00-13.00
14.00-15.00
16.00-17.00
None

Any questions or comments?

C.0.2 Questionnaires

The questionnaires were answered online, and participants were emailed links to the relevant ones. The format was somewhat different online than on the displayed PDFs; however, all content is the same.

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State Anxiety Inventory

Name

Sex

- Male
- Female

I have had a good night of sleep

Choose the alternative that most closely describes your previous night of sleep.

- Not at all
- A little bit
- Somewhat
- Quite a bit
- Very much

State Anxiety Inventory

A number of statements which people have used to describe themselves are given below. Read each statement and choose the statement that indicates most closely ***how you feel right now***. There are no right or wrong answers. Do not spend too much time on each statement, but give the answer that describes your present feeling best.

I feel calm

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel secure

- Not at all
- Somewhat
- Moderately so
- Very much so

I am tense

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel strained

- Not at all
- Somewhat
- Moderately so
- Very much so

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I feel at ease

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel upset

- Not at all
- Somewhat
- Moderately so
- Very much so

I am presently worrying over possible misfortunes

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel satisfied

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel frightened

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel comforable

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel self-confident

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel nervous

- Not at all
- Somewhat

- Moderately so
- Very much so

I am jittery

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel indecisive

- Not at all
- Somewhat
- Moderately so
- Very much so

I am relaxed

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel content

- Not at all
- Somewhat
- Moderately so
- Very much so

I am worried

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel confused

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel steady

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel pleasant

Not at all
Somewhat
Moderately so
Very much so

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PANAS

Name

Sex:

- Male
- Female

Indicate the extent you feel this way right now.

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel right now, that is, at THIS MOMENT, using the corresponding number of the key below.

Interested

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Distressed

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Excited

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Upset

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Strong

- Very slightly or not at all
- A little
- Moderately

- Quite a bit
- Extremely

Guilty

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Scared

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Hostile

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Enthusiastic

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Proud

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Irritable

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

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Alert

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Ashamed

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Inspired

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Nervous

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Determined

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Attentive

- Very slightly or not at all
- A little
- Moderately
- Quite a bit
- Extremely

Jittery

- Very slightly or not at all
- A little

Moderately
Quite a bit
Extremely

Active

Very slightly or not at all
A little
Moderately
Quite a bit
Extremely

Afraid

Very slightly or not at all
A little
Moderately
Quite a bit
Extremely

Nettskjema

Trait Anxiety Inventory

Name:

Sex

- Male
- Female

Trait Anxiety Inventory

A number of statements which people have used to describe themselves are given below. Read each statement and choose the statement that indicates most closely ***how you generally feel***. There are no right or wrong answers. Do not spend too much time on each statement, but give the answer that describes your general feeling best.

I feel pleasant

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel nervous and restless

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel satisfied with myself

- Not at all
- Somewhat
- Moderately so
- Very much so

I wish I could be as happy as others seem to be

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel like a failure

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel rested

- Not at all

- Somewhat
- Moderately so
- Very much so

I am "calm, cool, and collected"

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel that difficulties are piling up so that I cannot overcome them

- Not at all
- Somewhat
- Moderately so
- Very much so

I worry too much over something that really doesn't matter

- Not at all
- Somewhat
- Moderately so
- Very much so

I am happy

- Not at all
- Somewhat
- Moderately so
- Very much so

I have disturbing thoughts

- Not at all
- Somewhat
- Moderately so
- Very much so

I lack self-confidence

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel secure

- Not at all
- Somewhat
- Moderately so
- Very much so

Nettskjema

I make decisions easily

- Not at all
- Somewhat
- Moderately so
- Very much so

I feel inadequate

- Not at all
- Somewhat
- Moderately so
- Very much so

I am content

- Not at all
- Somewhat
- Moderately so
- Very much so

some unimportant thought runs through my mind and bothers me

- Not at all
- Somewhat
- Moderately so
- Very much so

I take disappointments so keenly that I can't put them out of my mind

- Not at all
- Somewhat
- Moderately so
- Very much so

I am a steady person

- Not at all
- Somewhat
- Moderately so
- Very much so

I get in a state of tension or turmoil as I think over my recent concerns and interests

- Not at all
- Somewhat
- Moderately so
- Very much so

Nettskjema

PROMIS

Name:

Sex:

- Male
- Female

Sleep Related Impairment

Please choose how well each statement describes how you have felt in the past month.

I had a hard time getting things donebecause I was sleepy.

- Not at all
- A little bit
- Somewhat
- Quite a bit
- Very much

I felt alert when I woke up.

- Not at all
- A little bit
- Somewhat
- Quite a bit
- Very much

I felt tired.

- Not at all
- A little bit
- Somewhat
- Quite a bit
- Very much

I had problems during the day because ofpoor sleep.

- Not at all
- A little bit
- Somewhat
- Quite a bit
- Very much

I had a hard time concentrating because ofpoor sleep.

- Not at all
- A little bit
- Somewhat
- Quite a bit
- Very much

I felt irritable because of poor sleep.

- Not at all
- A little bit
- Somewhat
- Quite a bit
- Very much

I was sleepy during the daytime.

- Not at all
- A little bit
- Somewhat
- Quite a bit
- Very much

I had trouble staying awake during the day.

- Not at all
- A little bit
- Somewhat
- Quite a bit
- Very much