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Exploring the Impact of CM-II Meditation on Stress Levels in College Students through HRV Analysis

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Published papers: 1. FIE 2023 IEEE conference, Texas, USA: EEG Spectral Analysis and Prediction for Inattention Detection in Academic Domain 2. AIMC 2023, Brighton, UK: Introductory Studies on Raga Multi-track Music Generation of Indian classical music using AI.

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Abstract

The demanding nature of engineering education, characterized by intensive coursework and tight project deadlines, often leads to high-stress levels among students, impeding their learning and performance. There is a growing body of literature that shows how meditation can help reduce stress among engineering students. Meditation, recognized for its stress-alleviating properties, has been shown to lower cortisol levels, improve autonomic balance, reduce sympathetic nervous system activity, and enhance immune function through heart rate variability (HRV) metrics. ChakraMarmaKosha meditation (CM-II), building on CM-I's foundation[1], is a three-stage meditation designed to address thoughts, emotions, and future visualization, key elements in mitigating stress. In this study, we intend to evaluate CM-II's impact on stress reduction among college students. An experiment of 15 students was conducted in a lab setting in which we measured the heart pulse data before, during, and after meditation sessions with a wired earphone-like device. From the raw data, we calculated pivotal HRV metrics such as heart rate, Heart Coherence (HC), Standard Deviation of Normal-to-Normal intervals (SDNN), Root Mean Square of Successive Differences (RMSSD), Baevsky Stress Index (BSI), and the Low Frequency/High-Frequency ratio (LF/HF ratio) to analyze stress. The results indicated a harmonizing effect on student hearts especially during the meditation. This study underscores the importance of integrating mindfulness and well-being into engineering education, fostering not only technical proficiency but also mental resilience and emotional intelligence in future professionals. Moving ahead, we would develop an application for wireless heart pulse data measurement for a broader reach.

Index Terms

Engineering education, stress reduction, meditation, heart rate variability, HRV metrics, Heart Coherence

INTRODUCTION

Engineering education is renowned for its rigorous academic demands and the high levels of stress it can impose on students. The cognitive load and competitive environment inherent in this field often lead to significant stress, which can adversely affect students' mental health, learning, and overall academic performance. Globally, the economic impact of stress is estimated at approximately $1 trillion annually [2], with projections suggesting a global economic burden of $16 trillion by 2030 [3]. Furthermore, a staggering 61% of college students seek counseling for issues such as anxiety, depression, and academic challenges [4]. A study in 2020 revealed that stress not only diminishes academic performance but also that 42.3% of students experience serious psychological issues, with a quarter of them requiring mental health support [4]. A significant drop in GPA during the first year of engineering studies has been linked to increased stress, which leads to college dropouts [5], [6]. Moreover, the academic outcomes of engineering students are not only influenced by the stress experienced during their coursework but also by their ability to manage and cope with these stressors effectively, which is essential for their persistence and success in the field [6].

In the face of such challenges, meditation has emerged as a popular and effective stress management practice. With over 9 million Americans engaging in meditation for wellness, focus, and stress relief, a significant majority report substantial benefits [7]. Recent interventions in engineering education have explored the benefits of yoga and meditation, finding that such practices can significantly reduce students' stress perception and anxiety levels, thereby potentially enhancing their academic performance and mindfulness skills [8]. A group mindfulness intervention study with undergraduate engineering students demonstrated that consistent mindfulness practice led to increased trait mindfulness and reduced perceived stress, suggesting that mindfulness could be a valuable component of engineering education [9]. Furthermore, EEG studies on engineering students practicing Simplified Kundalini Yoga meditation have shown positive alterations in brain wave patterns, indicating a beneficial impact on mental states conducive to learning and cognitive function [10].

The current literature reveals a noticeable gap in understanding the comprehensive effects of various meditation techniques on stress and depression in engineering students. A study by Cody Spears highlights the need for deeper exploration into the distinct impacts of mindfulness meditation and music therapy, particularly in terms of autonomic nervous system responses [11]. Similarly, research on compassionate mind training by M Matos et. al suggests a lack of focused studies on the specific effects of emotional therapy techniques on heart rate variability (HRV) and psychological well-being [12]. The absence of detailed research on the influence of specific music types, such as Raga music, in meditation practices the papers [13], [14] further underscores this gap. The CM-II meditation approach, with its structured methodology encompassing emotional processing, mindfulness, future visualization, and Raga music, could potentially address these gaps, offering a holistic solution to reduce stress and depression in this demographic.

In this research, we build upon previous research [15] to analyze the CM-II meditation[1] technique, a guided meditation with music designed to alleviate student stress. CM-II, an advancement of CM-I [**?**], not only facilitates emotional healing by guiding individuals through emotional cleansing and the release of past traumatic emotions but also provides a space for contemplation, helping to organize thoughts and plan for the future. This technique is particularly relevant for individuals experiencing stress-related disorders, characterized by psychological distress from unresolved emotional conflicts and stress-inducing cognitive patterns formed during traumatic events. This study intends to measure CM-II's effect on stress levels by conducting a detailed HRV analysis on the heart pulse data collected during the same experiment.

The central hypothesis of this study is that CM-II can reduce stress levels among college students. The contributions of this research are multifaceted and include:

1) Develop meditation practices.
2) Compose music for enhanced attention.
3) Conduct an in-person experiment with 15 participants to measure HRV.
4) Conduct time domain and frequency HRV analysis to measure the shifts in stress.

In short, we conducted an experiment where students underwent a visual reasoning test and CM-II meditation, measured their heart pulse data, and conducted an HRV analysis to determine the effect of guided meditation with music as an intervention for high student stress levels. This paper aims to explore the potential of regular meditation practice as a strategy to alleviate the profound impact of stress among engineering students.

Related Works

Stress reduces academic performance

Interventions can reduce stress

Borah et al. (2022) revealed a positive correlation between academic stress and performance, suggesting stress impacts students universally, irrespective of gender or academic discipline [16]. Thavaraj (2016) highlighted the potential of emotional intelligence in mediating stress effects, hinting at new stress management strategies) [17]. Jibril (2021) found that better study skills are associated with lower stress and improved academic outcomes, advocating for skill enhancement as a stress reduction tactic [18]. Paniagua et al. (2019) successfully reduced stress through gamification and innovative problem-solving techniques, leading to better academic results [19]. These

[1] https://youtu.be/mmKJ9E8-veo\?si\=ti3BQqBrH3qF6a-Q

insights affirm that while stress is a natural part of academic life, its effective management is key to educational success.

Meditation as an intervention

Emotional Processing: Watford and Stafford (2015) explored the relationship between mindfulness training and emotion regulation, finding that mindfulness can increase emotional awareness and potentially reduce emotional avoidance [20]. Linehan's (1993) framework posits that recognizing and fully experiencing our primary and secondary emotions without judgment can lead to healing. By mindfully observing emotions and their physical manifestations, individuals can process past events that trigger these emotions. This non-judgmental awareness allows emotions to ebb naturally, akin to tides, facilitating a release from past burdens and leading to emotional healing [21]. Emotional mindfulness, as described by Linehan, encourages acceptance and understanding of emotional experiences, which is a crucial step towards emotional processing and healing.

Linehan (1993) suggests an example of narration for emotional processing:

1) Be keenly interested in the flow of emotions within.
2) Recognize feelings such as Anger, Fear, Joy, Love, hatred, Sadness, and Shame.
3) Let your memories come and go freely. Give yourself the space and time for this process to unfold fully.
4) Notice the ebb and flow of emotions through your body as if they were waves.
5) Pay attention to the messages from your senses—touch, smell, vision, hearing, and taste.
6) Allow things to slip off your body and emotions like a nonstick pan.

Thus, Linehan (1993) states that to cope with the emotion, notice the feelings, and let them pass. As the emotions dissipate, the power of thought disturbances reduces and one gets the internal space to focus on the current task intensely [21].

Mental Processing: Empirical studies have shown that psychological interventions, including cognitive-behavioral therapy, emotional writing, and mindfulness training, can positively impact students' quality of life, anxiety, depression, stress, mental health, body image, disease management, interpersonal relationships, fatigue, and pain [22]. Mindful Awareness Practices improve executive functioning and help mentally deal with problems [23]. A study by Mindfulness training among nursing students led to decreased stress levels and improved academic skills such as concentration and time management [24]. Similarly, O'Donnchadha (2018) reported that mindfulness-based interventions not only alleviated stress in caregivers but also enhanced their ability to disengage from distressing thoughts and be more mindfully aware [25]. These practices, when integrated with the reflective observation of past problems can release the pressure of unresolved issues, providing mental clarity and a structured approach to problem-solving [26]. This enhances cognitive reappraisal (re-considering the perspective) which can help students manage stress and bring clarity on challenges and priorities.

Visualisation: Visualization meditation has emerged as a potent tool for reducing stress and enhancing motivation towards achievement [27]. Research indicates that Visualisation meditations can significantly diminish levels of stress, anxiety, and depression while fostering a rise in achievement-oriented motivation among students [28]. Additionally, programs focusing on visualization have been shown to cultivate self-awareness and lessen anxiety, particularly in female university students over an 8-week period [29]. Beyond its therapeutic effects, visualization also sharpens creativity, insight, and focus, contributing to a more productive and focused performance [30]. Thus, future envisioning successful outcomes can enhance self-efficacy and stress management [27].

Music during meditation

Music has been shown to enhance meditation practices, offering benefits such as stress reduction and increased mindfulness. A qualitative study on cancer patients revealed that incorporating music therapy into virtual mind-body programs helped in coping with stress and maintaining social connections [31]. Another study on college students indicated that music meditation could increase overall mindfulness, although it did not significantly change test anxiety levels ([32]). These findings suggest that music can be a valuable component of meditation, potentially improving psychological well-being and mindfulness in both therapeutic and educational environments. The background music in this meditation is composed by the author in Indian 'Hindol' Raga as it enhances memory and attention, and reduces stress [33].

Stress and fight-or-flight response

When students are stressed, the sympathetic system can dominate, leading to a state of heightened alertness that is not conducive to the sustained concentration required for academic tasks, potentially decreasing performance [34]. Moment-to-moment fluctuations in thoughts and emotions can vary stress levels, influencing heart rate and HRV that could be used to identify stress patterns [35]. Stress triggers the body's fight-or-flight response, engaging the sympathetic nervous system (SNS) to prepare for immediate action—increasing heart rate, blood pressure, and breathing rate while dilating pupils and redirecting blood flow to essential muscles [36]. Conversely, the parasympathetic nervous system (PNS) promotes the rest-and-digest state, calming the body by decreasing heart rate and blood pressure, constricting pupils, and enhancing digestion [37]. Chronic stress can disrupt the balance between these systems, leading to sustained SNS activation and reduced PNS activity, which may contribute to long-term health issues [38]. Studies have shown that interventions like relaxation techniques can help restore this balance, emphasizing the importance of managing stress for autonomic nervous system health [39].

Stress and Autonomic nervous system (ANS)

The dysregulation of the autonomic nervous system (ANS), which includes both the sympathetic and parasympathetic branches, is closely linked to stress and mental disorders. Disorders of arousal, characterized by ANS dysfunction, manifest in affective lability, anxiety, stress, and emotional disorder, impacting both physical and mental health. Chronic stress leads to an allostatic load, the physiological consequence of chronic exposure to heightened neuroendocrine response, which in turn affects heart rate and rhythm, among other physiological functions. This dysregulation can have negative impacts on physiological function, affecting arterial blood pressure, heart rate, rhythm, and vagal afference [40].

Psychological Health and Cognitive Function

HRV is a significant indicator of psychological health; higher levels are correlated with resilience and enhanced cognitive performance, while lower levels are associated with mental health challenges, including anxiety and depression [41]. HC improves self-regulation and cognitive function by promoting a state of wave coherence that positively influences brain function, especially in areas responsible for advanced cognitive processes [41].

Understanding Heart Rate Variability (HRV)

Heart rate variability (HRV) is the physiological phenomenon of variation in the time interval between heartbeats. It is measured by the variation in the beat-to-beat interval and is a reliable reflection of the many physiological factors that contribute to the heart's rhythm. HRV is a non-invasive marker of the autonomic nervous system's (ANS) activity and its balance between the sympathetic and parasympathetic branches [41].

Heart Rate (HR): Heart rate is a critical vital sign, representing the frequency of the heartbeat measured by the number of contractions (beats) of the heart per minute (bpm). It is determined by assessing the inter-beat intervals (IBIs), which are the time differences between consecutive heartbeats. The average heart rate can be calculated from a series of IBIs using the following formula:

$$\text{Pulse}(\{IBI_i\}) = \frac{60}{\frac{1}{N}\sum_{i=1}^{N} IBI_i}$$

This formula provides a simple yet effective way to convert the time between heartbeats into a rate per minute, offering a snapshot of cardiac activity.

Heart Coherence: Heart coherence in HRV analysis reflects a synchronized, efficient state of physiological function, characterized by stable, sine wave-like heart rhythms. This coherence is indicative of a harmonious autonomic nervous system and is associated with positive emotional states, cognitive performance, and overall well-being. It is quantified by analyzing the HRV power spectrum, focusing on the low-frequency peak compared to total power. Positive emotions enhance coherence, while negative emotions disrupt it, highlighting the heart's role in emotional regulation and the interconnectedness of physiological and psychological processes. HC, also known as cardiac coherence or resonance, is measured through HRV analysis, where an individual's heart rhythm pattern becomes more ordered and resembles a sine wave at a frequency of around 0.1 Hz (10 seconds) [41]. In our study, we used the absolute values of HC and analyzed them relative to other individual's responses during the sessions.

$$\text{Heart Coherence} = \int_{f_0 - 0.015\ \text{Hz}}^{f_0 + 0.015\ \text{Hz}} \text{Power Spectrum}(f)\, df$$

Methodology

In our methodology, we employ time-domain and frequency-domain analyses to assess Heart Rate Variability (HRV) from IBI data as shown in the pipeline diagram 1. We measure the Standard Deviation of NN Intervals (SDNN) and the Root Mean Square of Successive Differences (RMSSD) to represent overall variability and parasympathetic activity respectively. Frequency-domain measures include Low Frequency (LF) and High Frequency (HF) components, and their ratio (LF/HF), which indicates autonomic balance. Additionally, we calculate the Baevsky Stress Index (BSI) for stress estimation.

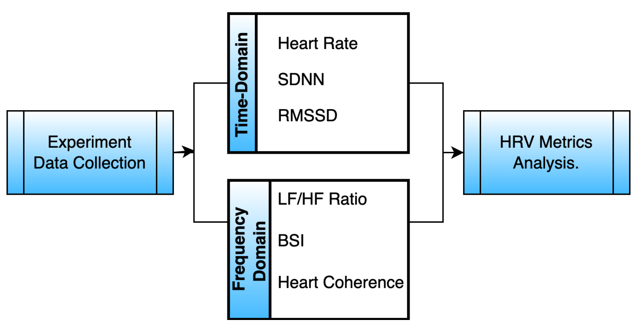


Fig. 1: HRV Analysis Pipeline

Time Domain Analysis of HRV

For the time domain, we calculate statistical measures directly from the inter-beat interval (IBI) data, such as the Standard Deviation of NN Intervals (SDNN) using theories as per the following frameworks.

Standard Deviation of NN Intervals (SDNN): The SDNN is a time-domain measure of HRV that reflects all cyclic components responsible for variability during the recording period. It is calculated as the standard deviation of all NN intervals (normal-to-normal intervals, which are all intervals between adjacent QRS complexes resulting from sinus node depolarizations) [42]. The formula is:

$$\text{SDNN}(\{IBI_i\}) = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(IBI_i - \overline{IBI})^2}$$

SDNN is a measure of overall heart rate variability and is considered a general marker of autonomic flexibility and cardiac health [42].

Root Mean Square of Successive Differences (RMSSD): The RMSSD is another time-domain measure that emphasizes the parasympathetic nervous system's influence on heart rate variability. It is particularly sensitive to short-term variations in HRV and is calculated as follows:

$$\text{RMSSD}(\{IBI_i\}) = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N-1}(IBI_{i+1} - IBI_i)^2}$$

RMSSD is often used to estimate the vagally mediated changes that occur in response to stress and relaxation [42].

Frequency Domain Analysis of HRV

In the Frequency Domain Analysis of HRV, we utilize Welch's method to conduct power spectral density (PSD) analysis for Heart Rate Variability (HRV) assessment. We import inter-beat interval (IBI) data using pandas and clean it for analysis. The PSD is calculated to determine the Low Frequency (LF) and High Frequency (HF) power bands, integral to HRV analysis.

Low Frequency (LF) and High Frequency (HF) Band: In the frequency domain, HRV is divided into different components based on the frequency of oscillations in the heart rate signal. The LF band (0.04 to 0.15 Hz) is influenced by both the sympathetic and parasympathetic nervous system, while the HF band (0.15 to 0.4 Hz) is predominantly a marker of parasympathetic activity, particularly respiratory sinus arrhythmia. The balance between these two bands is often expressed as the LF/HF ratio:

$$\text{LF/HF Ratio} = \frac{\text{LF Power}}{\text{HF Power}}$$

This ratio is a commonly used index of autonomic balance, with a higher LF/HF ratio indicating sympathetic dominance and a lower ratio indicating parasympathetic dominance [42].

Baevsky Stress Index (BSI)

The Baevsky Stress Index (BSI) is a composite measure derived from HRV that provides an estimate of stress levels. It is calculated using the mode of the IBI histogram binned at 50 ms intervals, the amplitude of this mode, and the SDNN of the IBI:

$$\text{SI}(\{IBI_i\}) = \frac{\text{amp}(\text{mod}_{50ms}(\{IBI_i\}))}{2 \times \text{mod}_{50ms}(\{IBI_i\}) \times 3.92 \times \text{SDNN}(\{IBI_i\})}$$

The BSI is particularly useful in assessing the physiological stress response, as it incorporates both the variability and the predominant rhythm of the heart rate [42].

HRV Metrics and Stress

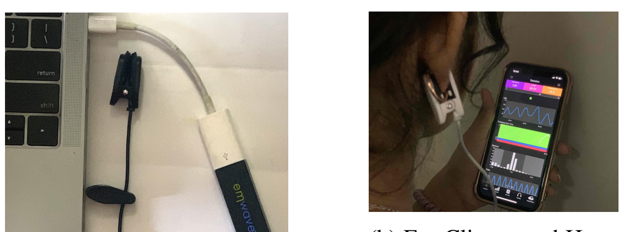
The study of HRV provides a unique window into the autonomic nervous system's adaptation to stress as shown in table I. Time-domain measures like SDNN and RMSSD, along with frequency-domain measures such as the LF/HF ratio, offer insights into the body's stress response. A high SDNN indicates a healthy response to stress, with the body showing adaptability and resilience. Conversely, a low SDNN may suggest a reduced capacity to cope with stress. The RMSSD reflects the body's ability to engage in rapid, dynamic modulation of heart rate in response to immediate stressors, indicative of a robust parasympathetic system.

Metric	**Description (Understandable)**	**Increased Stress**
Average Heart Rate	Beats per minute measurement.	+
SDNN	HRV indicator of heart-brain function.	-
RMSSD	Measures calmness response in the body.	-
BSI	Quantifies stress via heart activity.	+
LF/HF Ratio	Balance of stress and relaxation responses.	+
Heart Coherence	Stability and rhythm of heart rate.	-

TABLE I: Influence of stress on HRV metrics

The experimental setup and pre-meditation and post-meditation visual reasoning tests and their results are narrated in our previous paper [15]. During this experiment in this study, we used HeartMath[41] emWave Pro to measure the heart pulse data, as shown in the figure 2a. Figure 2a shows the earphone like emWave Pro device connected to the laptop and the Figure 2a how it is connected to the ear. Once connected,

In continuation of our previous work narrated in [15], this study utilized the HeartMath[41] emWave Pro for heart pulse data measurement, as depicted in Figure 2a. This figure illustrates the emWave Pro device, resembling an earphone, connected to both the ear (figure 2b) and a laptop (figure 2a). The emWave Pro operates using a pulse plethysmograph, where an LED emits light into the skin, and a sensor detects changes in the reflected light with each heartbeat [43]. This device measures the time interval between pulses and provides real-time feedback by charting heart rate changes and HRV, reflecting the autonomic nervous system's synchronization. For further analysis, the software allows exporting raw Interbeat Interval (IBI) data. These IBI values are then utilized to calculate various HRV metrics using Python for a detailed analysis of stress level fluctuations.



(a) HeartMath emWave Pro

(b) Ear-Clip to read Heart pulse data

Fig. 2: HeartMath emWave Pro Device

As shown in 1, we followed a systematic approach to HRV analysis, incorporating both time-domain and frequency-domain assessments to elucidate autonomic nervous system dynamics.

RESULTS

Experimental analysis

As mentioned in the methodology session above, we conducted a detailed analysis of Heart Rate Variability (HRV) metrics to assess the effects of CM-II meditation on stress and heart metrics. Using Python scripts[2], we

[2]https://github.com/datasci888/ASEEMarch2024

Metric	Mean Before	Mean During	Mean After	Before-During	During-After	p Before-During	p During-After
HC	5.295	6.134	4.7996	15.84%	-21.76%	0.0333	0.00037
SDNN	97.87	137.64	161.22	40.63%	17.13%	0.377	0.571
RMSSD	0.2	0.2	0.22	-1.61%	8.27%	0.784	0.295
LF/HF Ratio	0.5	0.5	0.56	0.12%	11.53%	0.996	0.723
BSI	0.00047	-0.00022	0.00368	-145.85%	-1797.22%	0.048	0.183

TABLE II: HRV metrics Statistical Analysis

processed and analyzed data collected through the Emwave Pro device, focusing on the heart metrics mentioned above. In our study, we observed that standard absolute values for these HRV metrics vary with person, age, health, mental state, etc., and are not firmly defined in the literature [44], [45], [46]. Thus, the analysis in this paper is based on relative analysis rather than on absolute values.

Our frequency analysis employed signal pre-processing techniques such as artifact removal, bandpass filtering, and peak detection, to remove artifacts and improve accuracy. We divided the meditation pulse data into three distinct phases: before(pre-test), during meditation, and after meditation (post-test), allowing us to track changes in HRV indices across these segments. This approach enabled us to gain deeper insights into the physiological impacts of meditation. We conducted a t-test to see the significance and the results can be seen in the figure II.

Heart Coherence: The analysis of HC revealed a significant increase during the meditation phase, with the mean coherence rising from 5.295 before meditation to 6.134 during meditation. This represents an approximate 15.84% increase in coherence during meditation. Post-meditation, HC decreased to a mean value of 4.800, marking an approximate 21.76% decrease from the during-meditation phase. The p-value for the before-during comparison is 0.0333, suggesting a statistically significant increase in HC during meditation. Furthermore, the p-value for the during-after comparison is even more pronounced at 0.00037, indicating a highly significant decrease in HC post-meditation. These results suggest that CM-II meditation has a measurable impact on HC, a key indicator of a harmonious autonomic nervous system and positive emotional states.

SDNN (Standard Deviation of NN intervals): SDNN increased by 40.63% during meditation and further by 17.13% post-meditation, with p-values of 0.377 and 0.571 respectively. These results suggest that meditation induces a state of physiological relaxation and recovery, with effects persisting beyond the meditation session.

RMSSD (Root Mean Square of Successive Differences): RMSSD showed a slight decrease of -1.61% during meditation and increased by 8.27% post-meditation. The p-values of 0.784 and 0.295 indicate these changes are not statistically significant, suggesting a more nuanced response of the parasympathetic nervous system to meditation.

LF/HF Ratio: The LF/HF ratio exhibited minimal changes, with a 0.12% increase during meditation and an 11.53% increase post-meditation, with p-values of 0.996 and 0.723, respectively. These minor changes imply that CM-II meditation may not have a significant impact on the autonomic balance as reflected by this ratio.

Baevsky Stress Index (BSI): The BSI showed a dramatic decrease during meditation (-145.85%) and a substantial increase post-meditation (-1797.22%). The corresponding p-values of 0.048 and 0.183 indicate a significant reduction in stress levels during meditation, followed by a rebound post-meditation.

Three Stage HRV analysis on Meditation

In the CM-II meditation analysis, heart metrics offer a comprehensive view of the autonomic nervous system's (ANS) responses during the different stages of the meditation. HC measures ANS balance and emotional harmony, while SDNN and RMSSD assess overall heart rate variability, influenced by both branches of the ANS. The LF/HF Ratio provides insights into the balance between sympathetic and parasympathetic activities, and BSI reflects stress levels. This multifaceted approach ensures a more holistic understanding of physiological and psychological states during meditation, encompassing emotional regulation, autonomic balance, heart rate variability, and stress responses.

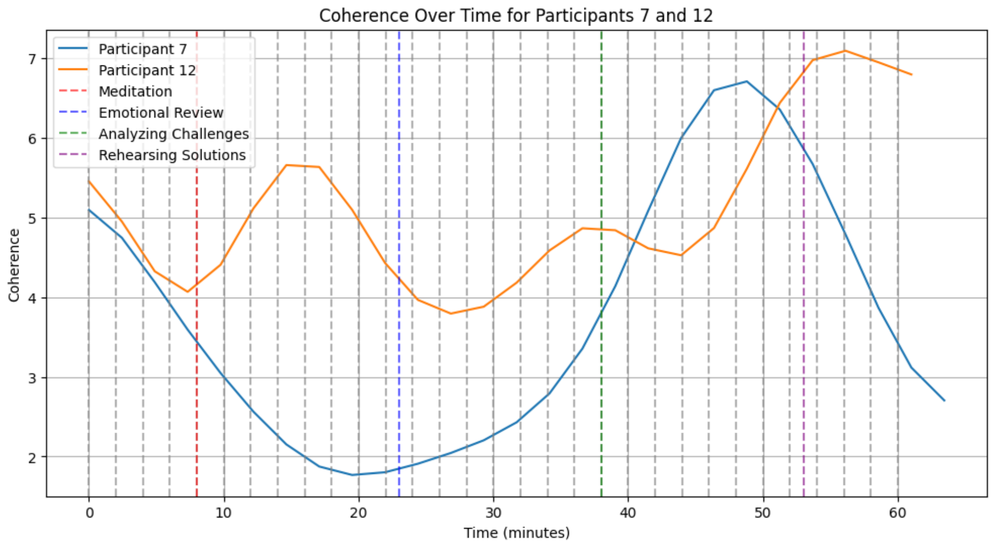


Fig. 3: Heart Coherence Curve - 7 and 12 participants

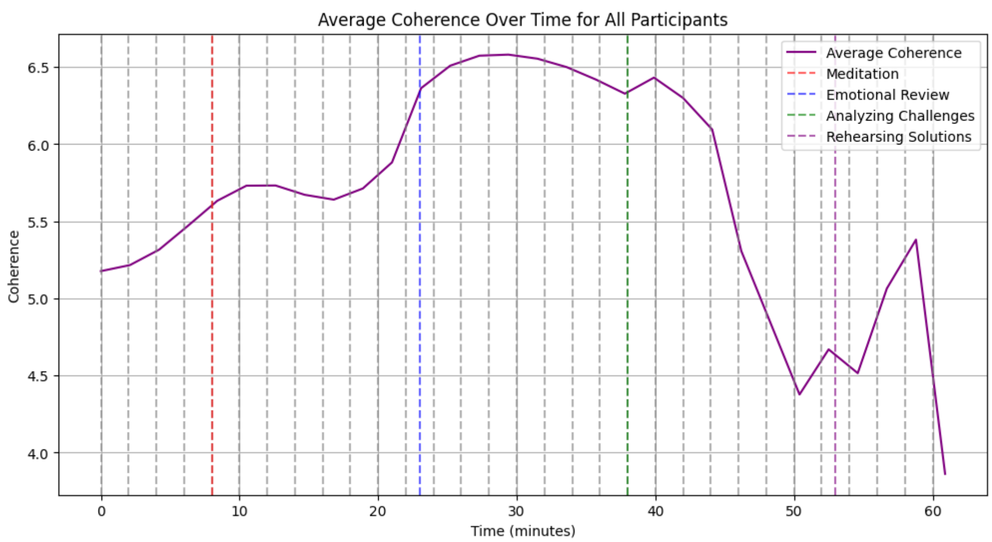


Fig. 4: Heart Coherence Curve

The plot (figure 4) depicts the aggregated variations in HC showing the HC variations during the three stages of the CM-II meditation session.

The initial average values of SDNN, RMSSD, and HC were 67.64, 57.93, and 5.295 respectively are used to reflect the participants' journey through the Emotional Review phase. In the HC curve(figure 4) and SDNN, RMSSD curves (figure 6), we can observe that these metrics rise over time during this phase indicating the participants' gradual reduction in stress. During the Analyzing Challenges phase, a decrease in SDNN to 54.00 and a slight decrease in RMSSD to 54.94 suggest a reduction in autonomic nervous system activity as participants engage in introspection. The HC data further supports this with a pronounced pattern and a higher average HC of around 6.044, indicating deep cognitive engagement, introspection, and stress reduction. The high HC peaks during this meditation phase might reflect moments of detachment from stressors, offering insight or clarity as participants re-frame their challenges. These patterns can also be noticed in figure 3 among randomly selected participants. Lastly, during the Rehearsing Solutions phase, we see a slight increase in SDNN to 59.79 but a significant decrease

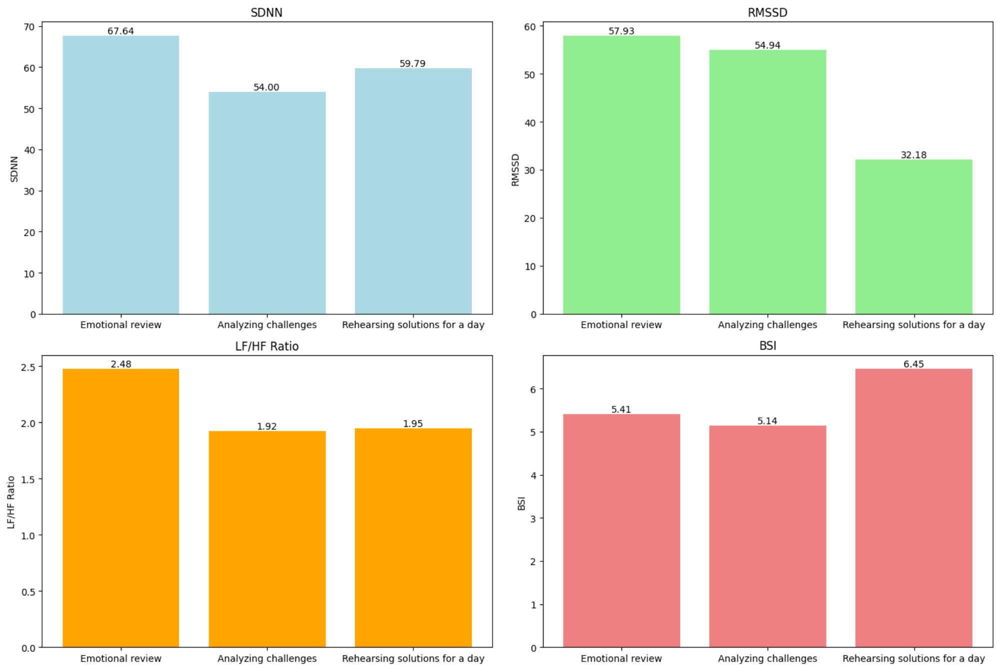


Fig. 5: Heart Metrics Bar Chart

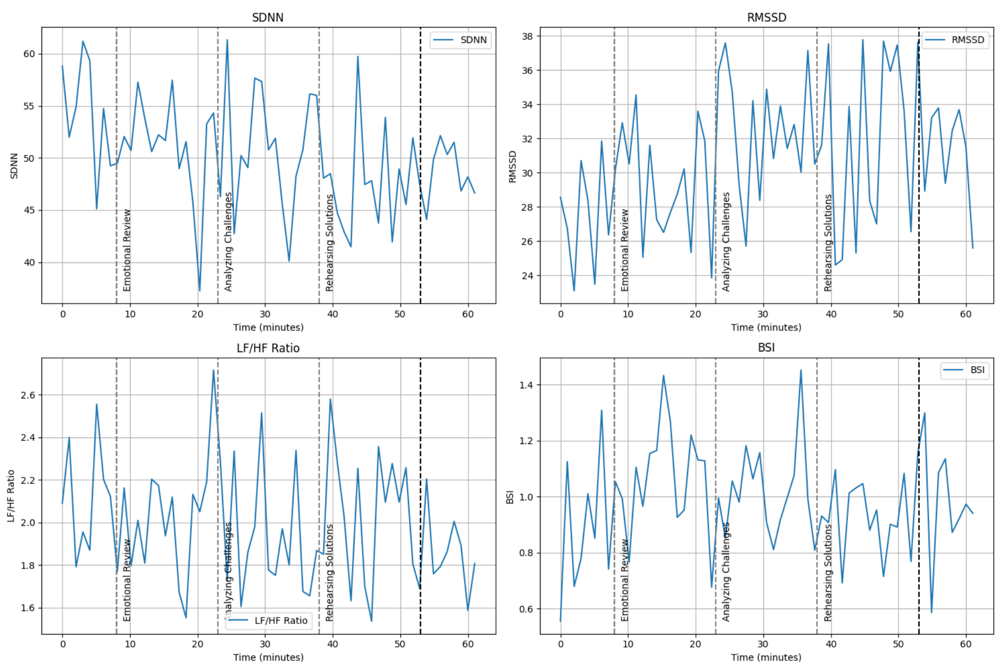


Fig. 6: Heart Metrics Curves

in RMSSD to 32.18, suggesting a transition to a more relaxed state. The HC data aligns with this, showing a decrease of about 5.9 during future visualization from 6.5 during the analyzing challenges phase. This drop in HC, despite a rise during the Analyzing Challenges phase, suggests a shift in consciousness towards relaxation, reduced cognitive intensity, and a focus on creative, future-oriented thinking, as participants visualize solutions and successful outcomes.

Discussion

This study's experimental analysis of CM-II meditation and its impact on HRV metrics revealed significant insights. The emotional Review component resonates with the principles of Emotional Processing Therapy, which emphasizes the importance of confronting and processing emotional stressors for psychological healing [47]. This phase's focus on exploring and releasing emotions related to fear and hurt is crucial for alleviating stress and trauma[47]. The second phase, Analyzing Challenges, parallels findings from mindfulness-based interventions that have been shown to improve mental health and wellbeing by fostering mindfulness on stressors [48]. This phase's emphasis on reviewing daily life challenges and cultivating mindfulness aligns with these findings, suggesting its potential to enhance mental health. Finally, the third phase, Rehearsing Solutions for a Day, incorporates elements of future-oriented mental imagery and gratitude, which have been linked to improved mental health outcomes. Deeprose and Holmes' exploration of prospective imagery [49] and Gavian's study on the effects of gratitude interventions [50] support the idea that visualizing positive outcomes and feeling gratitude can significantly impact psychological wellbeing.

Across all these phases, we observed notable changes in HC, SDNN, RMSSD, LF/HF ratio, and Baevsky Stress Index (BSI) across different meditation phases. HC significantly increased during meditation, indicating enhanced autonomic nervous system harmony. SDNN and RMSSD varied, reflecting slight shifts in physiological relaxation and parasympathetic activity. The LF/HF ratio changes were minimal, suggesting a lesser impact on autonomic balance. BSI indicated a significant reduction in stress during meditation.

The decrease in HC levels during the post-meditation test could be attributed to the transition from a meditative to a normal state of consciousness. This shift, often moving from deep relaxation to everyday mental activities, impacts physiological and psychological states, as reflected in HC levels. Individual responses vary, with some experiencing a more pronounced drop in HC during the transition to post-meditation activities. In contrast, others maintain higher coherence, influenced by personal relaxation techniques and the nature of subsequent activities. It is expected that consistent practice could sustain HC and other heart metric values.

Our findings highlight the potential of CM-II meditation as a tool for stress management and improved heart health. However, we emphasize the importance of long-term practice and mentorship in practicing the art of mindfulness and achieving sustained benefits. With continued practice, participants may experience heightened HC and performance in various life aspects, achieving high performance with low stress consistently. This aligns with the overarching goal of CM-II meditation: to cultivate calm and a state of high efficiency in the face of life's challenges.

Conclusion

Engineering education involves studying complex scientific theories and practicing them and the high-pressure curriculum demands stress management methodologies. As in CM-II, integrating meditation phases in a sequential manner – from emotional release, through mental stressor review, to positive future visualization – potentially offers a comprehensive approach to stress management and mental health improvement. Soothing background music could further enhance this effect by providing a calming and supportive auditory environment. Incorporating stress-reduction techniques, such as the CM-II meditation approach, into engineering education could significantly enhance various aspects of student performance and learning.

Limitations of the Study

The study's limitations include a small sample size of only 15 participants, reducing the generalizability of the results. All participants were novices in meditation, which might have influenced their response to the CM-II meditation technique. Conducted in a constrained college setting, the sessions were squeezed into a tight college schedule, possibly impacting participant engagement and outcomes. Additionally, the lack of participant diversity limits the applicability of the findings to different populations.

FUTURE DIRECTION

Future research will delve into the long-term impacts of CM-II meditation, exploring its sustained effects and efficacy across various demographic groups. We would delve into studying the effect of Raga music alone - separately conduct experiments only with music, conduct experiments with and without background music, and compare the results. Even more, a planned study would dissect CM-II meditation into three separate practices, each undertaken three times a week for three weeks, to thoroughly evaluate their individual and collective benefits. Furthermore, we would add a control group across various backgrounds and demographics to ascertain the effects of the meditation.

Besides, to facilitate widespread monitoring of heart metrics using a simple selfie camera, we have developed an app combining Remote Photoplethysmography (rPPG) with Large Language Models (LLMs) [3]. This innovative tool offers real-time HRV insights over a smartphone for students. Our next publication will detail its features and potential applications.

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