**Thesis draft start**

CM-II meditation as an intervention to reduce stress: A study of ML detection, Spectral Analysis, and HRV metrics.

**Abstract**

This thesis presents a comprehensive examination of the emotional and psychological challenges faced by college students, with a focus on meditation as an intervention for stress management and student attention. It is recognized that emotional suffering, which can be rooted in early childhood experiences, plays a crucial role in shaping students' mental health, and there exists a complex interplay of emotions and thoughts in the college environment.

Students frequently face heightened stress due to academic and social pressures, particularly in demanding fields like computer science and engineering. These challenges are often associated with serious mental health issues, including ADHD, depression, and an increased risk of suicide. The average student attention span has notably decreased from 2½ minutes to just 47 seconds, and now it typically takes about 25 minutes to switch attention to a new task~\cite{mark2023attention}. Research findings suggest that over 95\% of individuals who die by suicide have been diagnosed with depression~\cite{said2013}, and almost 20\% of students acknowledge experiencing significant suicidal ideation, with 9\% having made suicide attempts \cite{benton2022suicide}. Medical imaging studies indicate that meditation might combat or even prevent the psychological and physiological factors contributing to stress and depression~\cite{annells2016meditate}. Chronic stress has been linked to an increased risk of depression, and effectively managing stress can help reduce this risk~\cite{mcgonagle1990chronic} and potentially decrease suicide rates~\cite{rosiek2016}. A good body of research shows that meditation can help reduce stress and depression~\cite{Baer2014Meditation}.

In this study, we developed the ChakraMarmaKosha Meditation (CM-II), a novel guided meditation technique. CM-II consists of three stages: Emotional Review, Analyzing Challenges, and Rehearsing Solutions. Each stage is enhanced with voice guidance and flute music, specifically composed in the Indian Raga ‘Hindol’ to aid the meditation process. Additionally, we developed a machine learning model to predict and measure shifts in attention through spectral analysis. This program was further refined to assess HRV metrics from heart pulse data, enabling a detailed analysis of stress patterns over time.

In an experiment involving 15 students in a lab setting, participants went through a 61-minute session comprising 8-minute online attention tests before and after the 45-minute CM-II meditation. Throughout the session, EEG and heart pulse data were recorded using Muse 2 and emWave Pro devices, respectively, to assess changes in attention and stress levels. The EEG data analysis demonstrated a notable rise in attention among participants post-meditation, and HRV analysis showed improvement in stress levels and activation of the parasympathetic nervous system. These findings were substantiated by statistically significant results in the online attention test, where the Reasoning and Flanker tests showed p<0.05, indicating a meaningful impact of meditation on attention levels.

By combining psychological analysis, meditation techniques, and technological innovations, this research offers a holistic approach to improving mental health among college students. It underscores the importance of early identification, monitoring, and intervention in stress and mental health issues, aiming to enhance students' overall well-being and academic performance. However, the current study's reliance on expensive, connected devices limits its accessibility. To address this challenge, moving ahead, we would develop a smartphone app utilizing Remote Photoplethysmography (RPPG) technology, allowing real-time stress monitoring through a selfie camera of smartphone users.

**INTRODUCTION**

The journey through college represents more than a quest for academic achievement; it is a multifaceted emotional and psychological voyage. This thesis delves into the complex matrix of emotional and mental challenges that college students encounter, illustrating how these challenges can intensify into grave mental health concerns. It proposes an innovative resolution through the CM-II meditation technique, a nuanced approach designed to address and mitigate these issues. Addressing these issues, the thesis presents the CM-II meditation technique. This innovative three-stage guided meditation, complemented by background music, is specifically tailored to counteract the detrimental effects of stress and emotional turmoil. The first stage, 'Emotional Review,' encourages students to confront and process memories associated with fear, hurt, and inattention, acknowledging the foundational role of emotions in shaping thoughts and behaviors. The 'Analyzing Challenges' stage offers students an opportunity to scrutinize daily events and stressors, fostering a culture of internal solution-finding. The final stage, 'Rehearsing Solutions for a Day,' prioritizes future visualization and gratitude, emphasizing their importance in time management, task management, and overall stress reduction. This stage assists students in visualizing a future where they surmount their present challenges, thereby alleviating pressure and enhancing mental well-being. In the following sections, we do deeper into the literature review and the science behind the meditation, music, and stress management and attention regulation.

\subsection{Economic Burden - stress and depression}

The worldwide financial burden of mental illness amounts to US$2.5 trillion, primarily driven by indirect costs~\cite{frank2022approximation}. And the total economic productivity decline linked to mental health issues from 2011 to 2030 is estimated at a staggering US$16.3 trillion on a global scale~\cite{frank2022approximation}. For depression and anxiety alone, lost productivity is estimated to cost the global economy $1 trillion annually, with projections indicating a potential increase to $16 trillion by 2030 \cite{chodavadia2023}. Research findings suggest that over 95% of individuals who die by suicide have been diagnosed with depression~\cite{said2013}, and almost 20% of students acknowledge experiencing strong suicidal thoughts, with 9% having attempted suicide \cite{benton2022suicide}.

\subsection{Meditation can help reduce stress and depression}

Several studies have proven that meditation can help reduce stress and depression. For example, Baer et al. (2014) conducted a meta-analysis of 57 studies, revealing that meditation, especially when practiced daily for 30 minutes over 8 weeks, significantly reduces stress and depression symptoms, outperforming placebo~\cite{Baer2014Meditation}. In another analysis, it was shown that mindfulness-based cognitive therapy (MBCT), which emphasizes awareness of thoughts and feelings, to be equally effective as medication with medication for depression~\cite{Pieters2020MBCT}. Another study with 1731 participants, showed that mindfulness-based interventions significantly decreased levels of depression~\cite{li2023effectiveness}. Even more, a brief mindfulness meditation significantly reduced stress, as evidenced by lowered morning cortisol levels, in individuals with high suicidal ideation \cite{WuZhongWang2023BMM}. Furthermore, Liu et al. (2023) found that mindfulness training effectively improves sustained attentional capacity in college students. They reported a significant decrease in self-reported mind wandering and faster responses post-training in the mindfulness group~\cite{LiuHouQuan2023Mindfulness}. Therefore, meditation can reduce stress and depression and improve attention.

\subsection{**Structured** Meditation gives more effect}

The study by Juan et. al also indicated that shorter structured mindfulness-based interventions showed better results in reducing depression levels compared to longer programs with less structured components~\cite{li2023effectiveness}. Structured guided meditation has been shown to significantly reduce symptoms of anxiety and depression, with improvements observed within two weeks and sustained benefits over six weeks~\cite{hariri2022}. In hospitalized COVID-19 patients, guided meditation effectively improved anxiety, depression, and sleep quality compared to standard routine care~\cite{chowdhary2021}.

\subsection{Raga Music can help reduce stress and depression}

Music's role in enhancing mental well-being and academic performance is increasingly recognized in scientific studies. Research has demonstrated that music not only reduces stress and depression but also elevates liveliness, contributing to a more positive mental state \cite{Indira2018Music}. This is particularly evident in academic environments, where listening to music while studying has been linked to improved focus and better academic outcomes \cite{Indira2018Music}. A Raga, as described by Matanga in the 9th-10th century AD, is a specific arrangement of musical notes that evoke distinct emotions and moods, often leading to a cathartic, heart-clearing experience. Each Raga is designed to resonate a unique mood and emotional state \cite{Indira2018Music}. Specifically, Raga Hindola, chosen for the background music in this meditation, is known for its ability to enhance memory and sharpen attention, making it an ideal accompaniment for mindfulness practices \cite{Sarkar2015Ragas}. The unique influence of Raga music in an educational context underscores its potential as a valuable tool for reducing stress and boosting student attention .

\subsection{Emotions - root cause of stress and depression}

Negative emotions can have far-reaching impacts on various aspects of an individual's thought processes. Eysenck and Calvo (1992) found that past emotions such as sadness, anger, jealousy, fear, shame, guilt etc. can impair cognitive performance and Forgas (1994) noted that negative emotions create negative effects on interpersonal thoughts and thus social behavior. Negative emotions that aren't fully acknowledged at the moment they arise can accumulate as residual pain, persisting throughout life~\cite{Garland2019}. This pain that had the genesis from childhood, becomes entrenched in both mind and body and form negative thought patterns~\cite{Freeman2022}. Triggers, especially those resonating with past pain patterns, can activate this accumulated pain, leading to negative, stress-inducing thoughts often rooted in fear~\cite{Mathes2022}. These thoughts and feelings can spiral into negativity and self-destructiveness~\cite{Bowins2006} . However, being mindfully aware of these emotional memories can help dissipate and release these pent-up emotions~\cite{Mertens2020,thepowerofnow}.

Adverse childhood experiences (ACEs), fueled by negative emotions, significantly affect mental processes such as inattention, stress, and depression, as shown by various studies. Zare et al.'s research on children aged 6 to 11 years highlights the profound impact of ACEs on anxiety and depression~\cite{Zare}. These authors findings indicate that "toxic stress" resulting from ACEs induces chemical and physical alterations in neural networks and metabolic processes, adversely affecting both mental and physical health in children. Furthermore, chronic negative emotions are linked to diminished self-esteem and a tendency towards pessimistic thinking~\cite{lyubomirsky1999}. Therefore, learning the art of processing emotions is critical.

\subsection{The art of emotional processing}

The paper by Linehan M. (1993) outlines a practical approach for processing primary emotions like Anger, Sorrow, Joy, Fear, and secondary emotions such as nervousness and depression. This process begins with a keen observation of one's mental state. By simply noticing feelings without trying to alter them, individuals can identify and allow emotions to naturally arise and dissipate. Acknowledging emotions as they ebb and flow, akin to waves, without judgment or resistance, is crucial. This involves tuning into the body's sensory experiences and letting emotions and sensations pass through without clinging to them. Describing experiences in factual, non-emotional terms helps in distancing oneself from the intensity of these emotions. The practice of focusing on one thing at a time, maintaining a nonjudgmental stance, and embracing the present moment reinforces this mindful approach to emotional regulation. Such techniques not only quiet the mind and calm behavior but also foster intuitive, flexible, value-based thinking, ultimately easing the journey towards personal goals and enhancing self-respect~\cite{linehan1993skills}. The first stage of CM-II meditation is based on this - the science of experiencing and relieving from emotions.

\subsection{The art of mental processing}

Acceptance and Commitment Therapy (ACT) is a psychotherapeutic approach that emphasizes accepting and managing difficult emotions through present-moment awareness, rather than attempting to control or avoid them. This method is particularly effective in addressing inattention and mind-wandering, which are common challenges for individuals with ADHD. A study involving children and adolescents aged 8 to 13 with ADHD demonstrated that ACT, focusing on present-moment awareness, defusion, and acceptance of feelings, significantly enhanced attention and reduced hyperactivity~\cite{vanzin2020clinical}. Further research indicates that ACT can yield benefits for children with ADHD, showing significant improvements in congruence between learning and behaviors, as well as symptom reduction~\cite{murrell2015act, munawar2021act}. Additionally, a meta-analysis of 18 studies revealed that ACT effectively reduces depression, particularly post-intervention and at three-month follow-ups. In the educational context, Sofyan et al. (2023) found that integrating ACT and Mindfulness-Based Stress Reduction (MBSR) in group counseling effectively reduces academic burnout among high school students~\cite{Sofyan2023}. Similarly, Levin et al. (2020) reported significant improvements in psychological distress among college students using ACT and MBSR self-help books~\cite{Levin2020}. Goldsmith et al. (2023) further highlighted the effectiveness of ACT in treating chronic pain and mental health conditions, including stress disorders~\cite{Goldsmith2023}. Thus, ACT, which involves the observation, acceptance, and release of emotions, along with enhanced cognitions, has shown promise in reducing stress, depression, and improving attention.

The art of declutching from the mind, as detailed in Linehan's work focusing on the significance of being present and mindful. Linehan emphasizes the importance of observing one's mind and feelings without judgment or the urge to modify them. This approach of staying with the content involves being genuinely interested in how one feels, recognizing and allowing stress factors to arise and fade naturally. This process decouples the stressful mind from the related painful emotions that charge them~\cite{thepowerofnow} and gradually detach from the grip of stress. During this process, one could see the challenges in the mind and recognize potential solutions~\cite{linehan1993skills}. It is the power of observation that enables us to de-clutch from constant stressful thinking and associated internal dialogues and this produces an inner space of silence~\cite{thepowerofnow}. The second stage of CM-II meditation is based on this - the science of experiencing and relieving thoughts.

\subsection{The art of future visualization}

The previous process of relieving from stress, noting down actions, events, or solutions enables one to envisage future with indulgence, creativity and clarity. In this context, visualization meditation has been shown to significantly decrease students' stress and anxiety levels, simultaneously boosting their achievement-oriented motivation~\cite{AksuC2023}. Complementing this, another study highlights that an 8-week visualization meditation program can notably enhance self-awareness and alleviate anxiety in university students grappling with stress, anxiety, and depression~\cite{Margolin2011}. Extending these benefits into daily life, research indicates that integrating visualization and mindfulness practices significantly bolsters emotional regulation and stress management~\cite{McCloskey2013}. Furthermore, the practice of mentally rehearsing solutions and visualizing outcomes, especially when combined with a sense of gratitude, fosters enhanced attention, creativity, and insight during events~\cite{linehan1993skills,Chopra2022}. In addition, the focused visualization of set goals has been identified as a key factor in reducing stress and elevating performance in high-pressure sports environments~\cite{bump1989sport}. Similarly, goal-directed therapy, particularly in osteoporosis treatment, which involves directing energy towards specific outcomes, has demonstrated positive results~\cite{cummings2017goal}. The second stage of CM-II meditation draws upon this principle, embodying the science of creative visualization for future events.