Chapter 7

Discussion

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7.0. DISCUSSION

The most important results detailed in the previous section are discussed under the three main categories of variables

- Autonomic variables, pre, during, and post *trāṭaka* and eye exercise session.
- Performance in the Simple Visual Reaction Time task before and immediately after the *trāṭaka* and control session
- Visual strain and psychological well-being before and after two weeks of *trāṭaka* & Control group.
- Performance in the Corsi Block Tapping Task following the practice of *trāṭaka* and eye exercise session

7.1. STUDY 1: AUTONOMIC VARIABLES & VISUAL REACTION TIME:

The autonomic variables and respiratory rate were recorded at pre, during, and post *trāṭaka* and eye exercise. The maximum changes in autonomic variables and respiratory rate occurred during and post of the *trāṭaka*. They were all suggestive of reduced sympathetic activity or increased vagal modulation.

These were decreases in Heart rate and increases in SDNN, pNN50, RMSSD, H.F. Power, L.F. Power, and Total Power, SD1 & SD2 in both *trāṭaka* and eye exercise sessions, whereas a decrease in respiratory rate and skin conductance was seen in *trāṭaka* a session and increase of respiratory rate and skin conductance in the eye exercise session.

HRV is the physiological phenomenon of variation in the time interval between heartbeats. It is measured by the variation in the beat-to-beat intervals (Force, 2016). HRV is widely utilized to interpret cardiac autonomic regulation following various yoga practices (Tyagi & Cohen, 2016). Earlier it was believed that the L.F. (L.F., 0.04-0.15 Hz) band of the HRV is an index of cardiac sympathetic activity and H.F. (H.F., 0.15-0.4 Hz) band is correlated with both sympathetic and parasympathetic activity (Force, 1996). However, this has been questioned subsequently. Recent research findings say that neither the L.F. band (L.F.) nor the H.F. band is considered exclusive sympathetic and parasympathetic tone markers, respectively (Lombardi & Stein, 2011). It is found that sympathetic activity can also regulate the H.F. component of HRV, though to a lesser extent than the parasympathetic influence on the L.F. power. The association between H.F. power and cardiac parasympathetic activity is stronger. Hence the HRV provides broad changes in cardiac parasympathetic regulation and changes in the L.F. power and LF/HF ratio have to be considered carefully. The increase in L.F. power, H.F. power, and total Power during and after *trāṭaka* and eye exercise suggests increased vagal modulation. These findings were similar to earlier yoga studies demonstrating a decrease in L.F. power and an increase H.F. Power with *trāṭaka* (B. Raghavendra & Ramamurthy, 2014), with two meditative techniques (Peng et al., 1999; Telles, Raghavendra, et al., 2013).

The changes in the time domain components of the HRV were significant both in *trāṭaka* and eye exercise sessions with an increase in SDNN, RMSSD, and pNN50, thus indicating an enhanced HRV. Among the time-domain variables, SDNN indicates overall heart rate variability, whereas RMSSD and pNN50 are associated with vagal tone (Fotrce, 2016). This is the first study to observe the time-Domain variable of HRV during and post *trāṭaka*. However, earlier Yoga studies have shown similar changes in time-domain variables of HRV in participants with breath awareness (Telles et al., 2014).

The respiratory rate depends upon numerous factors ranging from physical activity to psychological stress (Stevenson & Ripley., 1952). A decrease in respiratory rate is correlated with relaxation, which can explain the decrease seen during *trāṭaka*. Though *trāṭaka* practice involves intense focusing, it ends with defocusing and silence. This might induce relaxation after the practice which can explain the decrease in respiratory rate. The increase in respiratory rate during eye exercise sessions could suggest sympathetic arousal.

The skin conductance level indicates the level of activity in the cholinergic sudomotor sympathetic nerves supplying the eccrine sweat glands (Shields et al., 1987). This is believed to be the main contributor to changes in spontaneous electrodermal activity (Fowles, 1986). The increase in the skin conductance level in *trāṭaka* suggests relaxation during and after the *trāṭaka* session.

The simple Visual Reaction Time task (SVRT), is the minimal time needed to respond to a stimulus and is a primary measure of processing speed (Stebbins, 2007). The shortening of stimulus in simple visual reaction time was observed in *trāṭaka* and eye exercise sessions. The improvement was significantly more significant in the *trāṭaka* session than eye exercise. This was observed in earlier yoga studies (Sharma et al., 2014; V.K. et al., 2014).

In Summary, considering changes in HRV, heart rate, respiratory rate, and skin conductance during and after the practice of *trāṭaka* and eye exercise sessions leads to increased vagal tone and reduced sympathetic arousal. However, in the SVRT task, the *trāṭaka* group showed a significant decrease in reaction time, indicating an improved sensory-motor performance and enhanced processing ability of the central nervous system compared to eye exercise sessions. Such improved performance in the SVRT was not found in the eye exercise session. Thus, *trāṭaka* induce a calm state of mind similar to meditation practice.

7.2. STUDY 2: VISUAL STRAIN & PSYCHOLOGICAL WELL-BEING:

In the current study, the effect of the two-week practice of *trāṭaka* was found to reduce self-reported mind wandering & Symptoms of Visual Strain along with enhanced state mindfulness. Further, we also noted a positive correlation between mind-wandering with symptoms of visual strain, and both were negatively correlated with state mindfulness. These findings indicate that the practice of *trāṭaka* can be used to reduce visual strain and its consequences on psychological well-being. This is the first study assessing the effects of *trāṭaka* on the visual strain, mind-wandering, and mindfulness to the best of our knowledge.

Several benefits of the digital revolution are known. The work and learning during the current pandemic have made us realize the umpteen possibilities associated with digital. However, excess use of digital displays has led to several physical and psychological implications, including increased visual strain and mind-wandering. A few studies have explored the possibility of the use of yoga techniques for managing such situations. A combination of yoga practices for sixty days reduced visual discomfort among computer professionals (Telles et al., 2006). The six weeks of yoga-based eye exercise reduced optometry students' eye fatigue symptoms (Gupta & Aparna, 2020). Another study indicated a reduction in visual fatigue among twenty nursing students following yoga practices (Kim, 2016). The results of the current study concur with these earlier studies on yoga-based techniques for managing visual strain.

The reduction in mind-wandering and increased state mindfulness is similar to earlier studies done on yoga practices such as yogic breathing (Saoji et al., 2018) and meditation techniques (Anusuya et al., 2021). A systematic review mentioned that yoga and meditation intervention nurture mindfulness and may be feasible and effective for building resilience in childhood and adolescence (Greenberg & Harris, 2012). A randomized controlled trial showed meditation practice could increase mindfulness and reduce mind-wandering (Garland et al., 2015). However, the effect of *trāṭaka* on these domains was not explored before our study. Earlier studies on *trāṭaka* have shown an improvement in cognitive performance and reduced anxiety (Raghavendra & Singh, 2016; Sherlee & David, 2020). Such enhanced cognitive functions could be due to improved mindfulness and reduced mind wandering. The observations from our study indicate the beneficial role of *trāṭaka* in such psychological domains.

The possible mechanism of action for reduction in visual strain could be giving deep rest to the extraocular muscles, through the practice of *trāṭaka*. Traditional texts of yoga describe the practice of *trāṭaka* to induce relaxation in the eyes (Muktibodhananda, 1999). Also, gazing at one point could reduce mind-wandering and increase mindfulness. Earlier studies indicate that the practice of *trāṭaka* may lead to a meditative state of mind (Raghavendra & Ramamurthy, 2014). Besides, a reduction in visual strain may have contributed to better mindfulness and reduced mind-wandering. Since mind-wandering and mindfulness are related to the emotional state of the individual (Killingsworth & Gilbert, 2010; Saoji et al., 2018), the practice of *trāṭaka* may have led to emotional regulation. Such positive emotional regulation is also associated with other yoga techniques (Daly et al., 2015; Menezes et al., 2015).

A major limitation of the study includes using only self-rated questionnaires to assess visual strain, mindfulness, and mind-wandering. Future studies may explore attention-related tasks as well as the neurological correlates of changes associated with *trāṭaka*. The application of yoga practices for influencing ophthalmological disorders is in a nascent stage. Further studies on *trāṭaka* with visual strain may use clinical assessment tools such as tear break-up time, corneal fluorescein staining, tear osmolarity, ocular scattering index, and an objective tool like the tear film thickness.

7.3. STUDY 3: PERFORMANCE OF CORSI BLOCK TAPPING TASK

The current study was designed to elicit if the practice of *trāṭaka* affects working and spatial memory through the performances in the CBTT. All four measures, viz., forward and backward Corsi spans, and total scores demonstrated significance within the subject's effect. The Corsi span and total scores were higher following *trāṭaka* while comparing with baseline and Eye exercises. Scores following eye exercises and baseline sessions were insignificant except in the Forward total score. The forward span and total score of CBTT measure material-specific slave systems. The backward test measures primarily tax central executive resources (Monaco et al., 2013). Thus, improvements in both forward and backward span and total scores indicate a positive effect of *trāṭaka* on working, spatial memory, and executive functions, while compared with baseline and eye exercises.

Earlier studies on *trāṭaka* and cognition have shown improvements in the domains of selective attention, cognitive flexibility, and response inhibition through the Stroop task (B. R. Raghavendra & Singh, 2016; Sherlee & David, 2020). Similar self a controlled trial showed improvement in cognition after the immediate practice of *trāṭaka* in thirty-five volunteers occurred when the performance of critical flicker fusion (Mallick & Kulkarni, 2010). After the practice of *trāṭaka* for twenty-six days, the performance of the digit span test, six-letter cancellation test, and trail-making test significantly improved in thirty elderly subjects compared to the waitlist control group (Talwadkar et al., 2014). Thus, improvements noted in our study in the cognitive abilities following *trāṭaka* are similar to the earlier studies.

Trāṭaka a practice is indicated to positively influence cognition from both classical texts of yoga (Muktibodhananda, 1999) and empirical studies (Swathi et al., 2020). Although classified as a cleansing procedure, the practice of *trāṭaka* is similar to focused meditation techniques. Earlier studies on meditation or focused mind for a total duration of 8 weeks showed decreased negative mood and enhanced attention, working memory, and decreased state anxiety on the Trier Social Stress Test (TSST) in a population naive to meditation practice (Basso et al., 2019). Another focused attention meditation showed significant improvement in working memory in the reading span test and activation of the bilateral dorsolateral prefrontal cortex (DLPFC) during the intervention in the experimental group (Yamaya et al., 2021). Similarly, other Yoga interventions showed improved cognitive communicative abilities (Namratha et al., 2017).

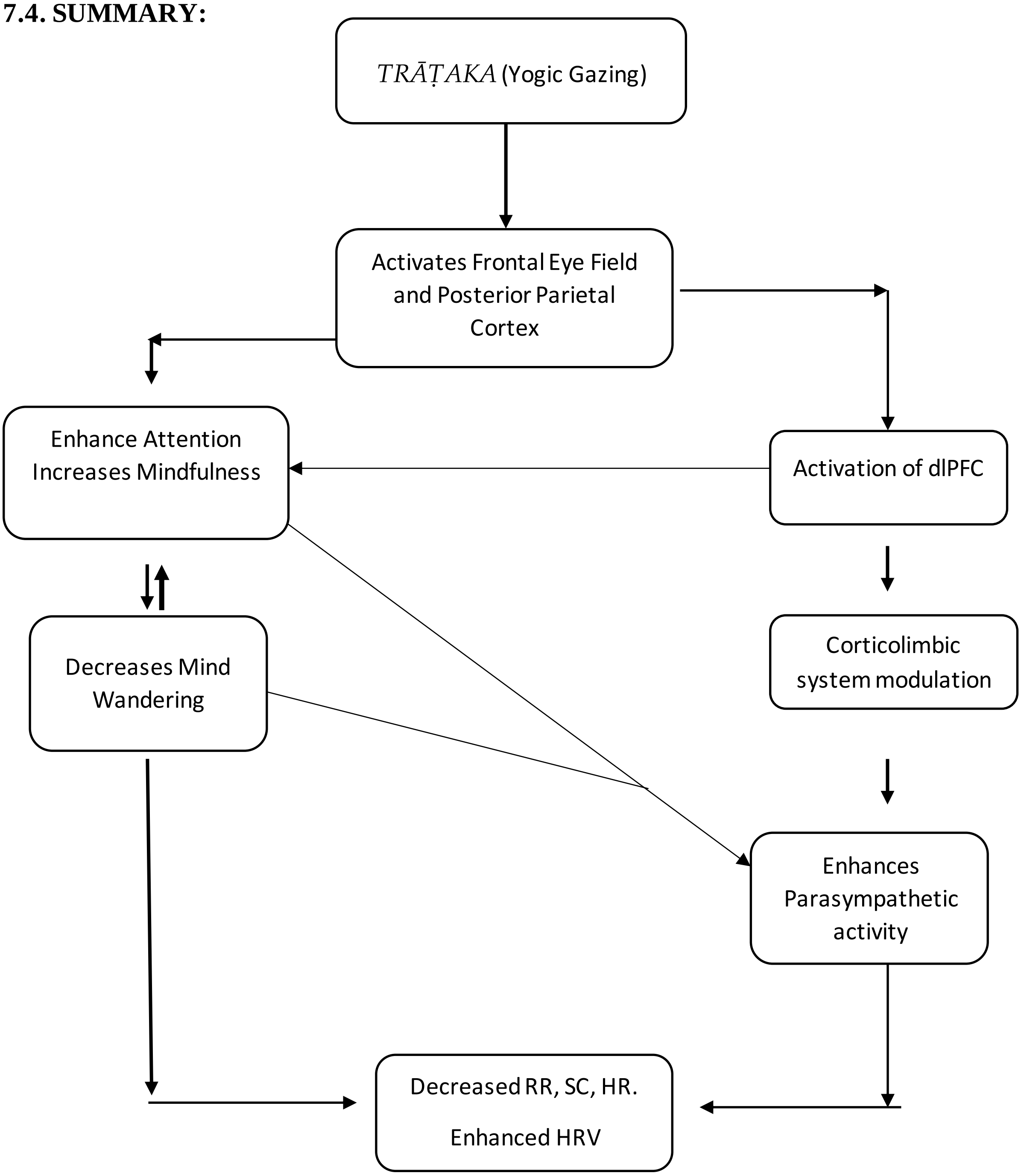
The improvement in the performance of CBTT may have been mediated through relaxation attained through the practice of *trāṭaka* (Raghavendra & Ramamurthy, 2014). The possible mechanisms for improving working and spatial memory following the *trāṭaka* session could be the process of *trāṭaka* itself, involving focussed attention. Such focus is also elaborated in the *Yoga Sutras* (aphorisms) of *Patanjali* (Taimni, 2010). A recent study has also demonstrated enhanced mindfulness, attention, and reduced mind wandering with the practice of *trāṭaka* (Swathi et al., 2021). Thus, improved working memory found in our study could be due to a reduction in mind-wandering and enhanced focusing. The prefrontal cortex is associated with memory, attention, executive functions, and other various other complex cognitive functions (Kofler et al., 2020). Thus, the results following the *trāṭaka* session could be due to activation of the prefrontal cortex. However, further studies with neuroimaging techniques may be required to confirm this mechanism of action.

Another possible mechanism could be a surge in melatonin release due to practice in dim light. It is known that bright light tunes the suprachiasmatic nucleus (SCN) that regulates the circadian rhythm. Exposure to bright light impedes melatonin synthesis, whereas dim light initiates the surge in melatonin release (Zisapel, 2018). Melatonin has been found to positively influence learning and memory (Zakaria et al., 2016). Thus, further studies on *trāṭaka* may assess the serum melatonin levels as one of the variables.

Our study indicated a beneficial role of *trāṭaka* in enhancing the CBTT performance in healthy volunteers. CBTT performance is commonly altered in neurodegenerative disorders such as early-stage Parkinsonism (Stoffers et al., 2003). Alzheimer's disease (Guariglia, 2007). Thus, future studies may be planned in a clinical population, where the CBTT performance is compromised.

Using a repeated measures design for immediate effect is one of the strengths of the study. We also used a computer-based program to execute CBTT, which enabled robust results (Brunetti et al., 2014). The limitation of the study includes not incorporating a neuro-imaging technique, which has limited our ability to predict the exact mechanism of action. Thus, future studies on *trāṭaka* and cognitive performance should include neuroimaging techniques. Another major limitation of the study is the control condition which had eye exercise for 10 min followed by 10 min of quiet sitting in which they were told not to meditate. However, we are not sure during quiet sitting did they focus on breathing or let their mind wander freely. We could not get an equal number of male and female participants and also the inability to study the impact of the long-term practice of *trāṭaka* is another limitation. Also, the effect of *trāṭaka* in the population with mild cognitive decline could be studied in the future.

7.4. SUMMARY:



Note: dlPFC: Dorsolateral Prefrontal Cortex

Figure 23: Possible Mechanism of action for Autonomic Modulation and Cognition due to Yogic gazing/visual concentration

The frontal eye fields (FEF) are a region located in the frontal cortex, more specifically in Brodmann area 8 or BA8, of the primate brain (Tehovnik et al., 2000). In humans, it can be more accurately said to lie in a region around the intersection of the middle frontal gyrus with the precentral gyrus, consisting of a frontal and parietal portion (Vernet et al., 2014). The cortical area called the frontal eye field (FEF) plays an important role in the control of visual attention and eye movements (Schall, 2004). The dorsolateral prefrontal cortex (dlPFC) is an area in the prefrontal cortex of the brain which lies in the middle frontal gyrus of humans (Broadman's Area 9 and 46) and has a function of executive functions such as working memory (Barbey et al., 2013), cognitive flexibility and planning (Chan et al., 2008; Monsell, 2003), response inhibition and abstract reasoning (Kaplan et al., 2016).

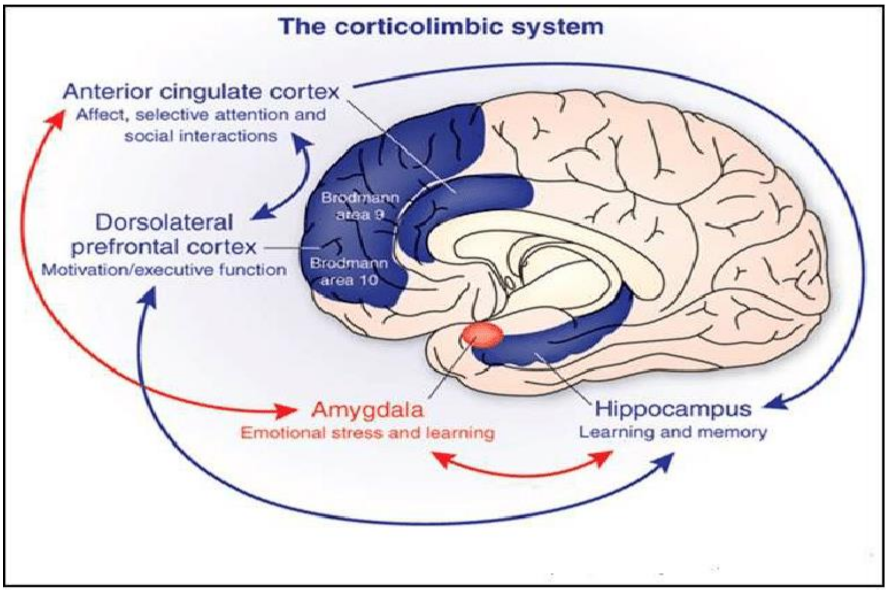


Figure 24: Interaction of Corticolimbic System

Gazing stimulates the frontal eye field which enhances attention and mindfulness (Moore & Zirnsak, 2017). Mindfulness meditators have shown decreased activation in cortical midline structures and amygdala and increased activation in somatosensory regions (Farb et al., 2007). EEG activations showed increased frontal midline theta and somatosensory alpha rhythms during meditation in the meditation group compared to the mind-wandering group, these activation often observed during executive functioning, cognitive control, and the active monitoring of sensory information (Brandmeyer & Delorme, 2018). Also, mindfulness meditation training showed an increase in resting state functional connectivity (rsFC) between dlPFC and frontoparietal control network regions (Taren et al., 2017). Another focused attention meditation showed significant improvement in working memory in the reading span test and activation of the bilateral dorsolateral prefrontal cortex (DLPFC) during the intervention in the experimental group (Yamaya et al., 2021).

Trāṭaka involves gazing at a fixed point (candle flame in the current doctoral work) and is supposed to lead to a meditative state. Thus, the practice of *trāṭaka* may lead to activation of the FEF and dlPFC and thereby improve attention and visual reaction time. Also, focussing the mind on a specific point has led to a reduction in mind-wandering, thus improving the cognitive abilities of the study participants. The cortico-limbic system is critically involved in emotional responses and resulting adaptive behaviours through the amygdala, anterior cingulate cortex (ACC), and dlPFC. Thereby, focussing the gaze on a specific point in *trāṭaka* led to a state of parasympathetic dominance, as depicted by the measures of HRV and reduced skin conductance, which is like earlier studies on meditation.

Considering the findings, we postulate that the changes associated with *trāṭaka* are mediated by the cortical centres such as dlPFC and FEF and downstream regulating the autonomic nervous system and enhanced cognitive abilities. However, further studies with neuroimaging techniques such as EEG, ERP, and fMRI may be required to confirm this mechanism of action.