COMPARISON OF PSYCHOACOUSTIC MEASURES IN INDIVIDUALS WHO PRACTICE YOGA AND WHO DON'T PRACTICE YOGA

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CERTIFICATE

This is to certify that this dissertation entitled **"Comparison of psychoacoustic measures in individual who practice yoga and who don’t practice yoga"** is the bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) of the student, Registration Number: P01II21S0074. This has been carried out under the guidance of the institute's faculty and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru
September 2023

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CERTIFICATE

This is to certify that this dissertation entitled **"Comparison of psychoacoustic measures in individual who practice yoga and who don’t practice yoga"** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"Comparison of psychoacoustic measures in individual who practice yoga and who don't practice yoga"** is the result of my study under the guidance of **Dr. Mamatha N. M.,** Assistant Professor in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru **P01II21S0074**

September, 2023 **Registration No**

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Abstract

Introduction: It has been shown that performing yoga in certain postures is known to circulate more amount of oxygenated blood to the cochlea and there by reduces the aging process and strengthens the efferent auditory system, potentially leading to better speech perception in noise and improved threshold and intensity discrimination. There are limited number of studies done on yoga and its effect on few psychoacoustical measures (frequency, intensity & duration discrimination).

Aim: The current study was aimed to determine the effect of yoga on few psychoacoustical measures (frequency, intensity & duration discrimination abilities) in older adults aged 50 – 65 years.

Methods: A total of 40 participants were selected for the study and these participants were divided into two groups. Group 1 (experimental group) included those individuals who practiced yoga for minimum duration of at least 2 years and Group 2 (control group) included those individuals who have not practiced yoga. All the psychoacoustic tests such as Difference Limen Frequency (DLF), Difference Limen Intensity (DLI) and Difference Limen Duration (DLT) were carried out using mlp toolbox, which implements a maximum likelihood procedure for threshold estimation in Matlab (Grassi & amp; Soranzo, 2009). In all the psychoacoustic tests, stimuli were presented binaurally at an intensity of 70 dB SPL. Three alternative forced choice method was used to track a 79.4% correct response criterion. In this two blocks had the standard stimulus and one block had variable stimulus. The participant's task was to identify the variable frequency.

Results: From the results of the current study it can be observed that the experimental group (older adults who practiced yoga regularly) had lower mean threshold (better) for psychoacoustic abilities i.e., difference limen for intensity (DLI), difference limen for frequency (DLF) and difference limen for duration (DLT) at all the four frequencies i.e., 500 Hz, 1000 Hz, 2000 Hz & 4000 Hz when compared to control group (older adults who did not practice yoga). The DLI, DLF and DLT obtained were found to be significantly better in older adults who practice yoga. The mean thresholds for DLI, DLF & DLT were smaller in low frequency and threshold increased as the frequency increased in both the groups.

Conclusions: The older adults who practiced yoga were able to detect smaller changes in intensity, frequency and duration compared to those older adults who did not practice yoga. It provides information about the positive effects of practicing yoga on psychoacoustic abilities in older adults. Yoga can be suggested as a therapeutic management option for improving psychoacoustic abilities in desired clinical population.

Keywords: DLI, DLF, DLT, Yoga, psychoacoustic measures, older adults.

Chapter 1

Introduction

Yoga is a traditional physical and mental disciplines originated in India. The word is derived from the Sanskrit meaning to control, to yoke or to unite. The goal of yoga is unity of the body, mind and spirit with the focus on body posture, breathing and meditation. It is found to affect nervous energy and the activities in the endocrine, cardiac, pulmonary, muscular, and nervous systems through stimulation. It is found to accelerate physical, emotional, and spiritual recovery of individuals. Yoga has been used as a therapeutic intervention, which began early in the twentieth century, and takes advantage of the various psychophysiological benefits of the component practices (Swami Kriyanand, 2009).

Practicing yoga has been found to have an effect both mental and physical manifestations in human body. Some of the physical benefits of yoga that are reported in literature are: increase in body flexibility, muscle strength and tone, improvement in respiration, energy and vitality, maintenance of balanced metabolism, weight reduction, cardio, and circulatory health, improved athletic performance and protection against injury (Iyengar, 2007).

Raub (2002) reported that there was a significant improvement noted in the cardiovascular system in young individuals performing yoga for various durations. In addition, yoga practice is speculated to have positive effect in individuals with depression (Pilkington et al, 2005; Uebelacker et al, 2010). Hariprasad et al (2013) has found that performing yoga showed a significant improvement in immediate and delayed recall of verbal and visual memory also there was improvement noted in other domains like working memory, attention, verbal fluency, and executive function in older adults. Also, Gothe, Kramer and McAuley (2014) and Gothe, Keswani and McAuley (2016) have shown that yoga has a positive impact on memory, cognitive function and improve executive function in older adults. Malathi and parulkar (1989) and Madanmohan (1992) have found that yoga reduces visual and auditory reaction time by enhancing the brains processing ability. The practice of yoga is known to improves the brains functioning ability.

Alathi and Parulkar (1989) and Madanmohan (1992) have noted that yoga reduces reaction time in older adults by enhancing the brains processing ability. Apart from improving physical and mental aspects, yoga is found to influences auditory system also. It has been inferred that performing yoga in certain postures is known to circulate more amount of oxygenated blood to the cochlea and there by slowing the aging process. This also has been found to help better repair and recovery of the system thereby reducing the chances of hearing loss (Varambally, 2017). Radhika (2013) & Tanvi (2015) have reported a change in brain waves and structural activation and concluded that yoga may be an effective treatment for a clinical and healthy aging population.

Ashique and Mamatha (2018) have reported that there is a positive effect of yoga on auditory processing abilities such as gap detection threshold (GDT) test scores, dichotic CV test scores, speech in noise scores and memory and sequencing. Oliveira, Faria, Rodrigues, Santaella (2016) have reported that the postural practice in yoga improves the balance system capacity. Ulger and Yaglt (2011) also have reported on the positive effects on balance and gait parameters of women who have balance and gait problem due to musculoskeletal dysfunction.

Sujeet, Kaushlendra & Jayshree (2010) have shown that amplitude reduction after 50yrs of age and latency prolongation after 60 years in cVEMP estimation with 500Hz Tone burst. Ranjitha, Supreetha & Niraj (2013) & Sharda, Swathi & Vanaja (2014) have also reported decrease amplitude and increases latency for cVEMP in older adults. A study by Prado, Raso, Scharlach, Kasse (2014) has shown that yoga can improve body balance in healthy young individuals. It has been found that in individuals who practice yoga had a better cVEMP response. This could be because yoga is found to strengthen the muscles and vestibular system (Tejaswini, Shubhaganga, Prashanth, 2017). Gauchard, Jeandel, Perrin (2001) have concluded that low-energy exercises, have the most positive effect on body balance control by relying more on proprioception and, also this exercise seems to develop vestibular sensitivity of older adults.

Hearing loss is evidenced to be the third most common health conditions in older adults (Lethbridge, Schiller & Benrnadel, 2004). The prevalence of significant hearing impairment is estimated to be 40 to 45% in individuals over 65 years and reaches 80% as they approach 70 years of age. Previous literature has conferred a wide range of studies in age- related changes in the auditory system and hearing. Research in this area has distinctly documented the physiological, anatomical, and audiological changes showcased by the aging auditory system (Fitzgibbons & Gordon-Salant, 1996 & Willott, 1991). These changes in aging auditory system majorly include deterioration of cochlear hair cells, degeneration of neurons in the central auditory pathways, and reduction in the plasticity of the central auditory system. Along with these changes, co-occurring cognitive decline leads to a bunch of classical features seen in age related hearing loss. The most evidently reported symptoms include overall threshold elevation, poor speech perception in degraded signal conditions (noise and reverberations), perception of rapid fluctuations or modulations in the signal, and impaired localization abilities (Koehnke & Besing. 2001; Willott, 1991).

In the latter decades of life, both anatomical and physiological changes take place in outer, middle, and inner ear. The sensory organs in the inner ear are utricle, saccule, semi-circular canal and cochlear when these areas undergo changes. It's mainly exemplified by increasing hearing thresholds, deterioration in signal perception, and degradation of temporal and spectral processing also disequilibrium, dizziness, and vertigo (Lang et al. 2010). Although the age of onset and rate of decline is disputed across reports, there is a universal agreement among authors which is documented that the degeneration is significant in nearly all types of cochlear and vestibular cells, including the sensory end organs, constriction of blood vessels that supply the sensory organ, vestibular nucleus neuron, and even a significant decline in the number of purkinje cells within the cerebellum (Gordon-Salant, Fitzgibbons and Komshian, 1994). The loss of sensory cells, strial degeneration and the loss of spiral ganglion neurons are the key contributors for the cochlear aging dysfunction (Schuknecht, 1955). Some collections of data have emphasized the role of a degraded endocochlear potential as the primary prompt for various aging-related changes in the cochlea (Schmiedt et al. 2002; Mills & Schmiedt, 2004). Kusunoki et al (2004) reported that 25-59 and 64-86-year groups showed a significant correlation between total spiral ganglion cell loss and aging.

Rosenhall (2009) analyzed vestibular hair cells using specimen technique. They found that as age increases the number of hair cells in the maculae of saccule and utricle and the Cristae ampullaris decreases. The reduction in the utricular hair cell was found to be least. The reduction of hair cells of saccule was reported to be 20% whereas that of the semicircular canals (SCC) were up to 40%. These reduced numbers of hair cells in SCC results in reduced capacity for detecting rotational head movement also most behavioral experiments have demonstrated a decline in functional vestibular test.

OAEs are affected by aging. Lonsbury-Martin et al. (1991) & Dorn et al (1998) also Glattke & Robinette (1997) have reported reduced DPOAE amplitude. According to Robinette et al (1992), TEOAE amplitude and reproducibility was found to be lower with advancing age. As a result of Mazelova et al (2003) study on older adults he reported that due the decrease in the OHCs there is a steady decrease in amplitude of DPOAEs. Kumar, Shambhu, Prabhu (2017) have studied OAE suppression in 40 participants in the age range of 20-40 years. They reported an increased amount of suppression in both TEOAEs & DPOAEs in individuals who performed yoga regularly compared to individuals who did not perform yoga. This suggests that yoga can strength the efferent auditory system. It has been known that activating efferent auditory system has an advantage on enhancing auditory performance like improvement in threshold detection and intensity discrimination (Micheyl & Collect, 1996), improvement of speech perception in noise (Soli & Linthicum, 1994). Girand et al. 1997 have assessed the function of efferent pathway (medial olivocochlear bundle) in normal and his results concluded that activation of MOCB improves the speech in noise intelligibility. Hence, strengthening of efferent auditory system through the practice of yoga is postulated to improve speech perception.

In the perception of speech, language and music, pitch, loudness and duration play a significant part. Sounds can generally be ordered on a scale from low to elevated pitch. Pitch, loudness, and duration in speech carry information about identification of speakers and emotions. By convention, pure tones are used as norms for judging the other sounds difference discrimination in people who are generally tested using psychophysical methods that rely on the whole auditory system (Shofer, 2008).

Time cues or temporal aspect of signal are usually poorly coded in older adults, this is being recognized as the cochlear mechanism disruption, studies have mentioned about the central auditory process's involvement in it. Numerous studies have reported that, the temporal acuity is found to be affected in older adults (Fitzgibbons and Gordon-Salant, 1996; Lutman 1991; Moore, Peters and Glasberg.1992). Many studies done on the part of auditory closure have reported that, the older adults perform poorly when the auditory system is challenged (Smith and Prather; 1971; Harris & Reitz, 1985; Versfeld & Dreschler, 2002; Hododshima &Arai, 2007).

Harris et al., (2007) reported that older adults have large difference limen intensity compared to young adults. Similarly, differential limen for time was longer in older adult compared to younger adults was reported by Fitzibbons and Gordon-Salant (1994). He et al., 1998, reported that older adults have larger different limen frequency compared to younger adults. Literatures have suggested that there is decrement in the psychophysical test scores from 4th and 5th decade of life. There is an effect on all psychophysical measures due to ageing. So, these psychophysical measures play a vital role in speech perception. Due to ageing there is a negative effect on speech perception (CHABA, 1998).

1.1 Need for the Study

Yoga is found to have a positive effect on nervous energy, activities in the endocrine, cardiac, pulmonary, muscular, and nervous system through stimulation. It is found to accelerate physical, emotional, and spiritual recovery and has been used as a therapeutic intervention (Nandha yoga school, Rishikesh (2009)). Practicing yoga has been found to affect both mental and physical manifestation in humans (Yoga Journal, 2007). Apart from improving physical and mental aspects, yoga is found to influence auditory system also.

It has been shown that performing yoga in certain postures is known to circulate more amount of oxygenated blood to the cochlea and there by reduces the aging process. This also has been found to help better repair and recovery of the system there by reducing the hearing loss (Asana, international yoga journal, 2017). Changes in brain waves and structural activation have been noted and it has been found that yoga can be an efficient therapy for a clinical and healthy ageing population (Radhika, Anisha & Tanvi, 2015).

Roland, Jakobi and Jones (2011) based on their study, said that yoga is found to improve fitness in older adults. Hariprasad et al. (2013) has found that performing yoga showed a significant improvement in immediate and delayed recall of verbal and visual memory also other domains like working memory, attention, verbal fluency and executive function in older adults.

There are few studies that have discussed about the advantage of activating efferent auditory system and enhanced auditory performance like improvement in threshold detection and intensity discrimination (Micheyl & Collect, 1996), and improvement of speech perception abilities in presence of noise (Soli & Linthicum, 1994). Giraud, Garnier, Stephen, Mycle (1997) has studied the function of efferent pathway (medial olivocochlear bundle) in normals, and the results indicated that activation of MOCB improves the speech intelligibility in presence of noise, while this effect was not observed in neurecotomised patients. Hence strengthening of efferent auditory system through the practice of yoga can improve speech perception skills in presence of noise, improvement in threshold detection and intensity discrimination. However, there are limited number of studies done on yoga and its effect on few psychophysical measures such as frequency, intensity, and duration discrimination abilities. Hence, the present study is planned with the following aim.

1.2 Aim of the Study

To determine the effects of yoga on few psychophysical measures (frequency, intensity & duration discrimination abilities) in older adults.

1.3 Objectives

- To know the effect of yoga on frequency discrimination in older adults.
- To know the effects of yoga on intensity discrimination in older adults.
- To know the effects of yoga on duration discrimination scores in older adults.

Chapter 2

Review of Literature

Psychoacoustics is concerned with the relationships between the physical characteristics of sounds and their perceptual attributes. Different abilities are used to detect sound perception, i.e., absolute sensitivity and differential sensitivity. The absolute sensitivity of the auditory system for detecting weak sounds and how that sensitivity varies with frequency (Moore et al., 2014).

The differential sensitivity abilities involve the smallest perceivable difference of sounds in terms of frequency, intensity, and temporal parameters. There are number of factors that is found to affect the perception of psychophysical abilities. They are age, hearing loss, background noise, cognition etc. There are changes noted in auditory abilities such as detection and discrimination as the age progresses (Freyman, 1986).

2.1 Effect of age on Psychoacoustic abilities (Frequency discrimination, Intensity discrimination & Duration discrimination)

2.1.1 Frequency Discrimination

Frequency discrimination is the ability of an individual to identify changes in frequency over time. There are number of studies done on individuals with normal hearing sensitivity. All the studies states that the difference limen increases with increase in frequency in individuals with normal hearing sensitivity (Harris, 1952; Moore, 1973; Wier, 1977).

Sek & Moore (1995) have explained the frequency discrimination for pure tones stimuli of 1000 Hz and above and it was found that frequency discrimination is found to be due to place mechanisms based on spatial changes in the basilar membrane excitation pattern. However, for stimuli less than 1000Hz, frequency discrimination is found to be based on temporal information.

He et al. (1998) studied frequency discrimination on 13 participants (7 young & 6 older adults) with normal hearing sensitivity. They measured frequency discrimination limen at 500, 1000, 2000 and 4000 Hz using the maximum likelihood procedure starting at 40 dBSPL followed by 80 dBSPL. Frequency discrimination was poorer for aged participants compared to younger participants with maximum difference at 500 Hz. Age related difference was more in low frequency than high frequency and older adults showed larger inter subject variability.

Jain and Kumar (2016) studied the effect of age on psychoacoustic abilities on 30 participants with the age range of 50-59.11yrs and 60-69.11yrs at different frequencies i.e., 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz. They measured the mean discrimination limen for frequency, and they reported that for 50-59.11yrs mean was 45.20 Hz for 500 Hz, 60.84 Hz for 1 kHz, 77.76 Hz for 2 kHz & 94.37 Hz for 4 kHz and for 60-69.11yrs mean was 66.22 Hz for 500 Hz, 67.66 Hz for 1 kHz, 85.77 Hz for 2 kHz & 98.91 Hz for 4 kHz.

McDermott et al. (1998) compared DLF among normal hearing individuals and persons with steeply sloping hearing loss at frequency region of 500Hz, 1000Hz, 2000Hz & 4000 Hz on 10 participants. They found that persons with steeply sloping hearing loss had higher DLF scores at 1000Hz and above when compared with normal hearing individuals. And steeply sloping hearing impaired had normal DLF scores at 500Hz where their thresholds were normal.

Zurek & Formby (1981) measured thresholds for frequency modulation by an adaptive, two-alternative, forced-choice method with ten listeners: eight who showed varying degrees of sensorineural hearing impairment, and two with normal-hearing sensitivity. Results for test frequencies spaced at octave intervals between 125 and 4000 Hz showed that, relative to normal-hearing listeners, the ability of the hearing-impaired listeners to detect a sinusoidal frequency modulation: (1) is diminished above a certain level of hearing loss; and (2) is more disrupted for low-frequency tones than for high-frequency tones, given the same degree of hearing loss at the test frequency.

2.1.2 Intensity discrimination

Intensity discrimination is the ability of the person to detect small changes in intensity. Gelfand (2009) reported that difference limen for intensity become smaller as the sensation level increases for mid frequency stimuli. He et al (1998) studied intensity discrimination on 13 participants (7 young & 6 older adults) with normal hearing sensitivity. They measured Intensity Difference Limen at 500, 1000, 2000 and 4000Hz using the maximum likelihood procedure starting at 40 dBSPL followed by 80 dBSPL. Differential limen was uniform across participants and frequency with an overall mean of 2.98 dB. Age related difference was more in low frequency than high frequency and older adults showed larger inter subject variability.

Lamore et al (2019) studied intensity discrimination on 22 participants (10 normal hearing & 12 severe sensorineural hearing loss individuals). They measured Intensity Difference Limen Intensity at 500, 1000, 2000 and 4000Hz using the maximum likelihood procedure at 10 dBSL. They found that intensity discrimination became poorer as the severity of hearing loss increased. And there was no difference in intensity discrimination among the frequencies.

Jain and Kumar (2016) studied the effect of age on psychoacoustic abilities on 30 participants with the age range of 50-59.11yrs and 60-69.11yrs at different frequencies i.e., 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz. They measured the mean discrimination limen for intensity, and they reported that for 50-59.11yrs mean was 4.52 dB for 500 Hz, 3.97 dB for 1 kHz, 3.86 dB for 2 kHz & 4.82 dB for 4 kHz and for 60-69.11yrs mean was 5.42 for 500 Hz, 5.08 for 1kHz, 4.40 dB for 2 kHz & 5.31 dB for 4 kHz.

Schroder et al. (1994) compared intensity discrimination in normal hearing and hearing-impaired listeners. Weber fractions ($\Delta I/I$) for gated 500-ms tones at 0.3, 0.5, 1, 2, and 3 kHz, and at levels of the standard ranging from absolute threshold to 97 dB SPL, were measured in quiet and in high-pass noise in five listeners with cochlear hearing loss and in three normal-hearing listeners. In regions of hearing loss, the Weber fractions at a given SPL were sometimes normal. When the Weber fractions were normal or near-normal, the addition of high-pass noise elevated the Weber fraction, strongly suggesting the use of spread of excitation to higher frequencies.

Inversely, when the Weber fractions were elevated, the addition of high-pass noise produced no additional elevation, suggesting an inability to use spread of excitation. In general, the relative size of the Weber fractions, the effects of high-pass noise, and to a lesser extent, the dependence of the Weber fraction on level, were consistent with expectations based upon the audiometric configuration and the use of excitation spread. There were several notable inconsistencies, however, in which normal Weber fractions were seen at a frequency on the edge of a steep high-frequency loss, and in which elevated Weber fractions were observed in a flat audiometric configuration. Finally, when compared at the same SL, the Weber fraction was sometimes smaller in cochlear-impaired than in normal hearing listeners. This was true even in high-pass noise, where excitation spread was limited, and may reflect the unusually steep rate versus level functions seen in auditory nerve fibers that innervate regions of pathology.

2.1.3 Duration discrimination

Duration discrimination is the ability of the auditory system to detect small change in the duration of the acoustic stimuli. The smallest detectable change in the duration of a stimulus increases with increase in baseline duration of a stimulus. Fitzgibbons & Gordon-Salant, (1994) studied duration discrimination on 40 participants in two groups consisting of younger and older adults with normal hearing sensitivity. Duration discrimination was measured for tone burst of 500 Hz and 4000 Hz using reference duration of 250 ms at 85 dBSPL. Results indicated that average discrimination for elderly was larger compared to younger listeners.

Jain and Kumar (2016) studied the effect of age on psychoacoustic abilities on 30 participants with the age range of 50-59.11yrs and 60-69.11yrs at 1000 Hz frequency. They measured the mean discrimination limen for duration and they reported that for 50-59.11yrs mean was 67.35ms and for 60-69.11yrs mean was 66.14ms.

Abel et al. (2009) studied duration discrimination on 11 participants in two groups consisting of younger (20-35 years) and older adults (40-60 years) with mild to moderate sensorineural hearing loss. Duration discrimination was measured for tone burst of 500 Hz and 4000 Hz using reference duration of 250ms. Results indicated that average discrimination for the elderly was larger than for younger listeners. Abel et al (1990), also reported that duration discrimination was poorer for 4000Hz tone burst than 500 Hz tone burst tone.

Fitzgibbons & Gordon-Salant (1994b) studied duration discrimination on 20 participants in two groups consisting of younger and older adults with mild to moderate sloping sensorineural hearing loss. Duration discrimination was measured for tone burst of 500 Hz and 4000 Hz using reference duration of 250 ms. Results indicated that average discrimination for elderly was larger than for younger listeners. And he also found that duration discrimination was more at 4000 Hz.

2.2 Effect of advancing age on hearing abilites

It has been observed that the older adults experience a significant increase in pure tone threshold and a reduction in speech recognition scores with advancing age (Brant & Fozard, 1990) have assessed pure-tone thresholds and speech discrimination scores of 813 male individuals (20-85years) as a function of age on a span of 20 years. The results indicated that there was an average longitudinal loss of 35.2 to 53 dB for the 50 years and 69 to 84 dB in the 80-years-old. An increase in rate of threshold was found in older adults particularly in speech frequencies. A reduction in speech scores was also seen but it did not correlate well with the degree of hearing loss (Pearson et al., 1995) have reported that deterioration in hearing threshold is found to be faster in male population compared to female population and females usually had better thresholds at higher frequencies and male individuals who had better thresholds at lower frequencies.

However, Dubno et al. (2008) based on a longitudinal study of 835 subjects, reported that both male and female population have a sharp decline in threshold in speech frequencies with advancing age. A significant reduction in speech recognition scores for NU 6 was also present.

Zurek & Delhorne (1987) assessed the effect of sensorineural hearing loss ranging from mild-moderate on speech perception scores in presence of noise in 21 older adults. They determined the perception of consonants in the presence of speech spectrum noise that was varied to stimulate a myriad of listening situation and the same test was performed on normal hearing individuals. The findings showed no significant difference between the performances of both the groups. Hence, it was concluded that most of speech perception difficulties are primarily due to loss of audibility (Humes & Roberts, 1990) noted that peripheral hearing loss to be an important aspect in determining the variability seen in speech discrimination difficulties that older adults encounter.

Humes and Christopherson (1991) examined the speech perception and central auditory processing skills of four groups of participants using test of basic auditory capabilities. The groups were young normal hearing groups, young normal hearing group with spectral noise stimulated hearing loss, an older adult group with hearing loss age ranging from 65 to 75 years and another older adult group with hearing loss age ranging from 76 to 85 years. In 4 tasks out of 8 tasks in Test for basic auditory capabilities (Frequency discrimination test, embedded test tone task, temporal ordering task for syllables and tones) older adult groups performed poorer than the younger group. Even though the younger noise masked group performed slightly better than older adult groups their performance were not very significant than the two older adults groups. It was observed that elevation of peripheral hearing sensitivity associated with aging was the most important factor that affected speech perception abilities.

Humes et al. (1994) assessed the speech recognition abilities of 50 older adults (63-83 years) for a range of test including nonsense syllables, sentences and monosyllables, along with 'Test of Basic Auditory Capabilities '(Watson, 1987) and Weschler adults intelligence scale were administered. The analyses were carried out for auditory, speech perception and cognitive measures. It was observed that the hearing loss play a large part to variability seen in speech perception performance in older adults.

The above research indicated that sensorineural hearing loss and general loss of audibility are the primary reasons that cause poor speech perception in older adults. However, it was also noted that not always the poor speech perception correlated with the peripheral hearing loss.

The age-related changes in the auditory system and balance system have been recorded in the literature. This change has recorded in terms of anatomical, physiological as well as audiological test scores (Fitzgibbons& Gordon-salant, 1996; Frisins & Walton, 2001; Willot, 1991). Apart from reduced hearing sensitivity, older adults are also found to develop auditory processing problems. It has been mentioned in the literature that with an increase in age the presence of auditory processing disorder (APD) has become evident. A lot of research has reported that the listening challenges encountered by the older adults can be mainly due to their presbycutic high frequency hearing loss (Humes et al1994; person et al 1995; Cruickshanks et al 1998; Halling & Humes, 2000).

OAEs are affected by aging (Lonsburv-Martin et al., 1991; Dorn et al., 1998). Also, Glattke & Robinette (1997) have reported reduced DPOAE amplitude with aging. According to Robinette et al. (1992), TEOAE amplitude and reproducibility were found to be lower with advancing age. As a result of Mazelova et al. (2003) study on older adults, he reported that due to the decrease in the OHCs there is a steady decrease in amplitude of DPOAEs.

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Time cues or temporal aspect of signal are usually poorly coded in older adults, this is being recognized as the cochlear mechanism disruption, studies have mentioned about the central auditory process involvement in it. Numerous studies have reported that, the temporal acuity is found to be affected in older adults (Fitzgibbons and Gordon-Salant, 1996; Lutman 1991; Phillips, Gordon-Salant, Fitzgibbons and Komshian, 1994; Moore, Peters and Glasberg.1992). Many studies done on the part of auditory closure have reported that, the older adults perform poorly when the auditory system is challenged (Smith and Prather; 1971; Harris& Reitz, 1985; Versfeld & Dreschler, 2002; Hododshima &Arai, 2007).

Harris et al. (2007) reported that older adults have large difference limen intensity compared to young adults. Similarly, differential limen for time was longer in older adults compared to younger adults was reported by Fitzibbons and Gordon-Salant (1994). He et al. 1998, reported that older adults have larger different limen frequency compared to younger adults. Literatures have suggested that there is decrement in the psychophysical test scores from 4th and 5th decade of life. There is an effect on all psychophysical measures due to ageing. So, these psychophysical measures play a vital role in speech perception. Due to ageing, there is a negative effect on speech perception (CHABA, 1998).

2.3 Effect of Yoga on physiology and auditory system

Yoga is an ancient Indian training scheme intended to bring equilibrium and health to an individual's physical, mental and emotional aspects. The practice of yoga comprises of a set of physical postures ("Asanas"), and for a certain period of time these postures are maintained (Ross & Thomas, 2010). The word yoga is derived from the Sanskrit meaning to control, to yoke or to unite. Yoga also includes voluntary breath control (pranayama), voluntary thought concentration (meditation) and/or repeated phrase recital (mantra). "Asanas" are exercises that are traditionally used in yoga practices, characterized by maintaining particular postures that involve bending, standing, twisting and balancing the body with the aim of enhancing flexibility and strength. Pranayama consists of breathing exercises that focus body awareness during their execution (Swami Kriyananad, 2009).

Meditation is a mental process involving the voluntary concentration of thoughts, aiming at a changed state of awareness, and is thought to generate changes in perception, attention and cognition. (Pilkington, Kikwood, Rampes, & Richardson, 2005; Ross & Thomas, 2010). Yoga has become more common as a supplementary manner of achieving healthy living since its introduction to western culture (Jayasinghe, 2004).

The practice of yoga is found to affect nervous energy and the activities in the endocrine, cardiac, pulmonary, muscular and nervous system through stimulation. It is found to accelerate physical, emotional and spiritual recovery. Yoga was used as a therapeutic intervention that started in the early twentieth century, taking advantage of the various psychophysical advantages of the component practices (Swami Kriyananad, 2009).

Practicing yoga has been found to affect both mental and physical manifestations in humans. Some well-known physical advantages of yoga are enhanced flexibility, enhanced muscle tone, enhanced breathing, energy, and vitality, keeping a healthy metabolism, reducing weight, and improving cardiovascular and circulatory health (Iyengar, 2007).

Moreover, investigations have shown the beneficial effects of yoga on cognition (Birdee et al., 2009) Rangan, Nagendra, and Bhat (2009) reported that, gurukula education system that was based on a yoga way of life was found to be more effective and resulted in increasing the performance on visual and verbal memory in students when compared with students of the modern education system. Another research showed that relaxation techniques based on yoga enhanced memory levels in volunteers instantly after the session (Subramanya & Telles, 2009). Among practitioners and trainers, it is believed that periodic practice provides advantages in both cognitive and impacts multiple elements of psychological activities, such as improving memory and reducing emotional tension, depression, anxiety and irritability (Andrade & Pedrao, 2005).

Physical exercises were generally regarded an acceptable method to improve and maintain physical and emotional health (Ross & Thomas, 2010). Studies comparing the impacts of yoga and standard physical exercise suggest that yoga can be as efficient or even better than exercising in health-related interventions in both healthy and unhealthy subjects (Ankad et al., 2011; Pilkington et al., 2005; Yurkuran, Alp, Yurtkuran, & Dilek, 2007).

Along with having an influence on the auditory system, yoga is found to influence the vestibular system. Oliveria Faria, Rodrigues and Santaella (2016) have reported that, the postural practice of yoga improves the balance system capacity. Ulgerand Yaglt (2011) also have reported on the positive effects of practicing yoga on the balance and gait parameters of women, who balance and gait problems due to musculoskeletal dysfunction. Prado, Raso, Scharlach and Kasse (2014) have shown that practicing yoga can improve body balance in healthy young individuals.

Tejaswini, Shubhaganga and Prashanth (2017) studied the effect of yoga on VEMP in 40 subjects aged, 20-40 years. The research findings suggested that there was a substantial rise in the amplitude of the complex of P1, N1 and P1-N1 and a substantial decrease in latency for those who frequently practice yoga compared to those who do not practice yoga. This could be because yoga is found to strengthen the muscles and vestibular system.

Sujeet, Kaushlendra and Jayshree (2010) have shown that amplitude reduction after 50 years of age and latency prolongation after 60 years in cVEMP estimation with 500Hz tone burst. Niraj, Ranjitha, Supreetha and Sahana (2013) & Sharda, Swathi and Vanaja (2014) have also reported decrease amplitude and increase latency for cVEMP in older adults. Gauchard Jeandel and Perin (2001) have conclude that low-energy exercise, have the most positive effect on body balance control by relying more on proprioception, also this exercise seems to develop vestibular sensitivity of older adults.

Literatures have shown that performing yoga in certain posture is known to circulate more amount of oxygenated blood to the cochlea and thereby reducing the aging process of hearing. This also has been found to help better repair and recover of the system thereby reduces the aging process of hearing (Varambally, 2009).

Kumar et al., (2017) found that individuals who performed yoga had an increased amount of suppression that was observed on both transient evoked otoacoustic emissions (TEOAEs) & distortion product Otoacoustic emission (DPOAEs), which suggest that yoga can strength the efferent auditory system.

Telles et al. (1993) has reported that in Middle Latency Auditory Evoked Potential Na-wave amplitude increased and latency decreased during the period of pranayamic practice, whereas the Pa-wave was not significantly altered. Telles et al., (2013) found that there was a significant increase in the P300 peak amplitudes at different scalp sites and a significant decrease in the peak latency at frontal scalp region, following alternate nostril Yoga breathing. Following breath awareness there was a significant increase in the peak amplitude of P300 at Vertex region.

Telles et al. (2015) evaluated long latency auditory evoked potentials (LLAEPs) during meditation. Sixty male participants, aged between 18 and 31 years (group mean ± SD, 20.5 ± 3.8 years), were assessed in 4 mental states based on descriptions in the traditional texts. They were (*a*) random thinking, (*b*) non-meditative focusing, (*c*) meditative focusing, and (*d*) meditation. The order of the sessions was randomly assigned. The LLAEP components studied were P1 (40-60 ms), N1 (75-115 ms), P2 (120-180 ms), and N2 (180-280 ms). For each component, the peak amplitude and peak latency were measured from the pre-stimulus baseline. There was significant decrease in the peak latency of the P2 component during and after meditation. The P1, P2, and N2 components showed a significant decrease in peak amplitudes during random thinking and non-meditative focused thinking. The results suggest that meditation facilitates the processing of information in the auditory association cortex, whereas the number of neurons recruited was smaller in random thinking and non-meditative focused thinking, at the level of the secondary auditory cortex, auditory association cortex and anterior cingulate cortex.

Ashique and Mamatha (2018) have reported that there is a positive effect of yoga on auditory processing abilities such as gap detection threshold (GDT) test scores, dichotic CV test scores, speech in noise scores and memory and sequencing. In GDT the thresholds were better for persons who practice yoga. In dichotic CV test scores, the performance was observed to be better in the right ear followed by left ear. However, the double correct scores were poorer in both the groups. Overall, the yoga participants showed higher scores than the normal adults. In speech in noise test yoga participants had better scores than normal adults. In memory and sequencing test yoga participants had better scores in memory test than normal. But there was no significant difference among both groups in sequencing task.

The practice of yoga is known to improve the brain functioning ability. Voss et al. (2016) have shown that yoga has a positive impact on memory, cognitive function and improve executive function in older adults. Alathi and Parulkar (1989) and Madanmohan (1992) have found that yoga reduces visual and auditory reaction time by enhancing the brains processing ability.

There are few studies that have discussed about the advantage of activating efferent auditory system and enhanced auditory performance like improvement in threshold detection and intensity discrimination (Micheyl & Collect 1996), and improvement of speech perception abilities in presence of noise (Soli & Linthicum, 1994). Girand et al (1997) has studied the function of the efferent pathway (medial olivocochlear bundle) in normal and their results indicated that activation of MOCB improves the speech in noise intelligibility, while this effect was not observed in neurecotomised patients. Hence strengthening of efferent auditory system through the practice of yoga can improve speech perception skills in presence of noise, improvement in threshold detection and intensity discrimination.

From the review, it is evident that, based on results of several audiologic test results many studies have shown that yoga is found to have a positive effect on both the auditory and vestibular systems. Also, Yoga is found to have an effect on central auditory processing abilities. However, there are very few studies done on the effect of Yoga on psychophysical measures. Hence, the current study has been planned to study the effect of frequency, intensity and duration discrimination in older adults.

Chapter 3

Methods

The current study was planned to compare the psychophysical abilities such as difference limen for intensity (DLI), difference limen for frequency (DLF) and difference limen for duration (DLT) in older adults aged 50-65 years who practice yoga regularly. In order to fulfil the aim, the following method was planned. All the data were obtained in compliance with the Ethical guidelines for BIO-Behavioural Research involving Human Subjects (2009) of the All India Institute of Speech and Hearing, Mysore. Before carrying out the study informed consent was taken from the participants.

3.1 Participants

A total of 40 participants were selected for study. These participants were divided into two groups. Group 1 (experimental group) included those individuals who practice yoga for minimum duration of at least 2 years and Group 2 (control group) included those individuals who have not practiced yoga. Individuals who performed yoga followed certain methods during yoga practice i.e., the yoga participants start their practice by chanting mantras, followed by body relaxation exercises, surya namaskara, practicing yoga postures then end with pranayama (breathing exercise) sessions. The completion of yoga takes about 1.5 hours. Also individuals recruited in group 1 needed to fullfil the criteria of practicing yoga for a minimum of 6 to 9 hours a week for at least 2 years.

3.2 Participant selection criteria

Participants fulfilling the following criteria were selected for participant selection in group 1 & group 2.

- Pure tone AC thresholds was less than 15 dB HL in the frequencies from 500 Hz to 4 KHz, indicating normal hearing sensitivity and thresholds at high frequencies was than 25 dB HL (Carhart & Jerger, 1959).
- Normal Otoscopy findings.
- Age range of 50 to 65 years.
- Normal cognition as revealed by Mini Mental Status Examination (MMSE) given by Folstein and McHugh (1975).
- No compliant and history of middle ear pathology in both the ears.
- No complaint of understanding speech in quiet with SIS scores of 80-100 %.
- No history of any psychological, neurological and communication problems.
- No history of diabetes, hypertension and any other medical problems.

3.3 Instrumentation

- Calibrated Inventis Piano Plus was used to perform pure tone threshold estimation (pure tone audiometry & speech audiometry). Calibrated TDH 50 headphones for AC threshold and calibrated B-71 bone vibrator for BC threshold were used.

- Calibrated GSI Tympstar Immittance meter was used to measure tympanometry with a probe tone frequency of 226 Hz. The same equipment was used for measuring ipsilateral as well as contralateral acoustic reflex threshold at 500, 1000, 2000, and 4000 Hz.

- Psychophysical measures for frequency, intensity and duration discrimination was done using MATLAB version 7.9 (The Mat Works, Inc., MA USA, 2009) which was installed in HP laptop 15s, Ryzen 5-5500U with SONY ZX110AP Headphone. Headphone was calibrated to produce desired output using Bruel and Kjaer 2270 sound level meter in a 6 cc coupler.

3.4 Test Environment

The audiological tests were performed in the sound-treated room. The noise levels will be within permissible limits as per ANSI (S3.1-1999) in the sound-treated space. In a silent space, the psychophysical tests were performed.

3.5 Pure Tone and Speech Audiometry

Pure tone audiometry testing were carried out using modified Hughson and Westlake procedure (Carhart & Jerger, 1959) using TDH 50 headphones and hearing sensitivity were assessed for all the octave frequencies from 250 Hz to 8000 Hz for air conduction thresholds and for bone conduction thresholds and B-71 bone vibrator was used for estimating bone conduction thresholds from 250 Hz to 4 KHz. SRT correlating within ± 12 dB of pure tone average (average threshold of 500, 1000, 2000 & 4000 Hz) and Speech identification scores greater than 80% at 40 dB SL (ref SRT) was considered. Speech identification scores were assessed through phonetically balanced word list in Kannada (Mayadevi, 1974).

3.6 Immittance Evaluation

Tympanometry was done to rule out any pathology in the middle ear. Tympanometry was done at 226 Hz probe tone and acoustic reflex threshold were elicited for both ipsilateral and contralateral stimulation at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

3.7 Assessment of Psychoacoustic Measures: Difference Limen Abilities

All the psychoacoustic tests such as Difference Limen Frequency (DLF), Difference Limen Intensity (DLI) and Difference Limen Duration (DLT) were carried out using mlp toolbox, which implements a maximum likelihood procedure for threshold estimation in Matlab (Grassi & amp; Soranzo, 2009). In all the psychoacoustic tests, stimuli were presented binaurally at an intensity of 70 dB SPL. The stimulus was presented through the laptop. To decide the stimulus to be presented in the trial, the psychometric function that provides the greatest probability was used. Within 20 trials, the mlp generally meets the stable approximation of the most probable psychometric function, which was used to approximate the thresholds (Grassi & Soranzo, 2009; Green, 1990, 1993).

3.7.1 Frequency Discrimination

It is the minimum frequency difference that is required to discriminate between the two closely spaced frequencies. Difference Limen Frequency (DLF) was measured at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. Both the standard and variable stimuli were of 250 ms long, pure tone with onset and offset of 10 ms raised cosine ramp (Grassi & Soranzo, 2009; Jain, Mohammed & Kumar, 2014). Three alternative forced choice method was used to track a 79.4% correct response criterion. In this two blocks had the standard frequency and one block had variable frequency. The participant's task was to identify the variable frequency. For example, the first and third blocks will have a frequency of 1000 Hz and second block will have a frequency of 1025 Hz. So now the task of participant was to identify the second block. A three-down, one-up rule was used to approximate the psychometric function's 79.4 percentage point frequency difference.

3.7.2 Intensity discrimination

It is the minimum intensity difference that is required to discriminate between two closely spaced sound intensities. Difference Limen Intensity (DLI) were measured for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. Both the standard and variable stimuli were of 250 ms long, pure tone with onset and offset of 10 ms raised cosine ramp (Grassi & Soranzo, 2009; Jain, Mohammed & Kumar, 2014). Three alternative forced choice method was used to track a 79.4% correct response criterion. The minimum and maximum intensity deviation was used at 0.99 dB and10 dB. Two blocks had pure tones at the standard intensity on each trial of three blocks, and another block chosen randomly included a pure tone of varying intensity that was always greater than the standard intensity. The participants task was to identify the variable block. A three-down, one-up rule was used to approximate the difference in intensity corresponding to the psychometric function's 79.4 percentage point.

3.7.3 Time Discrimination

It is the minimum time difference that is required to discriminate between two otherwise same sounds. Difference Limen Time (DLT) was measured for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. Both the standard and variable stimuli were of 250 ms long, pure tone with onset and offset of 10 ms raised cosine ramp (Grassi & Soranzo, 2009; Jain, Mohammed & Kumar, 2014). Three alternative forced choice method was used to track a 79.4% correct response criterion. On each trial of three blocks, two blocks had pure tones at the standard duration, and another block selected at random contains a pure tone of variable duration, which was always higher than the standard intensity. The participant's task was to identify the variable block which was of 0 to 25 ms difference in duration between the two stimuli. A three–down, one-up rule was used to approximate the duration difference corresponding to the 79.4% point of the psychometric function.

3.8 Statistical Analyses

The data obtained was subjected to statistical analyses using SPSS Version 26 software. Descriptive statistics was used to obtain the mean and standard deviation for threshold of difference limen for intensity, difference limen for frequency, difference limen for duration. As all the assumptions of parametric test were satisfied, and hence an independent sample t-test was used to see the significant difference between the groups.

Chapter 4

Results

The aim of the current study was to assess the psychoacoustic abilities of older adults who practice yoga. In order to fulfil the aim, three different psychoacoustic abilities: difference limen for intensity (DLI), difference limen for frequency (DLF) and difference limen for duration (DLT) were assessed. These tests were assessed using mlp toolbox, which impliments maximum likelihood procedure for threshold estimation in matlab. The psychoacoustic abilities were compared between yoga participants (experimental group) and non-yoga participants (control group) in older adults aged from 50 to 65 years. To analyze the data, Statistical Package for the social science Version 26 was used. The following Statistical tools used to analyze the obtained data:

- Shapiro wilks test of normality was used to check for the normality of the obtained data.
- As Shapiro Wilks test of normality indicated that the data were normally distributed ($p>0.05$), parametric tests (independent sample t-test) were done for the between the group comparisons.
- Descriptive statistics was done to calculate the mean, standard deviation for Difference limen thresholds for frequency, intensity and duration.
- Independent sample t-test was done to check for the significant difference between the groups.

4.1 Comparison of Psychoacoustic Abilities (DLI, DLF & DLT) in Experimental and Control Group

In order to compare the psychoacoustic abilities in both the groups (Experimental & control), descriptive statistics was carried out to obtain Mean and Standard Deviation (SD) for DLI, DLF, DLT at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. The Mean and SD of difference limen for intensity (DLI), difference limen for frequency (DLF) and difference limen for duration (DLT) obtained at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz in experimental and control group are given in table 4.1 and Figure 4.1.

Table 4.1:

Mean and SD of DLI, DLF and DLT at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for experimental and control group

Test for psychoacousti abilities		**500 Hz**		**1000 Hz**		**2000 Hz**		**4000 Hz**	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
DLI	Control	4.6	1.7	3.9	1.4	3.9	0.8	5.4	1.2
	Experimental	3.5	1.04	3.0	0.9	3.4	0.7	3.7	1.3
DLF	Control	67.08	20.32	79.5	18.34	89.18	17.87	101.39	21.43
	Experimental	58.57	18.22	64.6	21.64	76.46	23.76	85.88	24.32
DLT	Control	66.18	22.34	70.55	23.32	72.36	21.45	79.78	22.3
	Experimental	59.30	18.39	61.36	21.45	63.88	22.78	70.42	21.43

Note. DLI are given in dB, DLF are given in Hz and DLT are given in msec

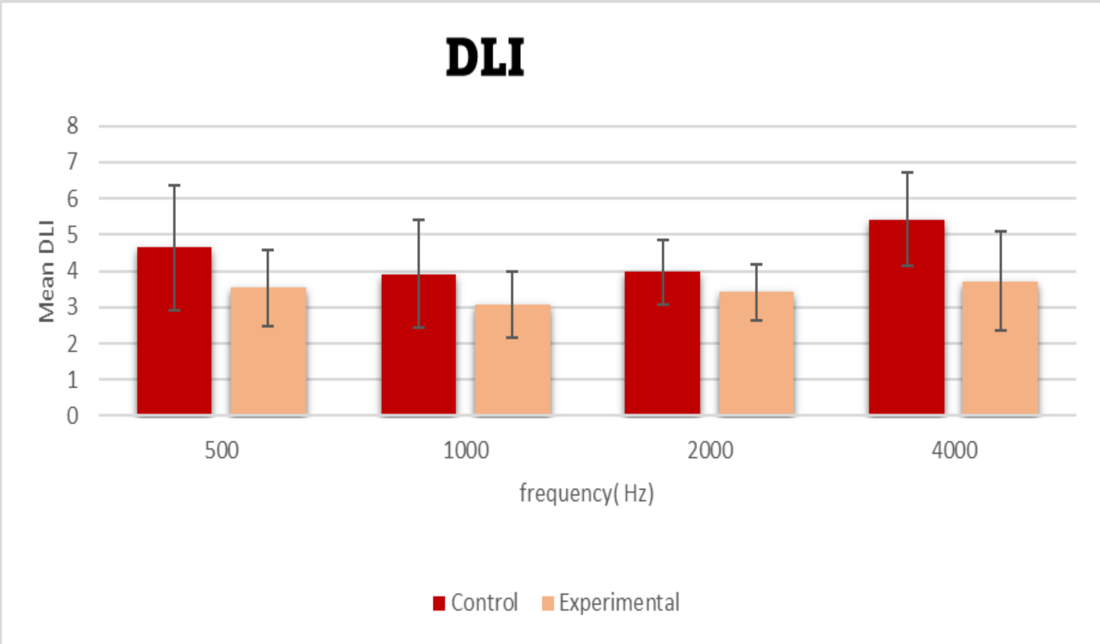

figure 4.1: *Mean DLI with SD at 500 Hz, 1000 Hz, 2000 Hz and 4000Hz for experimental and control group*

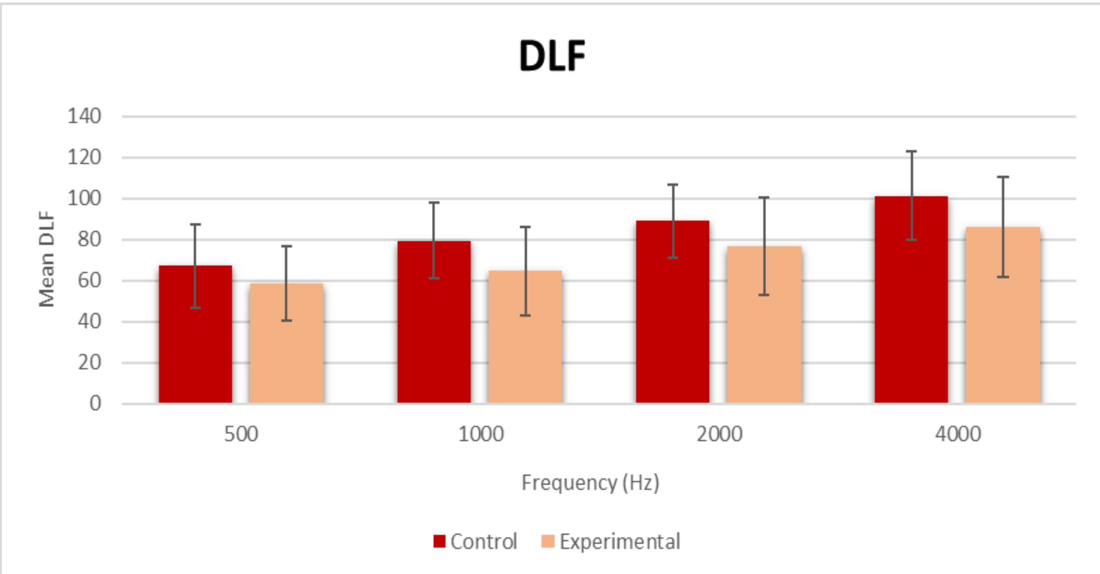

Figure 4.2: *Mean DLF with SD at 500 Hz, 1000 Hz, 2000 Hz and 4000Hz for experimental and control group*

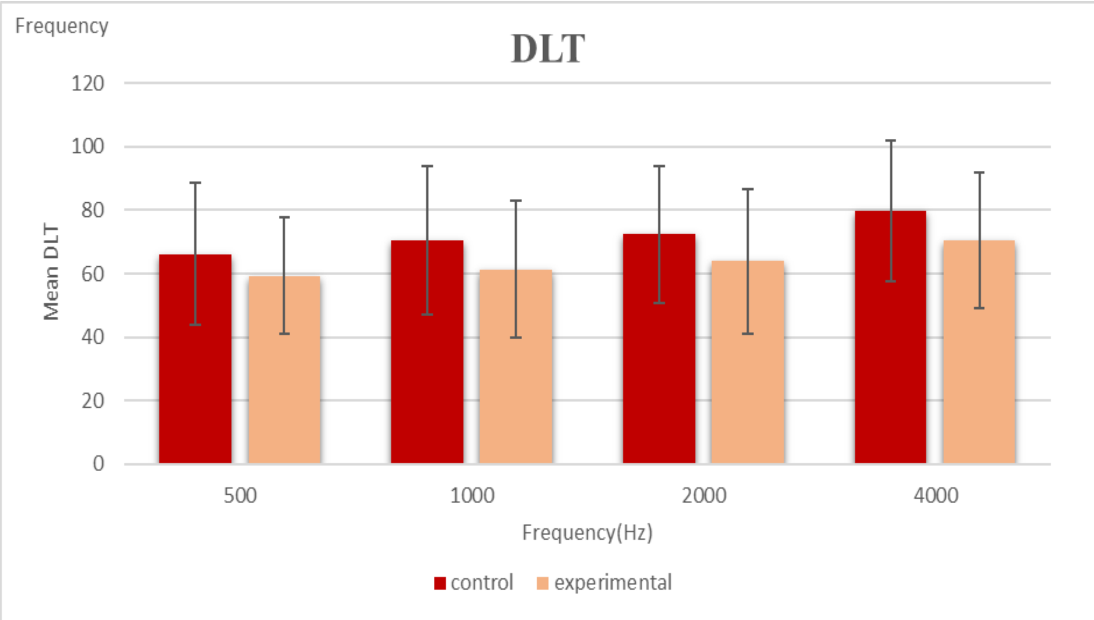

Figure 4.3: *Mean DLT with SD at 500 Hz, 1000 Hz, 2000 Hz and 4000Hz for experimental and control group*

From the table 4.1 and figure 4.1 , it can be seen that the mean difference limen for intensity obtained were lesser for the Experimental group compared to Control group at all the four frequencies tested i.e., 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz. It can also be noted from table 4.1 and figure 4.2 and figure 4.3 that the mean difference limen for frequency and mean difference limen for duration were found to be lesser in the experimental group compared to Control group. It can also be noted that the mean thresholds all the pshycoacoustic measures (DLI, DLF, DLT) were smaller in low frequency and threshold increases as the frequency increases in both the groups.

In the experimental group, the mean difference limen for intensity obtained were found to smaller compared to control group, which means individuals who practiced yoga were able to detect smaller change in intensity compared to individuals who did not practice yoga. The mean difference limen for frequency and difference limen for duration were also noted to be smaller in the experimental group, which indicates that the individuals who practiced yoga were able to detect smaller changes in frequency and duration in comparision to individuals who did not practice yoga.

Form the Figure 4.1, figure 4.2 & figure 4.3 we can see that the mean values of DLI, DLF and DLT were found to be different between experimental and control group. The mean DLI, DLF and DLT values were found to be better in the experimental group compared to control group. Hence, to see if there is any significant difference between the experimental and control groups, further parametric test was carried out as the data was normally distributed. Independent sample t-test was administered to compare the threshold of DLI, DLF, DLT between the experimental and control groups. This was done to examine if yoga has any significant on psychoacoustic abilities in individuals who practiced yoga regularly. The results of independent sample t-test obtained for DLI, DLF and DLT at 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz for both experimental and control group are given in Table 4.2.

Table 4.2

Results of independent sample t-test (t value & significance level) of DLI, DLF, DLT at 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz comparing experimental and control groups

Psychoacoustic Tests	***DLI***		***DLF***		***DLT***	
Frequencies	***t-value***	***p-value***	***t-value***	***p- value***	***t-value***	***p-value***
500 Hz	2.49	0.017*	5.12	0.00*	7.52	0.00*
1000 Hz	2.15	0.038*	9.91	0.00*	12.36	0.00*
2000 Hz	2.11	0.041*	7.03	0.00*	11.66	0.00*
4000 Hz	4.09	0.00*	6.93	0.00*	8.48	0.00*

*Note: p=level of significance, *p<0.05 indicates significant difference.*

From the results shown in table 4.2, it can be observed that there was a significant difference noted between the experimental and control groups for various psychoacoustic abilities (DLI, DLF & DLT): there was a significant difference noted between the experimental and control groups for DLI 500 Hz [t (38) = 2.49 ; $p < 0.05$], 1000 Hz [t (38) = 2.15 ; $p < 0.05$] 2000 Hz [t (38) = 2.11 ; $p < 0.05$], 4000 Hz [t (38) = 4.09 ; $p < 0.05$]; DLF 500 Hz [t (38) = 5.12 ; $p < 0.05$], 1000 Hz [t (38) = 9.91 ; $p < 0.05$] 2000 Hz [t (38) = 7.03 ; $p < 0.05$], 4000 Hz [t (38) = 6.93 ; $p < 0.05$]; DLT 500 Hz [t (38) = 7.52 ; $p < 0.05$], 1000 Hz [t (38) = 12.36 ; $p < 0.05$], 2000 Hz [t (38) = 11.66 ; $p < 0.05$], 4000 Hz [t (38) = 8.48 ; $p < 0.05$].

From the above results, it can be observed that the psychoacoustic abilities (DLI, DLF & DLT) were found to be better in experimental group (older adults who practiced yoga regularly) compared to control group (older adults who did not practice yoga). The difference limen for intensity obtained were found to be significantly better in older adults who practice yoga. Hence, it can be concluded that older adults who practiced yoga were able to detect smaller changes in intensity compared to those older adults who did not practice yoga. The difference limen for frequency and difference limen for duration were also found to be significantly better for the older adults who practiced yoga regularly, which indicates that the older adults who practiced yoga were able to detect smaller changes in frequency and duration in comparison to those individuals who did not practice yoga.

Chapter 5

Discussion

Yoga is a traditional physical and mental disciplines originated in India. The word is derived from the Sanskrit meaning to control, to yoke or to unite. The goal of yoga is unity of the body, mind and spirit with the focus on body posture, breathing and meditation. It is found to affect nervous energy and the activities in the endocrine, cardiac, pulmonary, muscular, and nervous systems through stimulation. There are several research carried out to find the effects of yoga on various physiological function and human auditory system and has revealed that Yoga has an effect and find to influence positively on overall physiological aspects and on auditory system. There are few studies that have discussed about the advantage of activating efferent auditory system and enhanced auditory. Giraud, Garnier, Stephen, Mycle (1997) has studied the function of efferent pathway (medial olivocochlear bundle) in normals, and the results indicated that activation of MOCB improves the speech intelligibility in presence of noise, while this effect was not observed in neurectomized patients. Hence strengthening of efferent auditory system through the practice of yoga can improve speech perception skills in presence of noise, improvement in threshold detection and intensity discrimination.

However, there are limited number of studies done on yoga and its effect on few psychoacoustic measures such as frequency, intensity, and duration discrimination abilities. Hence, the present study was aimed to study the effect of yoga on psychoacoustic abilities in older adults. Various psychoacoustic abilities such as difference limen for intensity, difference limen for frequency and difference limen for duration respectively. As the data was normally distributed, parametric test was used to find if there was any significant difference found in psychoacoustic abilities between the experimental who practice yoga and control groups who don't practice yoga. The aim of this study is to determine the effects of yoga on few psychophysical measures (frequency, intensity & duration discrimination abilities) in older adults.

The results of the present study revealed that the mean thresholds obtained for various psychoacoustic abilities such as difference limen for intensity (DLI), difference limen for frequency (DLF) & difference limen for duration (DLT) were found to be lower in older adults who practiced yoga regularly compared to those individuals who did not practice yoga regularly. The thresholds obtained for DLI, DLF and DLT were found to be significantly better in older adults who practiced yoga regularly compared to those individuals who have not practiced yoga. This indicates that individuals who practiced yoga regularly had significant better auditory ability to detect smaller difference between the stimulus noted in terms of intensity, frequency, and duration.

It is widely reported in the literature that as age progresses there is a general decline in the performance of auditory abilities along with other general physiological aspects. Age-related decline in the ability to perceive and discriminate between different auditory stimuli, particularly in terms of frequency and intensity. It suggests that this decline may be linked to various physiological changes in the auditory system like Neural Synchrony (Mills, Schmiedt, Schulte, & Dubno, 2006) and Inhibitory Neurotransmitters (Caspary, Ling, Turner, & Hughes, 2008) are affected and decrease in number of neurons in auditory nuclei. Kumar and Sangamanatha (2011) assessed Modulation Detection Threshold, Gap Detection Threshold, Duration Discrimination Test and Duration Pattern Test in individuals ranging from 20 years to 85 years. Except for duration pattern all other temporal processing skills showed age related decline by 4th decade.

Along with having positive effects on general body and mind functioning, yoga is also found to have a positive effect on inner ear physiology in adults. Yoga is found to have shown a significant improvement in amplitude and latency of cVEMP (Tejaswini, Shubhaganga, & Prashanth, 2017). It has also been reported that amount of suppression (TEOAE & DPOAE's) increases in individuals who practice Yoga compared non yoga practisers (Kumar, Shambhu, & Prabhu, 2017). Practicing yoga regularly is found to increase the speech perception abilities and auditory memory skills. This could be due to the fact that practice of yoga is found to strengthen the efferent auditory system and activation of efferent pathway is found to improve speech perception abilities in presence of noise (Girandetal, 1997).

Yoga is found to have positive effect on working memory, attention, cognitive function, verbal fluency, and executive function in older adults (Hariprasad et al. 2013). Yoga is found to reduce reaction time for sensory stimulus (auditory & visual) due to the increased neural firing and synchrony (Alathi & Parulkar, 1989; Madanmohan, 1992). Since yoga and mindfulness practices are found to improve these cognitive functions, it is plausible that they might indirectly enhanced the performance on intensity discrimination, frequency discrimination and duration discrimination tests.

Our result is consistent with the previous study by Gopinath, Bhat, Ranjan (2018) has found the better performance on pitch discrimination abilities in the middle aged participants who practiced SKY (Sudarsana Kriya Yoga) could be attributed to better Temporal Fine Structure coding due to improved oxygenated blood supply to the auditory system due to SKY practice.

Kumar, Sangamanatha, and Vikas (2013) studied Effects of Meditation on Temporal Processing and Speech Perceptual Skills in Younger and Older Adults who do effective meditation group performed significantly better than Adults who don't do meditation group on duration discrimination, duration pattern, and backward masking measures.

Hence, in the current study it has been evidenced that individuals who practice yoga regularly have shown an improved performance on most of the psychoacoustic abilities compared to individuals who had not practiced yoga. Yoga is also found to have positive effect on an individual's mental health and has benefited individuals with depression (Pilkington, Kirkwood, Rampes and Richardson, 2005 & Uebelackeretal, 2010). Tang et al., (2007) reported that even short-term meditation training for 5 days significantly improved the attention and reduced the stress.

There are no studies reported in literature about the effect of Yoga on individual's psychoacoustic abilities. From the literature, it has been evidenced that along with having an effect on general physiological function like respiration and, cardiovascular system. Yoga is also found to improve performance in cognitive function, attention, reaction time, and inner ear physiology. This indicates the overall improvement in functioning abilities of central nervous system and the physiology of inner ear. Hence, these improvements would have resulted in improving the psychoacoustic abilities and has been evidenced from the current study.

Chapter 6

Summary and Conclusions

Yoga is a traditional physical and mental disciplines originated in India. The word is derived from the Sanskrit meaning to control, to yoke or to unite. The goal of yoga is unity of the body, mind and spirit with the focus on body posture, breathing and meditation. Practicing yoga has been found to have an effect on both mental and physical manifestations in humans. Positive effects of yoga on muscular, respiratory, nervous, cardio and circulatory systems, regulation of metabolism, weight reduction, improvement in athletic performance, protection from injury are some of the well reported and documented benefits of yoga in literature.

Apart from improving physical and mental aspects, yoga is found to have an effect on inner ear functioning. The positive effects of yoga on suppression of OAEs and VEMP have been reported in the literature (Kumar, Shambhu, Prabhu, 2017; Tejaswini, Shubhaganga, Prashanth, 2017). Also, Hariprasad et al. (2013) has found that performing yoga showed a significant improvement in immediate and delayed recall of verbal and visual memory along with other domains such as working memory, attention, verbal fluency and executive function in older adults. From these reports, it can be concluded that yoga has significant effect on functioning of the cochlea, development and functioning of nervous system which in turn improves attention, working memory and executive function. However, there are limited number of studies done on yoga and its effect on few psychoacoustic measures such as frequency, intensity, and duration discrimination abilities. Hence the current study has been planned to measure the impact of yoga on different psychoacoustic abilities.

A total of 40 number of participants, age ranging between 50 to 65 years were enrolled for the study and divided into two groups; Group I consisted of an experimental group consisting of individuals who have practiced yoga regularly for a minimum of at least 2 years. Group II consisted of control group that included individuals who have no exposure to yoga.

All the participants were assessed for the psychoacoustic abilities using three different tests to determine and compare the psychoacoustic abilities of the individuals in two groups. The psychoacoustic tests such as difference limen for intensity (DLI), difference limen for frequency (DLF) and difference limen for the duration (DLT) were administered using mlp toolbox, which implements a maximum likelihood procedure for threshold estimation in matlab. The test stimuli were presented through the laptop with headphone.

From the results of the study it can be concluded that:

- The experimental group consisting of older adults practicing yoga regularly had a lower mean threshold in comparison to Control group for all the psychoacoustic measures i.e., difference limen for intensity, difference limen for frequency and difference limen for duration at all the four frequencies i.e., 500 Hz, 1000 Hz, 2000 Hz & 4000 Hz.
- The DLI, DLF and DLT obtained at all the four frequencies i.e., 500 Hz, 1000 Hz, 2000 Hz & 4000 Hz were found to be significantly better in older adults who practiced yoga regularly compared to those individuals who have not practiced yoga.
- The mean thresholds for DLI, DLF & DLT were smaller in low frequency and

threshold increased as the frequency increased in both the groups.

6.1 Implications of the Study

- The present study will help in better understanding of differential sensitivity for frequency, intensity and duration in older participants who practice yoga.
- The present study will provide information about the positive effects of practicing yoga in older adults if any.
- Based on results obtained, yoga can be suggested as a therapeutic management for improving psychophysical abilities in desired clinical population.

REFERENCES

Abel, S. M., Krever, E. M., & Alberti, P. W. (2009). Auditory Detection, Discrimination and Speech Processing in Ageing, Noise-sensitive and Hearing-impaired Listeners. *Http://Dx.Doi.Org/10.3109/01050399009070751*, *19*(1), 43–54. https://doi.org/10.3109/01050399009070751

Andrade, R. L. de P., & Pedrão, L. J. (2005). Some considerations about nurses' use of non traditional therapies in psychiatric nursing care. *Revista Latino-Americana de Enfermagem*, *13*(5), 737–742. https://doi.org/10.1590/S0104-11692005000500019

Ankad, R., Patil, S., Chinagudi, S., Herur, A., & Shashikala, G. (2011). Effect of short-term pranayama and meditation on cardiovascular functions in healthy individuals. *Heart Views : The Official Journal of the Gulf Heart Association*, *12*(2), 58. https://doi.org/10.4103/1995-705X.86016

Birdee, G. S., Yeh, G. Y., Wayne, P. M., Phillips, R. S., Davis, R. B., & Gardiner, P. (2009). Clinical Applications of Yoga for the Pediatric Population: A Systematic Review. *Academic Pediatrics*, *9*(4), 212-220.e9. https://doi.org/10.1016/J.ACAP.2009.04.002

Brant, L. J., & Fozard, J. L. (1990). Age changes in pure-tone hearing thresholds in a longitudinal study of normal human aging. *The Journal of the Acoustical Society of America*, *88*(2), 813–820. https://doi.org/10.1121/1.399731

Carhart, R., & Jerger, J. F. (1959). Preferred method for clinical determination of pure-tone thresholds. *Journal of Speech and Hearing Disorders*, *24*(4), 330–345.

de Oliveira, G., Fernandes, M. da C. C. G., de Faria Oliveira, J. D., Rodrigues, M. R., & Santaella, D. F. (2016). Yoga training has positive effects on postural balance and its influence on activities of daily living in people with multiple sclerosis: a pilot study. *EXPLORE*, *12*(5), 325–332.

Dorn, P. A., Piskorski, P., Keefe, D. H., Neely, S. T., & Gorga, M. P. (1998). On the existence of an age/threshold/frequency interaction in distortion product otoacoustic emissions. *The Journal of the Acoustical Society of America*, *104*(2), 964–971. https://doi.org/10.1121/1.423339

Douglas Creelman, C. (1962). Human Discrimination of Auditory Duration. *Journal of the Acoustical Society of America*, *34*(5), 582–593. https://doi.org/10.1121/1.1918172

Dubno, J. R., Lee, F.-S., Matthews, L. J., Ahlstrom, J. B., Horwitz, A. R., & Mills, J. H. (2008). Longitudinal changes in speech recognition in older persons. *The Journal of the Acoustical Society of America*, *123*(1), 462–475. https://doi.org/10.1121/1.2817362

Fitzgibbons, P. J., & Gordon-Salant, S. (1994a). Age effects on measures of auditory duration discrimination. *Journal of Speech and Hearing Research*, *37*(3), 662–670. https://doi.org/10.1044/JSHR.3703.662

Fitzgibbons, P. J., & Gordon-Salant, S. (1994b). Age effects on measures of auditory duration discrimination. *Journal of Speech and Hearing Research*, *37*(3), 662–670. https://doi.org/10.1044/JSHR.3703.66

Fitzgibbons, P. J., & Gordon-Salant, S. (1996). Auditory temporal processing in elderly listeners. *JOURNAL-AMERICAN ACADEMY OF AUDIOLOGY*, *7*, 183–189.

Gauchard, G. C., Jeandel, C., & Perrin, P. P. (2001). Physical and sporting activities improve vestibular afferent usage and balance in elderly human subjects. *Gerontology*, *47*(5), 263–270.

Grassi, M., & Soranzo, A. (2009). MLP: a MATLAB toolbox for rapid and reliable auditory threshold estimation. *Behavior Research Methods*, *41*(1), 20–28.

Green, D. M. (1990). Stimulus selection in adaptive psychophysical procedures. *The Journal of the*Acoustical Society of America, 87(6), 2662–2674.

Green, D. M. (1993). A maximum-likelihood method for estimating thresholds in a yes–no task. *The Journal of the Acoustical Society of America*, *93*(4), 2096–2105.

Hariprasad, V. R., Koparde, V., Sivakumar, P. T., Varambally, S., Thirthalli, J., Varghese, M., … Gangadhar, B. N. (2013). Randomized clinical trial of yoga-based intervention in residents from elderly homes: Effects on cognitive function. *Indian Journal of Psychiatry*, *55*(Suppl 3), S357.

Harris, R. W., & Reitz, M. Lou. (1985). Effects of room reverberation and noise on speech discrimination by the elderly. *Audiology*, *24*(5), 319–324.

Humes, L. E., & Roberts, L. (1990). Speech-recognition difficulties of the hearing-impaired elderly: the contributions of audibility. *Journal of Speech and Hearing Research*, *33*(4), 726–735. https://doi.org/10.1044/JSHR.3304.726

Humes, L. E., Watson, B. U., Christensen, L. A., Cokely, C. G., Halling, D. C., & Lee, L. (1994). Factors associated with individual differences in clinical measures of speech recognition among the elderly. *Journal of Speech, Language, and Hearing Research*, *37*(2), 465–474.

Jayasinghe, S. R. (2004). Yoga in cardiac health (A Review). *Http://Dx.Doi.Org/10.1097/01.Hjr.0000206329.26038.Cc*, *11*(5), 369–375. https://doi.org/10.1097/01.HJR.0000206329.26038.CC

Kumar, S., Shambhu, T., & Prabhu, P. (2017). Effect of practicing yoga on functioning of efferent auditory system. *Indian Journal of Otology*, *23*(4), 230–232. https://doi.org/10.4103/INDIANJOTOL.INDIANJOTOL_87_17

Lonsburv-Martin, B. L., Cutler, W. M., & Martin, G. K. (1991). Evidence for the influence of aging on distortion-product otoacoustic emissions in humans. *The Journal of the Acoustical Society of America*, *89*(4 Pt 1), 1749–1759. https://doi.org/10.1121/1.401009

Lutman, M. E. (1991). Degradations in frequency and temporal resolution with age and their impact on speech identification. *Acta Oto-Laryngologica*, *111*(sup476), 120–126.

Malathi, A., & Parulkar, V. G. (1989). Effect of yogasanas on the visual and auditory reaction time. *Indian J Physiol Pharmacol*, *33*(2), 110–112.

Mayadevi 1979). *The development and standardization of a common speech discrimination task for Indians* (Unpublished master's dissartation) University of mysore,mysore,india

Moore, B. C. J. (1973). Frequency difference limens for short-duration tones. *The Journal of the Acoustical Society of America*, *54*(3), 610–619. https://doi.org/10.1121/1.1913640

Moore, G., Audrey, S., Barker, M., Bond, L., Bonell, C., Cooper, C., Hardeman, W., Moore, L., O'Cathain, A., Tinati, T., Wight, D., & Baird, J. (2014). Process evaluation in complex public health intervention studies: the need for guidance. *Journal of Epidemiology and Community Health*, *68*(2), 101–102. https://doi.org/10.1136/JECH-2013-202869

Pearson, J. D., Morrell, C. H., Gordon-Salant, S., Brant, L. J., Jeffrey Metter, E., Klein, L. L., & Fozard, J. L. (1995). Gender differences in a longitudinal study of age-associated hearing loss. *The Journal of the Acoustical Society of America*, *97*(2), 1196–1205. https://doi.org/10.1121/1.412231

Pilkington, K., Kirkwood, G., Rampes, H., & Richardson, J. (2005). Yoga for depression:the research evidence. *Journal of affective disorders*, *89*(1-3), 13-24.

Prado, E. T., Raso, V., Scharlach, R. C., & Kasse, C. A. (2014). Hatha yoga on body balance. *International Journal of Yoga*, *7*(2), 133.

Raub, J. A. (2002). Psychophysiologic effects of Hatha Yoga on musculoskeletal and cardiopulmonary function: a literature review. *The Journal of Alternative & Complementary Medicine*, *8*(6), 797–812.

Roland, K. P., Jakobi, J. M., & Jones, G. R. (2011). Does yoga engender fitness in olderadults? A critical review. *Journal of aging and physical activity*, *19*(1), 62-79.

Sarda, S., Bhat, S., & Vanaja, C. S. (2014). Variation in the gaze, caloric test and vestibular-evoked myogenic potential with advancing age. *Indian Journal of Otology*, *20*(1), 4.

Shambhu, T., Kumar, S. D., & Prabhu, P. (2017). Effect of practicing yoga on cervical vestibular evoked myogenic potential. *European Archives of Oto-Rhino-Laryngology*, *274*(10), 3811–3815.

Schroder, A. C., Viemeister, N. F., & Nelson, D. A. (1994). Intensity Discrimination In Normal-Hearing And Hearing-Impaired Listeners. *Journal of the Acoustical Society of America*, *96*(5), 2683–2693. https://doi.org/10.1121/1.411276

Sek, A., & Moore, B. C. J. (1995). Frequency discrimination as a function of frequency, measured in several ways. *Journal of the Acoustical Society of America*, *97*(4), 2479–2486. https://doi.org/10.1121/1.411968

Singh, N. K., Kashyap, R. S., Supreetha, L., & Sahana, V. (2014). Characterization of age-related changes in sacculocolic response parameters assessed by cervical vestibular evoked myogenic potentials. *European Archives of Oto-Rhino-Laryngology*, *271*(7), 1869–1877.

Telles, S., Deepeshwar, S., Naveen, K. V., & Pailoor, S. (2015). Long Latency Auditory Evoked Potentials during Meditation. *Clinical EEG and Neuroscience*, *46*(4), 299–309. https://doi.org/10.1177/1550059414544737

Telles, S., Joseph, C., Venkatesh, S., & Desiraju, T. (1993). Alterations of auditory middle latency evoked potentials during yogic consciously regulated breathing and attentive state of mind. *International Journal of Psychophysiology : Official*

Journal of the International Organization of Psychophysiology, *14*(3), 189–198. https://doi.org/10.1016/0167-8760(93)90033-L

Uebelacker, L. A., Epstein-Lubow, G., Gaudiano, B. A., Tremont, G., Battle, C. L., & Miller, I. W. (2010). Hatha yoga for depression: critical review of the evidence for efficacy, plausible mechanisms of action, and directions for future research. *Journal of Psychiatric Practice®*, *16*(1), 22–33.

Ülger, Ö., & Yağlı, N. V. (2011). Effects of yoga on balance and gait properties in women with musculoskeletal problems: a pilot study. *Complementary therapies in clinical practice*, *17*(1), 13-15.

Versfeld, N.J., & Dreschler, W. A. (2002). The relationship bwteen the intelligibility oftime- compressed speech and speech noise in young and elderly listeners. *Journal ofAcoustical Scociety of America.* 111, 401-408.

Voss, M. W., Weng, T. B., Burzynska, A. Z., Wong, C. N., Cooke, G. E., Clark, R., Fanning, J., Awick, E., Gothe, N. P., Olson, E. A., McAuley, E., & Kramer, A. F. (2016). Fitness, but not physical activity, is related to functional integrity of brain networks associated with aging. *NeuroImage*, *131*, 113–125. https://doi.org/10.1016/J.NEUROIMAGE.2015.10.044

Wier, C. C., Jesteadt, W., & Green, D. M. (1977). Frequency discrimination as a function of frequency and sensation level. *The Journal of the Acoustical Society of America*, *61*(1), 178–184. https://doi.org/10.1121/1.381251

Yathiraj, A., & Vijayalakshmi, C. (2005). Phonemicall balanced word identification testin Kannada. *Developed in the Department of Audiology, AIISH, Mysore*.

Zurek, P. M., & Delhorne, L. A. (1987). Consonant reception in noise by listeners with mild and moderate sensorineural hearing impairment. *The Journal of the Acoustical Society of America*, *82*(5), 1548–1559. https://doi.org/10.1121/1.395145

Zurek, P. M., & Formby, C. (1981). Frequency-discrimination ability of hearing-impaired listeners. *Journal of Speech and Hearing Research*, *24*(1), 108–112. https://doi.org/10.1044/JSHR.2401.108