EFFECT OF AGE AND GENDER ON AUDITORY STREAM SEGREGATION IN ADULTS WITH NORMAL HEARING SENSITIVITY

Swati Goyal

Register No: 18AUD039

This dissertation is submitted in part fulfilment for the degree of

Masters of Science (Audiology)

University of Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI, MYSORE 570006

July, 2020

CERTIFICATE

This is to certify that this dissertation entitled "**Evaluation of age and gender on stream segregation in adults with normal hearing sensitivity**" is a bonafide work submitted as a part for the fulfillment for the degree of Master of Science (Audiology) of the student with Registration Number: 18AUD039. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

July, 2020

Dr. M. Pushpavathi

Director

All India Institute of Speech and Hearing

Manasagangothri,

Mysore-570006

CERTIFICATE

This is to certify that this dissertation entitled "**Evaluation of age and gender on stream segregation in adults with normal hearing sensitivity**" has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

July, 2020

Guide

Dr. Prashanth Prabhu P.

Assistant Professor in Audiology,

Department of Audiology,

All India Institute of Speech and Hearing

Manasagangothri, Mysore-570006

DECLARATION

This is to certify that this dissertation entitled "**Evaluation of age and gender on stream segregation in adults with normal hearing sensitivity**" is the result of my own study under the guidance of Dr. Prashanth Prabhu P., Assistant Professor in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore **Registration No:18AUD039**

July 2020

Dedicated to my

Parents, family,

friends and

Prashanth sir

ACKNOWLEDGEMENT

First of all, I thank almighty for always showing me the right path & direction.

I would like to thank the director Prof. M. Pushpavathi for providing us with academic support and my gratitude toward HoD Audiology Dr Prawin Kumar for providing all the necessary instruments needed for my data collection.

I would like to thank my guide Dr. Prashanth Prabhu for guiding & encouraging me at each & every step of my dissertation. Sir, I had a great time working with you & I have learned so much from you. Not only in dissertation, but you have helped me starting from my first year of BASLP till date. I feel short of words to express my gratitude to you for always taking out time to clear my doubts, for always motivating me to work hard & do better in life. Your unbiased smile has always lifted my morale whenever I felt low. Sir I will miss you.

I thank all the participants who participated in this study.

I thank my parents, sister & my brother for always believing in me & supporting me in every phase of my life. I don't think I could have asked for anything better than what you all have always given to me. Your love & belief in me has always motivated me & brought me so far.

I want to thank Prajwal, who was always there by my side. You made me a better person, filled my life with happiness & positivity. Thank you for always believing in us & me when I had given up on everything. You are the best thing ever happened to me. I Love You.

I want to thank Neha di for providing all the necessary help.

I would like to thank my seniors Devika di, Varsha di & Sneha di.

I would also like to thank my friends Kristi,Riddhi, Divya, Rajwinder, Kranti, Neha, Shashirekha, and Shradha.

I thank my school friends Komal, Prerna, Aqvia & Shruti for always being by my side.

I would thank Rohit sir for helping me anytime.

I thank my juniors Vijayeshwari, Vibhuti, Lakshmi & Apoorva for always helping me & understanding me.

I express my sincere gratitude to all the JRFs especially Reesha ma'am for helping me.

I thank Ravi Sir for always helping me in technical issues.

I thank everyone who helped me directly or indirectly in completion of this dissertation & also in my journey at AIISH.

Abstract

The ability of central auditory nervous system to perceptually group the similar sounds and segregate different sounds is called as auditory stream segregation or auditory streaming or auditory scene analysis. One of the major cues in analyzing an auditory scene is spectral profiling. Identification of a change in spectral profile when amplitude of a component of complex tone is changed is referred as spectral profile analysis. It serves as an important part in auditory stream segregation as the spectra of sound source varies. Aging and gender affect the psychoacoustic tests. In the present study, six groups of participants were included. There were three age groups 21-30 years, 31-40 years and 41-50 years. Each age group had two subgroups, males and females. Profile Analysis was assessed using "mlp" tool box which implements a maximum likelihood procedure in MATLAB. It was assessed at four frequencies (250 Hz, 500 Hz, 750 Hz and 1000 Hz) for all groups. Amongst age groups, the results of the study indicate that the profile analysis threshold (at all four frequencies) was significantly better for youngest age group (21-30 years). It can be hypothesized that the difference in performance is because of the decline in attention span, working memory and cognitive abilities due to aging. Aging also seems to have affected the neural structure of the auditory system. When thresholds for males and females were compared, the results yielded better thresholds for males; however, the results were not significant. The differences in the thresholds of males and females can be attributed to hormonal and neuro-anatomical differences between males and females which have been known to affect the performance of psycho-acoustical tests.

TABLE OF CONTENTS

List of Tables

List of Figures

Chapter 1

Introduction

It is from early childhood; the human auditory system is encountered with sources of acoustic information that overlap with each other. The auditory system has an important function, which is to classify the sounds to their sources and creating representation coinciding with the real auditory environment (Sussman, Ceponiene, Shestakova, Näätänen, & Winkler, 2001). "The process by which successive sounds are perceptually grouped and separated from other competing sounds is known as auditory stream segregation, or auditory streaming" (Bregman, 1994). Auditory system groups sound which are similar to one another, and this grouping is called streaming. The grouping can be sequential or simultaneous. In the sequential grouping, the auditory system groups sound, which follows one another immediately in time. In the simultaneous grouping, simultaneous frequency components that come from a similar source are grouped together.

Auditory stream segregation reflects what is included and excluded from our perceptual descriptions of distinct auditory events. It is the variety of acoustic cues that separate sequential sounds into different streams, as shown behaviorally for adults (Bregman, 1990). There are many acoustic cues that are important for the perceptual organization of sequential sounds to separated sounds (Bregman, 1990).

When the fused sounds have the same acoustic properties, the sound is heard as the fused sound image is from a single source of the sound; whereas when these properties of sound penetrate a multidimensional acoustic space, the mixture of sounds appears to be originated from multiple sources. This process groups the sounds with acoustic properties into a common auditory stream that show coherence across time, within an ecologically valid set of temporal, spatial, spectral, and timbral characteristics of the sound. Segregation of auditory input to sources allows us to hear an individual speaker in a crowd, detect an approaching train, or distinguish between a male voice and a female voice at a cocktail party.

Multiple cues help to distinguish simultaneous auditory objects, as shown by psychophysical studies. It sounds which have different intensities, different periodicity, or different stimulus onset are more likely to be perceived as originating from different sound sources as compared to which have the same intensities, same periodicity, or same stimulus onset (Hartman, 1988). The bottom-up cues (acoustic data) and top-down cues (controlled processes) also play an important role in auditory stream segregation (Bregman, 1990). Spatial cues such as interaural level and time differences, acoustic cues such as common onset, or continuity also help in auditory stream segregation. Spatial cues often have such a weak influence on auditory grouping compared to acoustic cues (Shinn-Cunningham, 2005). Spectral profiling is another important cue that helps in auditory stream segregation.

Spectral profile analysis refers to the ability of listeners to detect variations in the shape of complex acoustic spectra. The task of the listener is to detect a variation in the spectral shape of a complex multi-component waveform. The spectra of sound sources are characterized by their pattern of intensity variation as a function of frequency, which plays an important role in auditory stream segregation. These spectral patterns often remain unaltered across changes in the level of output from the source. Therefore, spectral profile analysis uses the ability to process the spectral pattern or profile of the source output independent of the overall level.

In an experiment where spectrum was changed by changing the intensity of single components of a multi-tonal complex, and it changed the overall intensity of the complex from one presentation to the next which involved a comparison of the relative intensities of the components of the complex, and this comparison was called as 'profile analysis' (Spiegel et al., 1981; Spiegel and Green, 1982; Green and Kidd, 1983; Green, 1983). It has been demonstrated that intensity discrimination of a single component in a complex tone appears to be mediated by some form of profile analysis (Green & Kidd, 1983). At present, there are no studies that talk about profile analysis threshold across different age groups in males and females.

1.1. Need for the study

It will be of great importance if the profile analysis threshold is measured in adults of different age groups, which would determine if there is an age effect on auditory stream segregation. Also, it would be interesting to know if there is any effect of gender on auditory stream segregation abilities. Comparisons across age will highlight the differences, if any, in spectral profile analysis threshold across age groups in adults with normal hearing sensitivity. Also, several studies have documented gender differences in several psychoacoustic tests, such as binaural beat perception, localization, and masking (McFadden, 1998). It is well reported in the literature that males can localize sounds better compared to females, have a better ability to detect binaural beats, and have better ability to detect signals in complex masking tasks compared to females. Hearing sensitivity is better for females. At high frequencies, females are more susceptible to noise exposure. Females have shorter latencies for auditory brainstem responses, more spontaneous otoacoustic emissions (SOAE), and stronger click-evoked otoacoustic emissions than males (McFadden, 1998).

There is a dearth of literature that has been attempted to study the auditory stream segregation across age and gender. Thus, the current study focuses on examining the differences in spectral profile analysis threshold across gender (male and female) and different age groups. The study will also attempt to understand if there are any differences across the different characteristic frequencies between the groups and gender (male and female).

1.2 Aim of the study

To evaluate the effect of age and gender on auditory stream segregation through spectral profile analysis tests in adults with normal hearing sensitivity.

1.3 Objectives of the study

1. To compare the profile analysis threshold at different frequencies (250 Hz, 500 Hz, 750 Hz, and 1000 Hz) across the age groups.
2. To compare the profile analysis threshold at different frequencies (250 Hz, 500 Hz, 750 Hz, and 1000 Hz) between males and females.

1.4 Null hypotheses

1. There is no significant difference in the profile analysis threshold at different frequencies (250 Hz, 500 Hz, 750 Hz, and 1000 Hz) across the age groups.

2. There is no significant difference in the profile analysis threshold at different frequencies (250 Hz, 500 Hz, 750 Hz, and 1000 Hz) between males and females.

Chapter 2

Review of literature

The aim of the study is to evaluate the effect of age and gender on auditory stream segregation through spectral profile analysis tests in adults with normal hearing sensitivity. "The process by which successive sounds are perceptually grouped and separated from other competing sounds is known as auditory stream segregation or auditory streaming" (Bregman, 1994). Auditory stream segregation has been investigated in infants (McAdams and Bertoncini, 1997).

There are spectral and temporal cues that help in auditory stream segregation. The spectral cues which help in analyzing an auditory scene are Spectral Separation and Spectral Profiling. The temporal cues include Temporal Separation, Temporal Ordering, and Temporal Regularity.

2.1 Spectral profiling

One of the spectral cue which helps in auditory stream segregation, and that is spectral profiling. The measurement of spectral profiling is called a profile analysis threshold. It was changing the intensity of the single component in a multi-tonal complex changes the profile of the signal by changing the overall intensity. This change in intensity keeps varying from one presentation to the next. When an individual detects the change in intensity in that complex in comparison to the relative intensities of the other complexes, it gives a threshold and is called as profile analysis threshold (Spiegel et al., 1981; Spiegel and Green, 1982; Green and Kidd, 1983; Green, 1983).

2.2 Studies supporting age differences

Effect of age has been studied for temporal processing, differential limen of intensity, differential limen of frequency, speech in noise test, and many more. Konig (1957) concluded that the ability to detect small changes in pitch starts to deteriorate in the fourth decade of life. Differential limen (DL) for Fo has been found in two groups, younger adults and older adults, the younger adults had better DL for Fo, and it did not correlate significantly with pure tone average (Vongpaisal & Pichora-Fuller, 2007).

Age effects have been studied for speech conditions, and non-speech conditions were, for the speech conditions, three conditions were there, which included reverberant speech conditions, time-compressed conditions and combined effects of time-compressed and reverberant conditions. For the non-speech conditions, duration discrimination and discrimination of temporal order were assessed. Duration discrimination was assessed in simple and complex tones. The effect of aging was observed on performance for all the three speech conditions in the older group. The age effect was also seen in non-speech conditions, but the effect was more prominent for the complex tones (Gordon-Salant & Fitzgibbons, 1999).

A study was done by Baba & Rajalakshmi in 2006 to study the effect of age and hearing loss on Gap Detection Threshold. The study was done in three groups. Three groups consisted of two older and one younger adults where the groups of two older adults included normal and mild-moderate sensorineural hearing loss. For the younger adults, only a mild-moderate sensorineural hearing loss population was considered for the study. The effect of age was seen on the test of gap detection for both the ears, but the effect was more significant for the right ear. The aging effect was more for the normal population group as compared to the hearing loss group.

Effect of age was also studied on psychophysical measures where temporal processing was assessed using gap detection test, duration discrimination test, modulation detection test, and duration pattern test. Kumar and Sangamanatha (2011) studied 176 participants in the age range of 20-85 years. Except for the duration pattern test, for the other three tests, mlp toolbox was used. A duration pattern test was carried out using Audacity software. It was found out that deterioration for the tests except for the duration pattern test, started from the fourth decade of life where individuals up to 40 years of age performed better, and this deterioration accelerated further after 70 years of age. The scores for the duration pattern test started to decelerate in the sixth decade of life. For the modulation detection threshold, it was also concluded that the modulation detection threshold for lower frequencies started to decline later in life as compared to the higher modulation frequencies (Kumar and Sangamanatha, 2011).

Jain and Kumar (2016) studied the effect of age on frequency, intensity, and duration. The tests administered were: frequency difference limen, intensity difference limen, and gap detection threshold. A total of 210 participants were considered for the study where age-range varied from 10-85 years. For frequency difference limen, it was found that the deterioration starts after 40 years of age for 1 kHz and 4 kHz, but for 500 Hz, it started to deteriorate after50 years of age. It was noted that the deterioration of IDL begins after the 50 years of life for 500Hz,1kHz, 4kHz, and 2kHz it begins after the 6^{th} decade. Thresholds for gap detection test deteriorated rapidly after 60 years of age, and for individuals more than 70 years of age, more variability was seen in gap detection thresholds. Since previous studies report, age affects the different behavioral tests; the effect of age should also be studied on the profile analysis threshold.

2.3 Studies supporting gender differences

There are studies that have documented gender differences in several psychoacoustic tests, such as binaural beat perception, localization, and masking (McFadden, 1998). It is well reported in the literature that males can localize sounds better compared to females, have a better ability to detect binaural beats, and have better ability to detect signals in complex masking tasks compared to females. Hearing sensitivity is better for females. At high frequencies, females are more susceptible to noise exposure. Females have shorter latencies for auditory brainstem responses, more spontaneous otoacoustic emissions (SOAE), and stronger click-evoked otoacoustic emissions than males (McFadden, 1998).

As reported by Szymaszek, Szelag, and Sliwowska in 2006, temporal order thresholds were found for clicks and tones in young and elderly population for men and women. It was found that temporal order thresholds were lower for men than the women irrespective of the stimuli. Thresholds were lower for the young population compared to the elder subjects. It was also concluded that binaural processing deteriorates more than the monaural processing, and it was attributed to differences in functional hemispheric asymmetry.

2.4 Studies related to profile analysis threshold

Auditory profile analysis has been studied in different conditions, i.e., in single-tone and multi-tone conditions by Green and Mason in 1985, it was reported that threshold was better in multi-tone conditions compared to single tone condition. It was also found out that detection is easier in the mid-frequency range, i.e., around 1000Hz.

An experiment was done to check the effect of pitch randomization on the profile analysis threshold by Richards, Onsan, and Green (1988). Whenever pitch was changed, it also produced changes in the spectrum, which in turn changed the threshold. It was concluded that when pitch randomization was of moderate range, the threshold became 3 dB poorer compared to when there was no randomization, but when pitch randomizations were large range, then threshold changes were larger.

Banerjee and Prabhu (2019) assessed auditory stream segregation using profile analysis tests in normal-hearing population, cochlear pathology, and auditory neuropathy spectrum disorder population. The study consisted of three groups, and the age range varied from 15-45 years. The test was carried at 250 Hz, 500 Hz, 750 Hz, and 1000 Hz. The test was carried out using mlp (maximum likelihood procedure) toolbox. A significant difference was seen among the profile analysis threshold of the three groups. It was concluded that the profile analysis thresholds were best for the control group, followed by the cochlear pathology group, and it was most affected by the individuals with ANSD group. However, in all the three groups, across frequency, any difference was not reported. There are studies in the literature that report the effect of age and gender on behavioral tests. There are limited studies carried out in this area to evaluate auditory scene analysis. Hence, this study is designed to determine auditory stream segregation abilities by assessing spectral profiling in subjects with normal hearing sensitivity.

Chapter 3

Methods

The study was implemented with a cross-sectional design. The selection of participants was based on a purposive sampling technique.

3.1 Participants

Three age groups of participants were considered in the study. The age groups which were considered are 21-30 years, 31-40 years, and 41-50 years. In each group, a total of 40 participants were included, where 20 were males and 20 females. Group A represented the age group of 21-30 years, Group B represented 31-40 years, and Group C represented 41-50 years. Group A, B, and C were further subdivided into I and II, where I was for males and II was for females. So, there were a total of six groups: Group AI, Group AII, Group BI, Group BII, Group CI, and Group CII.

3.2 Inclusion Criteria of the Experimental groups

All the participants were selected randomly for the study. Any of the participants did not have a pure tone average (average of thresholds at 500 Hz, 1 kHz, 2 kHz, and 4 kHz) of more than 25 dB HL. The individuals who reported any middle ear pathology were excluded from the study. All the participants had no history of otological complaints, noise exposure, ototoxic medications, diabetes/hypertension. The participants were not exposed to any training. The hearing assessment was done based on the conventional audiological evaluation, as described below.

3.3. Test environment

All the audiological tests were done in an anechoic room that met the specifications of ANSI S3.1-1999 (R2013). Also, the test room had optimum temperature and lighting and was free of distractions. Tests were done using non-invasive procedures and were approved by the ethical approval committee of the institute. All the participants were informed about the objectives and procedures of the study prior, and informed consent was obtained from each of them. The instruments used in the study comprised an audiometer, an immittance meter, an otoscope, and a personal computer (PC) installed with MATLAB software.

3.4 Procedure

3.4.1. Participant selection.

Participants were selected based on detailed case history, otoscopic examination, audiological evaluation (pure tone and speech audiometry), and tympanometry.

- ✓ The detailed case history was taken as an interview regarding the presence of ear pain, ear discharge, blocking sensation, tinnitus, symptoms related to vestibular disorders, also exposure to agents which are harmful to hearing, such as ototoxic drugs, occupational or leisure noise and general health conditions.
- ✓ Otoscopic evaluation preceded the audiological evaluation. It was done to visually inspect the status of the ear canal and tympanic membrane.
- ✓ Modified Hughson-Westlake procedure (Carhart & Jerger, 1959) was used to obtain pure-tone air conduction and bone-conduction thresholds. Thresholds were found at octave frequencies between 250-8000 Hz and 250-4000 Hz, respectively.

- ✓ Paired-words in Kannada developed at the Department of Audiology, AIISH, Mysuru were used to measure speech recognition thresholds (SRT). The presentation level was set at 20 dB SL (ref: PTA), and the intensity level was decreased until two out of three paired words were accurately repeated. This was used as a reference for the supra-threshold speech test.
- ✓ Speech identification scores (SIS) were obtained using phonetically balanced (PB) words in Kannada developed at the Department of Audiology, AIISH, Mysuru. The presentation level was set at 40 dB SL (ref: SRT). Twenty-five words were presented to each ear. The responses were calculated in percentage with 4% for each correct response.
- ✓ Tympanometry was done, and the probe tone was kept at 226 Hz using a calibrated middle ear analyzer to assess middle ear function. Acoustic Reflex thresholds were determined at 500 Hz, 1 kHz, 2 kHz, and 4 kHz, both ipsilaterally and contralaterally.

3.4.2 Assessment of auditory stream segregation

Spectral profiling was assessed using the "MLP" toolbox, which implements a maximum likelihood procedure in MATLAB (Soranzo & Grassi, 2014). From the MLP toolbox, the Profile Analysis Test was used to find out the thresholds. The test was conducted at four frequencies 250 Hz, 500 Hz, 750 Hz, and 1 kHz. A complex tone with five harmonics with the above mentioned fundamental frequencies was used where the amplitude of the third harmonic was varied adaptively, and the participant's task was to identify the sound with odd timbre in a three alternate forced-choice (3AFC) paradigm. The threshold for profile analysis was recorded in dB. The thresholds were calculated as the average of the last four reversals. All the stimuli were presented through personal computer routed through audiometer, equipped with TDH 39 circum-aural headphones, at 40 dB SL (ref SRT). The complete testing was carried out in anechoic double room setup.

3.5. Statistical Analyses

The data were analyzed using Statistical Package for Social Sciences (SPSS) software. Shapiro Wilks test of normality was performed to determine whether the data were normally distributed or not.

CHAPTER 4

Results and Discussion

The aim of the study was to evaluate the effect of age and gender on auditory stream segregation through spectral profile analysis test in adults of different age groups with normal hearing sensitivity.

The present study consisted of six groups. This study consisted of 120 participants, which included three age groups, and in each age group, two sub-groups which consisted of males and females. The data obtained were analyzed using the statistical package of social science (SPSS) software version 20.0.

Shapiro Wilks test of normality was done to check whether further tests are required to be parametric or non-parametric. It has been found that the data follows the non- normal distribution ($p \leq 0.05$). Since the data was observed to be non-normal, therefore non-parametric tests were used to perform inferential statistics. The results of the study are described under the following headings:

4.1 Age effect:

4.1.1 Descriptive statistics of profile analysis threshold across the frequencies for individuals in each age group

4.1.2 Comparison of profile analysis threshold across age for all the four test frequencies

4.2. Gender effect:

4.2.1 Descriptive statistics of profile analysis threshold across the frequencies in each age group for males and females

4.2.2 Comparison of profile analysis threshold in all the three age groups across all the frequencies for males and females

4.1 Age effect

4.1.1 Descriptive statistics of profile analysis threshold across the frequencies for individuals in each age group

The mean, median, and standard deviation (SD) of profile analysis threshold for individuals in each age group at various frequencies is shown in table 4.1 and figure 4.1.

The results of descriptive statistics showed similar scores across the frequencies in the age group 21-30 years and 31-40 years. However, there was a slight difference in the scores in the age group of 41-50 years when 250 Hz and 500 Hz thresholds were compared with 750 Hz and 1000 Hz.

Table 4.1

Mean, Median and Standard Deviation for individuals in each different age group

Frequency		21-30	31-40	41-50
	Mean	-57.80	-43.35	-38.58
250 Hz	SD	7.12	8.95	9.98
	Median	-56.42	-39.62	-32.42
	Mean	-56.20	-42.08	-35.41
500 Hz	SD	5.05	3.17	5.21
	Median	-54.22	-41.22	-32.82
	Mean	-56.52	-47.85	-41.96
750 Hz	SD	2.26	5.11	5.18
	Median	-51.22	-41.22	-34.02
	Mean	-57.38	-49.15	-46.12
1000 Hz	SD	9.52	3.53	6.79
	Median	-56.02	-47.02	-39.02

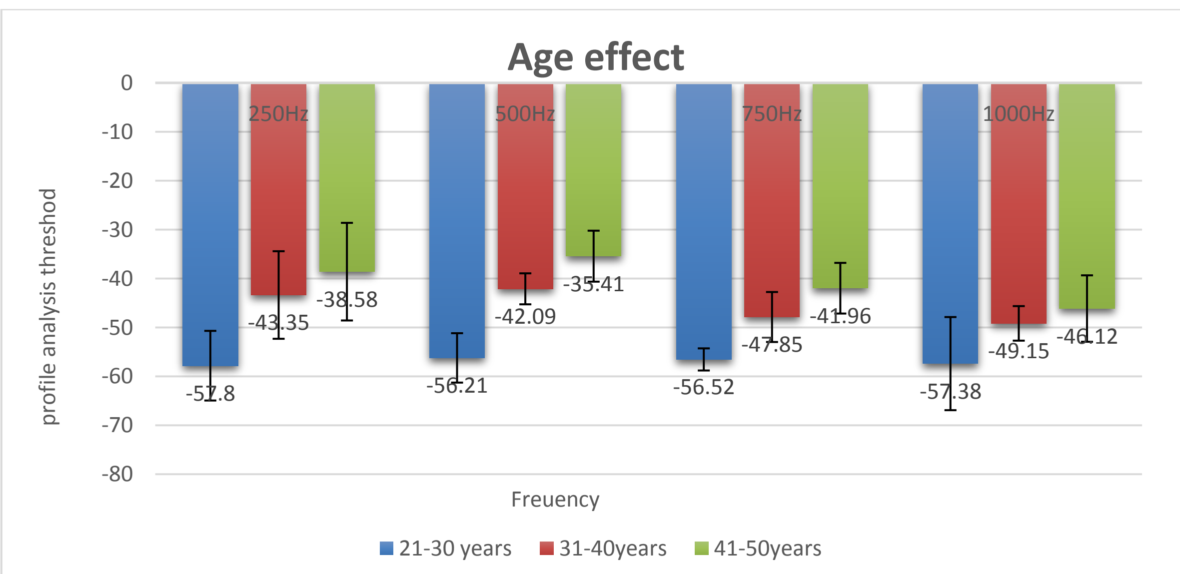

Figure 4.1 Mean and standard deviation of profile analysis threshold for individuals in each age group

4.1.2 Comparison of profile analysis threshold across the frequencies for individuals in each age group

Kruskal Wallis H tests were done to compare the profile analysis thresholds across age groups for all the four test frequencies. The results of the Kruskal Wallis H test are shown in table 4.2.

Table 4.2

Results of Kruskal Wallis H test comparing profile analysis threshold among the three age groups across frequencies

Frequencies	Chi-square	Degrees of freedom	Significance Value
250 Hz	8.9	2	.012
500 Hz	10.18	2	.006
750 Hz	2.29	2	.317
1000 Hz	2.77	2	.249

Since, there was significant difference ($p<0.05$) in Kruskal Wallis H test for 250 Hz and 500 Hz, Mann Whitney U tests were done to compare profile analysis thresholds between the groups separately. The results of Mann Whitney U tests are shown in table 4.3. The results show that the profile analysis threshold was significantly better ($p<0.05$) for age group 21-30 years compared to those who were in the age group of 31-40 years and when 41-50 years at 250 Hz and 500 Hz. There was no significant difference in profile analysis threshold ($p>0.05$) for all the frequencies when it was compared between the age group of 31-40 years and 41-50 years.

Table 4.3

Results of Mann Whitney U tests comparing two groups for all the four frequencies

	z		p	
Groups	**250 Hz**	**500 Hz**	**250 Hz**	**500 Hz**
21-30 Vs 31-40	-2.78	-2.95	.005	.003
31-40 Vs 41-50	-.74	-.68	.456	.494
21-30 Vs 41-50	-2.25	-2.34	.024	.019

4.2 Gender effect

4.2.1 Descriptive statistics of profile analysis threshold across the frequencies in each age group for males and females

The mean, median, and standard deviation of the profile analysis threshold are shown in Table 4.4 across the frequencies in each age group for males and females. The mean and standard deviation of the profile analysis threshold in the age group of 21-30 years across frequencies for both genders has been shown in Figure. 4.2. The mean profile analysis threshold in the age group 31-40 years across frequencies for both genders has been shown in Figure. 4.3. The mean profile analysis threshold in the age group 41-50 years across frequencies for both genders has been shown in Figure. 4.4. The results of the descriptive statistics show that the scores were slightly better for males compared to females.

Table 4.4

Mean, Median and Standard Deviation of profile analysis threshold in each age group for males and females.

		250		500		750		1000	
		M	**F**	**M**	**F**	**M**	**F**	**M**	**F**
21-30	**Mean**	-59.53	-53.55	-57.27	-54.78	-52.02	-48.02	-53.09	-49.09
	SD	9.43	6.55	6.41	4.55	5.29	8.25	4.35	9.08
	Median	-54.42	-49.62	-55.22	-48.32	-54.02	-44.42	-47.62	-42.42
31-40	**Mean**	-59.92	-54.51	-57.97	-53.20	-54.24	-49.51	-56.04	-49.08
	SD	2.71	7.95	5.35	5.66	8.83	5.09	8.61	2.88
	Median	-54.02	-59.62	-59.62	-54.42	-54.12	-52.82	-50.32	-47.32
41-50	**Mean**	-48.53	-43.17	-46.35	-44.82	-45.49	-43.43	-48.92	-42.32
	SD	9.35	7.04	7.03	2.36	6.36	4.80	7.26	7.48
	Median	-48.62	-41.62	-41.22	-42.42	-48.36	-42.82	-41.72	-46.82

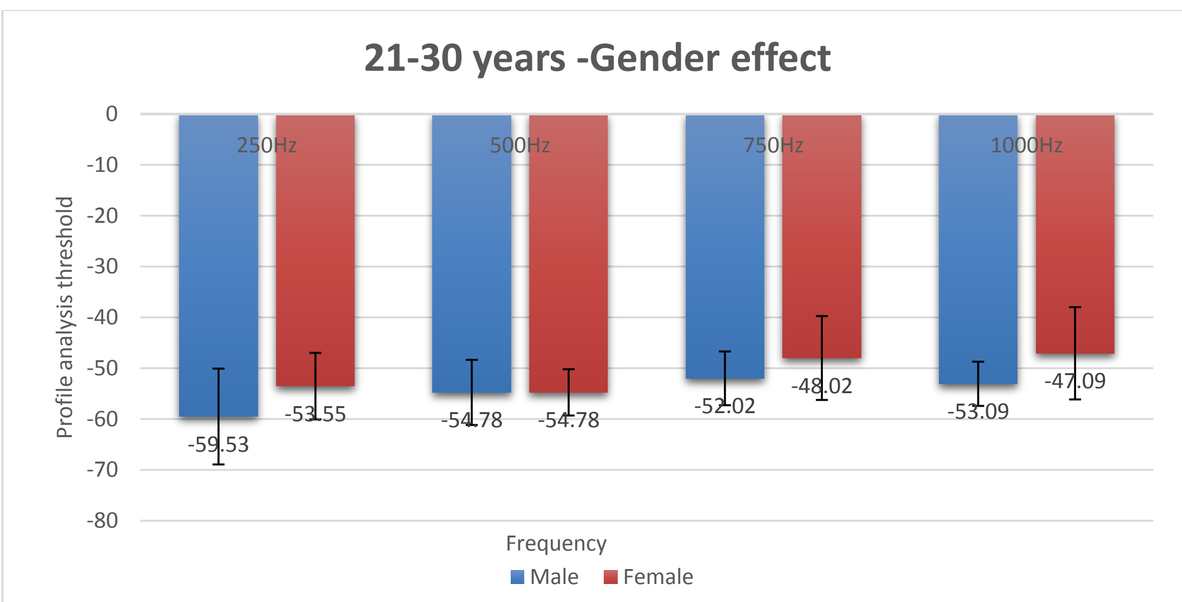

Figure 4.2 Mean and standard deviation of profile analysis threshold for individuals in age group 21-30 years in both the genders.

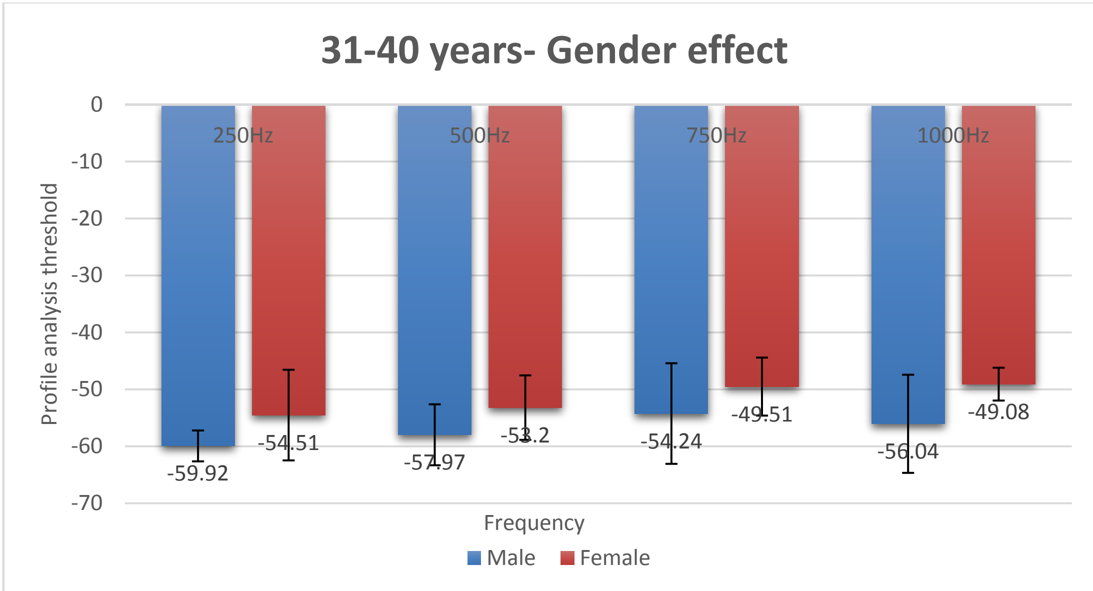

Figure4.3 Mean and standard deviation of profile analysis threshold for individuals in age group 31-40 years in both the genders

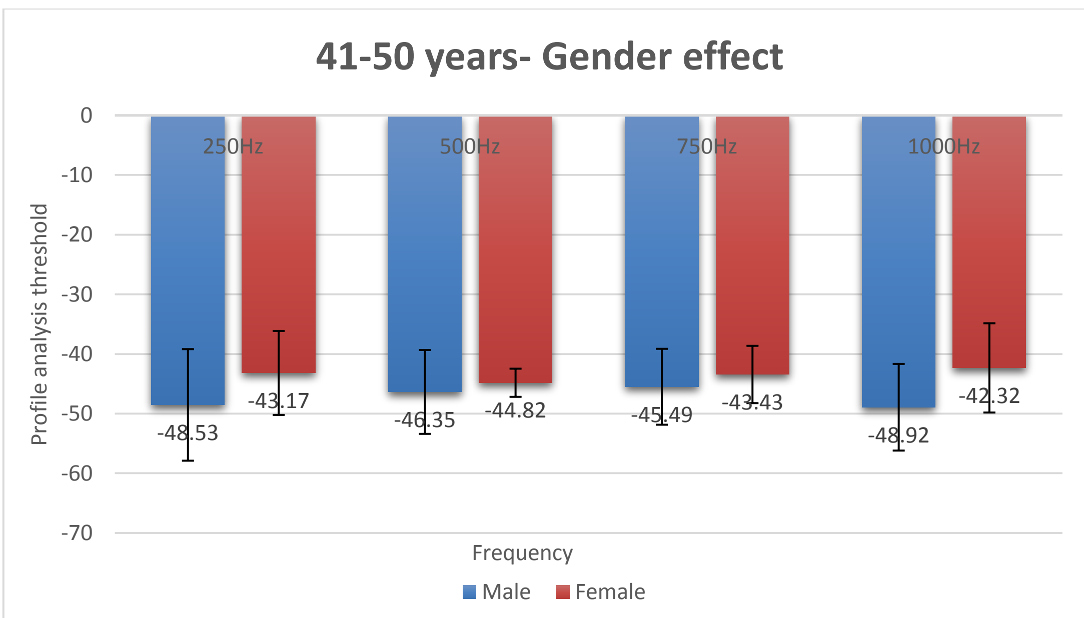

Figure 4.4 Mean and standard deviation of profile analysis threshold for individuals in age group 41-50 years in both the genders

4.2.2 Comparison of profile analysis threshold in all the three age groups across all the frequencies for males and females

Mann Whitney U tests were done to compare the profile analysis threshold across frequencies for males and females. The results of Mann Whitney U tests are shown in table 4.5. As shown in the table, there was no significant difference between males and females for all the frequencies.

Table 4.5

Results of Mann Whitney U test comparing profile analysis threshold between the males and females across frequencies

	U	**Z**	**p**
250 Hz	719.50	-1.76	.07
500 Hz	863.00	-.533	.09
750 Hz	709.50	-1.85	.06
1000 Hz	624.50	-1.91	.06

Mann Whitney U tests were done to compare the profile analysis threshold across frequencies for males and females in the age group of 21-30 years. The results of Mann Whitney U tests are shown in Table 4.6. As shown in the table, there was no significant difference between males and females for all the frequencies.

Table 4.6

Results of Mann Whitney U test comparing profile analysis threshold between males and females for the age group of 21-30 years

	U	Z	p
F250	133.50	-0.54	.95
F500	119.50	-0.56	.57
F750	94.00	-1.94	.06
F1000	123.50	-1.03	.08

Mann Whitney U tests were done to compare the profile analysis threshold across frequencies for males and females in the age group of 31-40 years. The results of Mann Whitney U tests are shown in Table 4.7. As shown in the table, there was no significant difference between males and females for all the frequencies.

Table 4.7

Results of Mann Whitney U test comparing profile analysis threshold between the males and females for the age range 31-40 years

	U	Z	p
F250	71.00	-4.60	0.64
F500	53.00	-1.37	0.16
F750	74.00	-0.30	0.75
F1000	73.50	-0.33	0.74

Mann Whitney U tests were done to compare the profile analysis threshold across frequencies for males and females in the age group of 31-40 years. The results of

Mann Whitney U tests are shown in Table 4.8. As shown in the table, there was no significant difference between males and females for all the frequencies.

Table 4.8

Results of Mann Whitney U test comparing profile analysis threshold between the males and females for the age range 41-50 years

	U	**Z**	**p**
F250	67.00	-0.96	0.18
F500	61.50	-1.16	0.24
F750	67.00	-0.87	0.38
F1000	53.50	-1.02	0.09

The purpose of the study was to evaluate the effect of age and gender on auditory stream segregation through profile analysis threshold. Investigations in the past have shown the effect of age on various psycho-acoustical tests (Fitzgibbons, 1995; Kumar & Sangamanatha, 2011). Few studies have reported an effect on gender (Szymaszek, Szelag & Sliwoska, 2006) as well. None of the investigations has been done to evaluate the effect of age and gender on spectral profiling.

Spectral profiling is one of the important spectral cues in analyzing auditory scene (Speigel and Green, 1982; Green et al., 1983). Failure to analyze an auditory scene efficiently can result in inadequate communication. There are no studies that report about the effect of age on spectral cues through psychophysical tests. However, there are many investigations that are done to see the effect of age on temporal processing. Psychophysical tests get affected due to the aging effect (Jain & Kumar, 2016) and hearing loss (Bertoli, Smurzynski & Probst, 2005). Hence, it was ensured that the thresholds of any of the participants do not exceed 25 dB HL at any frequency among 250 Hz, 500 Hz, 1 kHz, 2 kHz, and 4 kHz to eliminate the effects of hearing loss.

The thresholds of profile analysis test in each age group showed a significant difference for 250 Hz and 500 Hz. Statistical tests revealed a significant difference between 21-30 years age group and 31-40 years age group and 21-30 years age group and 41-50 years age group for the frequencies, 250 Hz and 500 Hz. These results suggest that the stream segregation was better for the 21-30 years age group compared to the other age groups. The results are consistent with the literature, which also reports poorer performance on psycho-acoustical tests with the advancement in age.

Kumar and Sangamanatha (2011) reported that thresholds for gap detection tests start deteriorating in the fourth decade, and the finding was consistent with other studies. Barsz et al. (1996) reported that gap detection thresholds become poorer with increasing age. As the age advances, there is also increased difficulty in discriminating complex communication signals (Gordon-Salant and Fitzgibbons, 1993; Frisina and Frisina, 1997; Gordon-Salant and Fitzgibbons, 2001; Hamann et al., 2004; He et al., 2007). It has been concluded that, in animals, loss of tonic inhibition resulted in an increase in neural noise, which affects the central auditory process (Caspary, Ling, Turner & Hughes, 2008). The best performance on auditory stream segregation in the 21-30 years age group can be attributed to the changes in the neural structures of the auditory system.

The present study shows no significant difference between males and females. However, males performed slightly better than the females. The differences in the performance between males and females can be attributed to hormonal changes in females during menstruation and pregnancy. There are hormonal changes for females due to the menstrual cycle and menopause. Oestrogen and progesterone are female ovarian hormones. The hormonal changes affect auditory processing (Yoder & Vicerio, 2012) and cognitive function (Farrar, Neill, Scally, Tuffnell & Marshall, 2015). It has been reported in the literature that males and females, the process sounds differently, where it was concluded that males perform better for the psychoacoustic tests (McFadden, 1998). There are studies that show that brain structure changes during the menstrual cycle due to the hormonal changes (Hagemann et al., 2011). Brain neuroanatomy has gender differences, which may lead to a difference in cognitive performance between males and females (Gur et al., 1999). Working memory tasks are performed better when the estrogen levels are high as compared to low levels of estrogen (Segal, 2012). It has been reported that the hormonal changes in the females affect the psycho-acoustical tests, namely, duration discrimination test, gap detection test, modulation detection test (Sao & Jain, 2016). During pregnancy, slow vertex response waves are delayed, which led to the conclusion that auditory processing is slow during pregnancy and it was attributed to the increased levels of estrogen and progesterone (Yadav, Tandon & Vaney, 2003). Hence, it can be concluded that males have performed slightly better than females due to the hormonal and neural structural changes over a period of time. However, the difference was not statistically significant to affect the test results.

Thus, the result of the study shows that age affects the auditory stream segregation abilities. The younger age group (21-30 years) performed significantly better compared to individuals with older age groups. However, there was no significant effect of gender on auditory stream segregation abilities. Hence, age is a factor that affects stream segregation, and gender is not a major factor that affects the test results. The effect of age can be further explored by including more age groups. Furthermore, the effect of age and gender can be explored on other spectral cues, which are important for stream segregation since there are limited studies on spectral cues.

CHAPTER 5

Summary and Conclusions

The ability of the central auditory nervous system to perceptually group the similar sounds and segregate different sounds is called auditory stream segregation or auditory streaming or auditory scene analysis (Bregman, 1994). Spectral and temporal cues that are inherent in a signal play an important role in analyzing an auditory scene. One of the major cues among the various spectral cues is spectral profiling. Identification of a change in spectral profile when the amplitude of a component of complex tone is changed is referred to as Spectral profile analysis. However, there are no studies to see the effect of age and gender in spectral profile analysis. The aim of the study was to evaluate the effect of age and gender in spectral profile analysis across frequencies.

Participants were divided into six groups in this study. There were three age groups 21-30 years, 31-40 years, and 41-50 years, and in each age group, males and females formed a separate group. Each group had 20 participants. All the participants had hearing thresholds $\leq$ 25 dB HL. For all the participants, the stimulus was presented at 40 dB SL. Spectral profiling was assessed using the "MLP" toolbox, which implements a maximum likelihood procedure in MATLAB (Soranzo & Grassi, 2014). Spectral profile analysis was done at four frequencies, 250 Hz, 500 Hz, 750 Hz, and 1000 Hz. The stimuli were presented via audiometer through the computer using circum-aural headphones.

Kruskal Wallis H test was done to see the effect of age across frequencies, and a significant difference was found to be present at 250 Hz and 500 Hz. Kruskal Wallis H test was followed by the Mann Whitney U test to evaluate the difference between age groups, which showed that the age group 21-30 years performed significantly better than the other two age groups. Results of the Mann Whitney U test, when done for the gender, showed that there is no significant difference between males and females. However, males performed slightly better than females.

On aging, there is a decline in attention span, working memory, and cognitive abilities. Aging also affects the neural structure of the auditory system, which in turn affects the system functionally as well. As age increases, there is a loss of tonic inhibition, which increases neural noise and, in turn, affects the central auditory process (Caspary, Ling, Turner & Hughes, 2008). It is well known that neural functioning plays an important role in auditory stream segregation. Also, there are many differences between males and females. Females have hormonal differences periodically due to menstruation and pregnancy. During menstruation and pregnancy, there is a surge in estrogen and progesterone hormone in females. These hormones have been known to affect the performance of psycho-acoustical tests in females (Sao & Jain, 2016). Also, the brain has neuroanatomical differences in males and females (Gur et al., 1999). Therefore, it is possible that the age groups 21-30 years have yielded significantly better thresholds, and males have performed better than females.

5.1 Implications of the study

- The study will help in a better understanding of auditory stream segregation abilities for normal hearing adults across different age groups.
- It can help us to understand if there are any gender differences in the spectral profile analysis threshold.
- The results can help counselling and a better understanding of auditory stream segregation.

5.2 Future directions

- To study the effect of other spectral and temporal cues on auditory stream segregation in individuals with normal hearing and clinical populations.
- To study the profile analysis abilities in children and older population

5.3 Limitations of the study

- The sample size considered for the study is less.
- Correlation of auditory stream segregation deficits with quality of life could have been done.

References

Banerjee, N. (2019) Evaluation of auditory stream segregation in individuals with cochlear pathology and auditory neuropathy spectrum disorder [Unpublished master's dissertation]. University of Mysore.

Barsz, K., Ison, J. R., Snell, K. B., & Walton, J. P. (2002). Behavioral and neural measures of auditory temporal acuity in aging humans and mice. *Neurobiology of aging*, *23*(4), 565-578.

Bertoli, S., Smurzynski, J., & Probst, R. (2005). Effects of age, age-related hearing loss, and contralateral cafeteria noise on the discrimination of small frequency changes: psychoacoustic and electrophysiological measures. *Journal of the Association for Research in Otolaryngology*, *6*(3), 207-222.

Bregman, A. S. (1990). Auditory scene analysis: The perceptual organization of sound. Cambridge, MA, US.

Bregman, A. S. (1994). *Auditory scene analysis: The perceptual organization of sound*. MIT press.

Carhart, R., & Jerger, J. (1959). Preferred method for clinical determination of pure-tone thresholds. *Journal of Speech & Hearing Disorders*, *24*(4), 330- 346.

Caspary, D. M., Ling, L., Turner, J. G., & Hughes, L. F. (2008). Inhibitory neurotransmission, plasticity and aging in the mammalian central auditory system. *Journal of Experimental Biology*, *211*(11), 1781-1791.

Jain, C. (2016) Relationship among psychophysical abilities, speech perception in noise and working memory on individuals with normal hearing sensitivity across different age groups [Doctoral thesis, All India Institute of Speech and Hearing].

D.B, Fakruddin. (2006) Effect of age and hearing loss in gap detection threshold [Unpublished master's dissertation]. University of Mysore.

Farrar, D., Neill, J., Scally, A., Tuffnell, D., & Marshall, K. (2015). Is objective and accurate cognitive assessment across the menstrual cycle possible? A feasibility study. *SAGE open medicine*, *3*, 2050312114565198.

Fitzgibbons, P. J., & Gordon-Salant, S. (1995). Age effects on duration discrimination with simple and complex stimuli. *The Journal of the Acoustical Society of America*, *98*(6), 3140-3145.

Frisina, D. R., & Frisina, R. D. (1997). Speech recognition in noise and presbycusis: relations to possible neural mechanisms. *Hearing research*, *106*(1-2), 95-104.

Gordon-Salant, S. (2001). Sources of age-related recognition difficulty for time-compressed speech. *Journal of Speech, Language, and Hearing Research*.

Gordon-Salant, S., & Fitzgibbons, P. J. (1993). Temporal factors and speech recognition performance in young and elderly listeners. *Journal of Speech, Language, and Hearing Research*, *36*(6), 1276-1285.

Gordon-Salant, S., & Fitzgibbons, P. J. (1999). Profile of auditory temporal processing in older listeners. *Journal of Speech, Language, and Hearing Research*, *42*(2), 300-311.

Green, D. M. (1983). Profile analysis: A different view of auditory intensity discrimination. *American Psychologist*, *38*(2), 133.

Green, D. M., & Kidd Jr, G. (1983). Further studies of auditory profile analysis. *The Journal of the Acoustical Society of America*, *73*(4), 1260-1265.

Green, D. M., & Mason, C. R. (1985). Auditory profile analysis: Frequency, phase, and Weber's Law. *The Journal of the Acoustical Society of America*, *77*(3), 1155-1161.

Gur, R. C., Turetsky, B. I., Matsui, M., Yan, M., Bilker, W., Hughett, P., & Gur, R. E. (1999). Sex differences in brain gray and white matter in healthy young adults: correlations with cognitive performance. *Journal of Neuroscience*, *19*(10), 4065-4072.

Hagemann, G., Ugur, T., Schleussner, E., Mentzel, H. J., Fitzek, C., Witte, O. W., & Gaser, C. (2011). Changes in brain size during the menstrual cycle. *PloS one*, *6*(2), e14655.

Hamann, I., Gleich, O., Klump, G. M., Kittel, M. C., & Strutz, J. (2004). Age-dependent changes of gap detection in the Mongolian gerbil (Meriones unguiculatus). *Journal of the Association for Research in Otolaryngology*, *5*(1), 49-57.

Hartmann, W. M. (1988). Pitch perception and the segregation and integration of auditory entities. *Aiditory Function, Neurobiological Bases of Hearing*, 623-645.

He, N. J., Mills, J. H., & Dubno, J. R. (2007). Frequency modulation detection: effects of age, psychophysical method, and modulation waveform. *The Journal of the Acoustical Society of America*, *122*(1), 467-477.

König, E. (1957). Pitch discrimination and age. *Acta oto-laryngologica*, *48*(5-6), 475-489.

Kumar U, A., & AV, S. (2011). Temporal processing abilities across different age groups. *Journal of the American Academy of Audiology*, *22*(1), 5-12.

McAdams, S., & Bertoncini, J. (1997). Organization and discrimination of repeating sound sequences by newborn infants. *The Journal of the Acoustical Society of America*, *102*(5), 2945-2953.

McFadden, D. (1998). Sex differences in the auditory system. *Developmental Neuropsychology*, *14*(2-3), 261-298.

Richards, V. M., Onsan, Z. A., & Green, D. M. (1989). Auditory profile analysis: Potential pitch cues. *Hearing research*, *39*(1-2), 27-36.

Sao, T., & Jain, C. (2016). Effects of hormonal changes in temporal perception, speech perception in noise and auditory working memory in females. *Hearing, Balance and Communication*, *14*(2), 94-100.

Segal, M. (2012). Effect of menstrual cycle related estrogen fluctuations on working memory.

Shinn-Cunningham, B. G. (2005, August). Influences of spatial cues on grouping and understanding sound. In *Proceedings of the Forum Acusticum* (Vol. 29). Hungary: Budapest.

Soranzo, A., & Grassi, M. (2014). Psychoacoustics: a comprehensive MATLAB toolbox for auditory testing. *Frontiers in Psychology*, *5*, 712.

Spiegel, M. F., & Green, D. M. (1982). Signal and masker uncertainty with noise maskers of varying duration, bandwidth, and center frequency. *The Journal of the Acoustical Society of America*, *71*(5), 1204-1210.

Spiegel, M. F., Picardi, M. C., & Green, D. M. (1981). Signal and masker uncertainty in intensity discrimination. *The Journal of the Acoustical Society of America*, *70*(4), 1015-1019.

Sussman, E., Ceponiene, R., Shestakova, A., Näätänen, R., & Winkler, I. (2001). Auditory stream segregation processes operate similarly in school-aged children and adults. *Hearing Research*, *153*(1-2), 108-114.

Szymaszek, A., Szelag, E., & Sliwowska, M. (2006). Auditory perception of temporal order in humans: The effect of age, gender, listener practice and stimulus presentation mode. *Neuroscience Letters*, *403*(1-2), 190-194.

Vongpaisal, T., & Pichora-Fuller, M. K. (2007). Effect of age on F0 difference limen and concurrent vowel identification. *Journal of Speech, Language, and Hearing Research*.

Yadav, A. S. H. A., Tandon, O. P., & Vaney, N. E. E. L. A. M. (2003). Mid latency and slow vertex responses during pregnancy. *Indian journal of physiology and pharmacology*, *47*, 423-428.

Yoder, K. M., & Vicario, D. S. (2012). To modulate and be modulated: estrogenic influences on auditory processing of communication signals within a socio-neuro-endocrine framework. *Behavioral neuroscience*, *126*(1), 17.