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Effect of Aging on Auditory Temporal Perception

Krishnapriya K.G., MASLP
Dr. Binoy Shany M.S., Ph.D.

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Introduction

Hearing being one of the most important abilities of human beings, its reduced sensitivity creates adverse effects on health and quality of life (Prates & Iorio, 2006). Aging is a natural consequence of the developmental process. Of all the changes in the senses that occur with age, deterioration in hearing is the most expected and the most accepted decline.

Aging can cause anatomical and physiological alternations in the auditory system. With aging, there is a decrease in the number of neurons in the cochlear nuclei and auditory centers of the brain. There is also a reduction in the size of cells and changes in the neurochemical makeup of the cells (Chisolm, Willott & Lister, 2003). This is associated with a reduction in the ability of the central auditory system to process sound (Pichora-Fuller & Souza, 2003).

Effect of Aging on the Auditory Temporal Processing

The effect of aging on the auditory system typically results in a bilateral symmetric sensorineural hearing loss in the frequencies above 2000 Hz. Conversation is not disturbed initially because the frequencies affected are above those of speech (500 to 2000 Hz). When the upper speech frequencies become involved, the person has increasing difficulty discriminating consonants in words and problems with understanding speech. As overall speech discrimination begins to be unsuccessful, the conversation becomes more and more difficult for the individual, especially within a group situation.

The ability to disregard competing speech becomes impaired as the age increases so for older individuals maintaining communication requires increasingly greater effort and energy (Babin, 1985). Changes in the auditory system can negatively affect different auditory processing skills. Auditory temporal processing is defined as the perception of the temporal envelope or the alteration of durational characteristics of a sound within a restricted or defined time interval (Musiek, Shinn, Jirsa, Bamiou, Baran & Zaida, 2005). Temporal processing is one of the components of auditory processing describing the processing of time-related changes of auditory information. Temporal processing abilities help in perceiving the signal which changes over time. Other auditory skills of temporal processing are temporal integration, temporal sequencing, temporal masking, and temporal resolution (American Speech-Language and Hearing Association, 1996). These skills are particularly crucial for phonemic distinction, lexical and prosodic distinctions and auditory closure (Chermak & Musiek, 1997).

Temporal Resolution

Temporal cues in the incoming signals are important for speech perception (Amaral & Colella – Santos, 2010; Price & Simon, 1984). Temporal processing deficits are well documented in age-related hearing loss (Glasberg & Moore, 1989; Irwin & Mc Auley, 1987). Most of the studies reported that temporal resolution skills decline before the age of 60 years even in individuals with normal hearing sensitivity (Grose, Hall, & Buss, 2006; Grose & Mamo, 2010; Helfer & Vargo, 2009). According to Kumar (2011), found that deterioration in temporal processing begins after the fourth decade of life and it is accelerated after 70 years of age which may be the reason for the difficulty in understanding speech in a noisy situation in elders.

Temporal resolution is the shortest time period over which the ear can discriminate two signals, or it is the ability of the auditory system to respond to rapid changes in the envelope of sound stimulus over time (Plack & Viemeister, 1993). Temporal acuity is one of the prerequisites of the auditory system to determine duration, interval and temporal organization of sound stimuli, and it is essential for the processing of speech and music (Durrant & Lovrinic, 1997).

Temporal resolution can be measured in many ways including detection threshold for amplitude modulation, forward masking and backward masking, temporal order discrimination and gap detection. Gap detection is probably the most commonly used measures of temporal resolution. In this test, the subject must detect the gaps or fluctuating silent periods in the stimulus. Gaps-in-noise (GIN) test (Musiek, Shinn, Jirsa, Bamiou, Baran, & Zaidan, 2005) is a commercially available test and it assesses the temporal resolution ability using gap detection procedure. In most of the studies conducted by different authors using Gaps-in-noise test stated that there is some correlation between aging and temporal resolution ability in the elderly population.

Research on Effects of Age

Snell (1997) studied the effects of age on temporal resolution. He compared temporal gap thresholds in groups of younger (17 -40 years) and older (age 64 -77years) listeners with normal hearing and closely matched audiometric thresholds and observed diminished gap resolution abilities in about one-third of the older individuals.

Strouse, Ashmead, Ohde & Grantham (1998) reported that monaural temporal processing was affected in older individuals than younger individuals. Bertoli, Smurzynski & Probst in (2002) using psychoacoustic gap detection task and mismatch negativity (MMN) reported that there were no significant differences in the psychoacoustic gap detection thresholds when compared with young and elderly and also longer gaps were needed to elicit mismatch negativity in elderly subjects, significantly reduced MMN peak amplitudes and increased MMN peak latencies. They also observed a significantly smaller P2 amplitude and longer P2 latency in elderly population when compared to the same measures in young subjects.

Helfer and Vargo (2009) examined speech understanding ability and temporal processing in middle-aged females with normal or near normal hearing threshold by comparing their performance with younger aged females and temporal resolution ability was evaluated using Gaps-in-noise test. The results showed that the performance of the middle-aged group was significantly poorer than that of the younger group and their findings also suggested a strong relationship between temporal processing and speech understanding in adverse listening situations.

Studies have shown that sensitivity to the temporal fine structure of acoustic signals, which seems to be important for successful speech identification in complex and noisy listening conditions and it is reduced in older adults (Moore, Glasberg, Stoev, Fullgrabe & Hopkins, 2012). It has been demonstrated that older subjects may present with increased temporal resolution thresholds in comparison to younger control subjects.

John, Hall & Kreisman (2012) conducted a study to find out the effects of aging and hearing loss on the performance on the gaps-in-noise test. The subjects were older adults with the Sensorineural hearing loss (SNHL), older adults with essentially normal hearing, and young adults with normal hearing. The authors reported that the approximate gap thresholds were different significantly across all groups, with the poorest thresholds found in older adults with Sensorineural hearing loss and with the best thresholds found in young adults with normal hearing.

Need of the Study

Most of the available research conducted by different authors as mentioned earlier (Snell, (1997); Strouse, Ashmead, Ohde & Grantham (1998); Bertoli, Smurzynski & Probst (2002); Helfer & Vargo (2009); Moore et al (2012); John, Hall & Kreisman (2012) stated that there is some correlation between aging and temporal resolution ability in elderly population. That is, as the age increases temporal resolution ability decreases. Very few of the earlier studies have systematically examined changes in temporal resolution and aging (Prem, Shankar & Girish, (2012); Kumar, (2011); Grose, Hall, & Buss, (2006); Grose & Mamo, (2010); Nair & Basheer, (2017); Perez & Pereira, (2010); Fitzgibbons & Gordon-Salant, (1995); Moore, Glasberg, Stoev, Fullgrabe & Hopkins, (2012). The current study focused on the influence of aging on temporal resolution skill. Considering the general trend of increased lifespan and high prevalence of central auditory processing difficulties, the present study has great social relevance. The subtle mechanisms involved in temporal resolution in different age groups need to be clearly understood. Further, the relationship between temporal resolution and effect of aging has not been thoroughly investigated in the Indian context; the existing literature suggested that most of the studies related to auditory temporal resolution skills were particularly done in the western scenario. Considering all these aspects, the present study was proposed.

Aim of the Study

The aim of this study is to identify the effect of aging on temporal resolution

Method

Proposed Setting

The study was conducted at the Department of Speech & Hearing, Mar Thoma College of special education, Kasargod, between January 2017 and July 2017.

Subjects

Total of 90 individuals, 30 from each age group were selected. Age groups: Group-I (10 - 17 years), Group-II (18 -45 years) and Group-III (46 -65 years) satisfied the below-mentioned criteria.

Inclusion criteria:

Subjects with:

1) An average threshold of 500Hz, 1000Hz, and 2000 Hz of less than 15 dBHL for air conduction and bone conduction.
2) Normal tympanometry and reflexometry.
3) Subjects between the ages of 10 to 65 years.
4) Normal auditory processing by the screening checklist 'Screening checklist for central Auditory processing (Vaidyanath and Yathiraj (2014) and Yathiraj and Mascarenhas (2003)).
5) Average scholastic performance as reported by class records.

Exclusion criteria:

Subjects with the following history or co-existing conditions were excluded from the study:

1) Subjects with hypertension and diabetes.
2) Continuous noise exposure for prolonged periods.
3) Drug ototoxicity.
4) Recurrent ear infections.
5) Head or ear injury.
6) Neurological problems.

Test Administered

Gaps-In-Noise Test (GIN) - (Musiek et al, 2005)

Other Instruments Used

Grason Stadler Incorporates (GSI) -61 clinical audiometer and GSI Tympstar-Immitance audiometer

Test Procedure

The individuals were screened for auditory processing disorder by the Screening checklist for auditory processing (SCAP) (Yathiraj & Mascarenhas, 2003) for children and the Screening checklist for auditory processing for adults (SCAP-A) (Vaidyanath & Yathiraj, 2014). The individuals were then tested with immitance audiometry (GSI-Tympstar) for 'A' type tympanogram with reflexes present, and pure tone audiometry (GSI-61) for air conduction and bone conduction threshold of less than or equal to 15 dBHL. The subjects selected according to the criteria were then administered with Gaps-in-Noise Test.

Gaps-In-Noise Test

The GIN is a test of auditory processing designed to measure temporal resolution. It is composed of four different lists identified as Test 1, Test 2, Test 3 and Test 4 with equivalent difficulty. The four lists contain a series of up to 36 different six- second white noise segments or trials. Each of the white noise segment contains anywhere between zero (none) to three silent periods (gaps). The duration of the gaps is 2, 3, 4, 5, 6, 8, 10, 12, 15, or 20 milliseconds in duration. Both gap duration and the location of gaps within the noise segments were randomized in regard to their occurrence. These variances in the number, duration, and placement (early, middle or late) of the gaps were incorporated as a test feature in the GIN to decrease both the probability of guessing correctly and the number of trials needed to obtain statistically significant information. Each GIN list contains a total of 60 gaps per list (6 repetitions of each gap). A five-second gap of silence separated each six-second noise segment. Usually, one list is administered in each ear.

The GIN stimuli, previously saved on a laptop computer, were played and transferred through a GSI 61 diagnostic audiometer to TDH – 50 matched earphones. The Gaps In Noise recording contains the Gaps In Noise stimuli routed through headphones heard by the participant and channel B contains gap indication signals which were routed through bone vibrator and heard by the clinician for the indication of the gap. The subjects were instructed to indicate the presence of the gap by pressing the patient response switch or by raising hands immediately. The patient was cautioned not to respond to the large gap between segments or trials. If the response button was not pressed when a gap occurred, it was counted as an error. If a button was pressed and no gap occurred, it was counted as a false positive.

The two possible measures of GIN test, the approximated Gap Detection Threshold (GDT) and a combined percent correct identification score (Total Percentage Score-TPS) across all gap durations were analyzed for each ear. The GDT was calculated by considering the shortest gap duration correctly identified (at least 4 out of 6 gaps) and performance for longer gap durations was not worse than 4 out of 6 gaps correctly identified. The TPS was calculated by dividing the total number of correct gap durations identified by the total number of gap durations presented (n=60) multiplied by 100. False positives were noted. When more than two false positives occurred per ear, it was counted as errors and subtracted from the number of gap durations identified.

Data Analysis

The data collected were subjected to analysis using SPSS (13.0). The mean and standard deviation values had been derived for all the participants across the three age groups. ANOVA was carried to find the significant difference between each of the groups. As there was a significant difference, Post hoc analysis using Bonferroni multiple comparisons was also carried out to find a significant difference between the three age groups.

Results

Total of Ninety individuals (180 ears) 30 from each age group: Group-I (10 -17 years), Group-II (18 -45 years) and Group-III (46 -65 years) who met the criteria participated in the study. The performance of three age groups on Gap-in-noise test (GIN) (Musiek, et al., 2005) was compared. The two measures in GIN test were Gap Detection Threshold (GDT) and Total Percentage Score (TPS). The data obtained were statistically analyzed in SPSS (13.0) using ANOVA to find the significant difference between different age groups. The obtained results are explained in the following sections.

1) **Performance of the individuals in 3 groups based on Gap Detection threshold**

2) **Performance of the individuals in 3 groups based on Total Percentage Score**

3) **Post hoc analysis using Bonferroni multiple comparisons**

4) **Performance of Gap Detection Threshold in right ear and left ear across three age groups.**

5) **Performance of Total percentage score in right ear and left ear across three age groups.**

Table-1: ***Performance of the individuals in 3 groups a based on Gap Detection threshold***

Group	N	Mean	S.D	ANOVA F	P	
RIGHT EAR						
Group I	30	4.53	.78	41.478	.000	HS
Group II	30	6.43	1.79			
Group III	30	8.57	2.24			
LEFT EAR						
Group I	30	4.57	.50	39.273	.000	HS
Group II	30	6.57	1.91			
Group III	30	8.73	2.46			

Performance of individuals in the three age groups for gap detection threshold in right and left ears is shown in Table-1. The mean GDT of group I (10 – 17 years) is 4.53 milliseconds (msec) in right ear and 4.57 msec in left ear, group II (18 - 45 years) is 6.43 msec and 6.57 msec respectively. In group III (45 – 65 years) the mean GDT of right ear is 8.57 msec and GDT of the left ear is 8.73 msec. The mean values of various age groups were highly significant as indicated by the p-value which was 0.000.

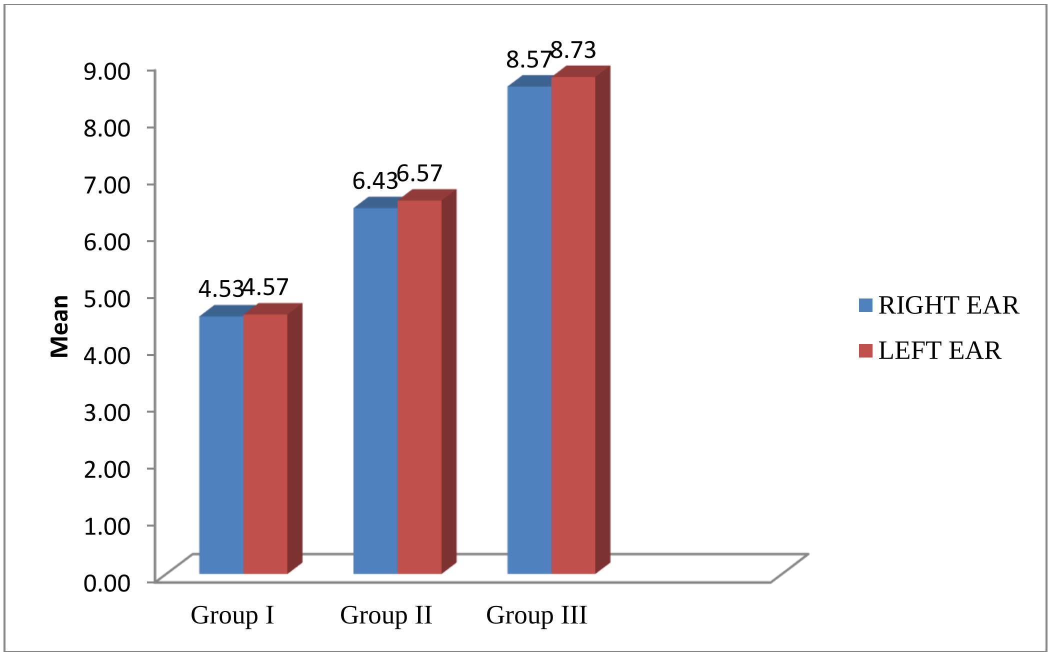

***Figure-1*: Mean gap detection threshold of right and left ears across three age groups.**

Figure-1 shows the gap detection threshold of the right and left ear across the three age groups. From the above bar diagram, it is clearly evident that the performance of group I was better compared with the other two groups.

Table-2: *Performance of the individuals in 3 groups for Total Performance Score*

Group	N	Mean	S.D	ANOVAF	P	
RIGHT EAR (%)						
Group I	30	73.33	6.78	83.871	.000	HS
Group II	30	60.83	11.75			
Group III	30	45.66	4.69			

LEFT EAR (%)						
Group I	30	72.27	7.56	73.680	.000	HS
Group II	30	60.77	12.61			
Group III	30	44.66	4.32			

Table 2

Table Table-2 indicates the TPS in group I is 73.33 % in right ear and 72 .27 % in left ear and 60.83% and 60.77 % are the mean TPS performance in group II respectively. In group III the mean TPS of right ear is 45.66 % and TPS of the left ear is 44.66 %

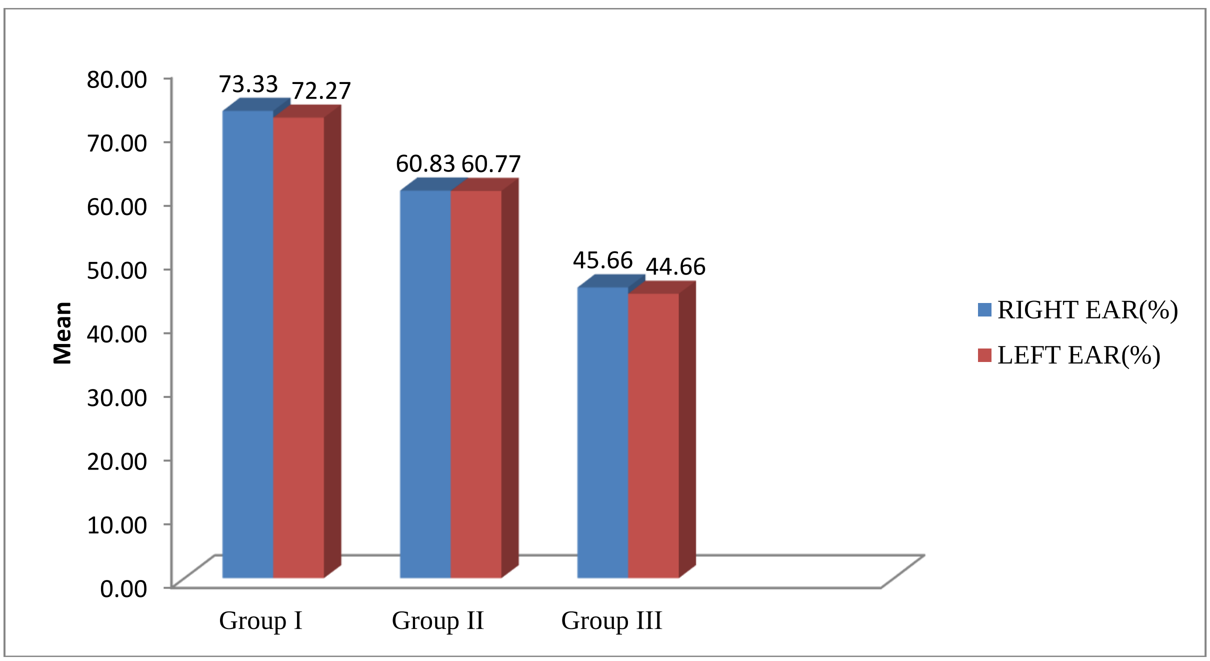

***Figure-2*: Mean total percentage score of right and left ears across three age groups**

Figure-2 shows the total percentage score of the right and left ear across the three age groups. From the above bar diagram, it is clearly evident that the performance of group I was better compared with the other two groups.

Table-3: ***Post hoc analysis using Bonferroni multiple comparisons***

Dependent Variable			**Mean difference**	**Standard error**	**p**	
GDT right	Group I	Group II	-1.900	.443	.000	HS
		Group III	-4.033	.443	.000	HS
	Group II	Group III	-2.133	.433	.000	HS
GDT left	Group I	Group II	-2.000	.470	.000	HS
		Group III	-4.167	.470	.000	HS
	Group II	Group III	-2.167	.470	.000	HS
TPS right (%)	Group I	Group II	12.499	2.139	.000	HS
		Group III	27.667	2.139	.000	HS
	Group II	Group III	15.167	2.139	.000	HS
TPS left (%)	Group I	Group II	11.501	2.285	.000	HS
		Group III	27.611	2.285	.000	HS
	Group II	Group III	16.110	2.285	.000	HS

As the data shows high significance between the age groups, a post hoc analysis was done using Bonferroni paired t-test (Table-3). Each age group within gap detection threshold in right ear, gap detection threshold in left ear, total percentage score in right ear and total percentage in left ear were compared with other age groups. All comparisons indicated that the mean difference is highly significant.

Table-4: ***Performance of gap detection threshold in right ear and left ear across three age groups.***

Group	N	Mean	Standard deviation	Mean difference	S.D of difference	t value	p value
Group I Right ear Left ear	30 30	4.53 4.57	.78 .50	-.03	.67	.273	.787 NS
Group II Right ear Left ear	30 30	6.43 6.57	1.79 1.91	-.13	1.57	.465	.645 NS
Group III Right ear Left ear	30 30	8.57 8.73	2.24 2.46	-.17	1.70	.536	.596 NS

Table-4 shows the performance of detection threshold in right ear and left ear in three age groups. Three groups showed no significant difference in right ear and left ear performance. When the mean values of three groups were compared, the result indicates that no right ear advantage.

Table-5: ***Performance of total percentage score in right ear and left ear across three age groups.***

Group (%)	N	Mean	Standard Deviation	Mean difference	S.D of difference	t value	p value
Group I Right ear Left ear	30 30	73.33 72.27	6.78 7.56	1.06	3.83	1.511	.142 NS
Group II Right ear Left ear	30 30	60.83 60.77	11.75 12.61	.06	3.41	0.91	.928 NS

Group III	Right ear	30	45.66	4.69	1.00	3.29	1.662	.107
	Left ear	30	44.66	4.32				NS

Table-5 shows the performance of total percentage score in right ear and left ear in three age groups. Three groups showed no significant difference in right ear and left ear performance. When the mean values of three groups were compared, the result indicates that no right ear advantage.

Discussion

The results of the present study showed a significant difference in scores between the three age groups. The table-1and 2 showed the performance of Group I, Group II and Group III and indicated that the performance gets poorer with increase in age. While comparing the results of the present and previous studies, it is clear that older individuals demonstrate increased GDT & TPS in comparison to younger individuals. The results were supported by different authors providing explanations on age related declines in the temporal processing (Snell,1997; Moore, Glasberg, Stoev, Fullgrabe & Hopkins, 2012; Strouse, Ashmead, Ohde, & Grantham, 1998); Helfer & Vargo, 2009; John, Hall & Kreisman, 2012; Prem, Shankar & Girish, 2012).

As the age increases the major pathology associated with acquired changes in the peripheral auditory system includes the changes in the cochlea. The cochlear contribution to aging likely includes the loss of sensory cells, strial degeneration along with associated changes in the endocochlear potential and the loss of spiral ganglion neurons. (Mills, Schmiedt, Schulte & Duubno, 2006; Ohlemiller, 2004; Schuknecht, 1955). As people gets aged, structural as well as neural degeneration occurs throughout the auditory system, therefore their scores in both gap detection threshold and total percentage score also gets reduced.

There are some studies which suggested that hearing loss is the primary factor for poor performance in temporal processing tests in older individuals (Moore, Peters & Glasberg, 1992., Takahashi & Bacon, 1992). However, there are studies of the opinion that the temporal processing started deteriorating from the early fourth decade of human life without the significant hearing loss (Kumar, 2011.) And most of the studies also reported that temporal resolution skills decline before the age of 60 years even in individuals with normal hearing sensitivity (Grose, Hall, & Buss, 2006; Grose & Mamo, 2010; Helfer & Vargo, 2009).

Results of the current study also showed that there was no significant difference between the right ear scores and the left ear scores across the three age groups in both two measures. This was supported by different studies conducted by different authors (Nair & Basheer, 2017; Prem, Shankar & Girish, 2012; Perez & Pereira, 2010). The present study revealed that the scores decreased with increase in age and showed a decline in the scores after 45 years. Many studies had demonstrated age related differences in temporal processing (Fitzgibbons & Gordon-Salant, 1995; Snell, 1997; Moore, Glasberg, Stoev, Fullgrabe & Hopkins, 2012; Strouse, Ashmead, Ohde, & Grantham, 1998; Helfer & Vargo, 2009).

Conclusion

Hearing being one of the most important abilities of human beings, its reduced sensitivity creates adverse effects on health and quality of life (Prates & Iorio, 2006). Aging is a natural phenomenon, age related changes mainly start from the 5th decade of life (Koopmann, 1991) and it can cause anatomical and physiological alternations in the auditory system.

The ability to distinguish temporal order alterations in a sound wave is named auditory temporal processing. Temporal resolution refers to the ability to detect changes in either the duration of an auditory event and or the intervals of silence or gaps embedded within an auditory stimulus. The ability of the brain to process small changes of pitch in time provides cues that help an individual for the better understanding of speech (Moore, 2003). As the age increases temporal processing abilities will gradually decrease. One of the most commonly used methods to assess temporal resolution of hearing is the silent gap in noise test.

In both measures of GIN test all three groups showed a highly significant difference with respect to their performance, except when the performance of right ear was compared with left ear there was no significant difference between three groups. In the present study, when the performance of the three different age groups was compared using GIN test, from the results it was clear that as the age increases temporal resolution ability decreases in both measures. The present study is in accordance with most of the studies conducted by different authors as mentioned earlier (Snell, (1997); Strouse, et al. (1998); Bertoli, et al. (2002); Humes, et al. (2010); Helfer et al (2009); Moore, et al. (2012); John, et al. (2012); and Yazaki, et al (2014) which states that as the age progresses temporal resolution ability declines.

Clinical Implication

- GIN test as a quick and easy way for the assessment of temporal resolution.
- The normative database that was obtained for GIN test in different population can be used in clinical assessment of hearing impaired population.

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Krishnapriya K G, MASLP
Marthoma College of Special Education
Institute of Speech & Hearing
Badiadka, Kasaragod-671551
Kerala
India
krishnapriyakg355@gmail.com

Dr. Binoy Shany M S, Ph.D.
Professor
Marthoma College of Special Education
Institute of Speech & Hearing
Badiadka, Kasaragod-671551
Kerala
India
Shany003@yahoo.com