# Effect of Age and Hearing Loss on Gap Detection Threshold

**Fakruddin D B & Rajalakshmi K***

## Abstract

Gap Detection Thresholds (GDT) were measured using a gap detection test for 3 groups of listeners: young adults with hearing loss, older adults with normal hearing sensitivity and older adults with sensorineural hearing loss. This study examined the effect of age and hearing loss on gap detection threshold. The test material was Gap detection test (using broadband noise) CD developed by Shivaprakash (2003). The results indicated that the age and hearing loss has effect on gap detection thresholds. However, there is very minimal effect of hearing loss on gap detection threshold in older adults than in young adults. There is no effect of configuration (flat and sloping) of hearing loss on gap detection threshold in old and young adults with mild and moderate sensorineural hearing loss. There is no significant dif erence between right and left ears gap detection thresholds in all groups.

## Introduction

Temporal resolution may be defined as the ability to follow and resolve rapid fluctuations over time. Often, the background noise found in every day listening situations is characterized by fluctuations in intensity over time. Temporal resolution is important for resolving brief dips in the intensity of the interfering noise and therefore it is critical for understanding speech in these situations (Dubno, Horwitz & Ablstrom, 2003; Oxenham & Bacon, 2003; Peters, Moore & Baer, 1998). The normal auditory system is remarkable in its capacity to extract and encode temporal features of a stimulus waveform. One of the factors identified in psychoacoustic experiments as contributing to poor speech perception is the reduced temporal resolving power of the auditory system (Dreshcler & Plomp, 1985; Gingel et al., 1982; Price & Simon, 1984; Schneider, 1997; Tyler et al., 1982).

Temporal resolution is measured in various ways, including detection threshold for amplitude modulation (Viemeister, 1979), forward masking and backward masking (Moore, Glassberg, Plack & Biswas, 1988) and temporal order discrimination (Green, 1973). Two other tests similar to gap detection are the Auditory Fusion Test – Revised (AFT-R) and the Random Gap Detection Test (RGDT). Temporal resolution can be studied using a gap detection paradigm. Typically, in this paradigm, a listener reports the observation interval, in which a silent gap is detected, with the smallest detectable silent interval being termed as Gap Detection Threshold (GDT). Gap detection is probably the most commonly used measure of temporal resolution. Gap detection test is a popular method because it provides a description of temporal resolution based on a single threshold; whereas other methods require multiple threshold estimates. Another advantage is that the gap detection is easy to measure in naive listeners, including infants. The GDT obtained from naive listeners are close to those obtained from well

* Reader in Audiology, All India Institute of Speech and Hearing, email:rajrose2000@yahoo.com

trained listeners (Werner, Marean, Halpen, Spetner & Gillenwater, 1992). Age and hearing loss related deficits have been demonstrated in the detection and discrimination of temporal gaps (Lister, Besing & Koehnke, 2002; Lister, Koehnke & Besing, 2000; Roberts & Lister, 2004). Such deficits may contribute to problems with speech understanding in noise experienced by listeners with presbycusis (e.g. Gordon-Salant & Fitzgibbons, 1993; Koehnke & Besing, 2001; Roberts, Koehnke & Besing, 2003; Snell, Mapes, Hickman & Frisina, 2002). Generally GDT in people with cochlear hearing loss are reported to be higher (Moore & Glassberg, 1998). Results obtained in a number of studies indicate that listeners with hearing loss have larger GDT than listeners with normal hearing for many different types of stimuli (Grose & Hall 1989). However, results of other studies revealed no effect of hearing loss on GDT (Moore, Peters & Glassberg, 1992; Buss, Hall & Grose, 1998).

Although one study (Moore, Peters & Glassberg, 1982) concluded that reduced temporal gap resolution does not accompany aging, other studies (Fitzgibbons & Gordon-Salant, 1992) have shown that age can have significant effect on auditory temporal measures, independent of effects of peripheral hearing impairment. Thus the effects of subject's age and hearing loss on gap detection ability are not clear. Although it is generally acknowledged that auditory temporal processing improves substantially over the first several years of life, there is considerable disagreement about the specific developmental schedule. For example, the age of achievement of adult-like temporal acuity is reported to be between 5 to 6 years of age by some investigators (Morrongiello, Kulipg & Clifton, 1984; Jensen & Neff, 1993) and between 9 and 11 years of age by others (Irwin, Grose, as cited in Sandra et al 1995). Shivaprakash (2003) developed normative data for Gap detection test in children and young adults with normal hearing. The findings suggest that normal hearing individuals start performing like adults on Gap detection test by the age of 6 to 7 years.

Oxenham (2000) proposes that the perceptual channels important for gap detection depend primarily on peripheral encoding of the marker spectra and higher level neural coding is much less important. This does not explain the findings of normal gap resolution when peripheral encoding of frequency is impaired (i.e. listeners with sensorineural hearing loss have normal gap detection and discrimination), impaired gap resolution when peripheral encoding of frequency is intact (i.e. older listeners with normal hearing have impaired gap detection and discrimination) or normal gap resolution by those whose peripheral auditory system is by-passed by an Auditory Brainstem Implant (Shannon & Otto, 1990). Further exploration of this topic using groups of listeners across the age range with and without hearing loss is warranted. Hence, in the present study it is intended to explore the effect of age and hearing loss on Gap Detection Test.

**Aim of the study**

- To study the independent and interactive effects of age and hearing loss on temporally based non-speech measure (Gap Detection Test)
- To study the configuration of hearing loss on gap detection test
- To develop normative data for older adults with normal hearing

# Method

## Subjects

40 subjects participated in the study. The subjects were divided into three groups. **Group-1** composed of 15 older subjects (> 55 years) with normal hearing (pure tone thresholds ≤ 25 dB HL in frequency range of 250 Hz-000 Hz) and no history of otological or neurological disorders. **Group-2** composed of 10 young adults (18-40 years) with mild to moderate sensorineural hearing loss (flat/sloping configuration of audiogram). **Group-3** composed of 15 older subjects (> 55 years) with mild to moderate sensorineural hearing loss (flat/sloping configuration of audiogram). All subjects had 'A' type tympanogram with reflexes present/ elevated. All subjects had average/above average intellectual functioning. A checklist was used to rule out subjects with auditory processing disorder.

## Stimuli/test material

Gap detection test (using broadband noise) CD developed by ShivaPrakash (2003).

## Instrumentation and test environment

A calibrated two channel diagnostic audiometer (Orbiter – 922) was used for subject selection and for the presentation of the stimulus. An immittance audiometer (GSI –TS) was used for evaluation of middle ear function. A tape recorder (Philips AZ 2160 cv) with CD on gap detection test connected to a two channel diagnostic audiometer was used for presenting the stimulus. The entire test was carried out in an air-conditioned sound treated double room with ambient noise levels within permissible limits (Re: ANSI 1991, as cited in Wilber, 1994).

## Procedure

The stimuli set (56 stimuli, including 6 catch trials) was presented monaurally at 40 dB SL (with reference to pure tone average) or at comfortable level, through the headphones of audiometer (orbiter –922) to each subject. Before the actual test sets, four practice sets were given to train the subjects. The gap duration in the four practice sets were 20, 16, 12, 10 msec. The subjects were instructed as "please listen to the set of three noise bursts, one of the three noise bursts contain a gap of varying duration. Please indicate verbally which of the three noise bursts in the set has the gap". Each time the subject detected the gap correctly, the size of the gap reduced to trace the smallest gap that subject could detect using bracketing technique. The minimum gap that was detected by the subject was taken as gap detection threshold. The gap detection thresholds were obtained for each subject in each group. The smallest gap was then tabulated for each ear of each subject in different groups.

# Results

Data on gap detection threshold were collected from three different groups in order to develop norms for older people and to know the effect of age and hearing loss on gap detection threshold. The data was tabulated for statistical analysis. The SPSS (Statistical Package for Social Sciences, version10) for windows was utilized for analysis.

### 1. Effect of age

Young adults and older adults with normal hearing were compared on gap detection threshold. The one sample t- test for right and left ears revealed a value of $t\ (14) = 12.965$, $P< 0.001$, $t\ (14) = 16.144$, $P< 0.001$ respectively. Hence there is a significant difference between the mean of normal young adults (given from previous study) and the older adults with near normal hearing (present study) on Gap detection threshold for both ears at 0.001 level.

Young adults and older adults with hearing loss were compared on gap detection threshold. The independent sample t- test on right and left ears revealed a value of $t\ (16) = 2.232$, $P< 0.05$, $t\ (17) = 2.504$, $P< 0.05$ respectively. Hence there is a significant difference between the young adults and the older adults with sensorineural hearing loss on Gap detection threshold for both ears at 0.05 level.

### 2. Effect of hearing loss

Older adults with and with out hearing loss were compared on gap detection threshold. The independent sample t- test on right and left ears revealed a value of $t\ (22) = 1.774$, $0.05< P< 0.1$, $t\ (24) = 1.531$, $P>0.05$ respectively. Hence there is no significant difference between older adults with and without hearing loss on gap detection threshold for both ears at 0.05 level. But a significant difference is seen at 0.1 level between older adults with normal hearing and with sensorineural hearing loss for right ear.

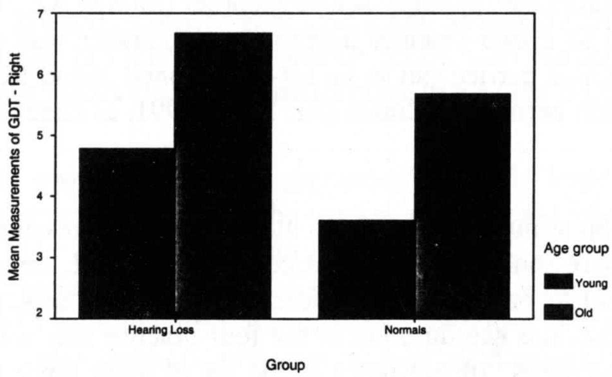


Figure 1: Comparison of young adults and older subjects in terms of hearing loss and gap detection threshold for right ear.

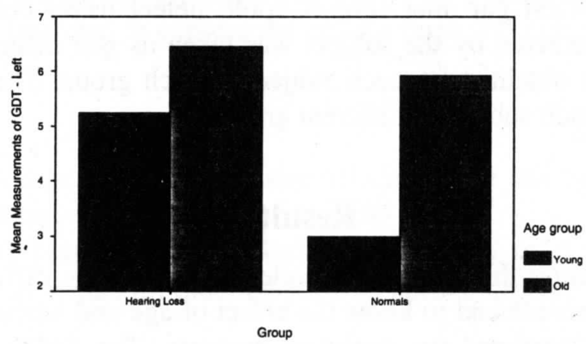


Figure 2: Comparison of young and older adults in terms of hearing loss on gap detection threshold for left ear.

**3. Effect of configuration of hearing loss**

Young adults with and without hearing loss were compared on gap detection threshold. The one sample t- test on right and left ears revealed a value of t (8) = 2.385, P< 0.05, t (7) = 6.148, P< 0.001 respectively. Thus there is a significant difference between the mean of normal young adults (given from previous study) and young adults with sensorineural hearing loss (in present study) on gap detection threshold for both the ears at 0.05 level. There is a significant difference between young adults with normal hearing (given from previous study) and young adults with hearing loss (in present study) on gap detection threshold for both the ears. There is no significant difference between old adults with and without hearing loss on gap detection threshold for both the ears at 0.05 level, but there is a significant difference between old adults with and without hearing loss on gap detection threshold for right ear at 0.01 level.

The significant difference was found between young and older subjects with hearing loss. The effect of configuration of hearing loss in young and old subjects was studied separately. Flat and sloping configurations in young adults with hearing loss were compared on gap detection threshold. The Mann Whitney 'U' test on right and left ears revealed a 'Z'value of -1.917, P>0.05, and -1.623, P>0.05 respectively indicating no significant difference between the flat and sloping configuration of hearing loss in young adults with sensorineural hearing loss on gap detection threshold for right and left ears.

Flat and sloping configurations in older adults with hearing loss were compared on gap detection threshold. The Mann Whitney 'U' test on right and left ear revealed a 'Z'value -0.582, P>0.05, -0.189, P>0.05 respectively, indicating no significant difference between the flat and sloping configuration of hearing loss in older adults with sensorineural hearing loss on gap detection threshold for right and left ears.

From these we can conclude that there is no significant difference between the flat and sloping configuration of hearing loss in young and older adults with sensorineural hearing loss on gap detection threshold for both the ears.

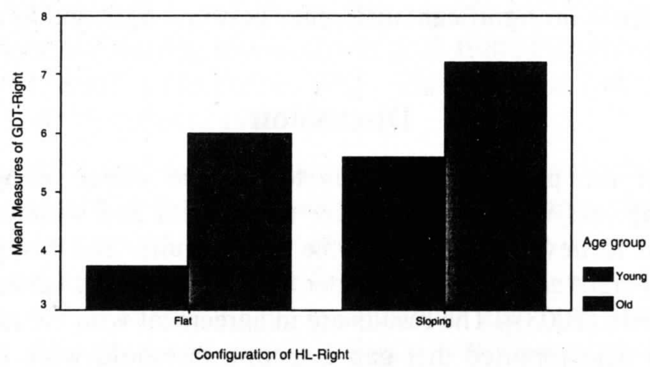


Figure 3: Comparison of young adults and older adults in terms of configuration of hearing loss (Flat vs sloping) on gap detection threshold for right ear

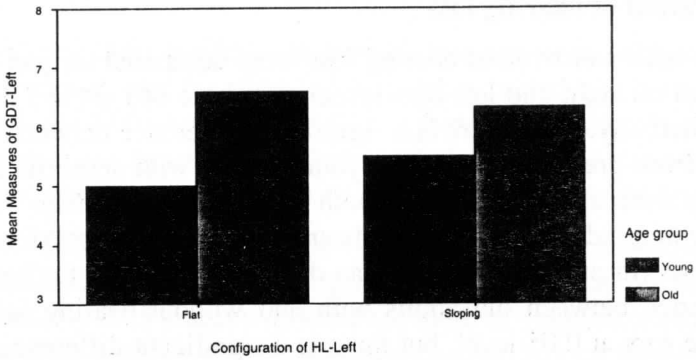


Figure 4: Comparison of young adults and older adults in terms of configuration of hearing loss (Flat vs sloping) on gap detection threshold for left ear.

**4. Comparison of right and left ear**

Right and left ear in young adults with hearing loss (in the present study) were compared on gap detection threshold. The paired t- test was performed and t (6) = 1.549, $p > 0.05$, indicating no significant difference between right and left ears of young adults with sensorineural hearing loss on gap detection threshold.

Right and left ears in older adults with hearing loss were also compared on gap detection threshold. The paired t- test was performed and t (7) = 0.174, $p > 0.05$, indicating no significant difference between right and left ears of older adults with sensorineural hearing on gap detection threshold.

Right and left ear in older adults normal hearing were compared on gap detection threshold. The paired t-test was performed and t (7) = 1.468, $p > 0.05$, indicating no significant difference between right and left ears of older adults with normal hearing on gap detection threshold. Therefore there is no significant difference between right and left ears in all groups.

## Discussion

The purpose of the present study was to see the effect of age, hearing loss and configuration of hearing loss in young and older adults with and without hearing loss on gap detection threshold and to develop norms for the older adults. The results showed larger gap detection thresholds for right and left ears in older adults than young adults with normal hearing [taken from ShivaPrakash, (2003)]. The results are in agreement with the results of the studies by Schneider et al (1994) who reported that gap detection threshold were significantly higher in older adults with normal hearing than in young adults with normal hearing. They reported gap detection threshold of 6.4 msec for their older subjects with normal hearing (pure tone threshold ≤25 dB HL from 0.25 to 3 KHz). The present study also reported the gap detection threshold of 5.67 & 5.93 for right ear and left ear respectively showing good agreement with Schneider et al (1994) values. Lister, Besing & Koehnke (2002) proposed a hypothesis that the perceptual channel appears to narrow with age are not limited by peripheral auditory filter widths but are influenced by both peripheral and central encoding mechanisms that become less acute with age.

Studies suggest that reduced within channel and across channel temporal resolution in older subjects may occur independent of peripheral hearing sensitivity (Fitzgibbons & Gordon-Salant, 1994; Lister, Besing & Koehnke 2000). This effect is attributed to age related changes within the central auditory system and to slowed auditory processing (Fitzgibbons & Gordon-Salant, 1994). Therefore it is reasonable to consider factors other than peripheral hearing loss that could account for age related differences in monaural temporal resolution. In the present study the results showed that there is a significant difference in gap detection threshold between older and young adults with hearing loss for both the ears. The results are in accordance with the results of Snell's (1997) study on older adults who were matched to a group of younger listeners with respect to their audiometric thresholds, had gap detection threshold that were 27-37% larger than those of the younger listeners for gaps in short noise burst.

The results of the present study showed that significant difference on gap detection threshold is more in older adults without hearing loss. The results are in accordance with the results of Schneider et al (1994) and Snell's (1997) studies suggesting that in the absence of significant sensorineural hearing loss there is more age-related loss in temporal acuity. Findings suggest that age-related factors other than peripheral hearing loss contribute to temporal processing deficits of elderly listeners.

The results of the present study also showed larger gap detection thresholds for right and left ears in young adults with sensorineural hearing loss (present study) than young adults with normal hearing [Shivaprakash, (2003)]. The results are in agreement with the many studies. Several groups of workers have reported that thresholds for the detection of temporal gaps in noise stimuli are usually larger for subjects with cochlear hearing impairment than for normally hearing subjects. This is true both for broadband noise stimuli (Irwin et al 1981; Florentine & Buus, 1984) and for band pass noise stimuli presented in a broadband or band stop background (Fitzgibbons & Wightman, 1982; Tyler et al 1982; Buus & Florentine, 1985; Moore et al 1985b). Fitzgibbons and Wightman (1982) found that subjects with hearing impairment had larger gap thresholds than normal subjects regardless of whether comparison was made at equal SPL or equal SL. A number of studies have shown that gap detection thresholds are elevated in individuals with sensorineural hearing losses. (Irwin et al 1981; Fitzgibbons & Wightman, 1982; Florentine & Buus, 1984; Buus & Florentine, 1985; Glassberg et al 1987; Long & Cullen, 1988; Moore & Glassberg, 1988; Moore et al 1989).

The present study showed no significant difference on gap detection thresholds for both the ears in older subjects with and without hearing loss at 0.05 level. But there is a significant difference on gap detection threshold for right ear in older adults with and without hearing loss at 0.1 level. The results are in accordance with the studies by Moore et al (1992) who measured thresholds for the detection of temporal gaps in sinusoidal signals as a function of frequency in elderly hearing impaired subjects and elderly subjects with near normal hearing (audiometric thresholds ≤ 25 dB HL from 250 to 2000Hz). Results were compared to previous data collected from normal hearing subjects (Moore et al 1993), revealing that elderly subjects with near normal hearing had higher gap detection threshold than young subjects. Moore et al (992) attributed this result to the inclusion in the elderly group of some individual who had large gap detection thresholds. Nevertheless, when they compared gap detection thresholds in elderly subjects with near normal hearing to those with hearing impairment, they found no difference between the two groups. Schneider et al (1994) reached a similar conclusion. Moore et al (1993) did not compare the right ear and left ear in older adults with and without hearing loss. There was no significant difference between flat and sloping configuration of hearing loss on gap detection threshold in young adults and older subjects with mild and moderate sensorineural hearing loss for both the ears. Also, results showed no significant difference between right and left ear on gap detection threshold in young and older adults with hearing loss and older adults with normal hearing. Shivaprakash (2003) reported no significant difference in gap detection threshold between the right and left ears in children and young adults with normal hearing.

There are no studies in literature reporting the presence or absence of significant difference between the right and left ear on gap detection threshold in young and older adults with hearing loss. In the present study, the results showed that there is no significant difference between right and left ears on gap detection threshold in young adults and older subjects with mild and moderate sensorineural hearing loss & older subjects with normal hearing. However, in the present study, an older adult (89 years) with bilateral mild to moderate steeply sloping sensorineural hearing loss had the gap detection threshold of 7 msec in left ear and 12 msec in right ear. He had difficulty in identifying the gaps when they were placed initially in the three-stimulus presentation or sequence.

## Summary and Conclusions

Temporal resolution refers to the ability of the auditory system to follow rapid changes in the envelope of sound. It is measured in various ways and using various stimuli. The gap detection test is one of the important psychophysical methods among them to measure temporal resolution, which in turn is important for speech perception. Gap detection, which is necessary for speech perception, is an effective and easy to evaluate aspect of temporal resolution or acuity. The objective of the present study was to develop normative data for older adults with normal hearing and to see the effect of age, hearing loss and configuration of hearing loss (flat Vs sloping) on GDT in young adults and older adults separately for both the ears. To study the objectives 40 subjects with and without hearing loss were divided into three groups. Group1 consisting of 15 old adults with normal hearing (> 55 years), Group 2 having 10 young adults with sensorineural hearing loss (18 to 40 years) and Group 3 consisting of 15 old adults with sensorineural hearing loss (>55 years).

From the results we can conclude that age has an effect on gap detection thresholds. The hearing loss has the effect on gap detection thresholds in young adults and there is very minimal effect of hearing loss on gap detection threshold in older adults than in young adults. There is no effect of configuration (flat and sloping) of hearing loss on gap detection threshold in old and young adults with mild and moderate sensorineural hearing loss.

**Clinical implications: -**

- Normative data for older listeners with normal hearing can be used as baseline on which the management procedures can be evaluated for elderly listeners.
- This is used to identify older individuals who might require auditory training for temporal cues or who might benefit from signal processing devices aimed at enhancing temporal cues.

## References

Allen, P.D., Tracy, M., Virag & Ison, J.R. (2002). Humans detect gaps in broadband noise according to effective gap detection without additional cues from abrupt envelope changes. *Journal of the Acoustical Society of America*, 112(6), 2967-2974

Bellis, T.J. (1997). *Assessment and management of Central Auditory Processing Disorders in the Educational setting.* London: Singular Publication.

Buumen, T.J. & Van Valkenberg, D.A. (1979). Auditory detection of a single gap in noise. *Journal of the Acoustical Society of America*, 65 (2), 534-536.

Dubno. J. R., Dirks, D.D. & Morgan, D.E. (1984). Effects of age and mild hearing loss on speech perception in noise. *Journal of the Acoustical Society of America*, 76 (1), 87-96.

Eggermont, J.J. (2000). Neural responses in primary auditory cortex mimic psychophysical, across-frequency channel, gap-detection threshold. *Journal of Neuro physiology*, 84, 1453-1463. Abstract retrieved from http:// www.Ncbi.nlm.nib.gov.

Elliot, L.L. (1975). Temporal and masking phenomena in persons with sensorineural hearing loss. *Audiology*. 14, 336-353.

Fitzgibbons, P. J. & Wightman, F.L. (1982). Gap detection in normal and hearing impaired listeners. *Journal of the Acoustical Society of America,* 72 (3), 761-765.

Fitzgibbons, P. J. & Gordon-Salant, S. (1986). Temporal gap resolution in listeners with high-frequency sensorineural hearing loss. *Journal of the Acoustical Society of America,* 81 (1), 133-137.

Fitzgibbons, P. J. & Gordon-Salant, S. (1987). Minimum stimulus level for temporal gap resolution in listeners with sensorineural hearing loss. *Journal of the Acoustical Society of America,* 81, (5), 1542-1556.

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

Florentine, M. & Buus, S. (1984). Temporal gap detection in sensorineural and simulated hearing impairment. *Journal of Speech and Hearing Research*. 27, 449-455.

Formby, C., Gerber, M.J., Sherlock, L.P. & Magder, L.S. (1998). Evidence for an across-frequency, between-channel process in asymptotic monaural temporal gap detection. *Journal of the Acoustical Society of America,* 103 (6), 3554-3560.

Glassberg, B. R. & Moore, B. C. J. (1988). Gap detection with sinusoids and noise in normal, impaired and electrically simulated ears. *Journal of the Acoustical Society of America,* 83 (3), 1093-1101.

Glassberg, B.R. & Moore, B.C.J. (1992). Effects of envelop fluctuations on gap detection. *Hearing Research*, 64, 81-92.

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

Gordon–Salant, S. & Fitzgibbons, P.J. (1999). Profile of Auditory Temporal Processing in older listeners. *Journal of Speech, Language, and Research*, 42, 300-311.

Hall, J. W. & Fernandes, M.A (1983). Temporal integration, frequency resolution and off-frequency listening in normal hearing and cochlear impaired listeners, *Journal of the Acoustical Society of America*, 74 (4), 1172-1177.

Hanekom, J.J. & Shannon, R.V. (1998). Gap detection as a measure of electrode interaction in cochlear implants. *Journal of the Acoustical Society of America*, 104 (4), 2372-2384.

He, N.J, Horwitz, A.R., Dubno, J. R. & Mills, J.H. (1999). Psychometric functions for gap detection in noise measured from young and aged subjects. *Journal of the Acoustical Society of America*, 106 (2), 966-978.

Irwin, R. J. & Purday, S. C., (1982). The minimum detectable duration of auditory signals for normals and hearing impaired listeners. *Journal of the Acoustical Society of America*, 71 (4), 967-974.

Irwin, R. J., Hinchliff, L. K. & Klump, S. (1981). Temporal acuity in normal and hearing impaired listeners. *Audiology*, 20 (3), 234-243.

Jesteadt, W., Bilger, R. C., Green, D. M. & Patterson, J. H. (1976). Temporal acuity in listeners with sensorineural hearing loss. *Journal of Speech and Hearing Research*, 19, 3157-3160

Klump, G. M. & Glitch, O. (1991). Gap detection in the European starting (Sturnus Vulgaris) III. Processing in the peripheral auditory system. *Journal of comparative Physiology*, 168, 469-479. Abstract retrieved from http://www.ncbi.nlm.nib.gov.

Lister, J.J. & Roberts, R.A. (2004). Effects of Age & Hearing loss on Gap Detection and the Precedence Effect: Broadband stimuli. *Journal of Speech, Language and Hearing Research*, 47, 965-978.

Lister, J.J. & Roberts, R.A. (2005). Effects of Age & Hearing loss on Gap Detection and the Precedence Effect: Narrow–Band stimuli. *Journal of Speech, Language and Hearing Research*, 48, 482-493.

Moore, B. C. J. (1997). An Introduction to Psychology of hearing. London. Academic press.

Moore, B. C. J. (1998). *Cochlear hearing loss.* Whurer Publishers

Moore, B. C. J., Glassberg, B. R. & Peters, R.W. (1992). Detection of temporal gaps in sinusoids by elderly subjects with and without hearing loss. *Journal of the Acoustical Society of America*, 92 (4), 1923-1932.

Schneider, B. A., Pichora-Fuller, M. K., Kowalchuk, D. & Lamb. K. (1994). Gap detection and the precedence effect in young and age adults. *Journal of the Acoustical Society of America*, 95 (2), 980-991

Schneider, B.A. & Hamstra, S.J. (1999). Gap detection threshold as a function of tonal duration for younger and older listeners. *Journal of the Acoustical Society of America*, 106 (1), 371-380.

Shannan, R. V. & Otto, S. R. (1990). Psychophysical measures from electrical stimulation of the human cochlear nucleus. *Hearing Research*, 47, 159-168.

Shivaprakash, S. (2003). *Gap Detection Test – Development of Norms.* Unpublished Independent Project. Mysore: University of Mysore.

Snell, K. B. (1997). Age related changes in temporal gap detection, *Journal of the Acoustical Society of America*, 101 (4), 2214-2220.

Trehub, S.E., Schneider, B.A. & Henderson, J.L. (1995). Gap detection in infants, children, and adults. *Journal of the Acoustical Society of America*, 98 (5), 2532-2541.

Tyler, R. S., Summerfiled, Q., Wood, E. J. & Fernandes, M. A. (1982). Psychoacoustic and phonetic temporal processing in normal and hearing impaired listeners. *Journal of the Acoustical Society of America*, 72 (3), 740-752.

Van. Rooij, J.C. & Plomp, R. (1990). Auditive and cognitive factors in speech perception by elderly listeners. II. Multivariate analysis. *Journal of the Acoustical Society of America*, 88 (6), 2611-2624.

Werner, L.A., Marean, G. C. Halpin, C. F., Spetner,N. B. & Gillenwater, J.M. (1992). Infant auditory temporal acuity: Gap detection. *Child development*. 63, 260-272. Abstract retrieved from http:// www.ncbi.blm.nib.gov.