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Research Article

Comparison of Performance of Older Adults on Two Tests of Temporal Resolution

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Purpose: Gap-detection thresholds have been reported to vary depending on the type of stimuli used. The current study compared the performance of older adults on 2 tests of temporal resolution, one with random gaps and the other with gaps in the center of a noise signal. The study also determined which of the 2 tests was able to detect more temporal resolution deficits in older individuals.
Method: Two tests of temporal resolution, the Gap Detection Test (GDT; Shivaprakash, 2003) and the Gaps-In-Noise test (GIN; Musiek et al., 2005), were administered to 31 older adults with near normal hearing, aged 55 to 70 years. The order in which the tests were administered was randomized.
Results: The gap-detection thresholds obtained using GIN were significantly higher than those obtained using GDT. The difference in thresholds was ascribed to the randomness with which gaps were interspersed within noise segments in the 2 tests. More individuals failed on GIN than GDT. The older adults with high-frequency hearing loss obtained poorer gap thresholds than those with normal hearing.
Conclusion: The results indicated that older individuals failed GIN more often compared to GDT. This was attributed to the differences in stimuli and procedure used in the 2 tests.

Temporal processing abilities have been found to affect the ability to understand speech in older adults (Price & Simon, 1984; Snell & Frisina, 2000; Tyler, Summerfield, Wood, & Fernandes, 1982; Working Group on Speech Understanding Aging, 1988). These studies have reported a positive relationship between gap-detection thresholds and word-recognition abilities, especially in the presence of noise. According to Price and Simon (1984), temporal-resolution abilities deteriorate with age, and this affects perception of temporal characteristics of speech, including perception of vowels and silent durations that help distinguish between speech sounds. In a similar manner, Snell and Frisina (2000) reported that temporal-resolution abilities could explain, to a certain extent, the variations observed in perception of spondee in the presence of babble, particularly in younger adults. Due to the negative impact of temporal processing problems on speech perception, it is essential to assess these abilities, especially in older adults, so that they can be provided further guidance in terms of deficit-specific rehabilitation.

Recognizing the importance of detecting temporal processing difficulties, researchers have developed several tests to assess temporal-resolution abilities (Keith, 2002; Lister, Roberts, Shackelford, & Rogers, 2006; Musiek et al., 2005; Shivaprakash, 2003). Tests used to assess temporal resolution include the Random Gap Detection Test developed by Keith (2002), the Gap Detection Test (GDT) developed by Shivaprakash (2003), the Gaps-In-Noise test (GIN) developed by Musiek et al. (2005), and the Adaptive Test of Temporal Resolution developed by Lister et al. (2006). These tests of temporal resolution assess the ability of individuals to detect the shortest gap embedded within a sound. However, they differ in terms of the type of test stimuli in which the gap is embedded (white noise, clicks, tones), the location of the gaps, or in the way the response is elicited (oral or using a response button). Two tests that have considerable differences are GDT and GIN. Although both tests have gaps embedded within a broadband noise and test monaural temporal-resolution abilities, they differ in several ways. In GDT, the gaps are placed in the center of a 300-ms broadband noise, whereas in GIN, they are placed randomly within a 6-s broadband noise. The difference in the location of the gap and the uncertainty in gap location were found to have an effect on the gap-detection threshold in older listeners by Harris, Eckert, Ahlstrom, and Dubno (2010). They used a noise burst with gaps fixed at 5%, 50%,

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or 95% that varied in location from trial to trial. It was reported that a gap fixed at 50% of the total noise burst duration was easier to identify compared to those at 5% and 95% of the total noise burst duration. They also reported that the uncertainty in the gap location within the noise burst also significantly affected the gap-detection threshold. Earlier, Green and Forrest (1989) and He, Horwitz, Dubno, and Mills (1999) reported similar effects of gap location and uncertainty in gap location. In addition, Harris et al. noted that mental demand was high for tasks involving gap detection in stimuli, with gap location varying from trial to trial.

GIN and GDT also differ from each other in the way the responses are elicited. GIN requires the listener to indicate the presence of a gap within the noise segment each time it occurs. On the other hand, GDT requires the listener to indicate which of the three noise bursts that are presented contains a gap. Another difference between the two tests is the order in which the stimuli are presented. In GIN, gaps of different durations are randomly presented, whereas in GDT, larger gaps are presented at first, and the gap size reduces progressively. In addition, in the former test, each gap duration is randomly repeated six times, and in the latter, it is repeated three times, one after the other.

A comparison of norms obtained on an Indian population on GIN (Aravindkumar et al., 2012) and GDT (Shivaprakash, 2003) revealed that the values vary. This occurred even though both studies evaluated similar age groups. Aravindkumar et al. (2012) studied young adults aged 21.13 to 31.47 years, and Shivaprakash (2003) evaluated individuals aged 18 to 35.11 years. The gap-detection thresholds were longer for the former study (5.22 ms) compared to that of the latter study (3.3 ms). This difference in the normative values could be due to the complexity of the task used in the tests. The design of GDT is such that individuals are able to anticipate the presence of a gap, resulting in the perception of shorter gaps. Thus, it is possible that, depending on the test administered, the number of individuals with temporal-resolution deficits detected will vary.

With advance in age, it has been noted that temporal resolution deteriorates (He et al., 1999; John, Hall, & Kreisman, 2012; Moore, Peters, & Glasberg, 1992; Schneider & Hamstra, 1999; Schneider, Pichora-Fuller, Kowalchuk, & Lamb, 1994; Snell, 1997; Strouse, Ashmead, Ohde, & Grantham, 1998). This deterioration has been demonstrated despite studies utilizing different tests having dissimilar stimuli. They all concluded that temporal-resolution abilities were poorer in the older listeners when compared to younger listeners. However, from the results of these studies, it is not clear as to which of these stimuli or methods are more sensitive to detecting deficits in temporal-resolution abilities in older individuals. The studies also do not provide information about the individual performance of older individuals but only provide group data, thus making it difficult to apply the information in clinical practice. Further, comparisons are made with the younger listeners on the basis of the mean thresholds obtained. This again makes the application of this information in clinical settings difficult.

Hence, the current study aimed to compare the performance of older adults with near normal hearing on two monaural tests of temporal resolution (GDT and GIN). Although both the tests had gaps located within a broadband noise, they differed in the manner in which the gaps were presented. Thus, the two tests differed mainly in terms of whether the gaps are presented randomly or not. The study also determined which of these two tests is able to identify a larger number of older adults with temporal-resolution difficulties. To study the effect of aging, the performance of the older adults was compared with the norms available for young adults. In addition, a comparison between older adults having normal hearing and high-frequency hearing loss was carried out.

Method

Participants

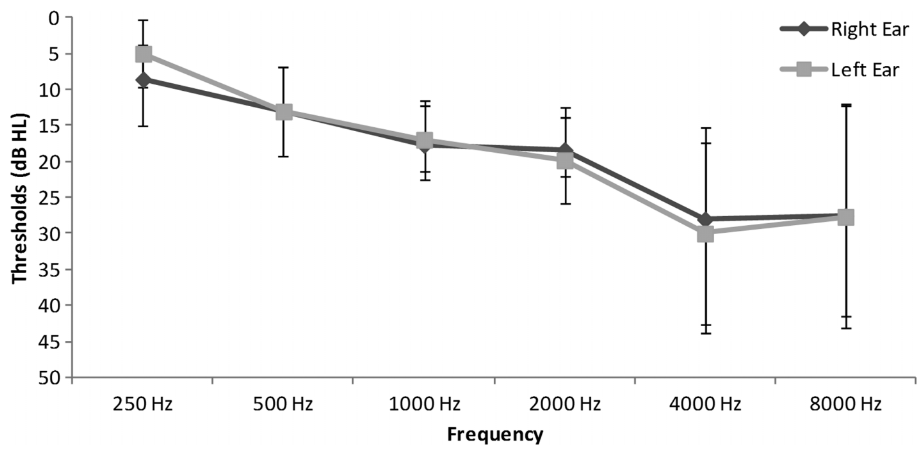
A total of 31 older adults (16 men and 15 women) in the age range of 55 to 70 years (mean age of 60.39 years) participated in the study. Those without any history of otological and neurological deficits were selected. All participants had pure-tone thresholds less than 20 dB HL from 250 Hz to 2000 Hz in both ears (see Figure 1). The presence of normal middle ear functioning was ensured using immittance audiometry. Only those with a minimum of middle school education (passed eighth grade) were chosen. Informed consent was obtained from all participants prior to their being tested. The current study was carried out in adherence to the *Ethical Guidelines for Bio-Behavioural Research Involving Human Subjects* of the All India Institute of Speech and Hearing (2009).

Test Description

The GDT developed by Shivaprakash (2003) consists of 60 stimulus sets that include four practice sets and six catch trials. Each stimulus set consists of three 300-ms broadband noise bursts, with one of them having a gap inserted in the center with a rise and fall time of 3 ms. However, the catch trials have no gap inserted in any of the three noise bursts. The duration of the gap within the noise burst gradually reduces from 20 ms to 1 ms from one stimulus set to the other. This reduction in gap begins in steps of 2 ms (from 20-ms to 11-ms gaps) and later reduces to 1-ms steps (from 10-ms to 1-ms gaps). A waveform and spectrogram of a sample stimuli having gap duration of 20 ms are shown in Figure 2. Each gap duration occurs three times consecutively. The stimuli are recommended to be presented at 40 dB SL (reference pure-tone average [PTA]). The smallest gap duration detected by an individual is required to be established using a bracketing technique. This is considered as the gap-detection threshold.

The GIN test (Musiek et al., 2005) consists of four lists, 10 practice stimuli and 29 to 36 test stimuli. The 6-s broadband noise segments have either no silent gap or up to three silent gaps. Each list contains up to 36 noise segments with a total of 60 gaps. Musiek et al. (2005) reported that the duration of the gaps varies pseudorandomly from 20 ms to

Figure 1. Mean pure-tone thresholds for the right and left ears of the participants. Error bars represent ±1 *SD*.



2 ms (2, 3, 4, 5, 6, 8, 10, 12, 15, and 20 ms), with each of them occurring six times randomly within a list. The interval between each noise segment in a list is 5 s. The minimum duration of the gap at which four out of the six gaps are correctly identified is considered as the approximate gap-detection threshold.

Procedure

The evaluations were carried out in an air-conditioned, acoustically treated double room situation, meeting the American National Standards Institute (ANSI, 1999) specifications of ANSI S3.1. All participants were evaluated on both tests of temporal resolution using a calibrated two-channel audiometer (Madsen Astra) under headphones (TDH 39) with each ear tested individually. Half the participants were tested using GDT first and the other half with GIN first to avoid a test-order effect. In addition, half were tested in the right ear first and half in the left ear first to prevent an ear-order effect.

GDT was administered at 40 dB SL (reference PTA) as the norms for the test were established at this level. The participants were asked to indicate which of the three noise bursts contained a gap. The smallest gap duration that was correctly identified twice out of the three presentations by the participants was considered as the gap-detection threshold. This was similar to the bracketing technique recommended by Hickling (1966) to estimate thresholds for pure-tones. Prior to the administration of the test, all participants were presented with a practice trial to ensure that the instructions were correctly understood.

The participants were tested with GIN at 50 dB SL (reference PTA) as recommended by Musiek et al. (2005). The participants were instructed to press a response button as soon as they heard a gap within the noise segment. Each ear was tested using a different list to avoid any familiarity effect. To begin, the practice trial was presented to ascertain that the instructions were understood.

In addition to the two tests of temporal resolution, the Screening Checklist for Auditory Processing in Adults (Vaidyanath & Yathiraj, 2014) was also administered to all participants. This screening checklist was used to select individuals who were likely to have an auditory processing deficit. The participants used a two-point rating scale to answer 12 questions that probed for symptoms of auditory processing difficulties. A score of four and above was considered to indicate the presence of auditory processing difficulties.

The responses were noted and scored after the completion of both tests, using the scoring procedure recommended in the original tests. The gap-detection thresholds obtained using the two tests were tabulated and analyzed.

Statistical Analyses

Descriptive statistics and inferential statistics were carried out using SPSS (Version 16). The inferential statistics included a repeated measures analysis of variance (ANOVA) and Pearson's correlation coefficient to determine the difference/relationship between the gap-detection thresholds obtained through the two tests. A paired-sample t test was also done to compare the performance between the two ears for each test as well as to compare the two tests for each ear.

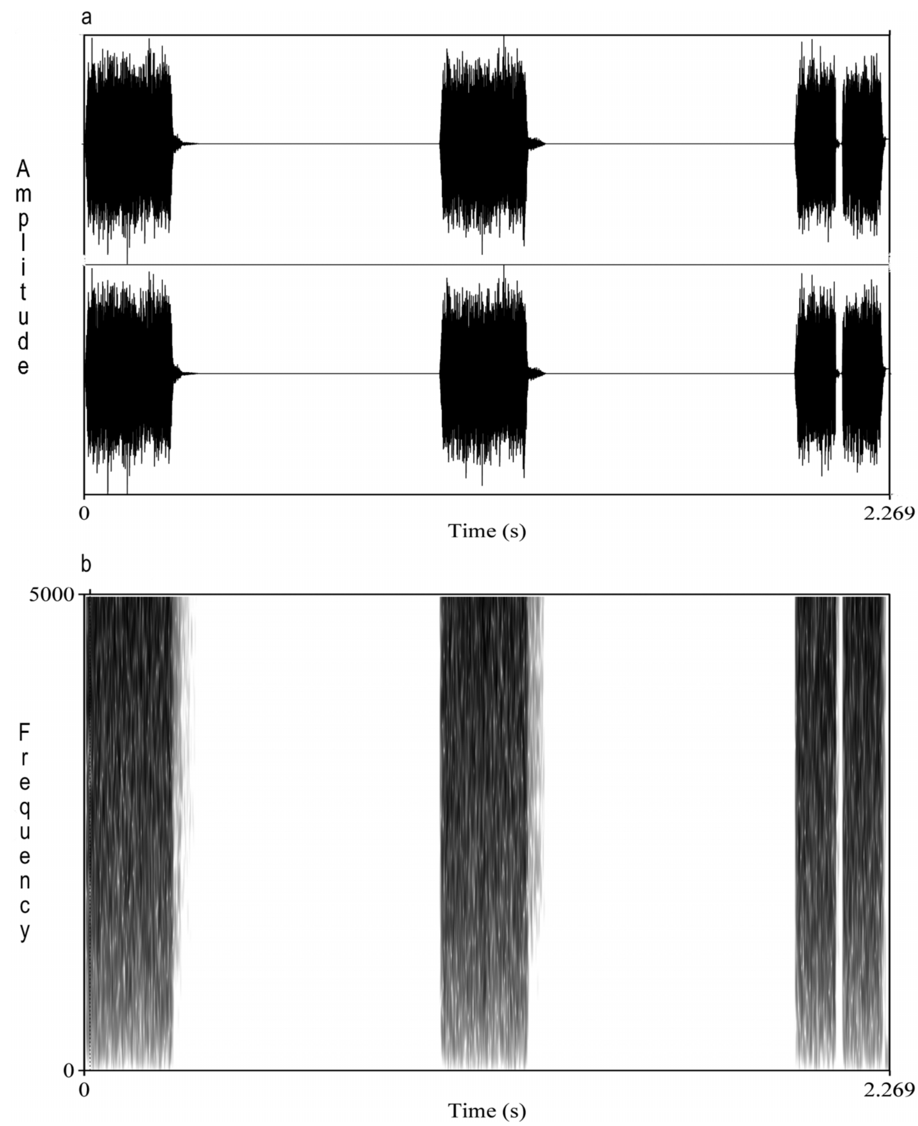
Results

The statistical findings of the data obtained from the 31 participants on the two tests of temporal resolution are furnished for each temporal test separately and between the two tests. In addition to providing the difference/similarity between the ears (left and right) and tests (GDT and GIN), the presence of an interaction between the tests and ears is provided.

Performance on Tests of Temporal Resolution

From the descriptive statistics given in Table 1, it can be observed that the mean gap-detection threshold was smaller for GDT compared to GIN. In a similar manner,

Figure 2. Sample waveform (a) and spectrogram (b) of a stimulus triad used in the Gap Detection Test, with the first two having no gap and the third having a gap duration of 20 ms.



the mean gap-detection thresholds obtained in the left and right ears using GDT were comparable. However, the same was not true for the gap-detection thresholds obtained using GIN, with which smaller gaps were detected in the left ear compared to the right ear.

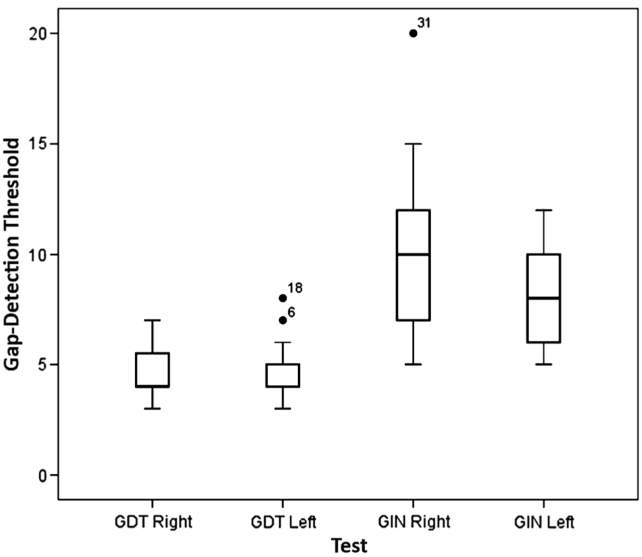
Table 1. Mean and standard deviation (in parentheses) of the gap-detection threshold obtained using the Gap Detection Test (GDT) and Gaps-In-Noise test (GIN).

	M (*SD*)	
Tests	**Right ear**	**Left ear**
GDT	4.42 (1.23)	4.39 (0.83)
GIN	9.28 (3.31)	7.6 (3.93)

Prior to determining the difference/similarity between the ears and tests, the data were analyzed to check for the presence of outliers/extremes. A box plot drawn for the responses obtained for each ear for the two tests indicated the presence of three outliers (see Figure 3). Hence, the data obtained from these three outliers were eliminated, and the statistical analyses were carried out for the data obtained from the remaining 28 participants.

A repeated measures ANOVA was carried out with the test and ear as within-subject factors. A significant main effect was found for the tests with ears combined, $F(1, 27) = 73.97$, $p < .001$, partial $\eta^2 = .73$, and ears with tests combined, $F(1, 27) = 8.3$, $p < .01$, partial $\eta^2 = .23$. Further, a significant interaction was also found between the test and ear, $F(1, 27) = 8.7$, $p < .01$, partial $\eta^2 = .24$.

Figure 3. Box plot representing data obtained from 31 participants on the Gaps-In-Noise test (GIN) and Gap Detection Test (GDT) for the two ears. Error bars represent the 95% confidence interval.



After Bonferroni correction, pairwise comparison of the two tests, with ears combined, revealed a significant difference ($p < .001$) between the two tests. Further, to obtain information regarding the difference between the two tests separately for the left and right ears, a t test was carried out. A significant difference was found between the performances of the right ear ($t = 7.82$, $df = 27$, $p < .001$) and left ear ($t = 7.01$, $df = 27$, $p < .001$) on the two tests.

Because a significant interaction was found between the tests and ears, a paired-sample t test was done to see if there was any significant difference between the performances of the two ears for each of the tests. A significant difference between the two ears was not found for GDT ($t = 0.16$, $df = 27$, $p > .05$) but was obtained for GIN ($t = 3.17$, $df = 27$, $p < .01$). In the latter test, the left ear performance was found to be significantly better than that of the right ear.

Further, to establish the relationship between the thresholds obtained through the two tests, a Karl Pearson's correlation coefficient was computed. No significant correlations were obtained between these measures for the right ear ($r = .2$, $p > .05$) and the left ear ($r = –.03$, $p > .05$).

Comparison of Performances With Norms of Young Adults

In order to check which of the two tests was able to detect the presence of a temporal resolution deviancy in older adults, the scores obtained by the participants were compared with available norms. The scores obtained by the participants on GDT were compared with the norms provided by Shivaprakash (2003), and the scores obtained on GIN were compared with the norms given by Musiek et al. (2005) for a Western population as well as Aravindkumar et al. (2012) for an Indian population.

The number of older individuals who passed or failed one or both temporal-resolution tests is depicted in Table 2. It can be observed from the table that more individuals failed GIN when compared to GDT. This was observed irrespective of whether the GIN scores were compared with the Western norms (Musiek et al., 2005) or Indian norms (Aravindkumar et al., 2012).

Figures 4 and 5 show the gap-detection thresholds of the 28 participants on the two tests. The shaded regions in the two graphs represent the normal range. As reported earlier, it can be seen from the two figures that a larger number of individuals fell outside the normative region on GIN compared to GDT. The participants who obtained gap-detection thresholds poorer than the norms of young adults included those with and without hearing loss in the high frequencies.

Comparison of Performances of Older Adults With and Without High-Frequency Hearing Loss

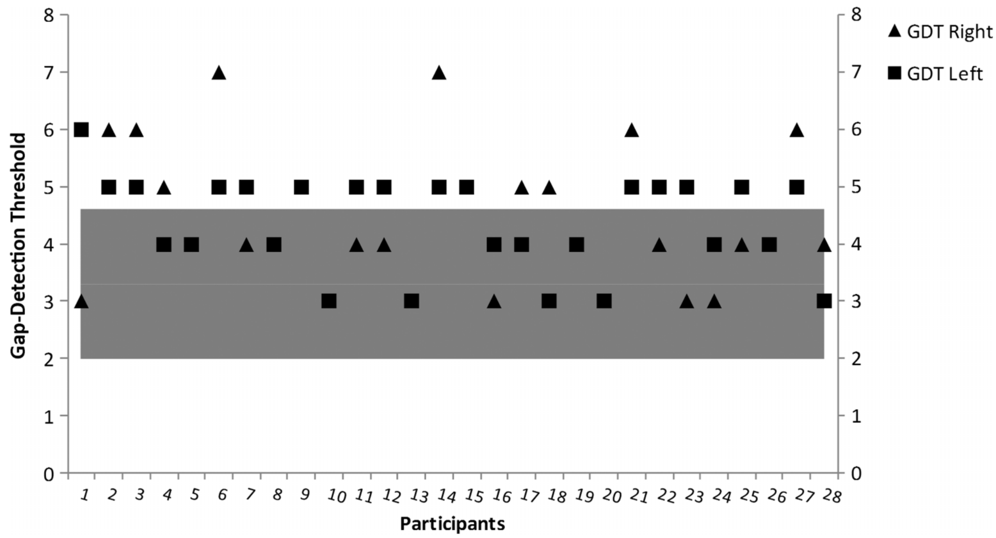
To determine the influence of the presence of a mild to moderate high-frequency hearing loss, the older adults were divided into two groups: 14 participants with normal hearing across all frequencies (≤25 dB HL) and 14 with high-frequency hearing loss (≥25 dB HL in the frequencies 4 kHz and 8 kHz). The 25-dB HL cutoff was chosen on the basis of the classification provided by the World Health Organization (2007). The gap-detection thresholds obtained on the two tests were compared across these two groups using a one-way ANOVA. For GIN, this was done for each ear independently, as a significant ear difference was present. However, the scores of the two ears were collapsed for GDT because no ear difference was observed. It was noted that there was a significant difference between the two participant

Table 2. Number of older individuals who passed or failed one or both of the temporal-resolution tests on the basis of norms of Shivaprakash (2003) for the Gap Detection Test (GDT) and Aravindkumar et al. (2012) and Musiek et al. (2005) for the Gaps-In-Noise test (GIN).

Right ear			
		GDT	
		Fail	**Pass**
GIN	Fail	11	10
	Pass	0	7
Left ear			
		GDT	
		Fail	**Pass**
GIN	Fail	9	6
	Pass	6	7

Note. Pass criteria as per the recommendations of Shivaprakash (2003) for GDT = 3.3 ± 1.32 ms. Pass criteria as per the recommendations of Aravindkumar et al. (2012) for GIN = 5.22 ± 2.22 ms. Pass criteria as per the recommendations of Musiek et al. (2005) for GIN = 4.9 ± 2 ms.

Figure 4. Scatter plot showing gap-detection thresholds obtained on the Gap Detection Test (GDT). The shaded area represents the norm given by Shivaprakash in 2003 ($M \pm 2$ *SD*s).

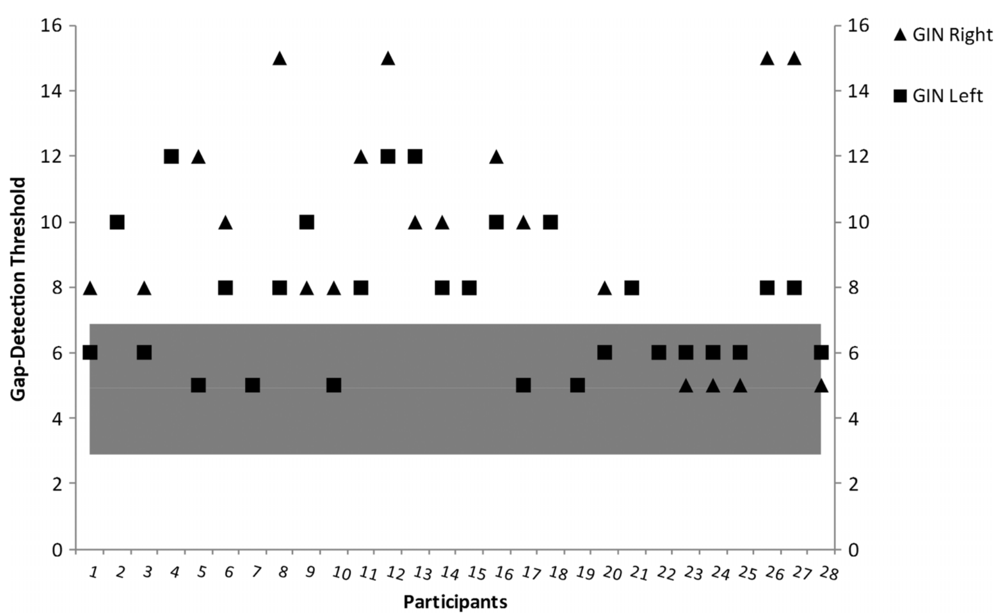


groups for GIN for the right ear, $F(1, 26) = 4.22$, $p = .05$, and for the left ear, $F(1, 26) = 6.11$, $p < .05$. No such difference was obtained for GDT, $F(1, 54) = 1.34$, $p > .05$.

In addition, a paired *t* test was carried out to check if there existed an ear difference between each of the participant groups. The results revealed that there was no significant difference found between the gap-detection thresholds of the two ears obtained on GDT in both the groups. In a similar manner, on GIN, no significant difference was found between the gap-detection thresholds of the two ears in the normal hearing group ($t = 1.76$, $df = 13$, $p > .05$). However, there was a significant ear difference for the group with a high-frequency hearing loss ($t = 2.73$, $df = 13$, $p < .05$).

A comparison was also made with the gap-detection thresholds obtained by John et al. (2012), who studied 28 older adults with normal hearing and 76 with hearing impairment. The mean and standard deviation of the

Figure 5. Scatter plot showing gap-detection thresholds obtained on the Gaps-In-Noise test (GIN). The shaded area represents the norm given by Aravindkumar et al. in 2012 ($M \pm 2$ *SD*s).



gap-detection thresholds obtained using GIN by their normal hearing participants (M = 6.6 ms, SD = 1.4) and their participants with hearing impairment (M = 8.8 ms, SD = 2.5) were compared with the values obtained in the current study. The findings of the single-sample t test indicated that the mean gap-detection thresholds were not significantly different in the two studies for those with normal hearing for the right ear ($t = 1.83$, $df = 13$, $p > .05$) and left ear ($t = 0.03$, $df = 13$, $p > .05$). Likewise, there was no significant difference between the means scores of the two studies for those with hearing impairment (right ear: $t = 1.93$, $df = 13$, $p > .05$; left ear: $t = 0.36$, $df = 13$, $p > .05$).

Further, to evaluate if the presence of a high-frequency hearing impairment had an effect on the gap-detection thresholds obtained on the two tests, a partial correlation was done. The r values were similar, with and without eliminating the influence of age, when correlations were carried out between average high-frequency pure-tone thresholds (4 and 8 kHz) and gap-detection thresholds obtained on the two tests. Although the r value obtained using a partial correlation to eliminate the influence of age was .43 and .29 for GDT and GIN, respectively, it was .4 and .3 when correlation was carried out without the elimination of age effects. This indicates that the difference in the gap-detection thresholds seen in the older adults was due to the effect of high-frequency sensitivity rather than age.

Thus, the results of the current study indicate that the performance of older adults on the two tests of temporal resolution differed significantly. The gap-detection thresholds were better with GDT compared to GIN. However, when the scores were compared with available norms of young adults, more individuals were found to fail GIN in contrast to GDT. Similar performance on GIN was observed when compared to that reported in the earlier studies. The reasons for this difference in performance on the two tests (GIN and GDT) as well as between the group with normal hearing and the group with high-frequency hearing impairment are discussed.

Discussion

The current study compared the performance of older adults on two tests of temporal resolution. These two tests used gaps of almost similar durations within a broadband noise; however, they differed in terms of other aspects of the stimuli and in the procedure used for administration.

The comparison of performance on the two tests of temporal resolution indicated that the thresholds were better on GDT and poorer on GIN. The difference in performance in the older adults on the two tests can be ascribed to the design of the stimuli and the procedure utilized in obtaining responses. The better performance on GDT, compared to GIN, could be due to the task being less taxing in the former compared to the latter test. For GDT, the participants were required to indicate which three noise bursts had a gap embedded in their center. On the other hand, in GIN they had to indicate the presence of a gap that randomly varied in terms of location within a noise signal. As the gaps always occurred in the center of a burst of noise in GDT, it probably enabled the participants to predict its occurrence, making the task easier than detecting the random gaps of GIN.

The better gap-detection threshold obtained using GDT is in consensus with the reports of Green and Forrest (1989), He et al. (1999), and Harris et al. (2010). They reported that the gap-detection threshold was found to be better for gaps fixed at 50% of the total noise bursts than when they occurred randomly over the duration of the noise bursts. The uncertainty in the gap location within the noise burst was found to affect the gap-detection threshold significantly. Harris et al. attributed this uncertainty to an increased mental demand when tasks involved detection of stimuli having a varying location from trial to trial.

Similar to the findings of the current study, Marshall and Jesteadt (1986), using pure-tone, found a two-interval forced-choice procedure to yield better thresholds compared to the ANSI S3.21 (1978) procedure. The authors attributed the better response using the two-interval forced-choice procedure to the participants having a defined interval in which they had to listen for the presence of a signal. In addition, the forced-choice method was also considered to reduce response bias on the part of the listener. Likewise, in the present study, such factors may have also led to the better gap-detection thresholds on GDT, which used a three-interval forced-choice procedure, in comparison to that obtained using GIN.

The gap-detection threshold obtained on GIN in the current study was similar to that obtained by John et al. (2012) in their group of older adults. This similarity existed for the normal hearing group as well as the group with high-frequency hearing loss.

In the present study, it was also established that the right ear scores for GIN were significantly poorer than that of the left. These findings are unlike what has been observed in young adults (Aravindkumar et al., 2012; Musiek et al., 2005). To determine the possible reasons for the ear difference, the participants were divided on the basis of their high-frequency audibility to check if hearing abilities had an effect. The group with normal hearing did not show an ear difference, whereas the group with high-frequency hearing impairment continued to have an ear difference. In addition, the data were further analyzed to check for gender differences and temporal-resolution abilities. An independent-sample t test indicated that there existed no significant gender difference unlike what has been observed in studies using dichotic tasks to evaluate auditory integration (Bryden, 1988; Jerger, Chmiel, Allen, & Wilson, 1994). As a significant ear difference persisted in both men and women, gender difference as a possible reason was ruled out. Further, the possibility of temporal resolution being a reason for the ear difference was eliminated because a paired t test indicated that a significant ear difference continued to exist in individuals who passed or failed GIN. Thus, it can be concluded that the difference between the two ears could be on account of the presence of hearing impairment.

In addition, the influence of age on gap-detection thresholds was ruled out in the present study, as there was a minimal change in correlation values between gap-detection thresholds on the two tests when the effects of age were controlled. This augments the contention that high-frequency hearing threshold is an important parameter that influences gap-detection threshold.

It is speculated that the way the two hemispheres function in those with hearing impairment in the high frequencies could have led to the ear difference in the GIN test. It is generally accepted that the right hemisphere responds better to nonverbal signals compared to the left hemisphere (Eulitz, Diesch, Pantev, Hampson, & Elbert, 1995). However, it has been noted by Binder et al. (2000) and Mirz et al. (1999) that both hemispheres do respond to nonverbal stimuli. In addition, it has been reported that the left hemisphere codes temporal-related information, and the right hemisphere codes spectral information (Liégeois-Chauvel, de Graaf, Laguitton, & Chauvel, 1999; Okamoto, Stracke, Draganova, & Pantev, 2009; Zatorre & Belin, 2001). Thus, it can be construed that in younger adults both hemispheres respond during temporal-resolution activities, responding to both spectral and temporal information. With aging, the performance of both hemispheres probably reduces. However, the ability to code temporal information is probably more affected, resulting in reduced performance in the right ear. This could have led to the better performance in the left ear compared to the right ear that stimulates the opposite hemispheres due to crossed fibers being stronger.

From Table 1, it can be noted that the ratio of gap-detection thresholds obtained using the two tests (GIN and GDT) was 2.2 and 1.8 for the right and left ears, respectively. This indicates that, at the threshold level, the gap had to be almost twice the duration in GIN compared to GDT. However, Green and Forrest (1989), using stimuli that had gaps that occurred randomly or constantly in the center, reported much smaller ratios, indicating that the two types of tests do not differ. Green and Forrest noted that, in their young listeners with normal hearing, the ratio of the two types of stimuli was 1.37. Similar to the findings of Green and Forrest, He et al. (1999) reported that the ratio of the slopes for the gap-detection threshold obtained for fixed and random conditions was 1.48 for older adults compared to the 1.3 seen in younger adults. He et al. also observed that there was no significant difference between the gap-detection threshold obtained for the gaps fixed in the center of a noise signal and gaps that were located randomly. This was seen in both age groups studied by them. Findings similar to those observed in the current study were noted by Harris et al. (2010). Their participants had more difficulty in detecting randomly occurring gaps compared to gaps that occurred at predictable intervals (at 5%, 50%, or 95% of the total noise burst duration). They also found a negative correlation between gap-detection thresholds obtained using random gaps and processing speed. Thus, they inferred that random gaps required increased mental demand and effort. In addition, they noted that reduced gap detection of random gaps was related to age-related differences in cognitive processing abilities.

In a real-life situation, it is known that gaps occur randomly and not at regular intervals. The acoustic gaps in continuous speech are known to occur in a pseudorandom order. Although GIN was found to result in poorer performance in the older adults in the current study, it can be construed that it gives a more realistic picture of the difficulties faced by individuals in a real-life situation for temporal resolution when compared to GDT that has gaps that occur at intervals that are more regular. Thus, it is recommended that GIN should be used if a more realistic idea about the problems confronted by older individuals in daily communication is to be detected. In addition, to get more holistic information about auditory processing difficulties of older adults in real life, administration of other speech-based tests is advised.

Studies using gaps placed in the center of stimuli have reported gap-detection thresholds of older adults being similar to those obtained by young adults. However, when the gap occurred at random, a significant difference in the performance was found (Bertoli, Smurzynski, & Probst, 2002; Harris et al., 2010; He et al., 1999; Moore et al., 1992). It can be construed that, if more subtle problems in temporal resolution need to be identified, then stimuli with gaps occurring randomly should be used.

The poorer response in GIN can also be attributed to the longer time an individual had to attend to a signal at a stretch. For GIN, the individual had to attend to a 6-s signal at a stretch, and for GDT, the person was required to attend to shorter spurts of noise of 300 ms. Thus, GDT did not tax the attention of a person to the same extent that GIN did.

The absence of a significant correlation between the gap-detection thresholds obtained using the two tests in the current study can be considered to indicate that the two tests do not provide identical information. Many factors may have influenced the performance on the two tests, including the randomness of the gap, location of the gap, and the duration of the noise in which the gap was inserted. On the basis of the findings of Stellmack, Viemeister, Byrne, and Sheft (2013), it can be inferred that the randomness and location of the gaps probably resulted in the difference in performance between the two tests rather than the duration of the noise. Stellmack et al. noted that gap-discrimination thresholds were better for a continuous noise having gaps interspersed at set intervals compared to noise markers having a duration of 300 ms with a gap in its center. However, when shorter noise markers of 3 ms were used, the gap-discrimination thresholds were similar to that seen for continuous noise. The current study used 300-ms and 6-s noise, similar to the 300-ms and continuous noise markers used by Stellmack et al. Hence, it can be construed that the difference in gap-detection thresholds obtained for GDT and GIN in the present study probably could be due to the location and randomness of the gaps rather than the length of the noise used.

Other factors could have led to the difference in performance in the two tests, one being the intensity level at which the stimuli were presented. However, this may not have had an effect, as the performance on GDT was better despite being presented at a lower level (40 dB SL) compared to that on GIN, which was evaluated at 50 dB SL. It can be concluded that a combination of factors, including the uncertainty in the location and duration of the gap, the reduced predictability of the gaps, the increased cognitive demand, and the extended duration for which an individual had to attend, may have led to poorer performance on GIN.

Comparison of performance of the older adults with norms of young adults revealed that the majority of the older individuals failed both tests of temporal resolution. This was seen irrespective of if Western or Indian norms were utilized. However, as evident from the scatter plots (see Figures 4 and 5), there were a few older individuals with gap detection thresholds similar to those seen in young adults. Thus, although the majority of older adults did demonstrate the presence of a temporal-resolution deficit in the current study, this problem did not exist in every one (see Table 2).

The number of individuals who failed the GIN test was similar when either the Western norms (Musiek et al., 2005) or the Indian norms were used (Aravindkumar et al., 2012). From this, it can be deduced that norms for GIN, developed on different populations, can be used interchangeably, as they yield similar results when identifying temporal deficits. It was speculated that because temporal characteristics of most Indian languages differ from that of native English, it could influence temporal-resolution abilities. Reports of variation in temporal characteristics such as voice onset time in native English and Indian languages have been noted by Lisker and Abramson as early as in 1964. The findings of the current study indicate that these temporal variations do not influence temporal-resolution abilities for nonverbal stimuli.

From the findings of the study, it is recommended that a temporal-resolution test with randomly presented gaps, such as GIN, be chosen instead of a test with predictable gaps, such as GDT. This is primarily suggested because more older adults were detected to have a problem with the former test compared to the latter test. It can be inferred that a test with random gaps requiring sustained attention is able to detect subtle difficulties in temporal resolution that may be missed if predictable gaps are used.

Conclusion

The comparison of the two temporal resolution tests (GDT and GIN) on older individuals indicated that the gap-detection thresholds obtained using GIN were higher compared to those obtained using GDT. The participants required almost double the duration of gap for GIN compared to GDT at the gap-detection threshold. GIN was able to detect more individuals having a temporal-resolution problem than GDT. A similar number of individuals failed the GIN test when either the Western norms or the Indian norms were used, indicating that the two norms could be used interchangeably. In addition, it was observed that the majority of older individuals obtained poorer thresholds than available norms of young adults. The older adults with high-frequency hearing loss obtained poorer gap thresholds than those older adults with normal hearing. On the basis of the findings of the study, it is recommended that temporal resolution should be assessed using a test with randomly occurring gaps that are less likely to be predicted rather than a test with gaps occurring at constant intervals.

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