Auditory temporal resolution and word recognition in noise in older women

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Objective: We examined women in their early 60s for age-related changes in both auditory temporal gap detection and word recognition in noise and investigated to determine if there was any relationship between them.

Methods: The subjects were 14 young women (aged 18 to 24 years) and 33 older women (aged 59 to 65 years) with essentially normal hearing in at least one ear. The temporal gap detection thresholds (GDTs) and word recognition scores (WRSs) under continuous and interrupted noise were evaluated in all the subjects. Test materials were low-pass filtered to eliminate the influence of high-frequency hearing loss in the older group.

Results: Significant differences were seen between the age groups both in GDTs and in WRSs in noise at poor signal-to-noise ratios (SNRs). Significant partial correlation between GDT and age was found when hearing sensitivity was controlled. Significant simple correlations were seen between GDT and WRS in noise at low SNRs (-10 dB and -15 dB), but WRSs in noise did not significantly correlate with GDT when hearing sensitivity and/or age were included as explanatory variables in the multiple regression analysis.

Conclusions: Deterioration in auditory temporal resolution and speech recognition in noise, the former most likely having a central origin, was confirmed in older women in their early 60s. No correlation between deterioration in auditory temporal resolution and that of speech recognition in noise was found.

Key words: auditory temporal resolution, gap detection, temporal acuity, speech recognition in interrupted noise

Introduction

Auditory temporal resolution is one aspect of temporal processing that is reported to deteriorate before 60 years of age,1 even in persons whose hearing is in the normal range.2,3 In general, age seems to affect temporal processing though some investigators suggest that temporal resolution does not deteriorate with age.4 It is still not clear whether or not temporal resolution deteriorates with age independently from hearing loss, when it starts to deteriorate, if indeed it does, and in which case, if deterioration of temporal resolution leads to speech recognition deficits in older people, especially in noise.

Most studies evaluating the effect of age on auditory temporal processing have included middle-aged and/or elderly participants whose hearing thresholds were slightly elevated compared with those of young people. These elevations of hearing thresholds are present at both middle and high frequencies, although the latter is more evident. Since hearing loss has been reported to affect temporal processing measures,5,7 it raises a question of whether slightly decreased peripheral hearing sensitivity in the mid- or high frequencies would affect the results of temporal processing measures in older people. Although some studies controlled hearing sensitivity statistically to rule out the hearing loss effect, those studies showed inconsistent results in relation to the effect of age. For example, Takahashi and Bacon7 reported that age had no effect on modulation detection of a broadband noise once hearing sensitivity was statistically controlled. On the other hand, elevated gap detection thresholds
(GDTs) have been observed for elderly people, even when their hearing sensitivity was matched to that of younger listeners. Schneider et al. reported GDTs of old adults when using brief tone pips at 2 kHz were about twice as large as those of young adults, while no correlation was found between old adults' audiometric threshold and GDTs. However, no correlations in their results were obtained within the results of young and elderly participants, respectively, with a limited range of audiometric threshold. When the data from young participants (Table II from their study) and older participants (Table III) were analyzed, the correlation became significant (P < 0.05), suggesting that there was a relationship between hearing sensitivity and GDTs.

In addition to temporal processing, speech recognition under noise has been reported to deteriorate with age, even with essentially normal peripheral hearing sensitivity. It has been well documented that the speech recognition performance of elderly people in adverse conditions such as in noise, in reverberation, and time-compressed speech is poor compared with young people. The same question as that of the above temporal processing measures can be raised about the influence of hearing loss in the elderly. Dubno et al. determined the effects of age on speech recognition ability under conditions of quiet and noise in young and elderly people with normal hearing and by matching subjects with hearing loss, and found that age effects were not observed for speech recognition in the absence of background noise. Contrastingly, age effects were found for speech recognition in noise in their study. Takahashi and Bacon's study, however, found no age effect for speech recognition, even in noise, once hearing sensitivity was statistically controlled.

Stuart et al. investigated word recognition in interrupted and continuous broadband noise, which is spectrally identical. They reported that speech understanding of elderly people in interrupted noise was significantly worse than that of young people, while speech understanding of elderly people in continuous noise was comparable to that of young people. They conjectured that the reason elderly people had poor performance of word recognition in interrupted noise could be related to their deteriorated temporal resolution. How well one can detect subtle silence between broadband noise stimuli should be related to how a person recognizes speech in interrupted broadband noise, because both processes seem to require the same kind of temporal processing. Therefore, we hypothesized that temporal resolution likely has a stronger relationship with speech recognition in interrupted noise than in continuous noise.

The purpose of the present study was to examine whether or not auditory temporal gap detection and word recognition in noise deteriorate in older people, even when the hearing loss is statistically controlled, and to find out whether or not word recognition in noise is related to temporal resolution. The effect of hearing sensitivity was minimized by using 4-kHz low-pass filtered stimuli to control for mild high-frequency hearing loss in the older subjects. Multiple regression analysis was used to control mid-frequency hearing sensitivity. We wanted to determine if there was a relationship between gap detection as an elementary function of temporal processing and speech recognition in noise as a performance measure of daily living. We also wanted to discover whether or not gap detection tests could be used to predict speech recognition in noise in the nonclinical older population. Some older patients who perceive difficulty hearing speech in noise come to the clinic only to find that their hearing is normal, but some patients' hearing difficulties may be related to temporal processing deficits. The present report describes a study of the Gaps-In-Noise (GIN) test, which is a commercially available measuring tool of temporal resolution, and assessing speech recognition in interrupted and continuous noise in young and older women. To the best of our knowledge, a direct comparison between GDTs measured with the GIN test and speech recognition in noise has not been reported except for Helfer and Vargo's study, but they did not use interrupted noise in their study.

Materials and Methods

The protocol for this study was approved by the Research Ethics Board, Kitasato University, Kanagawa, under protocol number 2011-001.

Participants

Young participants were recruited from among students at the university by word of mouth and posters, and older participants were recruited by a non-profit staff resource agency in the university area. Our data was collected from only women because of the potential differences in age-related speech recognition and temporal processing between men and women. Fourteen young women (mean age, 20.7 years; standard deviation (SD), 1.6 years) and 33 older women (mean age, 62.5 years; SD, 1.7 years) participated in the study. All the young participants presented with hearing thresholds of ≤20 dB hearing level (HL) from 0.25 kHz to 8.0 kHz bilaterally. The older participants presented with hearing thresholds of ≤25 dB HL from 0.25 kHz to
4.0 kHz bilaterally, except for 4 participants. Three participants had unilateral elevated hearing thresholds of 30 to 50 dB HL in the same frequency range in the right ear and 1 participant had unilateral elevated hearing thresholds in the left ear. Therefore, the left ear was used as the test ear for the 3 participants whose hearing thresholds were not ≤25 dB HL in the right ear. For the other participants, the right ear was used as the test ear. The average audiogram of the tested ears is shown in Figure 1. All participants were native speakers of Japanese.

Test stimuli and procedure
The GIN test was used to evaluate auditory temporal resolution. Eight lists of the CI-2004 Japanese word lists (Escor, Tokyo) were used to evaluate speech recognition in continuous and interrupted noise. In order to control for elevated hearing thresholds in the high frequencies (at 6.0 kHz and 8.0 kHz) in the older participants, all the stimuli were low-pass filtered at 4.0 kHz using a dual variable filter (Kemo Type VBF 8, Kemo, Kent, UK). These stimuli were copied to an audio CD and were played through a CD player (Sony Model CFD-E100TV,
Sony, Tokyo), routed through a RION AA-71 clinical audiometer (Rion, Tokyo) and presented monaurally to the test ear at approximately 65 dB sound pressure level (SPL) through a supra-aural earphone (Telephonics model TDH-39P, Telephonics, New York, USA) in a double-wall sound-treated room.

The GIN test
The GIN test CD (Auditec Inc., St. Louis, MO, USA) was used for this study. Using sound analysis software (Sony Sound Forge, Sony Pictures Digital Networks Inc., version 7.0, Tokyo), the English instructions before each presentation given by a male voice were replaced with Japanese instructions given by a female voice.

The task of each participant was to listen to 6-second durations of broadband noise 35 times (List 1) through a headphone in the test ear. The GIN test contained either 0, 1, 2, or 3 gap intervals, with the 10 different gap durations varying from 2 to 20 ms, and each gap duration was presented a total of 6 times within the list as shown in Figure 2. Within each 6-second presentation, gaps were separated by at least 500 ms. Gap duration and the number of gaps per presentation were randomized across the test. After each 6-second duration presentation, the participants had to write down the number of gap intervals they heard. Prior to the test, the participants were instructed that they would hear between 0 and 3 gap intervals and were given the opportunity to go through a practice list. The approximate threshold (approximate GDT) as described by Musiek\(^17\) was derived by looking at the shortest gap duration at which the participant responded correctly at least 4 of 6 times.

Word recognition in continuous and interrupted noise
The word recognition test material, the CI-2004 contains 8 lists, with each list consisting of 25 words. The words may be in the form of nouns, verbs, adjectives, and adverbs. The words could vary from 2 to 4 moras (moras are considered to be similar to syllables; however, mora phonemes, /N/, /Q/, /H/ are each counted as one mora while considered part of a syllable). The form of a word, the number of phonemes, and the number of moras in each word were balanced and equal in each list.

The copies of the continuous and interrupted noise files were provided by Dr. Andrew Stuart of East Carolina University (Greenville, NC, USA). The noises were essentially the same in spectral contexts but differed in temporal continuity. Continuous noise was white noise with the flat spectrum within 2 dB from 100 to 8,000 Hz. Interrupted noise consisted of noise bursts and silent periods, both of which randomly varied in duration from 5 to 95 ms. The noise duty cycle was 0.5. The details of interrupted noise are described elsewhere.\(^20\)

All 8 lists were recorded in the first channel of the audio CD, and continuous and interrupted noise was in the second channel (2 × 8 lists). Half of the participants listened to the words of four different lists under continuous noise first, and then listened to the words of the remaining four different lists under interrupted noise. For the other half of the participants, the sequence was reversed. The sequences of the presentations of the 8 lists were counterbalanced. Within the four conditions of each noise, the noise level was varied and presented randomly from the signal-to-noise ratio (SNR) -15 dB to 0 dB in 5 dB steps.

The participants were instructed to repeat the word they heard immediately after they heard each word through a headphone in the ear being tested. They were encouraged to guess even if they were not sure of the word. If they could not respond for the first 10 words, the test was terminated and the participant had a score of 0. This rule was applied to avoid tiring the participants; however, in the present study, this test only had to be terminated for the SNR -15 dB condition in continuous noise.

Results

The GIN test and GDTs
The results for the GIN test in 3 older participants had to be excluded from the analyses due to the high number of false responses (i.e., more than nine false positive responses). Therefore, only 30 elderly women underwent further GIN test analyses.

The average GDTs in the GIN test were 6.3 ms (SD = 1.4 ms) and 8.3 ms (SD = 1.3 ms) for young and older participants, respectively. Significant differences were observed in the GDTs between the young and the older group (t[42] = 4.72, P < 0.01). Correlation coefficient

### Table 1. Summary of correlation coefficient analysis of PTA, age, and GDT

<table>
<thead>
<tr>
<th>Variables</th>
<th>PTA</th>
<th>Age</th>
<th>GDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTA</td>
<td>-</td>
<td>0.73**</td>
<td>0.51**</td>
</tr>
<tr>
<td>Age</td>
<td>0.62**</td>
<td>-</td>
<td>0.58**</td>
</tr>
<tr>
<td>GDT</td>
<td>0.17</td>
<td>0.34*</td>
<td>-</td>
</tr>
</tbody>
</table>

PTA, pure-tone average; GDT, gap detection threshold. Upper triangular matrix represents simple correlation coefficient. Lower triangular matrix represents partial correlation coefficient. *P < 0.05; **P < 0.01 with test of no correlation.
analysis showed that GDTs significantly correlated with both age and the average of the pure-tone hearing thresholds (pure-tone average, PTA) at 500, 1 k, 2 kHz as shown in the upper triangular matrix in Table 1. To look at the relationship among the three variables more closely, partial correlation coefficients between two variables with the other variable being held constant were obtained. The result is shown in the lower triangular matrix in Table 1. Age indicated a significant partial correlation (P < 0.05) with GDTs while PTA showed no significant partial correlation with GDT.

![Figure 3](image-url)

**Figure 3.** Mean percent correct word recognition score after converting to RAUs (rationalized arcsine units) in interrupted and continuous noise as a function of the group and the SNR (signal-to-noise ratio). Filled marks represent young participants, and open marks represent older participants. Error bars represent ±1 SD of the mean. *Bonferroni multiple comparisons of the two groups showed a statistically significant difference (P < 0.05).

<table>
<thead>
<tr>
<th>Speech recognition condition</th>
<th>PTA</th>
<th>AGE</th>
<th>GDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNR 0 dB, IN</td>
<td>-0.18</td>
<td>-0.09</td>
<td>-0.22</td>
</tr>
<tr>
<td>SNR -5 dB, IN</td>
<td>-0.47**</td>
<td>-0.30</td>
<td>-0.25</td>
</tr>
<tr>
<td>SNR -10 dB, IN</td>
<td>-0.51**</td>
<td>-0.54**</td>
<td>-0.34*</td>
</tr>
<tr>
<td>SNR -15 dB, IN</td>
<td>-0.50**</td>
<td>-0.47**</td>
<td>-0.41**</td>
</tr>
<tr>
<td>SNR 0 dB, CN</td>
<td>0.05</td>
<td>0.05</td>
<td>-0.01</td>
</tr>
<tr>
<td>SNR -5 dB, CN</td>
<td>-0.09</td>
<td>-0.11</td>
<td>-0.27</td>
</tr>
<tr>
<td>SNR -10 dB, CN</td>
<td>-0.35*</td>
<td>-0.38*</td>
<td>-0.32*</td>
</tr>
<tr>
<td>SNR -15 dB, CN</td>
<td>-0.38*</td>
<td>-0.43**</td>
<td>-0.39**</td>
</tr>
</tbody>
</table>

PTA is the average of pure-tone thresholds in dBHL for 0.5, 1, and 2 kHz of the tested ear. Gap detection threshold (GDT) is performance on the Gaps-in-Noise test (in approximate gap thresholds) in the tested ear. Signal-to-noise ratio (SNR) indicates speech recognition task of each condition from 0 dB to -15 dB with either interrupted noise (IN) or continuous noise (CN), respectively (in rationalized arcsine units, RAUs).

*P < 0.05, **P < 0.01
Word recognition test in continuous and interrupted noise

The mean group word recognition scores (WRSs) obtained were converted to rationalized arcsine units (RAUs)\(^2\) prior to statistical analysis. The scores were converted to RAUs to produce a scale in which the size of the variance was unrelated to the size of the mean, which is not the case with raw data. The mean word recognition scores (in RAUs) as a function of group, noise, and the SNR conditions revealed that age group by the SNR and continuity of noise by SNR interactions were significant (F[3,126] = 131.1 and F[3,126] = 8.8, both P < 0.001), as were each of the main effects (age group: F[1,42] = 12.5, P < 0.01, continuity of noise: F[1,42] = 654.7, P < 0.001, SNR: F[3,126] = 964.4, P < 0.001). The young participants outperformed the older participants, the scores in interrupted noise were better than those in continuous noise, and the scores improved with increasing SNRs. The differences in the RAUs between the two kinds of noise and the two age groups were dependent upon the SNRs. Performance was better in interrupted noise when the SNRs decreased. The significant age group by SNR interaction indicated that the younger participants' performance was better as the SNRs decreased (Figure 3). Post hoc Bonferroni multiple comparisons with the results of both types of noise combined revealed that there were statistically simple main effects of age in the SNR -10 dB (P < 0.05) and the SNR -15 dB (P < 0.05) conditions.

There was no significant interaction between age group and continuity of noise (F[1,42] = 3.5, P = 0.068). There were no significant interactions among the three variables (F[3,126] = 0.1, P = 0.96). The RAU difference between the two age groups did not differ significantly when the type of noise was different.

Correlations among variables for speech recognition

Significant simple correlations were found between WRSs (measured in RAUs) at low SNRs (-10 dB and -15 dB) and GDTs, in interrupted noise (r = -0.34 and -0.41, respectively) and in continuous noise (r = -0.32 and -0.39, respectively) (Table 2). A similar trend was found in the correlations between WRSs and each of the variables of age and PTA (Table 2). However, by multiple regression analysis with WRSs at low SNRs as the objective variable and two pairs among age, GDT, and PTA as the explanatory variables, PTA and age significantly correlated with WRS in interrupted noise only when the GDT was held constant (Table 3). No significant partial correlation was found between the GDT and WRS either in interrupted or continuous noise. This revealed that speech recognition in interrupted noise was poor in the older group because of the hearing threshold elevation or advanced age, but not due to deterioration in temporal resolution that was measured with the GIN test. When the pair of variables (age and PTA), or when all three variables (age, PTA, and GDT) were selected as explanatory variables, no one of the variables had a significant relationship with WRSs at low SNRs.

Discussion

The GIN test

Our results documented that temporal resolution as measured by the GIN test was significantly poorer in the older participants compared with that in the young

| Table 3. Summary of multiple regression analysis with word recognition score as an objective variable and two pairs of explanatory variables |
| --- | --- | --- | --- |
| pair of explanatory variables | Standardized partial regression coefficient (\(\beta\)) | Pair of explanatory variables | Standardized partial regression coefficient (\(\beta\)) |
| **SNR -10 dB** | | | |
| PTA | -0.45** | PTA | -0.25 |
| GDT | -0.11 | GDT | -0.20 |
| **Interrupted noise** | | | |
| Age | -0.51** | Age | -0.29 |
| GDT | -0.05 | GDT | -0.16 |
| **SNR -15 dB** | | | |
| PTA | -0.39** | PTA | -0.24 |
| GDT | -0.20 | GDT | -0.27 |
| **Interrupted noise** | | | |
| Age | -0.36* | Age | -0.31 |
| GDT | -0.20 | GDT | -0.21 |

*P < 0.05, **P < 0.01
participants. The young participants’ mean GDT of 6.3 ms can be considered normal, while the older participants’ mean GDT of 8.3 ms is considered abnormal. This is because a GDT of up to 7 ms is considered normal according to Musiek et al. However, their study included 50 normal-hearing listeners with a mean age of 24.6 years and 18 patients who had been diagnosed with lesions of the central auditory nervous system to determine sensitivity and specificity. Therefore, their results need to be carefully interpreted when applied to a nonclinical population. The present study suggests that a nonclinical population may show high GDTs, even when the participants do not have any diagnosed lesions of the central auditory nervous system.

In the Musiek, et al. study, the mean GDT of 4.9 ms in the right ear was established for normal-hearing young people between the ages of 13 and 46. Another study found a mean GDT of 4.42 ms for young participants between the ages of 19 and 22; therefore, in the present study, the young participants’ GDT of 6.3 ms was somewhat longer. In this study, GIN stimuli were low-pass filtered at 4000 Hz, which may have caused the elevation of the approximate GIN thresholds because GDTs become higher as the center frequency of band noise stimuli becomes lower.

Simple correlation analysis showed that age and the average of participants’ hearing sensitivity, i.e., PTA, each had a significant correlation with GDT, respectively. On the other hand, GDT showed a significant partial correlation with age when PTA was controlled, while there was no significant partial correlation between PTA and GDT when age was controlled. As mentioned in the introduction of the present study, it is well documented that deterioration of temporal resolution is affected by the hearing loss. The reason why PTA was not a significant explanatory factor in the above analysis is because the participants had near normal hearing sensitivity with only a narrow range of hearing loss. These results suggest that due to age-related changes perhaps, in the central auditory system, and independent of hearing loss usually considered as peripheral dysfunction, gap detection of wideband noise starts to deteriorate from the age range of the early 60s in people with essentially normal hearing. Takahashi and Bacon did not find age effect on modulation detection of a broadband noise except a modest correlation (r = 0.39) found at low modulation frequencies once hearing sensitivity was controlled, and concluded that hearing loss was the dominant factor for poor performance by the elderly. It may be that temporal resolution processing required in modulation detection is more likely to be influenced by a hearing loss than is gap detection as used in the present study. It is attributed to larger temporal windows when older persons' performance of temporal resolution is poorer than that of young subjects. In fact, Martin and Jerger reported that “increasing evidence suggests that other aspects of central auditory aging, independent of peripheral hearing sensitivity, underlie some of the temporal processing deficits observed in basic gap-detection measures.” It should be noted, however, that little is known about how age-related changes in central auditory processing occurs or whether it occurs completely independent of peripheral auditory changes.

Speech recognition in noise
All participants showed speech recognition improvement with increasing SNRs and higher speech recognition in interrupted broadband noise than in continuous broadband noise. The noises used in this study differed only in temporal continuity; therefore, better performance in interrupted noise could be attributed to the listener’s auditory temporal capacity. In the present study, speech recognition in noise was significantly poorer in the older participants than that in the young participants, especially at low SNRs. Previous studies using a similar approach included groups of older participants with and without hearing loss, school-age children, or preschool children. Those groups of participants described in the latter two studies, like the older participants in the present study, performed poorly in both types of noise compared with young adults, and it was suggested that they inherently have poorer processing efficiency.

In Stuart and Phillip’s study, young normal-hearing people and older participants with and without hearing loss were investigated with English word recognition measures in interrupted and continuous noise. In their study, there was a significant group by the SNR interaction only in the interrupted noise. It was suggested that group effects observed in the interrupted noise implied that the older participants had an auditory temporal deficit compared with the young participants, and it was attributed to “inherent suprathreshold distortion within the older auditory system” which may be either peripheral, such as widening auditory filters with increasing age, or central. It is also interesting to note that their study revealed significant correlations between hearing sensitivity and word recognition performance for both noise conditions (r = -0.48 and -0.74 for continuous and interrupted noise, respectively), which is consistent with our results. Our results also showed a higher correlation between PTA and WRSs in interrupted than in continuous
noise. The result that higher correlation was found between PTA and WRSs in interrupted noise suggest that WRSs in interrupted noise may be more important measures to investigate the effect of peripheral contribution. Also, for everyday listening conditions, it is more likely to encounter interrupted noise than continuous noise, meaning that interrupted noise is more reflective of everyday speech listening conditions.

**Correlation between GDT and WRS**

Three distinct hypotheses have been proposed regarding the mechanisms associated with age-related deficits in speech understanding, i.e., the peripheral, central-auditory, and cognitive hypotheses.\(^{26}\) To date, the strongest evidence exists for the peripheral hypothesis, in which auditory peripheral changes are the main attributer for speech recognition difficulties in the elderly.\(^{11}\) Other proposed hypotheses have weak evidence, and the details of mechanisms in these hypotheses are described elsewhere.\(^{26}\)

The poorer speech recognition performance under adverse conditions in the elderly has been believed to be associated with suprathreshold deficits (central-auditory hypothesis and/or cognitive hypothesis) such as their deteriorated temporal processing in addition to their hearing sensitivity. However, it is still controversial how speech recognition under adverse conditions correlates with temporal processing.\(^{23}\) Some studies have found little relationship between basic temporal processing measures and age-related difficulties in speech recognition.\(^{27,28}\) Other studies have observed that discrimination abilities of sound duration is related to an elderly person’s difficulty in understanding reverberant speech.\(^{13}\) It has been reported that gap detection results are related to word recognition in masking conditions by certain speech maskers.\(^{2}\) To our knowledge, no strong evidence has been found that supports the idea that deteriorated temporal processing in the elderly is related to their speech recognition performance in noise.

In the present study, there was a significant simple correlation between GDT and WRS in both types of noise at low SNRs. However, no significant relationship was found between speech recognition and GDT when either PTA or age was included as an explanatory factor. Rather, PTA instead of GDT, and age instead of GDT showed a significant partial correlation with speech recognition in interrupted noise at low SNRs. When the pair of the two variables (age and PTA), or when all three variables (age, PTA, and GDT) were chosen as explanatory variables, no one of the variables had a significant relationship with WRSs at low SNRs. These results suggest that speech recognition under noise in the elderly is poor compared with the young generation due to the deterioration of peripheral auditory system as indicated by slightly elevated hearing thresholds in the elderly, and not due to the deterioration of temporal resolution as measured by GDT. We further compared word recognition in interrupted and continuous noise in the two age groups with significantly different GDT to see if deterioriation of auditory temporal resolution affects word recognition in interrupted noise more adversely than in continuous noise. The difference in WRSs between the two age groups did not differ significantly when the type of noise was different. This suggests that the ability to hear speech sounds in silent gaps between noises is not influenced by auditory temporal resolution measured by the GDT. The contribution to poor speech recognition in noise of deteriorated temporal resolution having a central origin could not be confirmed in this study, and GIN test would not be a good clinical measurement to predict speech recognition performance in noise at least in the nonclinical population. In conclusion, these results show that peripheral hearing change seems to play a more important role in word recognition in noise than does central temporal processing capacity, and word recognition was unrelated with GDT for subjects in their early 60’s. The results would likely have been different if older participants than these had been included. GDT using GIN test was used as one measure of temporal resolution. Speech recognition in noise may, however, be associated with other temporal processing aspects such as backward or forward masking; therefore, further studies are warranted using such temporal processing measures.

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**References**


