The 500 Hz Masking-Level Difference and Word Recognition in Multitalker Babble for 40- to 89-Year-Old Listeners with Symmetrical Sensorineural Hearing Loss

Richard H. Wilson*
Deborah G. Weakley*

Abstract

The purpose of this study was to determine if performances on a 500 Hz MLD task and a word-recognition task in multitalker babble covaried or varied independently for listeners with normal hearing and for listeners with hearing loss. Young listeners with normal hearing (n = 25) and older listeners (25 per decade from 40–80 years, n = 125) with sensorineural hearing loss were studied. Thresholds at 500 and 1000 Hz were ≤30 dB HL and ≤40 dB HL, respectively, with thresholds above 1000 Hz <100 dB HL. There was no systematic relationship between the 500 Hz MLD and word-recognition performance in multitalker babble. Higher SoNo and StNo thresholds were observed for the older listeners, but the MLDs were the same for all groups. Word recognition in babble in terms of signal-to-babble ratio was on average 6.5 (40- to 49-year-old group) to 10.8 dB (80- to 89-year-old group) poorer for the older listeners with hearing loss. Neither pure-tone thresholds nor word-recognition abilities in quiet accurately predicted word-recognition performance in multitalker babble.

Key Words: Antiphasic, hearing loss, homophasic, masking-level difference, multitalker babble, presbycusis, speech perception, word recognition

Abbreviations: ABR = auditory evoked brainstem responses; ANSI = American National Standards Institute; MLD = masking-level difference; NU No. 6 = Northwestern University Auditory Test Number 6; S/B = signal-to-babble ratio; S/N = signal-to-noise ratio; StNo = signal π radians (180°) out-of-phase at the ears and noise in-phase at the ears; SoNo = signal and noise in-phase at the ears

Sumario

El propósito de este estudio fue determinar si el desempeño en una tarea de MLD a 500 Hz y una prueba de reconocimiento de palabras en medio de un balbuceo de múltiples hablantes, variaba o co-variaba independientemente de que los sujetos fueran normo-oyentes o con hipoacusia. Se estudiaron sujetos jóvenes con audición normal (n = 25) y sujetos mayores (25/década de los 40-80 años, n = 25) con hipoacusia sensorineural. Los umbrales en 500 y 1000 Hz fueron de ≤ 30 dB HL y ≤ 40 dB HL, respectivamente, con umbrales por
Presbycusis is a nebulous type of hearing loss defined as hearing dysfunction caused by the aging processes along with other probable contributing factors like noise exposure. Schuknecht (1955, 1964) suggested that physiologically the decrease of auditory function associated with presbycusic hearing loss is attributable to deterioration in the auditory system from the periphery to the cortex. Functionally, Carhart (1951) suggested that hearing loss had two components—acuity and clarity. Subsequently, these two components became known as audibility (attenuation) and distortion (Stephens, 1976; Plomp, 1978). The “audibility factor” is a sensitivity issue like a reduction in pure-tone thresholds usually caused by dysfunction at the auditory periphery. The “distortion factor,” which can be introduced at any point in the auditory system, is manifested by a reduced ability to perform complicated (and probably simple) auditory tasks like various forms of speech recognition. Given the Schuknecht and Stephens/Plomp frameworks, it is easy to understand the complications that are associated with presbycusic hearing loss.

The (in)ability to understand speech in background noise often has been linked to poor performance on psychoacoustic tasks designed to study the temporal characteristics of the auditory system. These tasks include duration discrimination, gap detection, temporal integration, and temporal difference limen. Older listeners demonstrate poorer duration discrimination than younger listeners (e.g., Fitzgibbons and Gordon-Salant, 1994, 1998). Likewise, gap detection is poorer in older listeners than in younger listeners (e.g., Strouse et al, 1998). Tyler et al (1982) suggest that decreased performance on stimulus duration and gap detection tasks both affect the ability of the listener to understand speech. As an extension of these studies in the temporal domain, the purpose of this study was to examine the relation between the minute temporal information (phase) that operates in the antiphase listening condition and the ability of listeners with normal hearing and listeners with hearing loss to understand speech in background noise. These two auditory measures individually are robust and have been shown to be susceptible to the effects of aging and hearing loss. The first measure is the ability of the listener to achieve a bilateral release from masking using a 500 Hz masking-level difference (MLD) paradigm (Hirsh, 1948). The second measure is the ability of the listener to understand speech...
in background noise (Carhart and Tillman, 1970). The MLD, which can be considered a measure of temporal resolution, was selected as several studies suggest that the MLD in older individuals with hearing loss is reduced in comparison to the MLD of young adults with normal hearing (Jerger et al, 1984; Pichora-Fuller and Schneider, 1991; Grose et al, 1994). A word-in-multitalker babble background noise was selected as numerous studies have demonstrated that older listeners with hearing loss have a diminished ability to understand speech in terms of signal-to-noise ratio (e.g., Hirsh, 1950; Keith and Talis, 1970; Tillman et al, 1970; Olsen et al, 1975; Dubno et al, 1984; Gordon-Salant, 1987; Beattie, 1989; Souza and Turner, 1994; Divenyi and Haupt, 1997a, 1997b, 1997c; Wiley et al, 1998; Wilson, Abrams, et al, 2003). As points of reference, performances on the two conditions were obtained from a group of listeners with normal hearing.

**MASKING-LEVEL DIFFERENCE**

The MLD, which is a binaural phenomenon, is a release from masking that occurs when the phase of a signal (S) or noise (N) in one ear is reversed with respect to the phase of the signal or noise in the other ear (Hirsh, 1948; Webster, 1951). When the signals and noises presented to the ears are in-phase with one another, the condition is termed “homophasic” and is expressed as “SoNo” in which the “o” represents a 0° phase difference between the ears. When the signals (or noises) presented to the ears are 180° (π radians) out-of-phase with one another, the condition is termed “antiphasic” and is expressed as “SrNo” or “SoNr” in which the “π” represents the 180° phase difference between the ears. The conditions typically evaluated by audiologists involve establishing the threshold for a 500 Hz signal in a narrow band of noise both in an SoNo condition (homophasic) and in an SrNo condition (antiphasic). The MLD is the SoNo threshold minus the SrNo threshold. Depending upon several variables, the 500 Hz MLD for listeners with normal hearing ranges from 7 to 15 dB with the SrNo threshold being the lower threshold. The MLD also can be established for speech signals (Licklider, 1948) and other pure-tone frequencies, but generally the MLD for 500 Hz is the most robust (Hirsh, 1948; Webster, 1951; Egan, 1965).

Generally, when the magnitude of the MLD is diminished, the compounding factor is higher than normal SrNo thresholds observed in association with SoNo thresholds that are in the normal range (Hall et al, 1984; Jerger et al, 1984). Several factors diminish the magnitude of the MLD, the most common of which are asymmetrical hearing sensitivity and severity of the pure-tone hearing loss (McFadden, 1968; Jerger et al, 1984). Prior to the development of auditory evoked brainstem responses (ABR), the MLD was used to evaluate for possible lesions in the auditory brainstem. Abnormally small MLDs were reported for patients having central nervous system disorders in the lower brainstem (Olsen and Noffsinger, 1976; Lynn et al, 1981). Studies comparing ABR data with MLD data reported diminished MLDs in patients with abnormalities in the early ABR waves, which reflect lower brainstem activity (Jerger et al, 1982; Noffsinger et al, 1982).

The above studies suggest that lesions in the auditory pathways from the auditory periphery to the lower brainstem produce MLDs that are smaller than normal (i.e., typically ≤7–8 dB). The implication is that individuals with auditory central nervous system dysfunction are unable to use efficiently the phase (temporal) information in the form of timing differences between the ears that is contained in the antiphasic condition of the MLD paradigm. In an early study of the various types of hearing loss, Olsen et al (1976) evaluated the 500 Hz MLD on 20 listeners with presbycusis hearing loss (mean = 66.4 years). The Olsen et al data suggest that 20–40% of listeners with presbycusis have MLDs for 500 Hz signals that are considered abnormally small (≤7–8 dB).

**WORD RECOGNITION IN MULTITALKER BABBLE**

Most individuals with presbycusis hearing loss indicate that they can hear speech but that they cannot understand speech, especially in a background noise (Hirsh, 1950; Carhart and Tillman, 1970; Keith and Talis, 1970; Tillman et al, 1970; Olsen et al, 1975; Plomp and Duquesnoy, 1982; Dubno et al, 1984; Gordon-Salant, 1987; Beattie, 1989; Pekkarinen et al, 1990; Souza and Turner, 1994; Divenyi and Haupt, 1997a, 1997b, 1997c; Wiley et al, 1998; Wilson, Abrams, et al, 2003). The ability or inability of individuals to understand speech in a background noise can be measured with a variety of paradigms from words (Wilson, 2003) to sentences...
(Speaks and Jerger, 1965; Kalikow et al, 1977; Cox et al, 1987; Killion and Villchur, 1993; Nilsson et al, 1994). Although different techniques have been used to measure speech recognition in background noise, the results from most studies agree that in terms of signal-to-noise ratio, older individuals with hearing loss function at a 6 to 12+ dB deficit compared to young adults with normal hearing. These deficits with older individuals usually with sensorineural hearing loss often mimic some of the characteristics associated with auditory processing disorders (e.g., Duquesnoy, 1983; Jerger, 1992; Humes, 1996; Pichora-Fuller, 2003; Pichora-Fuller and Souza, 2003). Conceivably, these deficits in understanding speech in multitalker babble also can be considered in the perceptual (or informational) masking domain (Miller, 1947; Carhart et al, 1969; Tillman et al, 1973; Freyman et al, 2004).

Studies on the MLD and studies on the ability of listeners to understand speech in background noise both indicate that many individuals with presbycusic hearing loss demonstrate deficits in performance on these two auditory tasks. The current study examined the relation between performance on a 500 Hz MLD task, which involves temporal aspects of the auditory system, and performance on a speech-in-noise task, which is a more generalized auditory function. The question posed was this: Do performances on the MLD and speech-in-noise tasks covary or vary independently? The design of the study enabled examination of the relationships among pure-tone thresholds and performances on the MLD, words-in-babble, and words-in-quiet.

**METHODS**

**Test Instruments**

The development of the 500 Hz MLD procedure used in this experiment is detailed in Wilson, Moncrieff, et al (2003). The underlying principles were that the 500 Hz MLD protocol be simple for the listener, simple to administer, and efficient. Briefly, the paradigm involved a train of five 500 Hz tone bursts embedded in a 3 sec segment of narrow-band noise. A 3 sec segment of broadband noise with 25 msec rise-fall times was digitally generated and band-pass filtered (Butterworth) to produce a 200 to 800 Hz pass band centered around 500 Hz with 48 dB/octave skirts. A 300 msec, 500 Hz tone with 25 msec rise-fall times was generated digitally. Five of the tone bursts separated with 250 msec silent intervals were concatenated. The onset of the first tone was 250 msec after the onset of the noise burst. With the noise on one channel at a constant level and the tone bursts on the second channel, the SoNo and SnNo stimuli at the various signal-to-noise ratios (S/N) were created by attenuating the tones and then mixing (and inverting) the signals as appropriate on the two channels. The 33-item test paradigm involved 10 SoNo presentations from 1 dB S/N to -17 dB S/N (2 dB decrements), 12 SnNo stimuli from -7 dB S/N to -29 dB S/N (2 dB decrements), and 11 noise presentations with no tones present (no tone). The construct of the paradigm was such that groups of three stimuli, one SoNo, one SnNo, and one no tone, were randomized. For the initial set of three stimuli, the SoNo and SnNo conditions were at 1 dB and -7 dB, respectively. For the second set of stimuli, the SoNo and SnNo conditions, which again were randomized, were at -1 dB and -9 dB, respectively, and so on. The stimuli were recorded on audio CD (Plexwriter, Model 40/12/40A) from high to low signal-to-noise ratios.

The words in multitalker babble consisted of 70 monosyllabic words selected from the Northwestern University Auditory Test No. 6 (NU No. 6) lists recorded by the VA female speaker (Department of Veterans Affairs, 1998). Each word was time locked to a unique 6 sec segment of multitalker babble with which it was mixed at the appropriate signal-to-babble ratio (S/B) (Sperry et al, 1997). Based on recognition performance data (Wilson, 2003), ten unique words were selected for presentation at each of seven signal-to-babble ratios (70 total words) (24 to 0 dB in 4 dB steps). The ten words presented at each of the seven levels, which were always the same ten words at each level, were concatenated so that the babble was continuous during presentation of the ten words at each level. The boundaries of the babble segments were edited at the zero crossings and were transparent acoustically and perceptually to the listeners. The 70-word sequence was recorded on audio CD from high to low signal-to-babble ratios.
(Wilson et al, forthcoming). Additionally, words 1–25 and 26–50 from NU No. 6, List 1, were recorded in quiet as separate tracks on the CD.

**Subjects**

Twenty-five young adult listeners (mean = 22.8 years) with normal hearing (≤20 dB HL; ANSI, 1996) at the octave frequencies were recruited. The 125 subjects with sensorineural hearing loss were recruited from the ongoing Audiology Clinics at the VA Medical Center at Mountain Home. The selection criteria were simple. The thresholds at 500 and 1000 Hz were required to be ≤30 dB HL and ≤40 dB HL, respectively, with thresholds above 1000 Hz <100 dB HL. Because the MLD can be diminished by asymmetrical pure-tone thresholds (McFadden, 1968; Jerger et al, 1984), the threshold symmetry at 500 Hz had to be ±10 dB and ±15 dB at the frequencies above 500 Hz. Each of five age decades (40–49, 50–59, 60–69, 70–79, and 80–89 years) had 25 listeners with hearing loss. Human subjects approval was obtained, and the experimental procedures followed the standards of the institutional review board. Subjects who made a special trip to the laboratory were compensated.

The subjects were recruited into this study consecutively based on meeting the hearing criteria. There were three listeners recruited whose data were not included in the data analysis. These listeners were unable to respond to any of the signals in the MLD paradigm, even those at the most favorable signal-to-noise ratios. The reasons for this inability are unknown.

**Procedures**

The MLD and words-in-babble stimuli were reproduced on a compact disc player (Sony, Model CDP-497) and fed through an audiometer (Grason-Stadler, Model 10) to TDH-50P earphones encased in Telephonics P/N 510C017-1 cushions. The phase of the earphones was checked using 100 Hz tone bursts and the procedure described for phase determination of earphones on the Department of Veterans Affairs compact disc (Department of Veterans Affairs, 1998). Even number subjects received the MLD condition first whereas the odd number subjects received the words-in-babble first. For the MLD protocol, the presentation level of the noise was fixed at 70 dB SPL (42.2 dB SPL/Hz) with the level of the tones varied. A single-interval “yes-no” response task was used in which, following each noise presentation, the task of the listener was to respond “yes” that tones were heard in the noise or “no” that tones were not heard in the noise. For the words-in-babble protocol, the level of the babble was set at 80 dB SPL and the level of the words varied from 104 to 80 dB SPL. When all ten words were missed at a signal-to-babble ratio, the stopping rule terminated the protocol. Following the words-in-babble, words 1–25 and 26–50 from NU No. 6, List 1, were presented in quiet at 80 and 104 dB SPL, respectively. The listeners responded verbally to the speech signals. The responses for both tasks were recorded into a spreadsheet. All testing was conducted in a double-wall sound booth.

**Table 1. Mean Audiogram (in dB HL; ANSI, 1996) and Standard Deviations for the 25 Subjects in Each of the Six Age Categories**

<table>
<thead>
<tr>
<th>AGE (yr.) Mean</th>
<th>250 Hz Mean (SD)</th>
<th>500 Hz Mean (SD)</th>
<th>1000 Hz Mean (SD)</th>
<th>2000 Hz Mean (SD)</th>
<th>3000 Hz Mean (SD)</th>
<th>4000 Hz Mean (SD)</th>
<th>8000 Hz Mean (SD)</th>
<th>PTA* Mean</th>
<th>PTA † Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.5</td>
<td>3.6 (4.0)</td>
<td>2.9 (7.7)</td>
<td>1.9 (1.0)</td>
<td>3.5 (1.9)</td>
<td>4.9 (2.3)</td>
<td>5.5 (2.7)</td>
<td>5.5 (2.7)</td>
<td>2.8</td>
<td>4.1</td>
</tr>
<tr>
<td>44.8</td>
<td>17.0 (6.1)</td>
<td>16.8 (6.8)</td>
<td>17.1 (7.6)</td>
<td>32.7 (18.5)</td>
<td>48.6 (20.3)</td>
<td>56.2 (18.6)</td>
<td>47.8 (20.3)</td>
<td>22.2</td>
<td>38.5</td>
</tr>
<tr>
<td>54.8</td>
<td>17.5 (6.8)</td>
<td>18.4 (6.5)</td>
<td>19.8 (7.8)</td>
<td>43.1 (17.9)</td>
<td>63.1 (16.5)</td>
<td>68.6 (15.4)</td>
<td>59.5 (15.8)</td>
<td>27.1</td>
<td>47.9</td>
</tr>
<tr>
<td>64.8</td>
<td>21.1 (8.8)</td>
<td>19.9 (5.9)</td>
<td>21.8 (8.2)</td>
<td>46.0 (18.8)</td>
<td>63.4 (16.5)</td>
<td>70.0 (17.2)</td>
<td>64.7 (14.3)</td>
<td>29.2</td>
<td>50.6</td>
</tr>
<tr>
<td>73.9</td>
<td>21.1 (8.2)</td>
<td>20.6 (5.8)</td>
<td>24.3 (7.4)</td>
<td>47.0 (14.3)</td>
<td>62.7 (12.3)</td>
<td>69.2 (14.0)</td>
<td>67.1 (15.2)</td>
<td>30.6</td>
<td>51.9</td>
</tr>
<tr>
<td>82.0</td>
<td>20.3 (7.7)</td>
<td>20.4 (6.2)</td>
<td>25.1 (8.4)</td>
<td>49.2 (14.1)</td>
<td>62.9 (15.1)</td>
<td>71.4 (13.6)</td>
<td>75.2 (9.7)</td>
<td>31.6</td>
<td>55.2</td>
</tr>
</tbody>
</table>

*Note: Because there was no significant difference in pure-tone thresholds between ears, the data for both ears were combined.

*Average at 500, 1000, and 2000 Hz.
†Average at 1000, 2000, 4000, and 8000 Hz.
RESULTS

Pure-Tone Thresholds

A two within, zero between analysis-of-variance (ANOVA) indicated that the pure-tone thresholds for the right and left ears of the 125 listeners with hearing loss were not different. The threshold data for the two ears, therefore, were combined and are listed in Table 1 for each of the six groups of listeners. Also included in the table for each subject group are the mean pure-tone averages for 500, 1000, and 2000 Hz and the averages for 1000, 2000, 4000, and 8000 Hz. Several relations are apparent in the table. First, the thresholds for the listeners with normal hearing minimally were 12–13 dB lower than corresponding thresholds for the listeners in the other groups. Second, in the lower frequencies, the mean thresholds for the groups of subjects were about the same as was expected based on the pure-tone threshold inclusion criteria. Third, at 2000 Hz and above, the 40-year-old group had thresholds that were about 10 dB lower than the thresholds for the other groups of listeners. Fourth, at 2000, 3000, and 4000 Hz, the 50- through 80-year-old groups had mean thresholds that were essentially the same, varying only a few decibels. Fifth, at 8000 Hz, the most systematic decrease in threshold across the age groups was observed (about 5 dB/decade). Finally, both pure-tone averages reflect a gradual decrease in hearing sensitivity with increasing age that is in the 2–5 dB/decade range. Overall, hearing loss across the age groups, especially 50 to 80 years, was consistent, particularly in the 250 to 4000 Hz range.

Masking-Level Difference

In the MLD paradigm, there were 11 presentations of noise bursts with no signal embedded, the purpose of which was to get an indication of false-positive responses. In response to the total of 1650 noise bursts with no signal (11 by 150 listeners), ten false-positive responses were elicited, nine of which were in the two groups of listeners <50 years of age. This minimal number of false-positive responses indicates that spurious responses are not an issue.

The data from the MLD protocol are presented both in table and graph formats. The mean percent correct detection (and standard deviation) at each presentation level is listed for the six groups of listeners in Tables 2 and 3 for the SoNo and SrNo conditions, respectively. Also included in the tables are the mean 50% points and standard deviations determined with the Spearman-Kärber equation (Finney, 1952) that was used to compute the 50% points on the functions.
of the individual listeners. Although all are not depicted graphically, the dynamic segment of each data function in Tables 2 and 3 was fit with polynomial equations from which the 50% points and the slopes at the 50% points were calculated. These values also are listed in the tables (50% Mean and Slope). Finally in the tables, the mean MLDs (and standard deviations) derived for the individuals in each age group are listed.

The mean SoNo (circles) and SnNo (triangles) thresholds calculated with the Spearman-Kärber equation and the MLD data (in dB) are presented in Figure 1 for the six age groups along with the data from the individual subjects. In the upper panel of the figure, the thresholds are presented in decibels sound-pressure level with the vertical lines depicting ±1 standard deviation. The dashed lines with each set of data represent linear regressions derived for the individual data from the 40- to 80-year-old listeners. As the data in Tables 2 and 3 and Figure 1 indicate, the SoNo and SnNo thresholds increased 3.2 and 3.9 dB, respectively, between the 20- and 40-year-old groups. Between the 40- and 80-year-old groups, the thresholds were essentially unchanged, increasing only 1.2 dB (SoNo) and 0.9 dB (SnNo). Because the SoNo and SnNo thresholds were parallel across age groups, the MLDs were unchanged across the groups, varying randomly among groups from 12.5 to 13.5 dB. A one-factor ANOVA confirmed the relationships that are obvious in the graphs. For both ANOVAs on the threshold data, the main effect (age) was significant (SoNo—F [5,
144) = 8.125, p < .001; SnNo—F [5, 144] = 7.093, p < .001). Post hoc analyses using Scheffe’s “S” indicated that performance on the SnNo and SnπNo conditions by the 20-year-old group was significantly different from the performances by all other age groups. No other between-group difference was significant. In contrast to the threshold data, there were no significant MLD differences among all of the groups (F [5, 144] = 0.305, p > .05).

Four mean psychometric functions for the SnNo and SnπNo conditions are illustrated in Figure 2. Because the SnNo and SnπNo data for the 40- to 80-year-old groups were different only from the 20-year-old group data, the data from the 40- to 80-year-old groups were combined (filled symbols). The lines through the data points are the best-fit, third-degree polynomials. The numbers beside each mean function indicate the presentation level (in dB SPL) at which 50% detection occurred.

The percent correct detection in the SnNo (circles) and SnπNo (triangles) conditions for the 25 young adults with normal hearing (open symbols) and the 125 older adults with hearing loss (filled symbols). The lines fit to the datum points are the best-fit, third-degree polynomials. The numbers beside each mean function indicate the presentation level (in dB SPL) at which 50% detection occurred.

Figure 2. The percent correct detection in the SnNo (circles) and SnπNo (triangles) conditions for the 25 young adults with normal hearing (open symbols) and the 125 older adults with hearing loss (filled symbols). The lines fit to the datum points are the best-fit, third-degree polynomials. The numbers beside each mean function indicate the presentation level (in dB SPL) at which 50% detection occurred.

The mean percent correct word-recognition performances (and standard deviations) at the seven signal-to-babble ratios for the six groups of listeners are listed in Table 4. Also included in the table are (1) the mean 50% points (and standard deviations) calculated from the individual data with the Spearman-Kärber equation, (2) the 50% points calculated from the first derivatives of the polynomials used to fit the mean functions depicted in Figure 3, (3) the slopes of the mean functions at the 50% points in Figure 3, and (4) the mean percent correct (and standard deviations) for the NU No. 6 words presented in quiet at two presentation levels.
levels. The mean word-recognition functions are illustrated in Figure 3 for the six groups of listeners. The data for the listeners with normal hearing are shown in the upper left panel along with the polynomials representing the data from the other five groups. In each of the remaining five panels, the data for each of the five groups of listeners with hearing loss are depicted along with the function for the 20- to 29-year-old listeners (thin line). The decibel values at the 50% points in each panel note the differences between the two functions.

The 50% points calculated with the Spearman-Kärber equation (Table 4) provide a representative study of the data. The mean percent word recognition in quiet at the two presentation levels also is listed.

The 50% points (in dB S/B, SK 50%) calculated on the individual data with the Spearman-Kärber equation (and standard deviations) are shown along with the 50% points (in dB S/B) and slopes of the functions at the 50% points (%/dB) calculated from the polynomial equations used to describe each set of data. The mean percent word recognition in quiet at the two presentation levels also is listed.

**Figure 3.** The mean percent correct recognition depicted as a function of the presentation level of the words-in-babble for the six age groups of listeners. The thin function in each panel represents the function for the 20- to 29-year-old group. The vertical lines represent the standard deviations, and the numbers on the horizontal lines at the 50% points are the separation between performance by the 20- to 29-year-old group and the other groups.
is used in this report as the normal range (Wilson, 2003; Wilson, Abrams, et al, 2003).

**Word Recognition in Quiet**

The mean word-recognition performances obtained by the groups of listeners at 60 and 84 dB HL are listed at the bottom of Table 4. The results were as expected with all means above 70% correct indicating fair to good word-recognition abilities. For all groups, recognition performances were better when the materials were presented at 84 dB HL than at 60 dB HL. The recognition performances on the materials at both levels decreased slightly as a function of age. For the 60 dB HL condition, the change was about 6%/decade, whereas for the 84 dB HL condition, the change was reduced to 3%/decade. Finally, the standard deviations for the 60 dB HL condition were larger than the standard deviations for the 84 dB HL condition suggesting that differences in audibility are more involved at the lower presentation level than at the higher level. Because the listeners had little difficulty understanding the words in quiet at 60 dB HL, which corresponded to the presentation level of the words at 0 dB S/B, the inference is that the poor word-recognition performance at the lower signal-to-babble ratios was owing to factors other than the audibility factor.

**DISCUSSION**

**MLD versus Words in Multitalker Babble**

This study purposed to determine the relationship between the 500 Hz MLD and recognition performance on monosyllabic words presented in multitalker babble. The MLD was determined from the difference at the 50% points on the SoNo and SnNo functions of the listeners; likewise, the performance on the words-in-babble task was evaluated at the 50% point on the recognition functions of the listeners. Figure 4 is a bivariate plot of the MLD data (abscissa) and words-in-babble data (ordinate). Conveniently, but by happenstance, the data from the MLD and the words-in-babble were scaleable to the same values. Data for the 25 listeners with normal hearing are depicted with circles, and data for the 125 listeners with hearing loss are shown as squares. The diagonal line, which represents equal performance, and the numbers in parentheses, which give the number of listeners whose performance was above, on, and below the diagonal line, are shown only for reference purposes. There are no systematics in the pattern of the data points; in fact, the pattern is best characterized as a “shotgun” pattern. The dashed line represents the linear regression fit to the data of the listeners with hearing loss. The 0.09 dB/dB slope of the regression function indicates that as the MLD increased 1 dB, there was only a 0.09 dB increase in the 50% point of the words-in-babble. For practical purposes, the regression function is flat, substantiating the previously noted lack of a relationship between the two variables, at least on individuals with hearing loss like those included in this study. The lack of a relationship was confirmed by a Pearson Product-Moment Correlation ($r(150) = 0.04$, $p > .05$). The implication is that for the stimuli and methods employed in this study, the ability of the auditory system to process the temporal information that is necessary for the MLD phenomenon is not related systematically to the
ability/inability of the auditory system to process information from speech signals presented in background noise. Regarding the question posed at the outset, the 500 Hz MLD and word recognition in background noise do not covary but rather vary independently.

Finally, in the lower panel of Figure 1, there are five listeners with MLDs of <5 dB. These five subjects had a mean MLD of 1.2 dB with a mean 50% point in multitalker babble at 11.5 dB S/B. Thus, although these five listeners had negligible MLDs, their word-recognition performances in multitalker babble were not substantially poorer than the performances by the other listeners.

Masking-Level Difference

Earlier studies by Grose et al (1994) and Pichora-Fuller and Schneider (1991) both observed that elderly listeners had SoNo thresholds that were similar to the SoNo thresholds of younger listeners whereas the older listeners had SπNo thresholds that were at higher levels than the SπNo thresholds of younger listeners. Olsen et al (1976) and Hall et al (1984) reported smaller MLDs for groups of listeners with presbycusis than for groups of young listeners with normal hearing. These relations among age groups for the SoNo and SπNo thresholds and MLDs were not observed in the current study. The data in the upper panel of Figure 1 demonstrate that with increases in age both the thresholds for SoNo and SπNo increased slightly but retained their relative difference, hence the equivalent MLD across age groups. It is difficult to explain the differences among investigations, other than there were slight differences among all of the studies with respect to masker spectrum, psychophysical procedures, and subject composition.

The shaded region of the lower panel of Figure 1 defines the 5th percentile for MLDs observed with young adults with normal hearing (Wilson, Moncrieff, et al, 2003), that is, 95% of the listeners had MLDs ≥10 dB, which was the same normal range calculated with the 25 young adult listeners in the current study. One of the listeners with normal hearing and 15 of the older listeners with hearing loss (equally distributed among the age groups) had MLDs smaller than the normal range. Thus, 88% of the patients with hearing loss in the current study had MLDs that were within the normal range. This proportion of older patients with normal MLDs is somewhat larger than previously reported (Olsen et al, 1976; Jerger et al, 1984). Probably the differences in findings are attributable to several possible factors including the different types and degrees of hearing loss that were involved in the respective studies and procedural differences. Additionally, the current study had restrictions on pure-tone loss (≤30 dB HL at 500 Hz) and symmetry (±10 dB at 500 Hz), whereas the other two studies were more inclusive of the population with hearing loss.

Jerger et al (1984) retrospectively examined the MLD in 651 patients with conductive or sensorineural hearing loss. The data of 447 of the subjects with sensorineural hearing loss were examined to determine the relation between the MLD and the pure-tone thresholds at the frequencies above 500 Hz. A boundary frequency was established, that is, the lowest frequency at which the threshold was >20 dB HL. As the boundary frequency decreased from 8000 to 1000 Hz, the magnitude of the MLD in the Jerger et al
study decreased from 10.3 to 8.2 dB. A similar, but not identical, analysis was conducted on the current data (Figure 5). In the figure, the thresholds (dB HL) at the various frequencies for the 125 listeners with hearing loss are plotted on the abscissae with the MLD (dB) on the ordinates. The lines in each graph are the linear regressions fit to the data of the 75 selected listeners. The dashed line in each panel is the linear regression fit to the data from the original 125 listeners with normal hearing.

Figure 6. A bivariate plot of the pure-tone thresholds (ordinate) is shown versus the age (abscissa) of the 25 listeners with normal hearing (circles) and the 75 selected listeners with hearing loss (squares). The filled symbols depict the mean data, and the solid line in each graph is the linear regression fit to the data of the 75 selected listeners. The dashed line in each panel is the linear regression fit to the corresponding data from the original 125 listeners with normal hearing.

frequencies >500 Hz by Durrant et al (1989).

Words in Multitalker Babble

The subjects were recruited with strict inclusion criteria only at 500 and 1000 Hz. The mean pure-tone thresholds in Table 1 indicate that in the higher frequencies there were discrepancies among the mean thresholds for the groups. To equate the groups of listeners in terms of hearing sensitivity, 15 listeners in each group with hearing loss were matched based on their thresholds at 2000 and 4000 Hz. For the five groups, the mean thresholds for the 15 listeners at 2000 and 4000 Hz were 53.5 to 54.0 dB HL. For the 40- to 49-year-old group, the 15 listeners with the highest thresholds were selected, whereas for the 80- to 89-year-old group the 15 listeners with the lowest thresholds were chosen. The other three groups were between these extremes. The results of this parsing are illustrated in Figure 6 in which age (abscissa) is plotted against the pure-tone thresholds (ordinate). In each panel the data for the 25 listeners with normal hearing (circles) and the 75 selected listeners with hearing loss (squares) are shown along with the mean data points for each group (filled symbols). The solid line in each panel is the linear regression fit to the data of the 75 selected listeners with hearing loss, and the dashed line is the linear regression fit to the data of all 125 listeners with hearing loss. As expected because of the inclusion criteria, the two linear regressions for both the 500 and 1000 Hz conditions were essentially the same with slopes of 0.10 and 0.22 dB/year, respectively, indicating the thresholds for the groups of 75 and 125 were the same. This relation was also true for the data at 250 Hz (not shown). The threshold data for 2000, 3000, and 4000 Hz were somewhat different from the data for the lower frequencies. At 2000 Hz the slope of the regression was more gradual for the 75 selected listeners than for the 125 listeners, 0.14 and 0.41 dB/year, respectively. At 3000 and 4000 Hz the slopes for the 75 listeners decreased (-0.14 dB/year) in contrast to the slopes of the functions for the original 125 listeners that increased (0.29 dB/year). For the most part, the thresholds for the two groups of listeners at 8000 Hz were substantially unchanged with slopes of 0.47 and 0.60 dB/year. Except for the data at 8000 Hz, the
other data in Figure 6 indicate that the 15
selected listeners from each age group were
well equated in terms of their pure-tone
thresholds.

The data in Figure 7 are bivariate plots of
combinations of the following three variables:
(1) age in years, (2) bilateral pure-tone average
for 500, 1000, 2000, and 4000 Hz, and (3) the
50% point on the function for the words-in-
multitalker-babble. In the figure, the data for
the 25 listeners with normal hearing (circles)
are shown along with the data for the 75
selected listeners with hearing loss (squares).
Again, the solid line in each panel is a linear
regression fit to the data from the 75 listeners
with hearing loss, whereas the dashed line is
a linear regression fit to the data from the
original 125 listeners with hearing loss (their
data are not shown). The shaded areas in the
bottom two panels represent the 90th percentile
of performance on the words-in-babble task
by listeners with normal hearing (Wilson, 2003;

The top panel of Figure 7 shows the
bilateral pure-tone average at 500, 1000,
2000, and 4000 Hz (ordinate) versus age
(abscissa). The data, which are a summary of
the pure-tone data shown in Figure 6,
demonstrate how the selection of the 15
listeners in each group minimized the
threshold differences between groups. With
the original 125 listeners, the slope of the
regression (dashed line) was 0.60 dB/year (6
dB/decade), but with the selected 75 listeners,
the slope of the function (solid line) was only
0.09 dB/year (0.9 dB/decade). The middle
panel of Figure 7 depicts the 50% point on
the words-in-babble function (ordinate) versus
age (abscissa). Again, the slopes of the lines
are different for the two groups of listeners.
For the 125 listeners the slope of the function
(dashed) was steeper (0.17%/year,
1.7%/decade) than the slope of the function
(solid) for the 75 listeners (0.05%/year,
0.5%/decade). Thus with essentially
equivalent hearing sensitivity among the
groups there was little change in the
recognition performance that was achieved on
the words-in-babble task. The data in the
bottom panel of Figure 7 indicate that pure-
tone sensitivity is related closely to decreased
word-recognition ability of words presented
in multitalker babble. The linear functions for
the 75 and 125 member groups are almost
identical both in terms of the location in the
Cartesian coordinates and slope (0.27%/dB).
As pure-tone sensitivity decreased, there was a corresponding decrease in the ability of the listeners to understand words presented in babble. With the preliminary version of the current test materials, Wilson and Strouse (Figure 6, 2002) observed an almost identical relation between the 50% points on the words-in-babble functions and the pure-tone averages at 500, 1000, 2000, and 4000 Hz for 15 listeners in each of six age decades from 20 to 79 years. In summary, the data indicate that for the listeners in this study, hearing sensitivity had more of an effect on word recognition in babble than age. Although different paradigms were used, Souza and Turner (1994) made a similar observation.

**Word Recognition in Quiet**

The data in Figure 8 enables a comparison of word-recognition performance in quiet (ordinate) with performance in multitalker babble (abscissa) when the materials in quiet were presented at 60 dB HL (top panel) and 84 dB HL (bottom panel). Recall that these two presentation levels corresponded to the lowest and highest presentation levels of the words-in-babble. The same speaker spoke the materials used in both paradigms. The shaded region in the upper left of each panel defines normal performance on the two tasks (80 to 100% correct for the words in quiet and ≤ 6 dB S/B for the words-in-babble). The data from the listeners with normal hearing are depicted with circles, whereas squares represent the data from the 125 listeners with hearing loss. The curvilinear lines in both panels describe the data from the listeners with hearing loss. The percentages in parentheses indicate the percent of the listeners with hearing loss that had performances in the respective quadrants. For example, the 58% and 86% indicate the percent of the listeners with hearing loss who had normal word recognition in quiet (≥ 80% correct at those respective presentation levels) and abnormal word recognition in multitalker babble (≥ 6 dB S/B) at 60 and 84 dB HL, respectively. In contrast, only 35% and 7% of the performances by the listeners with hearing loss at 60 and 84 dB HL had abnormal performances both in quiet and in multitalker babble. Only 7% of the listeners with hearing loss had normal recognition performances on the materials presented in quiet and in babble. Overall, the relations depicted in Figure 8 closely mirror similar relations between speech-recognition abilities in quiet and in multitalker babble reported by Wilson and Strouse (Figure 5, 2002) with a preliminary version of the test materials. These relations indicate that generally the ability of an individual to understand speech in a noisy background cannot be predicted from her/his ability to understand speech in quiet. The exception is when word recognition in quiet is poor, then one can be assured that word recognition in noise also will be poor. As succinctly indicated by Killion and Niquette (2000), if you want to know the ability of an individual to understand speech in background noise, then you must make the measurement.

In summary, the main finding in the
current study was that performance on a 500 Hz MLD task varies independently of performance on a word-recognition task in multitalker babble, at least for the conditions and listeners studied. This finding suggests that the auditory mechanisms involved with the MLD phenomenon, which are usually thought of as temporal or phase processes, are not directly involved in the auditory processes required for successful performance on a word in multitalker babble task. Additionally, the data suggest the following for listeners like those included in the current study: (1) SoNo and SzNo thresholds for younger listeners are 3–4 dB lower than the corresponding thresholds for listeners >40 years of age; however, the MLDs for the older groups are the same; (2) word-recognition performance on a multitalker babble task is influenced more by the degree of hearing loss than by the age of the listener; and (3) except when word-recognition performance in quiet is poor, recognition performance in multitalker babble can not be predicted from recognition performance in quiet.

REFERENCES


