Published in final edited form as:

J Am Acad Audiol. 2009 April ; 20(4): 264–271.

Speech Recognition and Temporal Processing in Middle-Aged Women

Karen S. Helfer^{*} and Megan Vargo[†]

^{*}University of Massachusetts Amherst

[†]University of Pittsburgh

Abstract

Purpose—This study was designed to examine speech understanding ability and temporal processing in middle-aged women with normal or near-normal pure-tone thresholds.

Research Design—Speech understanding, temporal processing ability, and self-assessed hearing were measured in groups of younger and middle-aged females.

Study Sample—Participants were younger and middle-aged females ($n = 12$ per group) with normal hearing through 4000 Hz bilaterally. Subjects were drawn from nonclinical populations.

Data Collection and Analysis—Speech understanding was measured in the presence of steady-state noise and competing speech, with and without perceived spatial separation of the target speech and masker. The Gaps-In-Noise (GIN) test (Musiek et al, 2005) was used to assess temporal resolution ability. In addition, subjects completed a questionnaire with several items from the Speech, Spatial, and Qualities of Hearing Scale (Gatehouse and Noble, 2004) to gauge their subjective ability to understand speech in complex listening situations. Data were analyzed via repeated-measures ANOVA and Pearson r correlations.

Results—Results showed that the performance of the middle-aged subjects was significantly poorer than that of the younger participants in the presence of a spatially coincident speech masker. Although performance in this listening condition was unrelated to pure-tone thresholds, it was strongly correlated with scores on the GIN test. Speech understanding performance in the presence of a steady-state masker was related to high-frequency pure-tone thresholds.

Conclusions—These results suggest that some middle-aged women with little or no pure-tone hearing loss experience listening difficulty in complex environments. Results also suggest a strong relationship between temporal processing and speech understanding in certain competing speech situations.

Keywords

Aging; masking; speech recognition; temporal processing

It is not unusual to see middle-aged women self-referring for hearing assessment. The primary complaint of many of these individuals is difficulty understanding speech in adverse listening conditions. Despite these subjective problems, routine audiometric examination usually reveals clinically normal hearing sensitivity and no difficulty understanding words in quiet. This is not

an unexpected finding, since population-based studies of pure-tone hearing suggest that age-related threshold elevation typically does not occur in middle age (e.g., Morrell et al, 1996; Cruickshanks et al, 1998).

Difficulty understanding speech in adverse listening conditions has been demonstrated previously in older individuals with essentially normal peripheral hearing sensitivity (e.g., Helfer and Wilber, 1990; Dubno et al, 2002; Wingfield et al, 2006) as well as in younger people with discrete auditory nervous system dysfunction (e.g., Musiek et al, 2005). This raises the question of whether subtle, age-related changes in auditory processing occur in middle age. Although research studies rarely have focused on hearing in middle age, a number of investigations of aging effects in general have included one or more groups of middle-aged subjects. Data from many of these studies suggest that certain auditory abilities begin to decline in middle age. For example, middle-aged subjects have been shown to perform more poorly than younger listeners (but better than older individuals) on tasks such as perception of dichotically presented speech (Barr and Giambra, 1990; Martin and Cranford, 1991; Jerger et al, 1994), speech perception in noise (Ewertsen and Birk-Nielsen, 1971; Plomp and Mimpen, 1979; Era et al, 1986; Gelfand et al, 1986; but see Kim et al, 2006) or in reverberation (Nabelek and Robinson, 1982), perception of interrupted speech (Bergman, 1971, 1980; Era et al, 1986) and time-compressed speech (Vaughan and Letowski, 1997), localization or lateralization of sound (Abel and Hay, 1996; Abel et al, 2000; Babkoff et al, 2002), and duration discrimination (Abel et al, 1990).

It is tempting to attribute these subtle deficits to central causes, since the majority of subjects in the studies cited above had normal or near-normal peripheral hearing sensitivity. However, many of the participants had minor threshold elevation in relation to younger subjects. This raises the issue of whether slight threshold elevation and/or the underlying peripheral auditory dysfunction indicated by elevated thresholds contributed to reduced performance on these tasks. A number of studies cited above have noted that even mild high-frequency hearing loss can affect test performance (e.g., Gelfand et al, 1986) or that, once pure-tone thresholds were controlled statistically, differences between younger and middle-aged subjects were no longer significant (Takahashi and Bacon, 1992, for modulation detection and masking). Moreover, DPOAE amplitudes are smaller in normal-hearing middle-aged adults than in normal-hearing younger adults (e.g., Dorn et al, 1998), suggesting that subtle peripheral auditory changes may begin in this age range.

There is evidence, however, that the changes in auditory perception in middle age may at least in part be due to factors beyond the cochlea. Subtle differences between younger and middle-aged subjects are noted in event-related potentials (ERPs) (Geal-Dor et al, 2006) and on the mismatch negativity potential (Alain et al, 2004). A recent investigation (Ross et al, 2007) measured the processing of interaural phase differences both in behavioral and physiological tasks, demonstrating that age-dependent changes in binaural functioning occur in middle age. Furthermore, lipreading ability also begins to show age-related declines in middle age (Farrimond, 1959; Pelson and Prather, 1974; Dancer et al, 1994), which could indicate age-related changes in speech understanding on a more central level.

As mentioned above, there is a paucity of research specifically designed to examine hearing in middle-aged adults. One recent study, however, did focus specifically on auditory functioning in this age group. Grose et al (2006) measured two aspects of temporal hearing (gap duration detection and gap duration leading to perception of a stop consonant within a word [e.g., *say* vs. *stay*]) in younger and middle-aged (40–55 years) adults with normal hearing. Results of both of these experiments suggest age-related temporal processing changes can be demonstrated in middle age and that they may lead to subtle problems processing speech stimuli.

The data summarized above suggest that certain aspects of hearing begin to decline in middle age. The purpose of the present study was to compare the performance of younger and middle-aged adults on a measure of speech understanding that taps into the problems commonly reported by middle-aged listeners and to test whether any measured changes are related to temporal processing ability. Temporal processing was assessed because this ability has been shown to be particularly prone to the negative effects of aging (e.g., Gordon-Salant and Fitzgibbons, 1999; Gordon-Salant et al, 2006; Pichora-Fuller et al, 2006). A clinically feasible measure of temporal processing was used as we were interested in determining whether currently available tests may be useful in identifying individuals who have difficulty in real-life listening situations. Of particular interest was the assessment of performance of middle-aged adults who did not have specific auditory complaints; hence, our subjects were drawn from a nonclinical population. In addition to objective measures of speech understanding, we also obtained participants' subjective view of how they function under realistic listening conditions. Finally, because of potential differences in age-related speech recognition abilities between men and women (e.g., Dubno et al, 2008) data were collected exclusively from female listeners.

METHODS

Participants

Subjects were 12 younger (19–22 years, mean: 20.50 years) and 12 middle-aged (45–54 years, mean: 49.33 years) women with normal hearing sensitivity or no more than a mild high-frequency sensorineural hearing loss (see Table 1). All participants had thresholds no higher than 25 dB HL from 250 Hz to 4000 Hz. Seven of the middle-aged subjects had thresholds of 30–40 dB at 6 kHz and/or 8 kHz. The mean high-frequency pure-tone average (HFPTA; mean of thresholds at 4, 6, and 8 kHz) for the older group was 12.08 dB HL and for the younger group was 3.47 dB HL. ANOVA indicated that this difference in high-frequency thresholds between the two groups was significant ($F(1,22) = 11.94, p = .002$).

Test Measures

Speech Recognition—Our primary interest was determining whether we could demonstrate difficulty understanding speech under somewhat realistic listening conditions. The protocol chosen for this study is one that has been used previously in our laboratory for measuring the masking of speech (e.g., Freyman et al, 1999). This speech recognition procedure allows us to examine performance in the presence of both noise and speech maskers in situations with and without perceived spatial separation between the target and the masker. Hence, it allows us to sample speech recognition ability over a range of listening conditions.

Stimuli consisted of 80 syntactically simple sentences based on one of 12 topics, with three key words per sentence used for scoring. Sentences were recorded from a female talker and were subsequently digitized, edited, and equated for root mean square (RMS) amplitude. Details of the recording process can be found in Helfer and Freyman (2004).

Recognition of the sentences was measured in the presence of a speech masker and a noise masker. The speech masker consisted of sentences recorded from two other female talkers. These sentences were unrelated to any of the target sentence topics. Sentences were recorded and edited in a manner similar to that used for generating the target sentences. Sentences from each individual masking talker were concatenated and then combined to produce an ongoing two-talker masker. The noise masker was steady-state noise created by shaping white noise with the long-term spectrum of this two-talker complex. These two maskers were equated for RMS amplitude.

Stimuli were presented in two different spatial conditions. In the first condition (F-F [front-front]) the target and masker were both presented from a single loudspeaker located directly in front of the subject at a distance of 1.37 m and a height of 1.24 m. In the second spatial condition (F-RF [front-right front]), the target sentence was played from the front loudspeaker while the masker was played from both the front loudspeaker and from a loudspeaker located 60° to the right of the listener at the same distance and height as the front loudspeaker. In the F-RF condition the masking stimuli from the front loudspeaker were delayed by 4 msec relative to the right speaker. Due to the precedence effect, this leads to the perception of the masker being spatially separated from the target speech. The target sentences were played at a level of 65 dB SPL while the masker was presented at 69 dB SPL (−4 dB signal-to-noise ratio [SNR]), an SNR that was chosen based on previous data collected from young, normal-hearing listeners.

Each subject listened to and repeated 20 sentences in each of the four conditions (two maskers [two-talker speech and noise] × two spatial configurations [F-F and F-RF]). Stimuli were blocked by condition, and the order of blocks was randomized across subjects. The target sentences were sent from a computer sound card to a programmable attenuator (TDT PA4), a mixer (TDT Sum3), a headphone buffer (TDT HB 5), then a power amplifier (TOA P75D) before being presented from the front loudspeaker (Realistic Minimus 7). As mentioned previously the masker was presented to both the front and right loudspeakers with a 4 msec delay favoring the right. Testing was completed in an IAC sound-treated room with minimum reverberation. This test chamber has been used in several other studies of speech recognition incorporating the same paradigm (F-F vs. F-RF presentation) being used the present study (Freyman et al, 2001, 2005; Helfer and Freyman, 2004, 2008).

Listeners completed a brief practice session prior to data collection in which they heard 11 sentences in quiet and 9 sentences in the presence of the maskers. During practice and data collection the topic of the target sentence was presented via text on a computer screen just prior to and during stimulus presentation. Subjects responded by verbally repeating the target sentence, and their responses were scored by an experimenter using customized software.

Gaps-In-Noise (GIN) Test—The GIN Test (Musiek et al, 2005) was used in this study as a clinically feasible measure of temporal processing. In this test, subjects listened to 6 sec segments of broadband noise that contained 0, 1, 2, or 3 silent intervals (or gaps). The GIN test consists of stimuli having ten different gap durations between 2 and 30 msec. According to Musiek et al (2005), the broadband noise was turned off and on instantaneously to produce gaps. Within a trial, gaps were separated by at least 500 msec.

The GIN stimuli were played from a CD through a GSI 10 Clinical Audiometer and presented via circumaural headphones. Stimuli were played at a level of approximately 45 dB HL. Half of the stimuli (30 trials) were presented to the right ear, and the other half to the left ear, with first-ear randomized across subjects. Each gap duration was repeated six times within each 60-trial list. Gap duration, number of gaps per trial, and placement of gaps within a stimulus were randomized among trials. Listeners were instructed to raise their hand each time a gap was heard.

Self-Assessed Spatial Hearing—Selected items from the Speech, Spatial, and Qualities of Hearing Scale (SSQ; Gatehouse and Noble, 2004) were used to assess subjects' self-perceived ability to understand speech under adverse listening conditions. Items used in the current study can be found in Appendix 1. These specific items were selected to measure subjects' perceived ability to understand speech in situations consistent with the laboratory measure of speech recognition used in the present study (speech perception in the presence of competing speech or noise). Subjects completed this paper-and-pencil task prior to data collection.

RESULTS

Speech Recognition

Descriptive statistics for performance on all test measures are shown in Table 2. Percent-correct data from each of the four speech recognition conditions (F-F and F-RF, with noise and speech maskers) were converted to rationalized arcsine units (rau) (Studebaker, 1985) prior to data analysis. Performance on the speech recognition measure can be found in Figure 1. Repeated-measures ANOVA on these data showed a significant main effect of subject group ($F(1,22) = 5.45, p = .029$) as well as significant interactions between group and masker type ($F(1,22) = 8.93, p = .007$) and a significant three-way interaction between group, masker type, and spatial configuration ($F(1,22) = 9.82, p = .005$). Post hoc t-tests (using Bonferroni correction for multiple tests) indicated that the two groups differed significantly only for the F-F condition with the speech masker ($t = 3.241, p = .016$).

Gaps-In-Noise (GIN) Test

Data from the GIN test were analyzed in two ways. First, we calculated percent-correct performance across all 60 trials for each subject. The second measure derived from the GIN results was A.th (approximate gap threshold) (Musiek et al, 2005). This metric was the shortest gap duration where the subject responded correctly on at least four out of six of the presentations at that duration.

Results for the GIN test can be found in Table 2. Percent-correct scores for the GIN test (converted to rau) were subjected to ANOVA and found to differ statistically between subject groups ($F(1,22) = 8.64, p = .008$), with middle-aged listeners demonstrating significantly poorer gap detection ability than younger subjects. When the GIN data were examined in terms of A.th, scores did not differ significantly between the two groups ($F(1,22) = 3.36, p = .081$).

Subjective Hearing Ability

Ratings for each of the five individual SSQ questions were analyzed via Mann-Whitney U tests to determine where the two groups differed (see Table 2). Significant groups differences were found for Question 1 ("You are talking with one other person. There is continuous background noise, such as a fan or running water. Can you follow what the person says?"; $p = .001$) and for Question 3 ("You are in conversation with one person in a room where there are many other people talking. Can you follow what the person you are talking to is saying?"; $p = .009$). Interestingly, these were the questions with the highest overall ratings (i.e., least perceived difficulty) for both groups. Ratings for the other three questions did not differ statistically between the two groups, as both younger and middle-aged participants indicated self-perceived problems on the situations described in these questions.

Correlations among Variables

We were interested in determining whether there was an association between the small amount of high-frequency hearing loss in our middle-aged listeners and performance on the speech recognition measure. We also sought to determine whether there was a connection between performance on the GIN test and speech understanding in adverse listening conditions. To address these issues we completed a Pearson r correlation analysis on the middle-aged subjects' data using the following variables: high-frequency pure-tone average, GIN percent-correct score (in rau), and performance in each of the four speech recognition measures. Results are shown in Table 3.

The correlation analysis revealed two significant correlations of interest. High-frequency thresholds were negatively correlated with speech recognition performance in noise in the spatially coincident F-F condition. The significance of this correlation was just beyond the .05

level; due to the relatively small number of subjects, this connection should be viewed with caution. The GIN percent-correct score was positively correlated with speech recognition in the presence of a speech masker in the F-F condition. This relationship is depicted in Figure 2, which compares GIN scores to speech perception in the F-F speech masking condition. It should be noted that the correlation between these two variables was quite strong ($r = .72$, $p < .01$).

DISCUSSION

Results of the present study documented a difference between our younger and middle-aged subjects in the ability to understand speech in the most difficult listening condition (in the presence of a speech masker, without spatial separation between the target and masking sentences). Performance on this task was not significantly correlated with degree of hearing loss in our middle-aged women but was associated with scores on a clinical measure of gap detection. However, speech recognition ability in the presence of steady-state noise was correlated with degree of high-frequency hearing loss. Middle-aged participants in this study also reported more difficulty in realistic listening conditions than younger adults. This pattern of results suggests that some middle-aged women with clinically normal hearing experience difficulty understanding speech in adverse listening conditions. Moreover, it appears that even very slight hearing loss can negatively affect speech understanding in the presence of noise. This latter result is consistent with other studies that have shown that even mild hearing loss can lead to difficulty understanding speech under certain conditions (e.g., Takahashi and Bacon, 1992).

Although the small amount of peripheral hearing loss in our middle-aged participants was related to speech understanding in noise, it could not explain the presence of an age-related decline in the competing speech task. This finding is consistent with results of a recent study in our laboratory of speech-on-speech masking in older adults (Helfer and Freyman, 2008). In that study, high-frequency hearing loss in older listeners was not significantly correlated with speech perception in the presence of a same-sex spatially coincident masker. It appears that factors other than peripheral hearing loss contribute to problems experienced by middle-aged and older listeners in difficult listening situations.

The finding of reduced gap detection ability in our middle-aged women agrees with a previous report of temporal processing deficits in middle age (Grose et al, 2006). Based on results of these two studies, it appears that the auditory temporal processing deficits that have been well-documented in older listeners (e.g., Gordon-Salant and Fitzgibbons, 1999; Gordon-Salant et al, 2006; Pichora-Fuller et al, 2006) begin some time before 60 years of age. And, as found by Grose et al (2006), these subtle temporal changes appear to have some connection to real-life listening, as scores on the GIN test in the present study were significantly correlated with speech understanding ability in the presence of a speech masker. This connection could be an indication of subtle peripheral and/or central auditory processing changes affecting both gap detection ability and speech recognition under difficult conditions. One likely contributor to this connection is the small amount of high-frequency hearing loss shown in middle-aged listeners, as many previous studies have demonstrated a connection between high-frequency hearing loss and both temporal processing (e.g., Fitzgibbons and Wightman, 1982; Grose et al, 1989) and speech understanding in adverse listening conditions (e.g., Gelfand et al, 1986; Takahashi and Bacon, 1992).

It is tantalizing to consider that temporal processing may be an underlying cause of problems understanding speech in competing speech. Some possible explanations for this connection include temporal deficits leading to a reduced ability to listen in the gaps of a modulated masker such as speech and/or a disruption in the ability to segregate sounds. Previous work has

demonstrated age-related changes in the performance of elderly subjects on both of these tasks (e.g., Alain et al, 1996; Dubno et al, 2002); future research is necessary to determine whether these changes begin in middle age.

Results of this study document subtle age-related changes in auditory processing in middle-aged women. The clinical significance of these changes still has yet to be determined. Although the specific listening task where age-related differences were noted (three people talking in a spatially coincident condition) is not typical, it may be encountered occasionally outside of the laboratory (i.e., when spatial cues are not available in multitalker environments, such as when listening to a mixture of target and masking speech coming from a single source, or when individuals are forced to listen monaurally). Reduced performance by middle-aged listeners in this study also could reflect a generalized problem understanding speech in very difficult listening conditions.

Future research should focus on further defining situations that cause difficulty in a larger sample of middle-aged women. For example, a recent study from our lab (Helfer and Freyman, 2008) showed that older adults have difficulty in competing speech situations when the masking talker is of a different sex than the target talker. This is in contrast to younger adults, who have very little difficulty when the masker and target differ in sex. Performance of middle-aged subjects with different compositions of maskers may yield interesting findings. Subsequent studies also should determine the effect of small amounts of peripheral hearing loss on performance. Finally, longitudinal studies to track the performance of older individuals as they enter senescence would help determine the course of speech understanding problems experienced by older adults.

Appendix 1. Selected Items from the SSQ Scale (Gatehouse and Noble, 2004) Used in the Present Study

Sp 5. You are talking with one other person. There is continuous background noise, such as a fan or running water. Can you follow what the person says?

0	1	2	3	4	5	6	7	8	9	10
Not at all						Perfectly				

Sp 10. You are listening to someone talking to you, while at the same time trying to follow the news on TV. Can you follow what both people are saying?

0	1	2	3	4	5	6	7	8	9	10
Not at all						Perfectly				

Sp 11. You are in conversation with one person in a room where there are many other people talking. Can you follow what the person you are talking to is saying?

0	1	2	3	4	5	6	7	8	9	10
Not at all						Perfectly				

Sp 14. You are listening to someone on the telephone and someone next to you starts talking. Can you follow what's being said by both speakers?

0 1 2 3 4 5 6 7 8 9 10
Not at all Perfectly

Q 19. Can you easily ignore other sounds when trying to listen to something?

0 1 2 3 4 5 6 7 8 9 10
Not easily ignore Easily Ignore

Acknowledgments

This work was supported by NIDCD # 01625.

References

- Abel SM, Giguere C, Consoli A, Papsin BC. The effect of aging on horizontal plane sound localization. *J Acoust Soc Am* 2000;108:743–752. [PubMed: 10955641]
- Abel SM, Hay VH. Sound localization: the interaction of aging, hearing loss and hearing protection. *Scand Audiol* 1996;25:3–12. [PubMed: 8658023]
- Abel SM, Krever EM, Alberti PW. Auditory detection, discrimination and speech processing in ageing, noise-sensitive and hearing-impaired listeners. *Scand Audiol* 1990;19:43–54. [PubMed: 2336540]
- Alain C, McDonald KL, Ostroff JM, Schneider B. Aging: a switch from automatic to controlled processing of sounds? *Psych Aging* 2004;19:125–133.
- Alain C, Ogawa KH, Woods DL. Aging and the segregation of auditory stimulus sequences. *J Gerontol Psychol Sci* 1996;51B:P91–P93.
- Babkoff H, Muchnik C, Ben-David N, Furst M, Even-Zohar S, Hildesheimer M. Mapping lateralization of click trains in younger and older populations. *Hear Res* 2002;165:117–127. [PubMed: 12031521]
- Barr RA, Giambra LM. Age-related decrement in auditory selective attention. *Psychol Aging* 1990;5:597–599. [PubMed: 2278686]
- Bergman M. Changes in hearing with age. *Gerontologist* 1971;11:148–151. [PubMed: 5098321]
- Bergman, M. *Aging and the Perception of Speech*. Baltimore: University Park Press; 1980.
- Cruikshanks KJ, Klein R, Klein BEK, Wiley TL, Nondahl DM, Tweed TS. Cigarette smoking and hearing loss: the epidemiology of hearing loss study. *JAMA* 1998;279:1715–1719. [PubMed: 9624024]
- Dancer J, Krain M, Thompson C, Davis P, Glenn J. A cross-sectional investigation of speechreading in adults: effects of age, gender, practice, and education. *Volta Rev* 1994;96:31–40.
- Dorn PA, Piskorski P, Keefe DH, Neely ST, Gorga MP. On the existence of an age/threshold/frequency interaction in distortion product otoacoustic emissions. *J Acoust Soc Am* 1998;104:964–971. [PubMed: 9714916]
- Dubno JR, Horwitz AR, Ahlstrom JB. Benefit of modulated maskers for speech recognition by younger and older adults with normal hearing. *J Acoust Soc Am* 2002;111:2897–2907. [PubMed: 12083223]
- Dubno JR, Lee F-S, Matthews LJ, Ahlstrom JB, Horwitz AR, Mills JH. Longitudinal changes in speech recognition in older persons. *J Acoust Soc Am* 2008;123:462–475. [PubMed: 18177174]
- Era P, Jokela J, Qvarnberg Y, Heikkinen E. Pure-tone thresholds, speech understanding, and their correlates in samples of men of different ages. *Audiol* 1986;25:338–352.
- Ewertsen HW, Birk-Nielsen HB. A comparative analysis of the audiovisual, auditive and visual perception of speech. *Acta Otolaryngol* 1971;72:201–205. [PubMed: 5113393]
- Farrimond T. Age differences in the ability to use visual cues in auditory communication. *Lang Speech* 1959;2:179–192.
- Fitzgibbons PJ, Wightman FL. Gap detection in normal and hearing-impaired listeners. *J Acoust Soc Am* 1982;72:761–765. [PubMed: 7130534]
- Freyman RL, Balakrishnan U, Helfer KS. Spatial release from informational masking in speech recognition. *J Acoust Soc Am* 2001;109:2112–2122. [PubMed: 11386563]

- Freyman RL, Helfer KS, Balakrishnan U. Spatial and spectral factors in release from informational masking in speech recognition. *Acta Acustica United Acustica* 2005;91:537–545.
- Freyman RL, Helfer KS, McCall DD, Clifton RK. The role of perceived spatial separation in the unmasking of speech. *J Acoust Soc Am* 1999;106:3578–3588. [PubMed: 10615698]
- Gatehouse S, Noble W. The Speech, Spatial, and Qualities of Hearing Scale (SSQ). *Int J Audiol* 2004;43:84–99.
- Geal-Dor M, Goldstein A, Kamenir Y, Babkoff H. The effect of aging on event-related potentials and behavioral responses: comparison of tonal, phonologic and semantic targets. *Clin Neurophysiol* 2006;117:1974–1989. [PubMed: 16859986]
- Gelfand SA, Piper N, Silman S. Consonant recognition in quiet and in noise with aging among normal hearing listeners. *J Acoust Soc Am* 1986;80:1589–1598. [PubMed: 3794064]
- Gordon-Salant S. Speech perception and auditory temporal processing performance by older listeners: implications for real-world communication. *Semin Hear* 2006;27:264–268.
- Gordon-Salant S, Fitzgibbons PJ. Profile of auditory temporal processing in older listeners. *J Speech Lang Hear Res* 1999;42:300–311. [PubMed: 10229448]
- Gordon-Salant S, Yeni-Komshian GH, Fitzgibbons PJ, Barrett J. Age-related differences in identification and discrimination of temporal cues in speech segments. *J Acoust Soc Am* 2006;119:2455–2466. [PubMed: 16642858]
- Groose JH, Eddins DA, Hall JW. Gap detection as a function of stimulus bandwidth with fixed high-frequency cutoff in normal-hearing and hearing-impaired listeners. *J Acoust Soc Am* 1989;86:1747–1755. [PubMed: 2808923]
- Groose JH, Hall JW, Buss E. Temporal processing deficits in the pre-senescent auditory system. *J Acoust Soc Am* 2006;119:2305–2315. [PubMed: 16642844]
- Helfer KS, Freyman RL. The role of visual speech cues in reducing energetic and informational masking. *J Acoust Soc Am* 2004;117:842–849. [PubMed: 15759704]
- Helfer KS, Freyman RL. Aging and speech-on-speech masking. *Ear Hear* 2008;29:87–98. [PubMed: 18091104]
- Helfer KS, Wilber LA. Hearing loss, age and speech perception in reverberation and noise. *J Speech Hear Res* 1990;33:149–155. [PubMed: 2314073]
- Jerger J, Darling R, Florin E. Efficacy of the cued-listening task in the evaluation of binaural hearing aids. *J Am Acad Audiol* 1994;5:279–285. [PubMed: 7987016]
- Kim S, Frisina RD, Mapes FM, Hickman ED, Frisina DR. Effects of age on binaural speech intelligibility in normal hearing adults. *Speech Commun* 2006;48:591–597.
- Martin DR, Cranford JL. Age-related changes in binaural processing: II. Behavioral findings. *Am J Otol* 1991;12:365–369. [PubMed: 1789306]
- Morrell CH, Gordon-Salant S, Pearson JD, Brant LJ, Fozard JL. Age- and gender-specific reference ranges for hearing level and longitudinal changes in hearing level. *J Acoust Soc Am* 1996;100:1949–1967. [PubMed: 8865630]
- Musiek FE, Shinn JB, Jirsa R, Bamiou D-E, Baran JA, Zaidan E. GIN (Gaps-In-Noise) test performance in subjects with confirmed central auditory nervous system involvement. *Ear Hear* 2005;26:608–618. [PubMed: 16377996]
- Nabelek AK, Robinson PK. Monaural and binaural speech perception in reverberation for listeners of various ages. *J Acoust Soc Am* 1982;71:1242–1248. [PubMed: 7085996]
- Pelson RO, Prather WF. Effects of visual message-related cues, age and hearing impairment on speech reading performance. *J Speech Hear Res* 1974;17:518–525. [PubMed: 4418739]
- Pichora-Fuller MK, Schneider BA, Benson NJ, Hamstra SJ, Storzer E. Effect of age on detection of gaps in speech and nonspeech markers varying in duration and spectral symmetry. *J Acoust Soc Am* 2006;119:1143–1155. [PubMed: 16521775]
- Plomp R, Mimpfen AM. Speech-reception threshold for sentences as a function of age and noise level. *J Acoust Soc Am* 1979;66:1333–1342. [PubMed: 500971]
- Ross B, Fujioka T, Tremblay KL, Picton TW. Aging in binaural hearing begins in mid-life: evidence from cortical auditory-evoked responses to changes in interaural phase. *J Neurosci* 2007;27:11172–11178. [PubMed: 17942712]

- Studebaker GA. A “rationalized” arcsine transform. *J Speech Hear Res* 1985;28:455–462. [PubMed: 4046587]
- Takahashi GA, Bacon SP. Modulation detection, modulation masking, and speech understanding in noise in the elderly. *J Speech Hear Res* 1992;35:1410–1421. [PubMed: 1494284]
- Vaughan NE, Letowski T. Effects of age, speech rate, and type of test on temporal auditory processing. *J Speech Lang Hear Res* 1997;40:1192–1200. [PubMed: 9328889]
- Wingfield A, McCoy SL, Peelle JE, Tun PA, Cox LC. Effects of adult aging and hearing loss on comprehension of rapid speech varying in syntactic complexity. *J Am Acad Audiol* 2006;17:487–497. [PubMed: 16927513]

Abbreviations

GIN test	Gaps-In-Noise test
F-F	front-front
F-RF	front-right front
SSQ	Speech, Spatial, and Qualities of Hearing Scale

Figure 1.

Average performance on the speech recognition measure for younger (light bars) and middle-aged (dark bars) subjects in the presence of competing speech and a competing noise masker. F-RF represents performance in the spatially separated conditions; F-F is performance in the spatially coincident conditions. Error bars represent the standard error. Group performance differed significantly for the Speech F-F condition (denoted with a star).

Figure 2.

Scattergram depicting the relationship between speech recognition in the presence of a spatially coincident speech masker and performance on the GIN test. Data are for the middle-aged subjects. The 95% confidence interval for this correlation coefficient is .54–.83.

Table 1

Mean and Standard Deviation (in parentheses) Data for Pure-Tone Thresholds of Subjects in the Younger and Middle-Aged Groups

	Younger Participants	Middle-Aged Participants
Right Ear		
250 Hz	4.2 (5.6)	7.5 (7.8)
500 Hz	2.5 (4.5)	7.5 (6.0)
1000 Hz	-1.0 (2.9)	6.3 (4.3)
2000 Hz	3.8 (5.3)	5.0 (6.4)
3000 Hz	5.0 (7.1)	7.9 (9.2)
4000 Hz	5.4 (8.4)	11.3 (6.8)
6000 Hz	5.8 (3.6)	18.3 (11.1)
8000 Hz	3.8 (4.8)	18.3 (14.0)
Left Ear		
250 Hz	12.1 (7.5)	10.0 (6.0)
500 Hz	10.0 (8.5)	8.8 (5.3)
1000 Hz	-1.0 (2.9)	3.8 (5.7)
2000 Hz	5.4 (7.2)	8.8 (6.1)
3000 Hz	6.7 (8.6)	9.2 (8.2)
4000 Hz	4.2 (9.5)	13.3 (9.4)
6000 Hz	12.9 (7.5)	19.2 (11.0)
8000 Hz	5.8 (5.7)	20.8 (9.7)

Note: All values are in dB HL.

Table 2

Descriptive Statistics for Demographic Variables and Test Measures

Variable	Younger Group	Middle-Aged Group
Age (in years)	20.50 (0.15)	49.33 (3.37)
HFPTA	3.47 (1.01)	12.08 (2.28)
GIN	78.30 (2.14)	70.83 (1.38)
A.th	4.42 (0.23)	4.92 (0.15)
F-RFnoise	78.33 (3.48)	74.02 (1.78)
F-Fnoise	78.89 (3.63)	78.61 (2.09)
F-RFspeech	77.08 (3.26)	72.92 (2.91)
F-Fspeech	33.33 (4.55)	14.72 (3.85)
SSQ_Sp5	9.33 (0.18)	7.67 (0.33)
SSQ_Sp10	6.75 (0.57)	6.42 (0.53)
SSQ_Sp11	9.00 (0.33)	7.33 (0.48)
SSQ_Sp14	6.50 (0.73)	5.75 (0.57)
SSQ_Q19	8.00 (0.52)	6.67 (0.53)

Note: Mean values for each variable are followed by the standard error (in parentheses). HFPTA is the average of pure-tone thresholds for 4, 6, and 8 kHz, averaged between ears (in dB HL). GIN is percent-correct performance on the Gaps-In-Noise test, averaged between ears. A.th is performance on the Gaps-In-Noise test as measured by approximate gap threshold (in milliseconds), averaged between ears. F-RFnoise and FFnoise are performance on the speech recognition task with a noise masker, with and without spatial cues, respectively (in percent correct). FRFspeech and F-Fspeech are performance on the speech recognition task with a speech masker, with and without spatial cues, respectively (in percent correct). SSQ items are averaged responses to each individual question (see Appendix 1 for the content of each SSQ item).

Table 3
Pearson r Correlations among Variables for the Data from Middle-Aged Participants

	HPPTA	GIN	F-Fnoise	F-RFnoise	F-Fspeech	F-RFspeech
HPPTA	–	–.24	–.59*	.01	–.29	–.02
GIN		–	.55	.16	.72†	.51
F-Fnoise			–	.20	.65*	.17
F-RFnoise				–	.49	.64*
F-Fspeech					–	.42
F-RFspeech						–

Note: HPPTA is the average of pure-tone thresholds for 4, 6, and 8 kHz, averaged between ears (in dBHL). GIN is performance on the Gaps-In-Noise test (in percent correct), averaged between ears. F-RFnoise and F-Fnoise are performance on the speech recognition task with a noise masker, with and without spatial cues, respectively (in percent-correct). F-RFspeech and F-Fspeech are performance on the speech recognition task with a speech masker, with and without spatial cues, respectively (in percent-correct).

* Significant beyond the .05 level.

† Significant beyond the .01 level.