

# Intelligibility of Foreign-Accented Speech for Older Adults with and without Hearing Loss

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## Abstract

**Background:** Numerous studies have demonstrated that the negative effect of noise and other distortions on speech understanding is greater for older adults than for younger adults. Anecdotal evidence suggests that older adults may also be disproportionately negatively affected by foreign accent. While two previous studies found no interaction between foreign accent and listener age, these studies reported no audiometric data and assessed speech understanding in quiet only.

**Purpose:** To examine the effects of foreign accent, listening condition, and listener age and hearing status on word identification.

**Research Design:** A cross-sectional descriptive study.

**Study Sample:** Experiments 1 and 2 tested young adults with normal hearing ( $n = 20$  and  $n = 5$ , respectively), older adults with essentially normal hearing ( $n = 20$  and  $n = 10$ , respectively), and older adults with sloping sensorineural hearing loss ( $n = 20$  and  $n = 10$ , respectively).

**Data Collection and Analysis:** The intelligibility of English words produced by a native speaker of English and by a native speaker of Spanish was assessed. In Experiment 1, word intelligibility was measured in quiet, in noise (+3 dB signal-to-babble ratio, or SBR), and in a telephone filter condition. In Experiment 2, intelligibility was measured in three additional noise conditions (+6, +9, and +12 dB SBR).

**Results:** English words produced by the native speaker of English were significantly more intelligible than those produced by the native speaker of Spanish. While the negative effect of noise was significantly greater for older listeners than for younger listeners, the effect of foreign accent was independent of listener age, listener hearing status, and listening condition.

**Conclusion:** The results suggest that, unlike with other forms of distortion, older adults are not disproportionately affected by foreign accent. This suggests, in turn, that talker-related distortions of the speech signal have a qualitatively different impact on speech perception than distortions that are applied to the signal after it has been produced. The nature of these different types of distortion may be a fruitful area for future investigations of speech understanding in older adults.

**Key Words:** Aging, foreign-accented speech, hearing loss, speech perception

**Abbreviations:** HHIE = Hearing Handicap Inventory for the Elderly; OHI listeners = older adult listeners with hearing impairment; ONH listeners = older adult listeners with essentially normal hearing; RAUs = rationalized arcsine units; rms = root mean square; SBR = signal-to-babble ratio; TDT = Tucker-Davis Technologies; YNH listeners = young adult listeners with normal hearing

Speech understanding is affected by many variables. Some concern the listener, such as hearing status and age. Others, such as the presence or

absence of noise or reverberation, concern the listening environment. Studies of speech perception and aging have repeatedly demonstrated that listener characteristics

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Portions of these data were presented at the 150th meeting of the Acoustical Society of America in Minneapolis in October 2005 and at the 40th annual Academy of Rehabilitative Audiology Institute in Louisville in October 2006.

interact with the listening environment. For example, when testing younger and older adults with normal hearing for word-recognition abilities in quiet, most studies have found no age effects (e.g., Dubno et al, 1984; Gordon-Salant, 1987; Stuart and Phillips, 1996; Dimitrijevic et al, 2004). In more challenging listening environments, however, age differences emerge. Older adults have been shown to be disproportionately affected by distortions such as background noise (e.g., Dubno et al, 1984; Stuart and Phillips, 1996; Dimitrijevic et al, 2004; Gordon-Salant and Fitzgibbons, 2004; Kim et al, 2006), reverberation (e.g., Helfer, 1992; Gordon-Salant and Fitzgibbons, 1995a; Divenyi and Haupt, 1997), and certain types of time compression (e.g., Gordon-Salant and Fitzgibbons, 1995a, 2004; Schneider et al, 2005; Wingfield et al, 2006). Age effects are especially great when distortions are combined (e.g., Harris and Reitz, 1985; Gordon-Salant and Fitzgibbons, 1995b).

The disproportionate effect of background noise on the speech perception of older adults is consistent with their chief hearing-related complaint, difficulty understanding speech in noisy environments (e.g., Humes et al, 2006). Older adults also frequently report being able to hear speech but unable to understand it, a complaint rooted in an interaction between the sloping hearing loss typically experienced by older adults and the acoustic characteristics of speech. Because low-frequency hearing is normal or near normal, voicing and vowel information are usually easy to hear, while high-frequency hearing loss renders stop and fricative consonants very faint or even inaudible. Anecdotally, older adults seeking hearing help also complain of particular difficulty understanding female voices. This contrasts with studies using young listeners with normal hearing in which female talkers have been found to be generally more intelligible than male talkers (e.g., Bradlow et al, 1996; Ferguson, 2004). No comparable data exist for older adults with hearing loss.

Another common complaint among older adults seeking audiologic services is difficulty understanding talkers who speak with an accent (Pichora-Fuller, 2006). This complaint may refer to those who speak a different dialect of the language being used or to nonnative speakers of that language. The significance of this latter case is apparent when one considers two current trends in the United States: a rapid increase in the number of older adults (Himes, 2002) and a large proportion of foreign-born health care workers. According to Clearfield and Batalova (2007), 26% of physicians and 19% of nursing, psychiatric, and home health aides in the United States were born in another country. Older adults are frequent consumers of health care services, with nearly 90% of adults over 65 having at least one chronic health condition (Hoffman et al, 1996). Furthermore, the number of nursing home residents is projected to reach three million by 2030 (Siegel, 1996), versus 1.62 million in 2006

(U.S. Administration on Aging, 2007). If, as is the case with environmental sources of speech distortion, older adults are disproportionately negatively affected by the presence of a foreign accent, this would have health care implications for older adults who live at home as well as those who reside in long-term care settings. For example, difficulty understanding medical instructions could result in nonadherence to medical treatment, a significant public health concern often investigated in terms of listener-related variables, such as cognitive status (e.g., Mackin and Areán, 2007). Furthermore, for those residing in nursing homes, socialization opportunities consist chiefly of interactions with care providers (Williams et al, 2003). Any factor that negatively affects communication success can therefore have a major impact on quality of life for these individuals.

Only three studies have investigated the perception of foreign-accented speech by older adults. Burda and colleagues (2003) compared the performance of young, middle-aged, and older adults identifying English words and sentences produced by a native speaker of American English, a native speaker of Taiwanese, and a native speaker of Spanish. While speech produced by the nonnative speakers was significantly less intelligible than speech produced by the native English speaker, and overall performance was significantly lower for the older adults than for the young or middle-aged adults, the interaction between talker native language and listener group was not significant. That is, the three listener groups were all affected by foreign accent to roughly the same degree. Later, Burda and Hageman (2005) presented a subset of the materials used by Burda and colleagues (2003) to adults residing in assisted living facilities. As before, the speech produced by the nonnative speakers of English was significantly less intelligible than that produced by the native speaker of English. Finally, Shah and colleagues (2005) presented English sentences produced by a native speaker of English and by a native speaker of Croatian to younger and older adults. Like Burda and colleagues (2003), Shah and colleagues found significant main effects of talker native language and of listener age group but no disproportionate negative effect of foreign accent for the older listeners.

Based on these data, Shah and colleagues (2005) concluded that, in contrast with distortions such as noise or reverberation, the negative impact of foreign accent on speech understanding is about the same for younger and older adults. However, the Shah and colleagues and Burda and colleagues (2003) studies both have methodological limitations that weaken this conclusion. First, speech materials were presented only in quiet. In contrast, Rogers and colleagues (2004) presented English materials produced by native speakers of American English and of Mandarin Chinese to young adult listeners in three different levels of multiple-talker babble. They found that the intelligibility of speech produced

by even highly proficient nonnative speakers of English was more affected by noise than that produced by native speakers. It is possible, then, that an age-dependent effect of foreign accent might emerge in more realistic listening situations featuring background noise or other distortions. Second, the hearing status of the older listeners in Shah and colleagues and Burda and colleagues was not well specified. In Burda and colleagues, the older adult participants were required to pass a hearing screening at 40 dB HL for 500–4000 Hz (the criterion for young and middle-age adults was 20–25 dB HL). In Shah and colleagues, older listeners had to score 8 or lower (out of 40) on the Hearing Handicap Inventory for the Elderly (HHIE [Ventry and Weinstein, 1982]) to participate. Weinstein and Ventry (1983) reported that HHIE scores for participants with various degrees of hearing loss vary widely, with some participants who have moderate or moderately severe hearing loss reporting no hearing handicap. The older adult groups in the earlier studies, therefore, may have included both listeners with normal hearing and listeners with mild hearing loss. It is possible that only older adults with more severe hearing loss are disproportionately negatively affected by foreign accent.

The present investigation therefore explored, for several different listening conditions, whether the speech-understanding abilities of older adults with normal hearing or with mild to moderate hearing loss are disproportionately negatively affected when the talker has a foreign accent. English monosyllabic words produced by a native speaker of American English and by a native speaker of Spanish were presented to young adults with normal hearing, older adults with normal hearing, and older adults with hearing impairment in two experiments. Experiment 1 assessed word-recognition abilities in quiet, in a filtered condition similar to that experienced when listening on the telephone, and in a background of 12-talker babble. Floor effects in the last condition prompted Experiment 2, which tested word identification in 12-talker babble for three new groups of listeners at three more favorable signal-to-babble ratios.

## GENERAL METHODS

### Materials

Test stimuli for the two experiments were developed from a corpus (Wade, 2003) consisting of 12 talkers reading English monosyllabic words. Six of the talkers were native speakers of General American English, and six were native speakers of Spanish; half of the talkers in each language group were female. Within each group, each talker recorded a different set of three 50-word lists from Egan's (1948) 20 phonetically balanced word lists. Recordings were made in an anechoic chamber using a desktop Electrovoice RE-20 microphone connected to a Fostex D-5 DAT recorder. Talkers read individual words

from the screen of a laptop computer positioned to minimize unwanted noise. The words were presented on the screen at a rate of 3 sec per word. Each list was presented twice in random order, with five filler items presented at the beginning and with a pause between the two presentations. The filler items were selected randomly from lists that otherwise were not used. Prior to recording, each talker studied his or her particular word lists and was encouraged to ask questions regarding the meaning or pronunciation of any unfamiliar items. Later, the recorded items were digitized using a 22,050 Hz sample rate and segmented using Praat (Boersma, 2001).

For the current experiments, one male talker was selected from each language group. The native Spanish speaker was a native of Costa Rica who had been living in an English-speaking environment for two years. He was selected on the basis of word identification scores achieved by college-age listeners for the various native Spanish speakers during a training study (Wade, 2003; T. Wade, personal communication, January 19, 2005); the listeners' average word identification score for this talker was close to the average for the six native Spanish-speaking talkers. The native English speaker was selected because he was male and had recorded the same three lists as the native Spanish speaker. Both speakers read lists 8, 9, and 10 of the Egan (1948) lists. Gender and list differences were thus eliminated as confounding factors.

In general, the first of the two repetitions recorded by each talker was selected for use in the present experiments unless the recording was noisy, the word was produced with poor voice quality, or the word was mispronounced. Of the 150 words, the second token was used in 21 cases for the native English speaker and in 23 cases for the native Spanish speaker. Mispronunciation was the reason for selecting the second token in just one case for the native English speaker (one token of the word "dose" pronounced /doz/); mispronunciation occurred eight times for the native Spanish speaker. In these latter cases, the two tokens were pronounced differently. The test token was chosen based on the following three criteria, applied in order: (1) it sounded most typical of the talker's overall English production (based on subjective impressions of the entire recording), (2) it sounded most like the English target, or (3) the final consonant was released.

After the test tokens were selected, the waveform files were edited using Cool Edit 2000 so that each "unfiltered" file contained the test word preceded and followed by 50–100 msec of silence. A "filtered" version of each test stimulus was then created by applying Cool Edit's preset "Telephone Bandpass" fast Fourier transform filter to the waveform file. This filter has low- and high-frequency cutoffs of approximately 150 and 3500 Hz, respectively. Next, the unfiltered and filtered stimuli were scaled using a MATLAB script that identified the amplitude peak in the waveform, measured the root mean square

(rms) amplitude for a 50 msec window around that peak, and scaled the waveform to make the peak amplitude 75 dB (re: 1 bit). For five of the filtered stimuli, clipping occurred during this process. In two cases, both produced by the native English speaker, the clipping occurred only for a single pitch pulse, and so the clipped pulse was deleted from the scaled file. In the other three cases, all produced by the native Spanish speaker, the clipping occurred because the amplitude peak occurred during the initial consonant. The 50 msec window around this peak had a much lower amplitude than the vowel, resulting in a scale factor large enough to cause the vowel to clip during scaling. One of these three stimuli was replaced with the repetition token. For the other two, which had /k/ in the initial position, both tokens had similar amplitude patterns. The waveforms of the originally selected tokens were therefore scaled by identifying the peak rms amplitude during the vowel, calculating the scale factor based on that amplitude, and then applying the scaling factor to the entire waveform.

For the noisy condition, segments of background noise from a 15 sec sample of 12-talker babble were selected on each trial. The babble sample was previously digitized from a recording of the Speech Perception in Noise Test (Kalikow et al, 1977).

## Listeners

There were three groups of listeners in each experiment: young listeners with normal hearing (YNH listeners), older adult listeners with essentially normal hearing (ONH listeners), and older adult listeners with hearing impairment (OHI listeners). All were native speakers of American English who reported no history of speech or language disorders. YNH listeners were recruited by flyers posted at the University of Kansas; they were determined by hearing screening to have pure-tone thresholds  $\leq 20$  dB HL re: American National Standards Institute (2004) for 250–8000 Hz.

Older adult listeners were recruited from a participant pool maintained by the first author; all participants receive a complete audiologic evaluation upon joining the pool. To ensure a sufficient number of ONH participants, individuals were sought who had normal hearing (thresholds  $\leq 25$  dB HL) for 250–4000 Hz and no more than a moderate hearing loss (thresholds  $\leq 55$  dB HL) at 6000–8000 Hz. Similar criteria have been used in previous studies (e.g., Schneider et al, 2005) comparing younger and older adults with good hearing sensitivity. OHI listeners were required to have mild to moderately severe sloping sensorineural hearing losses. All older adult listeners were required to have good word-recognition abilities ( $>80\%$  correct) for Northwestern University Auditory Test No. 6 words (Tillman and Carhart, 1966) presented in quiet at 40 dB re: the speech-recognition threshold. All listeners were paid for their participation.

## Procedures

Listeners in both experiments were tested individually in a double-wall sound-treated booth, seated in front of a computer monitor and mouse. On each trial, a test word and a segment of 12-talker babble were played from separate channels of a Tucker-Davis Technologies (TDT) RP2 real-time processor, attenuated (by separate TDT programmable attenuators, PA-5) to achieve the desired overall level and signal-to-babble ratio (SBR), mixed (TDT SM5), and routed via a head-phone buffer (TDT HB-7) to an insert earphone (E-ARTONE 3A) for monaural presentation. The segment of babble, which was 1 sec longer than the test word, was selected from a random location within the stored 15 sec sample of 12-talker babble; the test word and babble segment were centered temporally. The sentence "I'm ready for the next word" was displayed on the monitor along with a box saying "OK." The listener identified each test word by writing it on a prepared answer sheet and then clicked "OK" to initiate the next trial.

The three test lists and the three test conditions in each experiment were combined so that each list was presented in a different listening condition for each talker. For example, if list 8 for the native English speaker was presented in a given condition, it would be presented in a different condition for the native Spanish speaker. This scheme yielded 12 possible combinations of the six test blocks. The presentation of these combinations was counterbalanced in Experiment 1 by assigning each of them to at least one and no more than two listeners in each listener group. In Experiment 2 the combinations were assigned to listeners randomly without replacement so that each of the 12 combinations was heard by at least two listeners across groups. The order of the test blocks and the order of the test items within each list were randomized for each listener.

Prior to testing, listeners were familiarized with the test procedures. A list of English words produced by a female talker (recorded by Wade, 2003, but not otherwise used in the current experiments) was divided into five lists of 10 words. The words in one list were filtered as described above, and all items were scaled to the same peak rms amplitude. After orientation to the test protocol, each listener identified several practice lists. Conditions for the practice lists varied between the two experiments and were designed to acquaint the listeners with listening in noise as well as with the experimental task. To avoid possible list order effects, listeners were given a written list of the 150 test words prior to performing the first test block. Listeners were instructed to study the list for 5 min without attempting to memorize the items.

Each test list was scored by hand and assigned a percent correct score by two independent research assistants; disagreements between scores were resolved by

the first author. To normalize variance across the range of performance, percent correct scores for each individual listener for each talker in each condition were converted to rationalized arcsine units (RAUs [Studebaker, 1985]). The RAU scores were then submitted to a three-way repeated-measures analysis of variance (ANOVA) with two within-subjects effects (condition and talker) and one between-subjects effect (group). Tukey post hoc tests were used to explore the details of any significant effects or interactions involving the between-subjects factor. For the within-subjects factors, estimated marginal means and 95% confidence intervals were examined to identify significant contrasts.

## EXPERIMENT 1

### Methods

#### Listeners

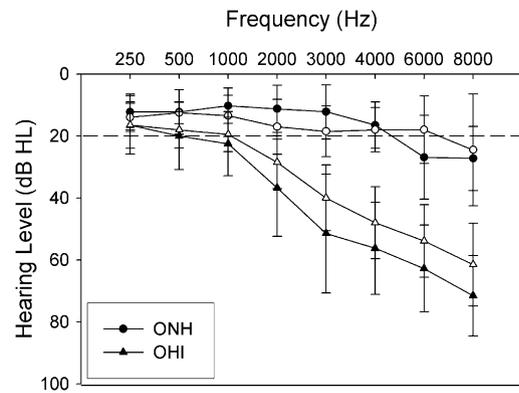
There were 20 listeners in each group. The YNH listeners were aged 18 to 24 yr (mean = 19.7 yr), the ONH listeners were 66 to 83 (mean = 73.2 yr), and the OHI listeners were 66 to 92 (mean = 77.8 yr). Mean audiograms for the older adult listeners are shown as filled symbols in Figure 1; the dotted line indicates the screening level for the YNH listeners. Note that mean thresholds for the ONH listeners were better than the YNH screening level for all but the highest frequencies (i.e., 6000–8000 Hz).

#### Procedures

There were three listening conditions in this experiment; in all three conditions, the English words were attenuated to a presentation level of 70 dB SPL. In the *quiet* condition, the unfiltered version of the words was presented and the babble was attenuated maximally. In the *filtered* condition, the filtered version was presented and the babble was attenuated maximally. In the *noisy* condition, the unfiltered words were presented in a background of 12-talker babble. The babble in this condition was attenuated to 67 dB SPL, resulting in an SBR of +3 dB. Familiarization consisted of one practice list of unfiltered words in quiet, one practice list of filtered words in quiet, and three practice lists of unfiltered words in babble noise (at SBRs of +10, +6, and +3 dB).

### Results and Discussion

Average percent correct scores for each listener group and each combination of talker and listening condition are shown in Table 1. To facilitate comparison with previous studies, the average score across both older adult listener groups for each talker/condition is also given. Consistent with previous studies examining the impact of foreign accent on speech intelligibility, the main effect



**Figure 1.** Mean audiometric thresholds for older adults with normal hearing (ONH) and older adults with sloping sensorineural hearing loss (OHI) participants. Filled symbols represent participants in Experiment 1; open symbols represent participants in Experiment 2. Error bars indicate one standard deviation around the mean. The dotted line corresponds to the screening level for the young adults with normal hearing who participated.

of talker was significant ( $F[1, 57] = 981.90, p < .001$ ): English words produced by the native English speaker were more intelligible than those produced by the native Spanish speaker (70 vs. 34 RAU, averaged across listener group and listening condition). The main effect of listener group was also significant ( $F[2, 57] = 79.86, p < .001$ ). Again consistent with the previous literature, post hoc testing showed that intelligibility scores (averaged across talker and listening condition) were significantly greater for the YNH listeners (69 RAU) than for the ONH listeners (57 RAU,  $p < .001$ ), who had significantly higher scores than the OHI listeners (30 RAU,  $p < .001$ ).

The main effect of listening condition was significant ( $F[2, 114] = 331.57, p < .001$ ), but so was the interaction between listening condition and listener group ( $F[4, 114] = 13.06, p < .001$ ). This interaction is illustrated in the left panel of Figure 2. Post hoc testing on the group effects showed that the ONH listeners performed significantly worse than the YNH listeners only in noise ( $p < .001$ ); in the quiet and filtered conditions, the YNH and ONH listeners were not significantly different ( $p = .56$  and  $.99$ , respectively). Performance of the OHI listeners was always significantly poorer than that of the other listener groups (all  $p < .05$ ). Post hoc tests on the condition effect for each group revealed that for the YNH listeners, all three listening conditions differed significantly ( $p < .01$ ). For the older adult listener groups, in contrast, the quiet and filtered conditions did not differ ( $p > .7$ ), though intelligibility was significantly lower in noise than in these conditions ( $p < .01$ ).

In Figure 2, the difference between the filtered and noisy conditions appears greater for the older adults than for the YNH listeners. To explore this, a “noise effect” score was calculated for each listener for each talker by subtracting the RAU score in noise from the RAU score in the filtered condition. The scores for each listener were averaged

**Table 1. Means and Standard Deviations of Percent Correct Intelligibility Scores for English Words Produced by a Native English Speaker and a Native Spanish Speaker for Three Listener Groups in Three Listening Conditions in Experiment 1**

Listener Group	Quiet		Telephone Filter		Babble (+3 dB Signal-to-Babble Ratio)	
	English	Spanish	English	Spanish	English	Spanish
Young Adults with Normal Hearing	92.5 (6.48)	62.8 (7.21)	87.6 (7.78)	52.3 (12.18)	75.5 (7.67)	36.2 (8.46)
Older Adults with Normal Hearing	87 (11.25)	48.6 (8.44)	82.8 (7.82)	49.2 (10.08)	52.4 (9.68)	17.9 (12.94)
Older Adults with Sloping Sensorineural Hearing Loss	57.1 (23.08)	25.2 (16.79)	59.8 (22.00)	28 (11.18)	22.9 (18.19)	3.7 (4.51)
Mean, All Older Adult Listeners	72.05	36.9	71.3	38.6	37.65	10.8

Note: Standard deviations appear in parentheses below mean values.

across the two talkers, and the means were submitted to a one-way ANOVA. As suspected, the main effect of listener group was significant ( $F[2, 57] = 22.84, p < .001$ ). In post hoc testing, the noise effect was significantly greater for the two older groups than for the YNH listeners ( $p < .001$ ), but the two older groups did not differ significantly ( $p = .2$ ). The results thus suggest that both groups of older adults, regardless of hearing status, were disproportionately affected by background noise, showing a significantly greater drop in intelligibility in the 12-talker babble background than the YNH listeners. This is consistent with previous literature (e.g., Gordon-Salant and Fitzgibbons, 2004) showing that older listeners are differentially affected by speech distortions.

No other interaction was significant. The relationship between the three listening conditions was the same for the native and nonnative talkers ( $F[2, 114] = 0.64, p = .53$ ), as was the increased effect of noise on older adult versus YNH listeners ( $F[4, 114] = 0.65, p = .63$ ). In addition, and unexpectedly, the talker effect was about the same for all three listener groups ( $F[2, 57] = 3.1, p = .053$ ). The left panel of Figure 3 shows intelligibility as a function of talker for the three listener groups. This nonsignificant interaction seems to support the conclusions of Burda and colleagues (2003) and Shah and colleagues (2005) that older adults are not disproportionately affected by foreign accent. Note, however, that the group  $\times$  talker interaction in the present study just missed significance. When the effect of talker accent is calculated for each group by subtracting the percent score for the non-native talker (averaged across conditions) from that of the native talker, the difference scores are 34.8, 35.5, and 27.6 percentage points for the YNH, ONH, and OHI listeners, respectively. That is, the effect of foreign accent was actually smaller for the OHI listeners than for the listeners with normal hearing. This difference can be attributed, however, to a floor effect for the OHI listeners. As seen in Table 1, these listeners performed very poorly in noise, even for the native English speaker. For the nonnative speaker, nearly half of the OHI listeners scored 0%. To determine whether age and foreign accent might interact under less degraded listening conditions, Experiment 2

assessed identification of native-produced and accented English words in three additional noise conditions.

## EXPERIMENT 2

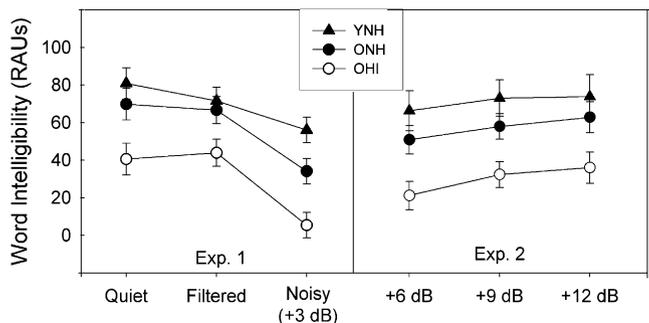
### Methods

#### Listeners

There were five listeners in the YNH group and 10 listeners in each older adult group. None of the listeners had participated in Experiment 1. The YNH listeners were aged 20 to 24 yr (mean = 22.2 yr), the ONH listeners were aged 64 to 73 (mean = 68.3 yr), and the OHI listeners were aged 65 to 85 (mean = 72.2 yr). Mean audiograms for the ONH and OHI listeners are shown as the open symbols in Figure 1. Mean thresholds for the ONH listeners were better than the YNH screening level (20 dB HL) at all frequencies.

#### Procedures

The English words were attenuated to a presentation level of 70 dB SPL for all test conditions. Unfiltered



**Figure 2.** Word intelligibility scores, in rationalized arcsine units (RAUs), for the three listener groups—young adults with normal hearing (YNH), older adults with normal hearing (ONH), and older adults with sloping sensorineural hearing loss (OHI)—averaged across the two talkers in each listening condition in Experiment 1 (left panel) and Experiment 2 (right panel). Error bars indicate 95% confidence intervals.

words were presented in a background of 12-talker babble, the level of which was attenuated to either 58, 61, or 64 dB SPL (resulting in SBRs of +12, +9, and +6 dB, respectively). Familiarization consisted of one practice list of unfiltered words in quiet and two practice lists of unfiltered words in babble noise (at SBRs of +12 and +6 dB).

## Results and Discussion

Average percent correct scores across the two repetitions for each listener group and each combination of talker and listening condition, along with average scores across the two older adult groups, are shown in Table 2. As in Experiment 1, the repeated-measures ANOVA showed significant main effects of talker ( $F[1, 22] = 854.4, p < .001$ ), of listener group ( $F[2, 22] = 30.4, p < .001$ ), and of listening condition ( $F[2, 44] = 23.5, p < .001$ ). Scores (averaged across listener group and listening condition) were much higher for English words produced by the native speaker of English (73 RAU) than for the native speaker of Spanish (32 RAU). In addition, scores (averaged across talker and listening condition) for the OHI listeners (30 RAU) were significantly lower than those of the two groups with normal hearing in post hoc tests ( $p < .001$ ); the contrast between YNH and ONH groups (71 and 57 RAU, respectively) just missed significance ( $p = .064$ ). Performance was significantly higher in the +12 dB SBR listening condition (58 RAU, averaged across talker and listener group) than in the +6 dB SBR condition (46 RAU), and neither of these differed significantly from the +9 dB SBR condition (54 RAU).

Contrary to Experiment 1, the interaction between listening condition and listener group (shown in the right panel of Figure 2) was not significant. This contrast can likely be attributed to the nature of the listening conditions in the two experiments. The key feature of the interaction in Experiment 1 was a significantly greater effect of noise, when compared to the quiet and filtered conditions, for the older adults than for the younger adults. In Experiment 2, all three conditions featured noise and varied only

in signal-to-babble ratio. The results suggest that once noise is present, changes in SBR have similar effects for older adults with and without hearing loss as for young adults with normal hearing. Stuart and Phillips (1996) found comparable results for similar listening groups identifying English words in continuous broadband noise at signal-to-noise ratios ranging from -20 to +10 dB.

Consistent with Experiment 1, neither the condition  $\times$  talker nor the condition  $\times$  talker  $\times$  listener group interactions were significant ( $F[2, 44] = 0.35, p = .7$ ; and  $F[2, 44] = 0.7, p = .6$ ). Changes in SBR had the same effect on performance, and the relationship between the noise conditions and listener group was the same for both the native and the nonnative talker. Most importantly, the talker  $\times$  group interaction was not even close to being significant ( $F[2, 22] = 0.5, p = .6$ ). This noninteraction is shown in the right panel of Figure 3. The effect of talker accent, calculated as before by subtracting the score for the nonnative talker from that of the native talker (both scores averaged across condition), was 41 RAU for the YNH group, 42 RAU for the ONH group, and 39 RAU for the OHI group. The results of Experiment 2 thus support the conclusions of Experiment 1 and of Burda and colleagues (2003) and Shah and colleagues (2005) that the word-identification abilities of older adults are not disproportionately negatively affected by the presence of a foreign accent.

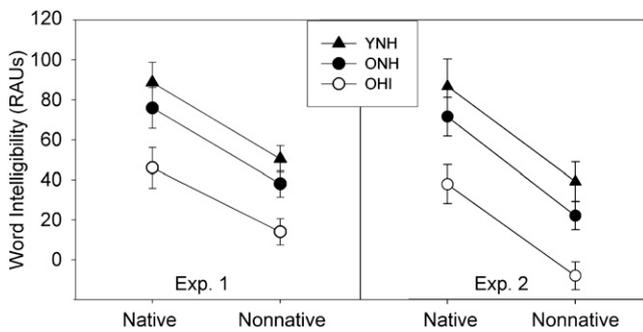
## GENERAL DISCUSSION

The overall results of the present study are consistent with those of earlier studies examining the intelligibility of foreign-accented speech for young adult listeners (e.g., Munro and Derwing, 1995; Derwing and Munro, 1997; Munro, 1998; Imai et al, 2005). English words spoken by a nonnative speaker of English were less intelligible than those produced by a native speaker. The poorer performance for older versus younger listeners found here is also consistent with the two previous studies comparing the understanding of foreign-accented speech by younger and older adults

**Table 2. Means and Standard Deviations of Percent Correct Intelligibility Scores for English Words Produced by a Native English Speaker and a Native Spanish Speaker for Three Listener Groups at Three Signal-to-Babble Ratios (SBRs) in Experiment 2**

Listener Group	+12 dB SBR		+9 dB SBR		+6 dB SBR	
	English	Spanish	English	Spanish	English	Spanish
Young Adults with Normal Hearing	89.2 (8.07)	54.0 (9.17)	90.0 (6.16)	52.0 (10.95)	85.2 (3.35)	46.0 (7.48)
Older Adults with Normal Hearing	81.8 (5.61)	43.2 (13.64)	78.4 (6.45)	36.8 (6.61)	74.8 (7.73)	26.8 (8.39)
Older Adults with Sloping Sensorineural Hearing Loss	56.4 (19.45)	18.0 (10.75)	51.6 (16.97)	16 (11.23)	41.6 (20.50)	8.2 (6.70)
Mean, All Older Adult Listeners	69.1	30.6	65.0	26.4	58.2	17.5

Note: Standard deviations appear in parentheses below mean values.



**Figure 3.** Word intelligibility scores, in rationalized arcsine units (RAUs), averaged across listening condition for the two talkers for each listener group—young adults with normal hearing (YNH), older adults with normal hearing (ONH), and older adults with sloping sensorineural hearing loss (OHI)—in Experiment 1 (left panel) and Experiment 2 (right panel). Error bars indicate 95% confidence intervals.

(Burda et al, 2003; Shah et al, 2005), neither of which specified the hearing sensitivity of the older listeners. Experiment 1 in the present study showed significant differences not just between YNH and OHI listeners but also between the YNH and ONH listeners. The difference between these groups in Experiment 2 was of similar magnitude to the difference observed in Experiment 1 (14 vs. 12 RAU, averaged across talker and listening condition) but just missed significance, likely because Experiment 2 used fewer listeners. Interestingly, any significant (or nearly significant) differences between the YNH and ONH groups occurred only in the presence of background noise. In the quiet and filtered conditions of Experiment 1, the two groups of listeners with normal hearing performed similarly. This is consistent with previous studies in which age effects on speech understanding have been found only under unfavorable listening conditions (e.g., Dubno et al, 1984).

We hasten to note, however, that the difference observed here between YNH and ONH listeners in noise cannot be attributed solely to age effects. Although the ONH listeners had better hearing than is typical for their age, only four of the ONH listeners in each experiment had thresholds at or better than 20 dB HL (the screening level used for the YNH listeners) at all test frequencies. Given the strong contribution of hearing sensitivity to speech understanding (e.g., Humes, 2002), it is possible that the mild hearing losses of some of the ONH listeners at the highest audiometric frequencies contributed to their reduced performance in noise. To tease apart the contributions of aging versus hearing loss to the perception of accented speech by older adults, future experiments should take steps, such as those used by Humes and colleagues (2006), to present a speech signal that is equally audible for the younger and older listeners with normal hearing. The threshold variability evident in Figure 1 also suggests that signal audibility varied among the OHI listeners. Future studies should investigate

whether the relationship between speech audibility and understanding varies as a function of talker native language status. In the present data, correlations between average thresholds at 1000, 2000, and 4000 Hz and performance in the various conditions were much higher for Experiment 2 than Experiment 1 but were similar for the two talkers.

The key result of both experiments carried out here is a lack of interaction between listener age and talker accent. The negative effect of foreign accent on speech understanding was no greater for the older adults than for the young adults. The present data, therefore, confirm the conclusions of Burda and colleagues (2003) and Shah and colleagues (2005) that older adults are not disproportionately affected by the presence of a foreign accent. This result contrasts sharply with the numerous studies showing older adults to be disproportionately negatively affected by speech distortions such as background noise, reverberation, and time compression and suggests that perceptually, a foreign accent is a very different type of distortion than these others. This may be because the distortions associated with a foreign accent are talker-related and inherent to the signal. Noise, reverberation, and time compression, in contrast, are applied after the speech signal has been produced and reduce the availability of the information it contains through energetic masking, temporal smearing, or arbitrary removal of certain parts of the signal.

The idea that foreign accent is a qualitatively different type of distortion than noise or reverberation is further supported by the failure of the present experiments to find any interaction between talker accent and listening condition. Several studies have shown that age effects on speech understanding in the presence of external distortions, in contrast, are even greater when distortions are combined (e.g., Harris and Reitz, 1985). The present results are consistent with those of Lane (1963), who presented accented and unaccented English words in various low-pass filter conditions and in white noise at various signal-to-noise ratios. Noise and filtering affected the accented and unaccented speech to roughly the same extent, and the effect of foreign accent was essentially equivalent under all listening conditions. Our results are also consistent with Munro's (1998) description of young listeners' transcriptions of native-produced and accented sentences in a background of cafeteria noise, although Munro did not test the interaction statistically. All of these results, however, contrast with those of Rogers and colleagues (2004), who found much greater effects of noise on sentence intelligibility when the talker was a nonnative speaker of English than when the talker was a native speaker. Rogers and colleagues attributed the contrast between their results and those of earlier studies to methodological differences, including speech

materials, listening condition, and nonnative talker proficiency. While the present study differed from Rogers and colleagues in terms of material (words vs. sentences), and the relative proficiency of the talkers is difficult to assess, both used multitalker babble as noise, and the signal-to-babble ratios used here (+3 to +12 dB) were mostly within the range Rogers and colleagues tested (+10, 0, -5 dB). The question of whether the effects of noise and of foreign accent on speech understanding interact thus remains inconclusive.

Although the older adults in the present study were not disproportionately negatively affected by the presence of a foreign accent, note that the intelligibility of accented English words was quite low, never exceeding 50% even for the ONH listeners in quiet. Word identification scores obtained in quiet by Burda and colleagues (2003) were similarly poor. Ross (2004) notes that listeners with high-frequency hearing loss “may be hanging onto speech comprehension with their finger tips; any further distortion in the speech signal, such as ... a foreign accent ... and they lose it” (p. 31). That is, when communicating with a native speaker, an older adult with hearing loss may struggle but ultimately can extract the message with an acceptable level of accuracy. The intelligibility of a communication partner with a foreign accent, in contrast, may remain unacceptably low despite great effort on the part of the listener with hearing loss. As Shah and colleagues (2005) noted, this may explain why older adults complain of particular difficulty understanding foreign-accented speech. They suggest that older adults confronted with a foreign accent may “no longer be able to comprehend enough of the input to feel that [they] have succeeded in listening” (p. 2119).

Older and younger adults may also differ on other aspects of the perception of foreign-accented speech. For example, Clarke and Garrett (2004) showed that young adult listeners adapt very quickly to a foreign accent, as assessed by measures of processing speed. It may be that older listeners are less able to adapt than younger listeners. It is also unknown whether older and younger adults differ in terms of how they rate foreign-accented speech in terms of accentedness or comprehensibility. Older adults may be less tolerant of deviations from native speech production than younger adults. However, none of these issues has yet been addressed in any population other than young adult listeners. There are thus many avenues for future research in the perception of foreign-accented speech by older adults, an area of considerable importance given the demographic trends noted in the introduction. Older adults can be expected to come into increasing contact with nonnative speakers in health care settings in the coming years. It is thus essential that audiologists and others understand how older adults are affected by foreign-accented speech and how negative effects like those found in the present study may be ameliorated.

## CONCLUSIONS

This study explored whether older adults with normal or impaired hearing differ from younger adults with normal hearing in terms of how word intelligibility is affected by the presence of a foreign accent. In two experiments, English words produced by a native speaker of American English and by a native speaker of Spanish were presented to young listeners with normal hearing, older adult listeners with normal hearing, and older adult listeners with hearing impairment. Listening conditions included quiet, a condition mimicking the bandpass filtering performed by most telephones, and a background of 12-talker babble at several signal-to-babble ratios. While intelligibility scores differed among the three listener groups, among the various listening conditions, and between the two talkers, the only significant interaction that occurred was between listener group and listening condition in the first experiment. This interaction indicated that the impact of background noise was significantly larger for the older adults than for the younger listeners, a result consistent with the extensive literature on speech understanding and aging. In contrast, the interaction between listener group and talker was not significant in either experiment, suggesting that all three groups were affected by foreign accent to roughly the same degree. This suggests that talker-related distortions of the speech signal have a qualitatively different impact on speech perception than distortions that are applied to the signal after it has been produced.

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