The Interaction of Hearing Aid Release Time Settings and Age for the Perception of Sentences in Speech Babble

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The purpose of this study was to determine if varying release times affected speech perception for younger adults with normal hearing, older adults with slight high frequency hearing loss, and older adults with moderate hearing loss. Speech perception was assessed with fast, slow, and intermediate release times. Aided participants repeated sentences presented in babble at 2 signal-to-babble ratios. Older adults performed more poorly than younger adults. Varying release times did not result in significant differences in speech perception. No significant interactions among age, hearing status, and release time were observed. The results suggest it may not be advantageous to make adjustments to release time settings based only upon age.

Modern hearing aids use compression technology to allow individual wearers greater speech intelligibility and comfort for a wider range of input levels. Using compression, a listener with hearing loss receives more amplification for soft sounds that are inaudible and little if any amplification for loud sounds, without having to adjust a volume control. The speed with which the hearing aid moves in and out of compression is called attack and release time (the onset and offset of compression respectively). Current devices allow for fast-acting (syllabic) compression with release times <150 ms and slow-acting compression (AGC) with release times >200 ms (Fabry, 1991; Moore, Stainsby, Alcántara, & Kühnel, 2004). Both strategies can be used to increase user comfort and improve speech

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understanding, although there is little agreement on the single best attack and release settings because of the complex interaction among degree of hearing loss, listener characteristics, and listening environment.

It has been suggested that cognitive factors may play a role in listener preference for attack and release settings. Gatehouse (2000) found a small but statistically significant correlation between level of cognitive function and hearing aid preference. In his study, listeners with reduced cognitive function preferred AGC to syllabic compression settings for listening in noise. Lunner (2003) has argued that older adults, who are more likely to exhibit diminished cognitive function as measured by speed of processing, may benefit from slower release times. It has also been suggested that older listeners with better cognitive abilities may derive greater benefit from faster time-constant settings (Gatehouse, Naylor, & Elberling, 2003).

The results of empirical investigations addressing these claims have been equivocal for both subjective and objective tasks. For example, Neuman, Bakke, Mackersie, Hellman, and Levitt (1998) found no difference between release time settings at a low compression ratio and subjective ratings of background noise, pleasantness, and sound quality. Similarly, using a paired-comparison paradigm, Bentler and Nelson (1997) had subjects select preferred release time settings for music, speech in quiet, and speech in the presence of one talker. Their results demonstrated no differences in preference for release time settings for any of the stimuli (Bentler & Nelson, 1997). Hansen (2002) also measured aided subjective preference of sound quality and intelligibility of speech and non-speech signals for a range of release time settings. Adults with normal hearing and hearing loss rated their preferences for attack and release time constants as they were changed in a paired-comparison paradigm. His results showed significant preferences for the longest release time, 4 s, over two shorter release times, 400 and 40 ms, for both young and older adult groups.

Similarly, objective assessments of aided speech intelligibility of nonsense syllables and words in quiet for adults with normal hearing and hearing loss have demonstrated no differences in performance for different release time settings (Jenstad & Souza, 2005; Schweitzer & Causey, 1977). Bentler and Nelson (1997) used a nonsense syllable test in background cafeteria noise to determine differences in speech intelligibility following changes to release time settings. The results demonstrated no differences in speech intelligibility due to changes in release time settings for 14 adults of varying ages (Bentler & Nelson, 1997). In a study measuring objective identification of nonsense syllables in quiet and in three types of background noise (cafeteria, babble, and single speaker), Moore et al. (2004) reported that aided speech intelligibility was not affected by changes in the multichannel compression algorithms that differed based on attack and release time.

There are a number of limitations to the previously mentioned investigations that may make interpreting results difficult. Most studies of release time settings did not focus specifically on differences among young and older adult populations with normal hearing and hearing loss (Bentler & Nelson, 1997; Jenstad & Souza, 2005; Moore et al., 2004; Neuman et al., 1998; Schweitzer & Causey, 1977). A comparison of younger and older adults with hearing loss is important to establish whether age is a determinant of preferred release time. In addition, more complex stimuli, such as sentences in background noise, should be utilized instead of nonsense syllables or words in quiet (Jenstad & Souza, 2005; Moore et al., 2004; Schweitzer & Causey, 1977). Difficult listening environments with level variations should force hearing aids in and out of compression (Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004), possibly demonstrating greater differences in speech intelligibility among release time settings. Also, the range of release times utilized in some studies might not have been great enough to elicit differences in speech intelligibility or sound quality judgments. This may have been an issue in studies that utilized "long release times" which were less than 1 s (Bentler & Nelson, 1997; Jenstad & Souza, 2005; Schweitzer & Causey, 1977). Finally it is difficult to reconcile the discrepant findings when different subjective and objective paradigms were utilized to measure speech intelligibility differences for variable release time settings.

In order to address some of these limitations, Cienkowski, Ballingham, Vasil, and Bizzarro (2005) reported on the use of the Performance-Perceptual Test (PPT; Saunders & Cienkowski, 2002) to evaluate both objective (performance) and subjective (perceptual) speech intelligibility with varying release times for younger and older adults with and without hearing loss. Hearing in Noise Test (HINT) sentences (Nilsson, Soli, & Sullivan, 1994) were presented to participants in the presence of steady-state background noise. PPT performance was determined by the signal-to-noise ratio (SNR) at which the participant could repeat the sentences 50% of the time and PPT perception was the SNR at which the participants reported they could just understand the sentences 50% of the time. Performance and perceptual results were obtained for four release times (40, 160, 640, and 2560 ms) representing a range of fast to slow release time settings. Repeated measures analysis of variance (R-ANOVA) demonstrated no significant differences in performance or perception SNRs among the four release time settings for either age group. As a result, this study did not support an interaction between age and release time setting for the perception of speech in noise.

However, the intensity variation of the sentence stimuli and background noise may not have had sufficient variability to maximize the compression characteristics of the hearing aid in the previously mentioned study. In steady-state noise, the compression circuits may not be released due to the consistent level of the noise (Killion et al., 2004). High levels of steady-state background noise may further counteract the positive effects of compression. Fast-acting wide-dynamic range compression has been shown to degrade SNRs in the presence of steady-state background noise, such that the hearing aid output SNR is poorer than the input SNR (Souza, Jenstad, & Boike, 2006). This effect is supported by research indicating that hearing-impaired individuals with poor speech performance may not benefit from compression in steady-state background noise (Verschuure, Benning, Cappellen, Dreschler, & Boeremans, 1998).

Therefore, the purpose of this study was to utilize different sentence stimuli that have more intensity variation within each sentence in the presence of multi-talker-background babble. Computer-Assisted Perception Testing and Training: Sentence-level (CASPERSENT) stimuli were chosen because they may have greater intensity variation and may better simulate real-world speech understanding environments in comparison to the PPT stimuli (A. Boothroyd, personal communication, April, 2005). The multitalker babble was selected from the QuickSin test (Etymotic Research, 2006). This Auditec four-talker babble recording with one male and three females represents a simulated social gathering (Etymotic Research, 2006). It has been suggested that this babble noise has the most intensity variation in comparison to other commercially available babble (Fikret-Pasa, 1993).

The primary goal of this study was to investigate the relationship among age, speech perception, and release time setting utilizing sentences in background babble, with sufficient intensity variation to engage the compression system. The hypotheses were: (a) Processing strategies with varying release times would be distinguishable by differences in scores on the speech-perception task; (b) older adults with slight to moderate hearing loss would have poorer performance on the speech perception task than young adults; and (c) older adults with slight to moderate hearing loss would require a slower release time setting, in comparison to young adults, for maximum speech-perception performance. Results would provide more insight into the usefulness of different release time settings for individuals with hearing loss across the adult lifespan.

METHOD

Participants

Participants were recruited from the University of Connecticut Storrs campus and the surrounding communities. They were assigned to one of three groups on the basis of age and hearing status: young adult normal hearing (YANH), older adult with slight hearing loss (OASH), and older adult with moderate hearing loss (OAHI). Fourteen participants from 18 to 35 years of age were included in the YANH group and 7 participants from 65 to 85 years of age were included in the OASH group. All participants in the normal group had thresholds better than 20 dB HL from 250-4000 Hz. Participants in the slight hearing loss group had thresholds better or equal to 20 dB HL from 250-4000 Hz. Finally, the OAHI group contained 5 participants from the ages of 65 to 85 years with a moderate to moderately-severe flat or slightly sloping hearing loss. None of the participants had any indication of auditory pathology or impacted cerumen as determined by otoscopic examination and brief interview at the time of testing. Two OAHI participants had less than 1 year of binaural hearing aid experience and 3 OAHI participants did not wear hearing aids. The 2 OAHI participants with hearing aids had behind-the-ear (BTE) aids with compression settings set according to manufacturer recommendations. All participants were native speakers of English. See Figure 1 for mean auditory thresholds.

Stimuli

Speech. Sentence stimuli were City University of New York (CUNY) topic-related sentences administered through the CASPERSENT version 3.2 software (Boothroyd, 2006). Sentences varied in type (question, command, and statement), ranged between 3 and 14 words in length, and contained content that was typical of exchanges among adults (Boothroyd, 2006). Within the CASPERSENT software, sentences were organized into 60 sets of 12 different sentences. Each set was counterbalanced for length, sentence type, and topic. Sentences were spoken by Talker 1, a female native speaker of English, in the auditory-only condition. CASPERSENT 3.2 software was installed on an

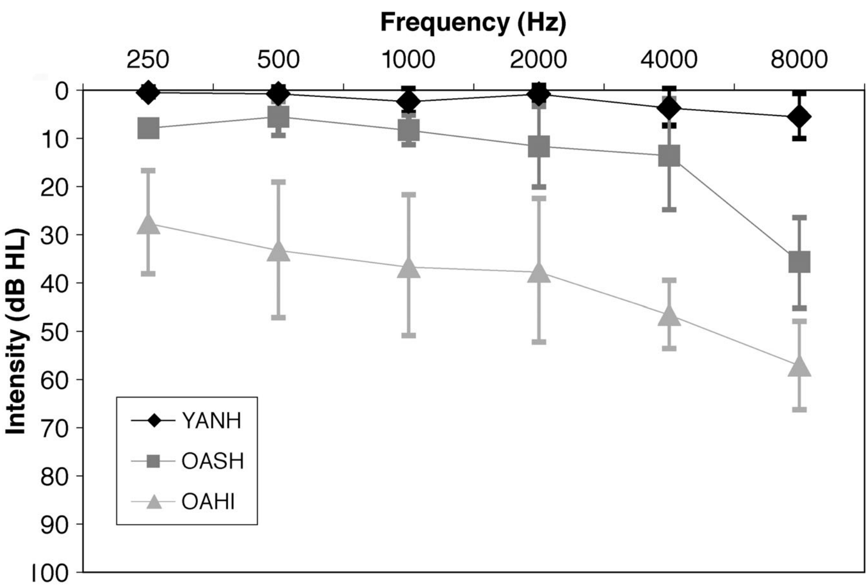

Figure 1. Mean (*SD*) pure tone thresholds for each participant group. *Note.* YANH = young adults with normal hearing. OASH = older adults with slight hearing loss. OAHI = older adults with moderate hearing loss.

IBM ThinkPad R50e laptop computer with an Intel® Pentium® M 1.60GHz processor. Stimuli were routed using RCA cords through External A of a GSI-61 audiometer.

CASPERSENT sentences were presented at 40 dB SL re: pure-tone average (PTA) from both ears in dB SPL. Prior to testing each subject, the stimuli were calibrated. The intensity control on the IBM laptop was set to maximum volume. Calibration tones provided through both sets of software were played individually through separate channels on the audiometer and the volume units (VU) meters for each channel were set to zero. The levels of the CASPERSENT calibration tone and the babble noise were verified using an A-weighted 215 Quest Electronics ANSI S1.4 Type 2 sound level meter.

Babble. QuickSin 1.3 multitalker babble (Etymotic Research, 2006), tracks 24 through 26 on a compact disc, was utilized as the background stimulus. The QuickSin babble was played on a Sony CDP-XE370 Digital Audio Output compact disc player and routed to External B on the GSI-61 audiometer.

Equipment

Hearing aids. The NoahLink Version 01.50.04 with an Ezurio bluetooth connection and NOAH 3 (version 3.1.2) were utilized to connect and program the hearing aids. All participants were fit with binaural Oticon Gaia BTE hearing aids using the manufacturer recommended fitting targets based on their auditory thresholds. Adaptation level was set to three and vent size was set to "none." Compression ratios for both ears were less than 2.0, as suggested by the Oticon Genie 7.0 fitting software. Compression threshold was set at <50 dB HL and the attack times for low frequency and high frequency channels were set to 5 ms. Four release time settings were chosen for comparison to represent a range from fast to slow compression characteristics. The minimum and maximum release times clinically available through the fitting software (40 and 2560 ms respectively) as well as two intermediate release times that were options in the software (160 and 640 ms) were utilized in this study. Hearing aids were coupled to the participants' ears using Disposable Demonstration Tips.

Speech Perception Task

Procedure. All participants underwent a pure-tone hearing evaluation in which auditory thresholds from 250 through 8000 Hz were obtained using TDH-50 headphones. A three-frequency PTA was calculated for the thresholds at 500, 1000, and 2000 Hz. Participants were seated in a sound-treated booth approximately 3 ft away from a speaker at 0° azimuth for the speech perception task. Participants were instructed to listen to the female talker's sentences and verbally repeat back exactly what they heard. Prior to testing, each participant was presented five sentences in quiet at 40 dB SL re: PTA dB SPL to familiarize them with the talker. Following this, sentences in babble were presented to each participant in an unaided condition at a signal-to-babble ratio (SBR) of +7 dB. Participants needed to obtain a score of 70% words correct in a sentence set of 12 sentences in order to continue with the study. Two older adults with hearing loss were excluded from the study because they could not attain a percentage correct score over 70%.

In the experimental conditions, aided speech perception ability was judged at two SBRs, +3 and +5 dB, each with the four different release time settings: 40, 160, 640, 2560 ms. The SBRs of +3 and +5 were chosen from results of a pilot study which demonstrated that these SBRs would prevent ceiling and floor effects for young adults with normal hearing. As the participants repeated back the words they heard, the researcher selected the words that were stated correctly by highlighting the words within the CASPERSENT software. The software calculated number of words correctly repeated per sentence and overall percentage correct out of 100% for each sentence set. The researcher was not blinded to the release time settings. Babble noise was paused after each sentence presentation in order for the researcher to hear the response of the participants. Two sets of sentences were presented for each release time setting at each SBR. Order of release times were randomized across subjects. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), Version 14.0.

RESULTS

Hearing Thresholds

One-way analyses of variance (ANOVAs) revealed that there were significant group differences at all test frequencies from 250 Hz through 8000 Hz at $p < .05$ significance level. Tukey post-hoc tests indicated that the OAHI group average thresholds were significantly different from the YANH and OASH thresholds for all tested frequencies at the specified Bonferroni corrected significance level, $p < .008$. Tukey post-hoc tests comparing the average thresholds for YANH and OASH thresholds also differed significantly at 250, 2000, 4000, and 8000 Hz ($p < .008$). As a result, the older and younger groups with normal or slight hearing loss did not have the same degrees of hearing; mean thresholds indicated that the OASH group had significantly poorer hearing than the YANH group at the previously mentioned frequencies.

Speech Perception

Mean results for the speech perception in babble task are displayed in Figure 2. A repeated measures ANOVA Huynh-Feldt test of within-subjects effects demonstrated that there was no significant interaction between release time and age group, $F = 0.732$, $p = .626$ at either SBR. Paired *t*-tests within each group revealed that there were no significant differences in performance at either SBR among release time settings, as all *F* and *T* values were above the specified significance level, $p > .05$, for all analyses. These results indicated that speech perception scores were not significantly different among release time settings at either SBR for any of the three groups. The large amount of variability in speech perception scores for each group, as seen in Figure 2, may account for the nonsignificant relationship between release time and speech perception ability.

The R-ANOVA Huynh-Feldt test of within-subject effects also indicated that there was a significant difference in speech performance for the main factor of SBRs, $F = 55.216$, $p = .000$. This suggests that all groups performed significantly poorer in the +3 SBR condition in comparison to the +5 SBR condition. In addition, the R-ANOVA results demonstrated that there were no significant

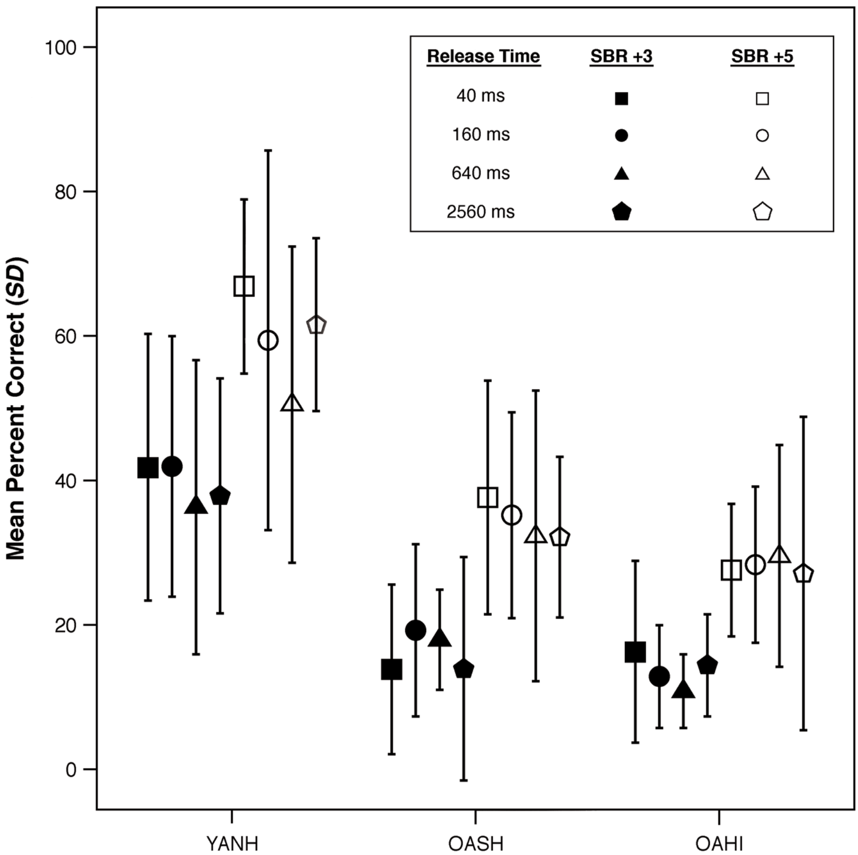

Figure 2. Mean (*SD*) speech perception in babble score (percentage words correct) at +3 and +5 signal-to-babble ratio (SBR) for each group and release time setting. *Note.* YANH = young adults with normal hearing. OASH = older adults with slight hearing loss. OAHI = older adults with moderate hearing loss.

differences between the main factor of release time setting, $F = 0.789$, $p = .506$. As a result, there were no overall changes in speech perception performance based upon release time setting.

Further analysis of group differences using Tukey post-hoc tests revealed that the YANH group had scores for each release time setting that were significantly different from the other groups at the specified significance level, $p < .05$, for all release times. Overall, the YANH group had the highest mean speech perception scores at each release time for both SBRs. In addition, the post hoc analyses indicated that there were no significant differences among the OASH and OAHI speech perception scores at any of the four release time settings, $p > .05$. These results indicated that the young adults had higher performance on the speech perception task than both older adult groups. In addition, scores from both older adult groups were not significantly different from each other, suggesting that degree of hearing loss did not influence the scores for both older adult groups.

DISCUSSION

Consistent with previous investigations (Bentler & Nelson, 1997; Cienkowski et al., 2005; Jenstad & Souza, 2005; Moore et al., 2004), the results for this speech perception task demonstrated that release time settings did not influence speech perception scores for any of the three groups at either SBR. Participant performance did not follow any significant trend based on release time setting. As demonstrated in previous findings of speech perception in background noise (Committee on Hearing, Bioacoustics, and Biomechanics [CHABA], 1988; Gordon-Salant & Fitzgibbons, 2004; Kalikow, Stevens, & Elliot, 1977; Pichora-Fuller & Souza, 2003), young adults with normal hearing in this study outperformed the older adults with slight and moderate hearing loss.

It is interesting to note that speech perception scores for both older adult groups were not significantly different. It would seem likely that the older group with hearing loss would have poorer performance on this task in comparison to peers with normal to slight hearing loss since reduced audibility will result in poorer performance on complex speech perception tasks (Gatehouse et al., 2003; Humes, 1996; Wingfield, McCoy, Peelle, Tun, & Cox, 2006). However, Gordon-Salant and Fitzgibbons (2004) reported that older adults with hearing loss perform more poorly than normal hearing counterparts on sentences in quiet, but not in background noise. It has been suggested that since the presence of background noise may alter audibility for normal-hearing listeners more than hearing-impaired listeners, similar performance in noise for these two groups may be observed (Gordon-Salant & Fitzgibbons, 2004).

In this study, normal hearing was determined by threshold results through 4000 Hz. However, many of the OASH participants did have hearing loss at 6000 Hz and beyond. Therefore, these results may also reflect the OASH group's significantly poorer thresholds in the high frequencies in comparison to the YANH group. As a result, hearing loss may have contributed to the performance of both older adult groups and may account for the similar speech perception scores of these groups (Pichora-Fuller & Souza, 2003).

Results indicated that there were no significant differences in performance among or within groups when release time settings were varied. Contrary to our hypothesis, older adults did not consistently perform better with a slower release time setting. The mean speech perception scores demonstrated a few non-significant trends when release time conditions were varied. At the +5 SBR, there was a trend for both YANH and OASH to perform best with the fastest release time and for OAHI to perform best with the slower release times. This would suggest that there was an interaction between hearing loss and release time, since both the YANH and OASH groups did seem to perform best with the fastest release time. However, at +3 SBR, there was a trend for YANH and OAHI to perform best with the fastest release time and for OASH to perform best with the intermediate release times. The trends between SBRs are only consistent for the YANH group. Increasing the sample size may result in sustaining or dissolving these trends.

Additional statistical analyses of the individual subject data were conducted to determine if any individual subjects had a release time effect. Speech perception scores at +5 SBR were compared for both the 40 and 2560 ms release times for all participants. Those participants that had greater than one standard deviation between the speech perception scores for each release time were reviewed. Two members of the YANH group and 2 members of the OAHI group had significantly better speech perception scores in the 40 ms release time conditions in comparison to the 2560 ms condition. These results suggest that release time may influence speech perception performance for some individuals. Further evaluation of individual characteristics including temporal resolution, cognitive abilities, and degree of hearing loss may provide more insight into why these individuals performed better with the shorter release time. Since only 2 of the 5 OAHI group members wear hearing aids, it cannot be determined if hearing aid use was an influencing factor.

Some caution should be used in interpreting the results. First, the verification of the intensity variation of the stimuli should be confirmed via oscilloscope. This would ensure that the hearing aids were being forced into and out of compression by the stimuli utilized in this study. If the compression characteristics of the hearing aids were not activated, that would explain the similarities in speech perception scores for all four conditions. Second, unlike other research paradigms that allowed participants to adapt to hearing aid settings prior to testing (Gatehouse et al., 2003), this paradigm did not allow for an acclimatization period for each processing strategy. As a result, the scores may not reflect best possible performance with the different hearing aid compression schemes.

The fact that the speech perception scores were low at +5 and +3 SBRs for all groups is concerning considering that they were reaching the criterion level at +7

SBR. The young adult group was achieving 90% or better at +7 SBR while the older adult groups were just meeting the 70% criterion at the same SBR. At the +5 SBR, all groups had an average decrease in performance of more than 20%. This is a steep drop in performance for a 2 dB change in SBR. Since the practice sentences were conducted while the participants were unaided, it is likely that the change from unaided to aided listening (and lack of acclimatization period) may have resulted in a larger decrease in speech perception ability than would be expected otherwise. However, these results are similar to those found by Bentler (2000) on the Speech in Noise Test (SIN) at +5 and 0 SBRs for both normal hearing and hearing impaired participants.

Listeners may have also utilized the context of the sentences to resolve any misperceptions; this is a disadvantage of utilizing a sentence test. Therefore, it is possible that release time did make a difference, but the effect was so small that it could not be observed due to the nature of the task. Also, the use of percentage correct score as the measure of speech perception ability may not have been sensitive enough to detect slight differences in speech perception ability. Therefore, another method of quantifying speech perception ability could be utilized in future studies.

Verification of release time settings also demonstrated that the slowest release time setting was faster than it should have been according to the manufacturer's software. The Frye Fonix 6500 CX Hearing Aid Test Box was used to verify hearing aid release time settings for the slowest and fastest settings. Results from the Advanced Attack and Release Time test on the Fonix system are displayed in Table 1. A composite signal was utilized to run the test. The fastest release time setting (40 ms) was within 10 ms of the manufacturer software. However, the slowest release time (2560 ms) was faster by 1160 ms. As a result, the slowest release time setting was faster than expected but was still significantly slower than the fastest release time setting. The difference in measured versus programmed release time may contribute to why there were minimal differences observed between release times and lack of trends between groups.

Finally, the sample was not optimal. Participants were recruited in the surrounding areas of a University campus that are heavily populated by retired Uni-

Table 1

Manufacturer Release Times Compared to the Actual Measured Release Times for the Fastest and Slowest Release Time Settings

Manufacturer release time settings	Measured release time settings
40 ms	30 ms
2560 ms	1400 ms

versity faculty and staff. This sample may not be representative of the older adult population as a whole. In addition is the large amount of variability across the data for the older adult groups. Some of the variability may be attributed to hearing aid experience (new vs. experienced users). Future investigations with a larger sample size and equal numbers of participants may help to address these issues.

In conclusion, there were no differences in speech perception of sentences in multitalker babble when release time was varied for adults with normal hearing and older adults with slight to moderate hearing loss. The results did not support a relationship or an interaction between age and release time setting. This study suggests that audiologists should consider more than patient ages prior to determining the best compression characteristics, specifically release time settings, for patients with hearing aids.

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