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Research Article

The Influence of Sensorineural Hearing Loss on the Relationship Between the Perception of Speech in Noise and Dysarthric Speech

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ABSTRACT

Purpose: The ability to understand speech under adverse listening conditions is highly variable across listeners. Despite this, studies have found that listeners with normal hearing display consistency in their ability to perceive speech across different types of degraded speech, suggesting that, for at least these listeners, global skills may be involved in navigating the ambiguity in speech signals. However, there are substantial differences in the perceptual challenges faced by listeners with normal and impaired hearing. This study examines whether listeners with sensorineural hearing loss demonstrate the same type of consistency as normal-hearing listeners when processing neurotypical (i.e., control) speech that has been degraded by external noise and speech that is neurologically degraded such as dysarthria.

Method: Listeners with normal hearing (n = 31) and listeners with sensorineural hearing loss (n = 36) completed an intelligibility task with neurotypical speech in noise and with dysarthric speech in quiet.

Results: Findings were consistent with previous work demonstrating a relationship between the ability to perceive neurotypical speech in noise and dysarthric speech for listeners with normal hearing, albeit at a higher intelligibility level than previously observed. This relationship was also observed for listeners with hearing loss, although listeners with more severe hearing losses performed better with dysarthric speech than with neurotypical speech in noise.

Conclusions: This study demonstrated a high level of consistency in intelligibility performance for listeners across two different types of degraded speech, even when those listeners were further challenged by the presence of sensorineural hearing loss. Clinical implications for both listeners with hearing loss and their communication partners with dysarthria are discussed.

The ability to understand speech in adverse listening conditions is complex, and it is widely acknowledged that there is often substantial variability across listeners on performance in these types of challenging perception tasks. Efforts to explain these individual differences have revealed relationships with cognitive, perceptual, and linguistic skills of the listeners (e.g., Benard et al., 2014; Humes et al., 2013; McLaughlin et al., 2018; Ou et al., 2015). More recently, there has been an effort to explore the relationship between the perception of speech across different types of listening adversity. From these data, it appears that individual normal-hearing listeners demonstrate a high degree of consistency in their ability to perceive speech across different types of challenging or degraded conditions such as speech in noise, disordered speech, and time-compressed speech (e.g., Bent et al., 2016; Borrie, Baese-Berk, et al., 2017; Rotman et al., 2020).

In a large-scale study involving 90 normal-hearing listeners, Borrie, Baese-Berk, et al. (2017) found a strong correlation between the perception of dysarthric speech

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(speech produced by an individual with dysarthria) and neurotypical speech in noise (speech produced by a speaker who presents with no neurological history of disease, such as Parkinson's disease, that often causes dysarthric or otherwise disordered speech). In this study, all listeners heard both dysarthric and neurotypical speech. Both speech types resulted in average intelligibility scores of 40% words correct. The findings indicated that despite a large degree of subject-to-subject variability, there was a strong correlation between performance on the two types of speech—listeners who were successful at understanding neurotypical speech in noise were also successful at understanding dysarthric speech. The authors also found evidence that similar cognitive-perceptual processing mechanisms may support the understanding of both types of degraded speech. That is, listeners used similar perceptual strategies (i.e., relied heavily on suprasegmental stress cues to parse both types of listening adversity) to understand neurotypical speech in noise and dysarthric speech. These findings suggest that while the origin of degradation differs, for normal-hearing listeners, there may be global skills (e.g., the ability to use suprasegmental cues when segmental cues are ambiguous; see Mattys et al., 2005, for a hierarchal model of cue use modulated by the quality and quantity of available cues) involved in navigating the ambiguity in degraded speech signals.

Other studies have also reported on a similar relationship. Individual listeners have shown consistency in perception across different types of speech such as accented or disordered speech (Bent et al., 2016; Borrie, Baese-Berk, et al., 2017), native and nonnative speech (Fuhrmeister et al., 2023), and speech presented in noise and time-compressed speech (Rotman et al., 2020). Consistency has also been shown for individual listeners in speech perception tasks under multimodal (auditory–visual) conditions (Gurler et al., 2015), as well as during testing of the same tasks across disparate time periods (Carbonell, 2017; Kong & Edwards, 2016). A few studies have indicated some inconsistencies for individual listeners and that different cognitive processes may be used across different tasks. For example, the results of Bent et al. (2016) were mixed, showing a statistically significant correlation in listeners' perceptions of accented speech with both a regional dialect and dysarthric speech, but not for the regional dialect with dysarthric speech. In addition, Francis et al. (2021) showed that working memory had a greater influence on the comprehension of nonnative speech in quiet than on native speech in noise. Despite some nuances, the findings collectively suggest relative consistency in the perception of listening adversity.

Although consistency within individual listeners has been observed across several studies involving participants with normal hearing, the degree to which this may be observed for individual listeners with sensorineural hearing loss (SNHL) is less established. Large individual-to-individual differences in speech perception skills certainly exist for this population of listeners, and there is evidence that cognitive factors play a role in these differences (Cienkowski & Vasil-Dilaj, 2010; also see Akeroyd, 2008, for a review). However, the consistency, or potential lack of consistency, of speech perception abilities for individual listeners with hearing impairment across different types of listening adversity may be influenced by the complex interplay between the many perceptual deficits associated with hearing loss and the type of speech signal degradation.

Although listeners with mild hearing loss often perform similarly to normal-hearing listeners once reductions in audibility have been corrected for, such as through the use of amplification devices like hearing aids, individuals with more severe losses demonstrate suprathreshold deficits in several aspects of auditory processing including frequency discrimination, temporal discrimination, and loudness recruitment (Glasberg & Moore, 1988). Broadening of the auditory filters with SNHL and the associated reduced frequency selectivity has been shown to not only impact the discrimination of individual phonemes but also be associated with an increased deleterious impact of background noise on speech perception. For example, studies have shown that these effects reduce a listener's ability to "listen in the dips" of background noise maskers (e.g., Festen & Plomp, 1990; Takahashi & Bacon, 1992). In other words, listeners with SNHL are often unable to utilize the portions of a speech–noise mixture, which are relatively favorable with regard to the signal-to-noise ratio (SNR) to improve speech intelligibility. The influence of SNHL on temporal resolution abilities is less clear. Many aspects of temporal processing are impaired by cochlear hearing loss; for example, deficits have been noted in the ability to detect gaps in noise (Fitzgibbons & Gordon-Salant, 1987) and in the ability of listeners with hearing loss to detect modulations in a signal (Bacon & Viemeister, 1985). However, low sensation levels of signals associated with reduced audibility in listeners with hearing loss often play a role when such deficits are noted (see Reed et al., 2009, for a review). For example, when the audible bandwidth of a speech signal is reduced due to a severe high-frequency hearing loss, temporal resolution may be impaired, which can impact discrimination of phonemes.

Given the many perceptual deficits associated with SNHL, and in particular the outsized impact of background noise on speech perception in this population, it may be expected that perception of speech in noise and perception of speech that is degraded at the source (i.e., dysarthria) rely on different perceptual strategies for these listeners. For example, dysarthria is associated with degraded suprasegmental (i.e., rhythm) and segmental properties. For listeners with relatively severe SNHL, for whom frequency resolution can be highly impaired, this type of disruption to the rhythmic properties of speech may be differently challenging relative to navigating an intact speech signal degraded by the presence of background noise.

Therefore, the purpose of this study was to replicate and extend the findings of Borrie, Baese-Berk, et al. (2017) to the clinical population of listeners with SNHL. Here, we examined the relationship between the perception of neurologically degraded (dysarthric) speech and neurotypical speech degraded by noise. Due to the vast differences in the perceptual challenges faced by normal-hearing listeners and listeners with hearing impairment, and in particular the exaggerated impact of noise in the latter population, it is expected that there will be less consistency across listeners with hearing impairment than across normal-hearing listeners in the perception of the two types of degraded speech. To account for the negative impact of SNHL on the overall intelligibility of speech, a higher level of baseline intelligibility was chosen for this study compared to the previous study (80% vs. 40%). The specific research questions addressed in this study were as follows: (a) Is there a relationship between intelligibility performance for neurotypical speech in noise and dysarthric speech for listeners with normal hearing and listeners with hearing impairment, and if so, (b) does the degree of hearing loss for listeners with hearing impairment affect the relationship between the perception of the two types of speech?

Method

Participants

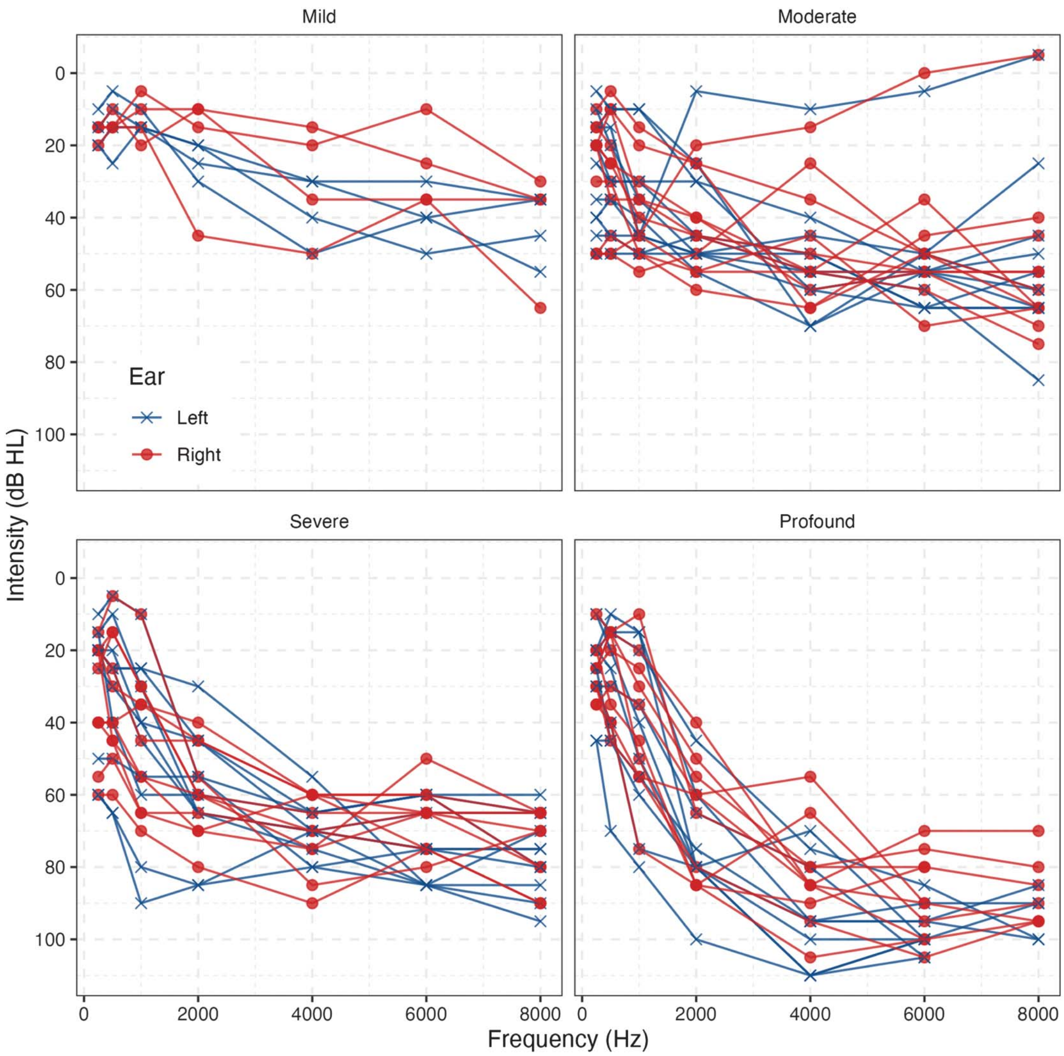
Two groups of listeners were recruited for this study. The first group consisted of 31 listeners with normal hearing (16 women, 15 men) aged between 18 and 65 years (M = 22). These listeners were recruited from undergraduate courses at Utah State University and the surrounding community of Logan, Utah. All normal-hearing participants had pure-tone audiometric thresholds at or below 20 dB HL at octave frequencies from 250 to 8000 Hz (ANSI, 2004, 2010). The second group consisted of 36 listeners with SNHL (17 women, 19 men) aged between 18 and 81 years (M = 66). These listeners were recruited from the Utah State University Hearing Clinic, as well as the surrounding community of Logan, Utah. Cochlear implant users and listeners known (via chart review and/or self-report) to have diagnoses of cognitive disease such as dementia were excluded. All listeners with SNHL were current hearing aid users (minimum duration of use of 6 months). Listeners with hearing loss underwent a full audiological test battery on the day of participation including otoscopy, tympanometry, and air- and bone-conduction audiometry. The degree and configuration of hearing loss varied among the listeners, with degrees from mild to profound, and sloping, flat, and rising configurations represented. Due to the variability in configurations of hearing loss across participants, degree of hearing loss was classified by averaging the six worst thresholds across ears: Four participants were classified as mild (pure-tone average [PTA] of 25–45 dB HL), 11 were classified as moderate (PTA of 46–65 dB HL), 11 were classified as severe (PTA of 66–85 dB HL), and eight were classified as profound (PTA of 85 dB HL or higher). Audiograms for all 36 listeners with hearing loss are shown in Figure 1. All participants (listeners with normal hearing and hearing loss) were native speakers of Standard American English and reported no known experience with people with dysarthria. All participants completed informed consent in accordance with the institutional review board of Utah State University.

Stimuli

The speech materials were 160 syntactically plausible but semantically anomalous phrases (e.g., amend estate approach). The phrases, modeled on the original work of Cutler and Butterfield (1992), were created specifically to examine speech perception in adverse conditions (Liss et al., 1998). Each phrase ranged from three to five words, and each phrase contained six syllables, with alternating strong and weak syllables. The phrases, which reduce the influence of lexical cues on word recognition and speech segmentation, have been frequently used in studies examining the perception of dysarthric speech (e.g., Borrie et al., 2012; Lansford et al., 2023; Liss et al., 2000), including the original comparison study (Borrie, Baese-Berk, et al., 2017) that motivated this present work.

The 160 phrases were divided into two speech sets of 80 phrases. The speech sets were balanced for number of phrases, number of words, and alternating stress patterns. This stimuli design facilitates unbiased interpretation and comparison within and between speech sets. One speech set was produced by a 72-year-old male speaker with dysarthria, and the other speech set was produced by a 72-year-old male control speaker with no neurological condition (neurotypical speech). The speaker with dysarthria presented with a mild-to-moderate ataxic dysarthria secondary to cerebellar disease. The dysarthric speech deviated from neurotypical speech in terms of perceptual features that represent cardinal features of ataxic dysarthria, including excess and equal stress, prolonged phonemes and intervals, monotone, monoloudness, and

Figure 1. Audiograms for all 36 participants with hearing loss, grouped by severity. Right ear thresholds are shown in red circles; left ear thresholds are shown in blue Xs. Of note, a total of nine thresholds were beyond the limits of the audiometer (eight thresholds of four listeners classified as profound, one threshold of one listener classified as severe).



imprecise articulation. The diagnosis and feature detection was made by three independent speech-language pathologists with expertise in differential diagnosis of motor speech disorders.

All phrases from each speaker were equated based on root-mean-square, and a minimum of 100 ms of silence was added to the beginning and end of each phrase. The control speaker phrases (i.e., neurotypical speech) were mixed with a speech-shaped noise (SSN) at an SNR of 0 dB. This SNR was chosen based on pilot testing with a group of normal-hearing listeners to determine the level that would result in scores approximately equal to the scores of the dysarthric speech in quiet (80% correct). The SSN was created by shaping a 10-s white noise in MATLAB with a 1,000-order FIR2 filter with the response characteristics of a 65,000-point, Hanning-windowed fast Fourier transform of the concatenated phrases from the talker.

Procedure

Listeners were presented with four blocks of 40 phrases each. Each block consisted of either neurotypical speech in noise or dysarthric speech in quiet. Prior to formal testing, participants were presented with a brief familiarization period (approximately 10 min in duration) during which they heard stimuli not used during the test but processed in the same manner as the formal stimuli. For the formal test, the starting condition was randomized across listeners, and listeners alternated between the two conditions across the four blocks. Stimuli were converted from analog form using a personal computer and a digital-to-analog converter and presented diotically via Sennheiser 280 Pro headphones. Stimuli were presented at 65 dBA for normal-hearing participants and 65 dBA plus frequency-specific gains as prescribed by the NAL-R hearing aid fitting formula (Byrne & Dillon, 1986) for each individual participant with SNHL. Participants were instructed to repeat back as much of each phrase as possible, and an experimenter typed out the participants' responses. Responses were scored in terms of words correct, and all words of each phrase were scored. The total duration of the study was less than 1 hr for each participant.

Statistical Analyses

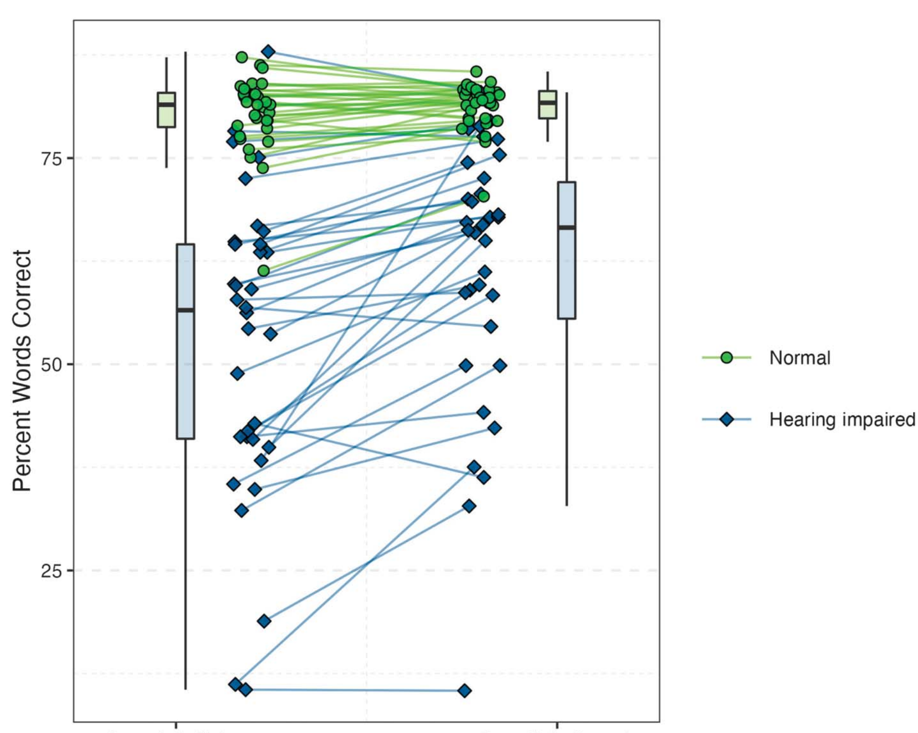
All analyses, unless otherwise stated, were stratified by hearing status, with normal-hearing listeners and listeners with hearing impairment being assessed separately. Descriptive statistics were used to assess characteristics of the sample and distributions of intelligibility. Differences in intelligibility between speech in noise and dysarthric speech were assessed via *t* tests stratified by hearing status. To assess the relationship between intelligibility for speech in noise with intelligibility for dysarthric speech, Pearson correlations were used to determine the degree and direction of this relationship across all listeners and for those with hearing impairment. Partial correlations assessed this same relationship controlling for age, gender, and hearing status. Lastly, the impact of hearing impairment on the relationship between intelligibility for speech in noise and dysarthric speech was assessed stratified by degree of hearing loss using *t* tests. All analyses were completed in R Version 3.6 or higher.

Results

Intelligibility Performance

Intelligibility performance, expressed by the mean percent words correct (PWC) scores, for each listener type (listeners with normal hearing or hearing loss) across the two types of listening adversity (neurotypical speech in noise and dysarthric speech) is illustrated in Figure 2. Figure 2 shows that as a group of normal-hearing listeners, intelligibility performance on speech in noise (M = 80.4, SD = 4.8) was comparable to that of dysarthric speech (M = 81.3, SD = 2.8), $t(48.9) = 0.923$, $p = .36$. This finding is not surprising given that the SNR used to create the speech-in-noise stimuli was specifically selected, through piloting, to approximate the intelligibility level of the dysarthric speech stimuli for normal-hearing listeners. Figure 2 also shows that as a group of listeners with hearing impairment, intelligibility performance on speech in noise

Figure 2. Boxplot and line graph for speech in noise and dysarthric speech for each listener by hearing status.



(*M* = 52.4, *SD* = 18.5) was lower than that on dysarthric speech (*M* = 61.7, *SD* = 16.0), $t(64.7) = 2.22$, $p = .030$. Notably, the scores of normal-hearing individuals were significantly higher for dysarthric speech, $t(69.9) = 2.06$, $p = .043$, but not for speech in noise, $t(59.9) = 0.60$, $p = .549$.

Relationship Between Speech in Noise and Dysarthric Speech

To address the research question regarding whether there is a relationship between intelligibility performance on the two types of listening adversity, a correlation between listeners' PWC scores on speech in noise and dysarthric speech was conducted. As shown in Figure 3, this analysis revealed a significant positive association between the two PWC scores, $r = .912$, $p < .001$. Note, both the *x*- and *y*-axis are standardized (*z* scores) of the PWC, and the lines are the lines of best fit for listeners with hearing impairment and normal-hearing listeners separately. Even when controlling for age, gender, and hearing status, the correlation remains high at $r = .828$, $p < .001$. Finally, when only listeners with hearing impairment are included in the model, the correlation is $r = .846$, $p < .001$. Thus, the relationship between processing the two types of adversity holds for listeners with hearing impairment, as well as for normal-hearing listeners in conditions of overall higher intelligibility.

To further investigate the impacts of hearing impairment on the relationship between perception of speech in quiet and disordered speech, the data were broken down by degree of hearing loss. Group mean intelligibility scores for listeners as a function of degree of hearing loss are shown in Figure 4. As shown, the intelligibility gap between speech in noise and dysarthric speech becomes larger as hearing impairment increases. For mild, moderate, and severe hearing loss, there was no statistical difference ($p = .136$, $p = .156$, $p = .609$, respectively). For profound hearing loss, however, there was a significant difference, $t(15.9) = 2.59$, $p = .020$.

Discussion

The current results suggest that despite large individual differences in processing degraded speech signals, listeners demonstrate consistency in their ability to perceive speech in different challenging conditions. More specifically, listeners who are successful at understanding speech in noise are the same listeners who are successful at understanding dysarthric speech. While this relationship has previously been reported with normal-hearing listeners, this study demonstrates that the relationship holds true in conditions of overall higher intelligibility and for both

Figure 3. Scatter plot showing the relationship between percent words correct (PWC) for speech in noise and for dysarthric speech, grouped by hearing status. Lines represent lines of best fit (least squares) by hearing status. Axes are both in standardized units (i.e., *z* scores) centered at zero and with an *SD* of 1.

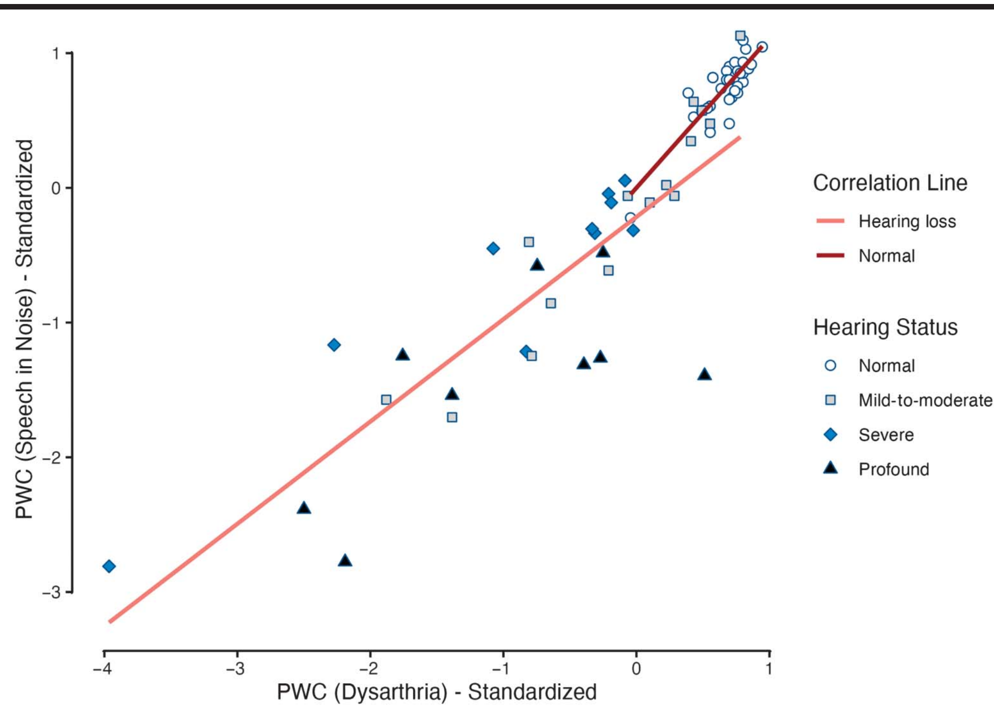
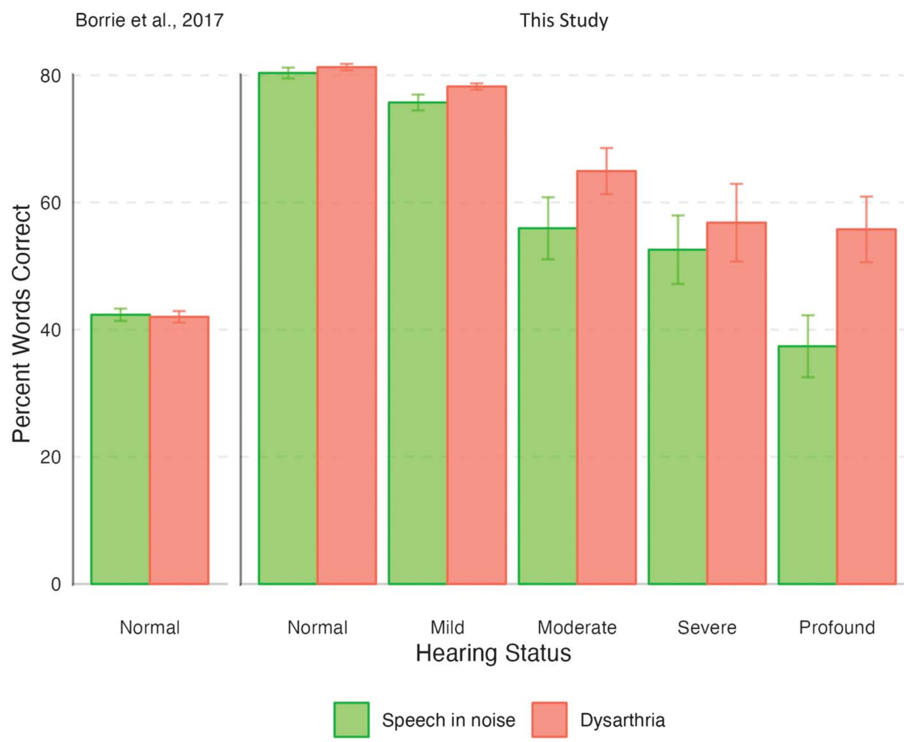


Figure 4. Bar chart showing the means by degree of hearing for speech in noise and dysarthric speech. Error bars represent ±1 standard error. Both data from the study of Borrie, Baese-Berk, et al. (2017) and this study are presented.



normal-hearing listeners and listeners with hearing impairment across a wide range of hearing loss severity.

These results are consistent with the prior work of Borrie, Baese-Berk, et al. (2017), which found a significant correlation between the ability to perceive neurotypical speech in noise and dysarthric speech for normal-hearing listeners. Additionally, as previously stated, these results extend those findings to signals that are overall more intelligible. The average intelligibility of the two types of degraded speech in Borrie, Baese-Berk, et al. (2017) was approximately 40%, whereas this study used speech signals with average percent correct scores for normal-hearing listeners of approximately 80%. This indicates that the previous results were not simply a factor of the relatively low level of intelligibility, which may be especially taxing to listeners, but rather that listener consistency with processing different types of degraded speech is a robust finding across various degrees of intelligibility.

The correlation for all listeners, both with normal hearing and with hearing impairment, in this study was high (r = .912) and remained high even when controlling for age, gender, and hearing status (r = .828). Importantly, even when the normal-hearing data were removed from analysis, the correlation remained robust (r = .846). This indicates that the findings were not solely driven by the inclusion of normal-hearing listeners, but rather, that the relationship between processing neurotypical speech in noise and dysarthric speech is a more global skill, or listening attribute, that remains consistent regardless of the detrimental impacts of SNHL.

This consistency for individual listeners with hearing loss is an interesting, and perhaps surprising, finding. It is well known that background noise often produces substantial negative impacts on speech perception for listeners with sensorineural hearing due to suprathreshold deficits such as impaired frequency resolution related to broadened auditory tuning and other factors. It appears from these data that the same listeners who perform more poorly in background noise also perform more poorly on tasks involving inherently degraded (e.g., dysarthric) speech even in the absence of external noise. Previous studies involving listeners with hearing loss have demonstrated deficits in perception of inherently degraded speech-in-quiet conditions such as dysarthria (Lansford et al., 2018) and accented speech (Gordon-Salant et al., 2010). While the exact mechanisms responsible for the consistency observed in this study are unclear, it may be posited that a global cognitive–perceptual skill set plays a dominant role in perceiving speech in challenging conditions not only for normal-hearing listeners but also for listeners with hearing loss. In other words, it may not be specific and isolated perceptual abilities such as spectrotemporal modulation detection (Moore & Glasberg, 2001) or glimpsing speech in the dips of noise maskers (Cooke, 2006) that dominate a listener's ability to perceive degraded speech but rather a larger, more encompassing skill set including these perceptual abilities along with other cognitive–linguistic factors such as working memory (e.g., Francis & Nusbaum, 2009; Millman & Mattys, 2017), cognitive flexibility (e.g., Bent et al., 2016; Lansford et al., 2023), and vocabulary knowledge (e.g., Borrie, Lansford, & Barrett, 2017; McAuliffe et al., 2013).

The findings also revealed that for the group of listeners with hearing loss, intelligibility of speech in noise was significantly worse than intelligibility of dysarthric speech. When the data were analyzed by severity of hearing loss, it was found that this difference was driven primarily by the listeners with profound impairment (see Figure 4). That is, individuals with profound hearing loss were more challenged by the environmental degradation than the source degradation. While the relationship between processing speech in noise and dysarthric speech has not previously been examined for listeners with hearing loss, this finding is in line with decades of data that indicate that deficits associated with SNHL result in a disproportionate impact of noise on the intelligibility of speech relative to performance for normal-hearing listeners (Carhart & Tillman, 1970; Eisenberg et al., 1995; Summers & Molis, 2004), particularly for listeners with more severe losses. As many of the degradations present in dysarthria are temporal in nature, frequency-domain processing deficits associated with SNHL may not be expected to play a substantial role in listeners' perceptions of this type of disordered speech signal. Although potential difficulties with temporal processing have long been studied in listeners with SNHL, the data overall indicate that many of these skills appear impaired as a secondary consequence of reduced audibility (Reed et al., 2009), which can often be overcome with amplification. Therefore, it may be expected that listeners with more severe degrees of SNHL with generally more severe spectral processing deficits would display the difference observed here between neurotypical speech in noise and dysarthric speech. Yet, despite this disparity in overall percent correct scores between the two types of speech, results indicate that even individual listeners with severe or profound losses are consistent in their ability to perceive these two types of degraded speech generally. That is, listeners with hearing loss who are relatively good at perceiving speech in noise are also relatively good at perceiving dysarthric speech.

Limitations and Future Directions

Cognitive decline associated with advanced age, and in particular for individuals with hearing loss that often goes untreated for many years (Fortunato et al., 2016), may be expected to play a role in processing degraded speech. Therefore, differences between normal-hearing listeners (who are largely younger) and listeners with hearing loss (who are largely older) may be explained by age effects. In this study, recruitment for listeners was performed without respect to participant age. Given the disproportionate representation of hearing loss in the older population (National Institute on Deafness and Other Communication Disorders, 2023), the mean age of listeners with hearing loss was 66 years. Therefore, hearing status and age were highly correlated, and age significantly predicted the performance gap between PWC scores for neurotypical speech in noise and dysarthric speech. Although we did not specifically seek out to examine the impact of age here, there were a small number of participants who were either older with normal hearing or younger with hearing loss. Based on these very limited data, it appears that the observed results in the gap between the two types of degraded speech may have been driven primarily by hearing status rather than age (see Table 1). This may have been in part due to the specific speech stimuli used in this study. Older adults have been shown to demonstrate reduced abilities in top-down processing of speech relative to younger adults, with reductions in cognition and memory capacity playing a role (Aydelott et al., 2010; Wingfield et al., 1994). The corpus utilized here consisted of nonsensical phrases, which limits the amount of top-down processing involved in perception.

Age effects have been observed in several auditory processing and speech perception tasks, including the perception of speech in noise and temporally interrupted, time-compressed, and filtered speech, and for frequency

Table 1. Age, degree of hearing loss, and intelligibility scores for four participants who were older with normal hearing or younger with hearing loss.

Group	Age	Degree of loss	Dysarthria (%)	Speech in noise (%)
NH	65	Normal	83	82
SNHL	21	Moderate	75	65
SNHL	26	Severe	65	54
SNHL	19	Profound	44	37

Note. NH = normal hearing; SNHL = sensorineural hearing loss.

and duration discrimination (see Rawool, 2015, for a review). Existing literature on the impact of listener age on the perception of dysarthric speech has shown mixed results, with some studies indicating that older listeners perform more poorly than younger listeners on dysarthric speech tasks (Garcia & Hayden, 1999; Jones et al., 2004; McAuliffe et al., 2017), whereas others have shown no difference (Dagenais et al., 1999; McAuliffe et al., 2013). However, some of these results may have been confounded by the hearing status of the older listeners. Lansford et al. (2018) examined older listeners with and without hearing loss relative to young normal-hearing listeners and found that only the older listeners with hearing loss demonstrated poorer overall intelligibility performance, indicating that it is hearing status and not age that negatively influences perception of dysarthric speech. The influence of listener age, independent of hearing loss, on the processing of speech in background noise is also somewhat unclear, but it appears that differences between older and younger normal-hearing listeners may be most evident in background noise with a high level of information content (i.e., competing speech background), as Schoof and Rosen (2014) found no differences in older and younger normal-hearing listeners on a sentence intelligibility in noise task when the noise was steady state, as it was in this study.

Of note, this study was not designed to elucidate the specific perceptual and cognitive mechanisms responsible for individual listener consistency in the perception of dysarthric speech and speech in noise, and no specific cognitive measures were assessed here. Given the many factors associated with SNHL, including reduced audibility and several, often co-occurring, suprathreshold deficits, as well as individual factors such as duration and etiology of hearing loss, cognitive status, and participant age, the particular mechanisms responsible for individual listener consistency in these tasks may be difficult to conclusively determine. The only statistically significant difference in overall percent correct scores between the two types of speech, for example, was observed in the profound loss group. It is possible that this group had additional characteristics that set them apart from the milder groups, such as duration of deafness and whether they were pre- or postlingually deafened. Future studies to assess these perceptual and cognitive influences on speech perception across different adverse conditions for listeners with hearing loss, as well as whether this consistency is evident for this population across other types of challenging listening conditions, are certainly warranted.

Lastly, while reduced audibility for listeners with hearing loss was corrected for in this study with amplification, these individuals were not utilizing the hearing aid technology (and potential noise reduction settings) that they were accustomed to wearing. Differences in the perceptual quality of the speech in background noise from these listeners' everyday experience may have influenced their overall perception of intelligibility to some degree.

Clinical Implications

This study has important clinical implications for both listeners with hearing loss and their communication partners with dysarthria. It is well known that individuals with hearing loss are at a disadvantage in noisy environments when trying to converse, but the current data indicate that they are also at a substantial disadvantage when trying to understand disordered speech. Although there are currently no statistics on the co-occurrence of hearing loss and dysarthria among communication partners, anecdotal reports from clinicians who work with patients with dysarthria indicate that many of their patients' primary communication partners (e.g., spouses, siblings, and friends) have hearing loss. This is not surprising given that many common etiologies of dysarthria (e.g., Parkinson's disease, cerebral vascular accidents) are associated with advanced age, at which point, the number of people with hearing loss is very high. In the United States, approximately 50% of adults aged 75 years and above have disabling hearing loss (National Institute on Deafness and Other Communication Disorders, 2023). For listeners with and without SNHL, these findings indicate that those individuals who struggle considerably when listening to neurotypical speech in background noise may be more predisposed to struggle when listening to dysarthric speech. This is an important point for clinical practice, as it may be possible to predict which listeners will be challenged most by disordered speech, and these patients and their communication partners can then be counseled and intervened appropriately. Indeed, such communication partners may make ideal candidates for listener-targeted perceptual training to better understand the dysarthric speech signal (see Borrie & Lansford, 2021, for a review of this intervention approach). Furthermore, although perception of disordered speech is not tested clinically for patients with hearing loss, it may be possible to extrapolate results from speech-in-noise testing to perception of dysarthric speech. Overall, the current results may inform clinical practice for professionals working with people suffering from communication disorders more broadly, both in validating the patients' experiences and in transforming how the patient is treated regarding their communication partner's particular perceptual challenges.

Conclusions

To summarize, this study demonstrated a strong relationship between the perception of neurotypical speech in background noise and dysarthric speech. It extended the results of Borrie, Baese-Berk, et al., 2017 with normal-hearing listeners to a higher level of overall intelligibility, indicating that the correlation observed in the previous study was not simply a result of listener performance in particularly challenging conditions but rather is a robust finding across varying levels of overall speech intelligibility. In addition, it was found here that, regardless of severity of hearing loss and despite substantial listener-to-listener variability, individual listeners with SNHL also display a high degree of consistency across the two types of degraded speech. Finally, although degree of hearing loss did not alter the correlation between the perception of the two types of degraded speech, it did have an impact on overall intelligibility. Specifically, while listeners with more severe losses did more poorly overall, they performed most poorly in the neurotypical speech-in-noise condition, in agreement with previous data indicating a disproportionately negative influence of noise with increasing hearing loss severity. Perhaps most importantly, the current data strongly indicate the importance of considering both the speaker and listener characteristics when working to improve overall speech intelligibility and quality of life for people impacted by these communication disorders.

Author Contributions

Sarah E. Yoho: Conceptualization (Lead), Methodology (Lead), Project Administration (Lead), Writing – original draft (Lead), Writing – review & editing (Lead), Formal Analysis (Supporting), Software (Supporting), Visualization (Supporting). **Tyson S. Barrett:** Formal Analysis (Lead), Software (Lead), Visualization (Lead), Conceptualization (Supporting), Methodology (Supporting), Writing – original draft (Supporting), Writing – review & editing (Supporting). **Stephanie A. Borrie:** Conceptualization (Lead), Methodology (Lead), Formal Analysis (Supporting), Project Administration (Supporting), Writing – original draft (Supporting), Writing – review & editing (Supporting), Visualization (Supporting).

Data Availability Statement

Anonymized listener data, analysis code, and model outputs associated with this work are available at the study repository hosted at https://osf.io/5vuft/.

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