ASHA American Speech-Language-Hearing Association

AJA

Clinical Focus

Hearing Aid Technology Settings and Speech-in-Noise Difficulties

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ARTICLE INFO

Article History:
Received August 27, 2021
Revision received October 18, 2021
Accepted November 8, 2021

Editor-in-Chief: Ryan W. McCreery
Editor: Erin M. Picou

https://doi.org/10.1044/2021_AJA-21-00176

ABSTRACT

Purpose: Hearing aids are the primary method to manage hearing loss. However, there are limited recommendations for when and how to set advanced hearing aid features. The purpose of this study is to describe how hearing aid features are utilized in clinically fit devices and to evaluate the relationship between the fitted hearing aid feature and the Quick Speech-in-Noise Test (QuickSIN).
Method: Data from two laboratories were evaluated retrospectively, resulting in 107 bilateral hearing aid participants who obtained their hearing aids at clinics in their communities. Ages ranged from 60 to 93 years. Degree of speech-in-noise difficulty was evaluated using the QuickSIN (mild, moderate, or severe). Settings for directionality, digital noise reduction (DNR), and hearing assistive technology (HAT) use were documented. Directionality was categorized as omnidirectional, fixed (full-time directional), or adaptive (adjusts automatically based on noise source). DNR was recorded as either on or off. HAT use was recorded as either yes or no.
Results: QuickSIN scores ranged from −1.5 to 25 dB SNR loss (M = 7). A moderate correlation was determined for QuickSIN scores and pure-tone averages. Adaptive directionality was used most often, most participants had DNR turned on, and HAT use was low. The biggest contributions to the Chi-square test for directionality and degrees of speech-in-noise difficulty together were fixed/severe, fixed/moderate, and adaptive/mild.
Conclusions: In this clinical sample, there was limited HAT use and advanced features are not set in a way that is consistent with speech-in-noise abilities. It is likely that patients fit with noise management that is not suited to their listening abilities are experiencing increased difficulties in challenging listening environments that could potentially be mitigated with alternative management. Evidence-based research on prefitting measures of speech in noise to help inform patient-centered clinical decisions is needed.

The majority of hearing loss management plans today include recommending hearing aids. Modern hearing aids have adjustable features that can be changed by an audiologist to better fit the individual needs of the patient. These features can include directional microphone technology, digital noise reduction (DNR), multiple programs, and connection to additional hearing assistive technology (HAT). Early work by the American Academy of Audiology (AAA) Taskforce developed general audiologic management guidelines for when these features should be utilized (Valente et al., 2006). These guidelines include but are not limited to the following: (a) Adaptive directionality (switchable directional/omnidirectional microphones) is recommended for patients that have complaints of speech understanding in noise. (b) DNR is recommended to improve sound quality and patient comfort, especially in noise. (c) HAT is recommended for patients with extremely poor speech understanding in noise who may need a greater signal-to-noise ratio (SNR) for communication (Valente et al., 2006).

Although these guidelines are a good starting point for clinicians, terminology such as "complaint of speech

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understanding in noise" is not specific enough for a clinical protocol on when to utilize specific features. Other investigators agree that speech recognition in noise tests should be utilized when fitting hearing aids (Kodera et al., 2016; Ricketts et al., 2019). However, the specific speech-in-noise test or how poor a patient's speech recognition in noise must be to set specific features is not indicated. This becomes a problem for standardization across clinics because there are numerous clinical speech-in-noise tests to choose from (e.g., Hearing in Noise Test [Nilsson et al., 1994]; Connected Speech Test [Cox et al., 1987]; Revised-Speech Perception in Noise Test [Bilger, 1984]; and Quick Speech-in-Noise Test [QuickSIN; Killion et al., 2004]), and they provide a variety of different measures. Of the speech-in-noise tests that are clinically available, the QuickSIN is the only one that provides a semistructured recommendation on how to set hearing aid features, specifically directionality and HAT use. Furthermore, studies comparing different measures have found that the QuickSIN had advantages over other measures when it came to clinical use (Duncan & Aarts, 2006; Wilson et al., 2007). Specifically, the QuickSIN was sensitive to individual variation in recognition scores. Quantifying that variability should support more structured recommendations and clinical utility.

With regard to structured recommendations, Killion et al. (2004) separate individual performance on the QuickSIN into degree of speech-in-noise difficulty, measured by SNR loss: near normal/normal (up to 3 dB SNR), mild (3–7 dB SNR), moderate (7–15 dB SNR), and severe (15 dB SNR or greater). No specific feature recommendation is provided for those with normal/near-normal to mild SNR losses. When an individual's performance is categorized into moderate or severe SNR loss, directional amplification is recommended over omnidirectional amplification. Although, at the time the QuickSIN recommendations were published, hearing aids had more limited directionality options. Individuals in the severe SNR loss category are designated to need maximum SNR improvement. As such, it is recommended that these patients use HAT in addition to hearing aids with directional amplification. Importantly, management options (e.g., directionality, noise reduction, and HAT) are also modifiable between shared decision making between the patient and the audiologist. This is an area where the quality of the selection process, coupled with the patient's subsequent adherence to use of the recommended settings, will likely influence outcomes. Implementation of these features in hearing aids across manufacturers differs, often in proprietary ways. As such, descriptions of the general categories of features will be defined here and used throughout this study. Each of the management options will next be briefly described.

Hearing Aid Directionality

In the early 2000s when the QuickSIN user manual recommendations were provided, the available directionality settings were mainly separated into omnidirectional (Omni), fixed, and adaptive based on a systematic review of the effectiveness of directional amplification (Bentler, 2005). Since publication of this systematic review, the availability of directional technology settings has progressed to include other types of directionality (e.g., binaural directionality). The QuickSIN test manual recommendations, however, do not specify which technology within directional settings would be the most beneficial (i.e., fixed, adaptive, or binaural).

Full-time fixed directional amplification can significantly improve SNRs when compared to omnidirectional settings (Hawkins & Yacullo, 1984; Picou et al., 2017) but is seldom prescribed because it reduces signals of interest that occur around the listener (Browning et al., 2019; Ricketts et al., 2003; Ricketts & Hornsby, 2003). Adaptive directionality allows the listener to maximize directional benefit by selecting the optimal polar plot for the source and level of background noise in an environment. In practice, the type of directionality described here is automatic-adaptive, in that the microphone switches automatically from an omnidirectional to a directional (adaptive) setting without requiring the user to make a manual change. For simplification purposes, the term adaptive in this clinical focus article represents automatic-adaptive. Binaural directional hearing aids operate in an adaptive way as well, but unlike single-microphone adaptive technologies, binaural directionality uses aggregate information obtained from bilateral devices to select the best overall set of directional patterns for the surrounding environment. A limitation to all adaptive settings is that a threshold level is determined within the hearing aids in order to automatically switch polar patterns and the background noise levels may not be high or constant enough for the hearing aid to reach that threshold (Banerjee, 2011).

DNR and HAT

Currently, there are no published recommendations on how to set other hearing aid features based on individual ability. DNR is suggested to improve patient comfort but has not been shown to improve speech recognition in noise (Chong & Jenstad, 2018 [review]; H. J. Kim et al., 2020; Lakshmi et al., 2021 [review]). However, improving comfort by reducing the amount of noise can also be attained with a directional polar pattern. It is possible that those who are recommended to have directional amplification based on their speech-in-noise performance may receive additional benefit from DNR. HATs, particularly remote microphones, are especially beneficial to improve SNR (J. S. Kim & Kim, 2014; Thibodeau, 2020). Although these devices are available from a variety of device and hearing aid manufacturers, they do not necessarily work with all hearing aids and are typically an additional cost to the patient. As a result, the benefits of this technology compared to the cost should be considered on a patient-specific basis.

Implementation Into Clinical Practice

Despite great potential for basing hearing aid feature setting decisions on individual speech recognition in noise abilities, these measures are not routinely being used in practice. A survey of 107 audiologists found that, although the QuickSIN was the most commonly used speech-in-noise test clinically, only 10% of audiologists were using it routinely and 20% reported using it only "some of the time" (Mueller, 2016). These percentages are surprisingly low considering that speech-in-noise testing is the recommended practice for fitting, selecting, and adjusting hearing technology (Ricketts et al., 2019). Specifically, the results from the QuickSIN can, in theory, provide the information for when to use directional settings over omnidirectional settings and when to recommend HAT. However, the recommendations do not provide specific guidance on when to use fixed, adaptive, or binaural directional amplification technology.

When audiologists do incorporate clinical measures of speech-in-noise performance scores, they may not use test results to guide hearing aid feature selection. Studies variously show that speech-in-noise tests have been used as baseline measures to compare loss over time, as counseling tools for realistic situations, and to evaluate the benefits of one microphone setting compared to another (Picou & Ricketts, 2017, 2018; Walden & Walden, 2005).

One potential reason for the lack of implementation into clinical practice could be gaps in research. To provide insight into these issues, this study evaluates a clinical measure of speech-in-noise (QuickSIN) and uses the degree of difficulty categories (Etymotic Research, 2001) to determine how often clinically fit hearing aid feature settings are consistent with the patient's speech-in-noise abilities. The aims of this study are to (a) describe how hearing aid features are utilized in clinically fit hearing aids and (b) evaluate the relationship between the fitted hearing aid feature and QuickSIN. The patients included in this study received their hearing aids from university clinics as well as many community practices. This design therefore represents the fitting habits of a range of hearing care professionals.

Method

An analysis was conducted using de-identified clinical data from two research laboratories, the Audiologic Rehabilitation Lab (ARL) at The University of Arizona and the Hearing Aid Lab (HAL) at Northwestern University. The majority of participants were fit with hearing aids in a university setting, whereas others were fit from outside clinics. Data were combined from the two laboratories to increase the heterogeneity of the sample by hearing loss severity and to represent clinically fit hearing aids across two states. The participants had been previously recruited for other studies on hearing loss and hearing aids. Postfitting unaided QuickSIN scores were evaluated and subsequently compared against the participant's current hearing aid fitting.

Participants

Table 1 shows the demographic information for the participants included in the study. Data for 107 participants with at least 1 year of hearing aid experience were included (78 from the ARL; 29 from the HAL) with an age range of 60–93 years (M = 75.3, SD = 8.4). The majority of the sample was male, and most participants were 70 years or older. Data show that most participants from this sub–data set were non-Hispanic (92.5%). The current analyses included data for participants with sensorineural hearing loss that were tested binaurally on the QuickSIN and had information on advanced hearing aid features (directionality, DNR, or HAT use) in their personal hearing aids. On average, participant's current hearing aids were 3.7 years old for the ARL and 3.4 years old

Table 1. Demographics of study participants.

Characteristic	Cohort (n = 107)
Gender, *n*	
Men	60 (56%)
Women	47 (44%)
Age groups, *n*	
60–69	32 (30%)
70–79	41 (38%)
80–89	30 (28%)
90+	4 (4%)
Ethnicity, *n*	
Hispanic	7 (6.5%)
Non-Hispanic	99 (92.5%)
Other	1 (1%)
Current hearing aid use (yrs), *n*	
0–4	73 (68%)
5–9	29 (27%)
10–14	5 (5%)
Audiometric hearing status[a], *n*	
Normal	21 (20%)
Mild	48 (45%)
Moderate	24 (22%)
Severe	11 (10%)
Profound	3 (3%)

[a]Hearing status categorized by the better ear pure-tone averages (500, 1000, and 2000 Hz). Normal: $x \leq 25$ dB HL; mild: 25 dB HL < $x \leq 40$ dB HL; moderate: 40 dB HL < $x \leq 60$ dB HL; severe: 60 dB HL < $x \leq 80$ dB HL; profound: 81+ dB HL.

for the HAL for a combined average of 3.7 years. Evidence suggests that most people listen most of the time in the primary program and seldom switch to other programs even if they have a manual switch (Banerjee, 2011). When data on secondary programs were available, they were reviewed to determine the presence of additional features and whether the conclusion drawn would be different than that from the primary program. In nearly all cases, these did not indicate the selection of situation-dependent use of features. Consistent with Banerjee's findings, our participants used a secondary program for less than 1 hr a day on average based on data logging. As such, data for this clinical focus article was collected on participant's primary program. Daily hearing aid use based on data logging in the primary program was on average 6.4 hr/day. Subjects had previously participated in laboratory studies and had given consent for their data to be retained for further analysis. Data analyzed for this clinical focus article were fully de-identified.

Audiometric Evaluation

Clinical test procedures were the same for both laboratory data sets unless otherwise specified. All audiometric testing took place in a sound-treated, double-walled booth with single-use foam ear tips and insert earphones. First, otoscopy was conducted to evaluate participants' outer ear health including a cerumen build-up inspection. Next, an audiologic evaluation was conducted including air- and bone-conduction pure-tone threshold assessment (250–8000 Hz) and word recognition in quiet (using the NU-6, 50-word list for ARL and 25-word list for HAL) for each ear. Thresholds were measured using a calibrated diagnostic audiometer (Otometrics Astera for ARL and Interacoustics AC40 for HAL). Pure-tone averages (PTAs) of 500, 1000, and 2000 Hz were calculated for each ear separately. A subsequent evaluation for high-frequency PTA (HF-PTA) was calculated for 1000, 2000, and 4000 Hz. Words in quiet were presented 30–40 dB above the participant's PTA.

Clinical Measure of Speech Recognition in Noise

The QuickSIN evaluates individual performance in comparison to a normative sample of the SNR needed for 50% correct performance. A postfitting unaided QuickSIN was administered binaurally to determine each participant's SNR loss under insert earphones in the sound booth. Two QuickSIN lists of six sentences with five key words each were presented in multitalker babble under earphones (Etymotic Research, 2001). Initially, the SNR is 25 dB and gets progressively more challenging by lowering the SNR 5 dB after each sentence. Participants were asked to repeat back any of the words in the sentences for an overall score. Scores were calculated based on how many of the five key words they correctly repeated across all six sentences. SNR loss was determined using the QuickSIN's user manual for each list with the following equation:

$$\text{SNR loss} = 25.5 - \text{total number correctly repeated key words across all six sentences.} \quad (1)$$

Participants were first given a practice list. Then, two test lists were administered, and test list scores were averaged together to determine a participant's speech recognition in noise ability.

Based on the user manual guidelines, a score of better than 3 dB SNR loss is considered near normal/normal, 3–7 dB SNR loss is considered a mild SNR loss, 7–15 dB SNR loss is considered a moderate SNR loss, and greater than 15 dB is considered a severe SNR loss (Etymotic Research, 2001). Test documentation also suggests that a score of 7 dB or greater would warrant directional amplification over omnidirectional and a score of greater than 15 dB would indicate the need for additional HAT to maximize the SNR, especially in challenging environments.

Hearing Loss Management: Amplification and HAT

Data from participants' clinically fit hearing aids were collected by connecting each hearing aid to its respective manufacturer software through NOAH. Specific to this study, hearing aid feature setup was recorded in terms of directionality, DNR, and paired HATs. When it was not possible to connect the hearing aid to the manufacturer software, directionality and DNR were quantified using the dedicated test features of the Audioscan Verifit.

Directionality was categorized into omnidirectional, fixed, and adaptive. Any technology that was selected among different polar patterns without the user having to do so manually was categorized as adaptive technology. Each manufacturer implements adaptive directional processing differently, and these differences depend on the device's signal classification system. The type and strength of DNR were manufacturer specific and were different across participants. As such, DNR information was recorded as either turned on (activated) or turned off (not activated), regardless of the strength and type. In addition to recording any paired HAT from the hearing aid manufacturer software, participants were asked if they used any assistive devices in addition to their hearing aids. If they reported that they did use additional devices, the type of HAT was noted (e.g., frequency-modulation [FM] system, induction loop, remote microphone, television streamer, and phone connector).

Data Analysis Procedure

The information collected from both laboratories was compiled and evaluated together. Each feature setting was assessed separately from the others. The recommendations from the QuickSIN user manual in terms of categorizing results based on degree of speech-in-noise difficulty were utilized to further compare feature settings. For example, the number of participants with DNR on compared to off were evaluated for each of the four QuickSIN categories: normal/near normal, mild, moderate, and severe SNR loss. Descriptive statistics in addition to chi-square analyses were conducted. Chi-square tests of independence were calculated in the R statistical computing language (R Core Team, 2020).

Results

Audiometric Evaluation

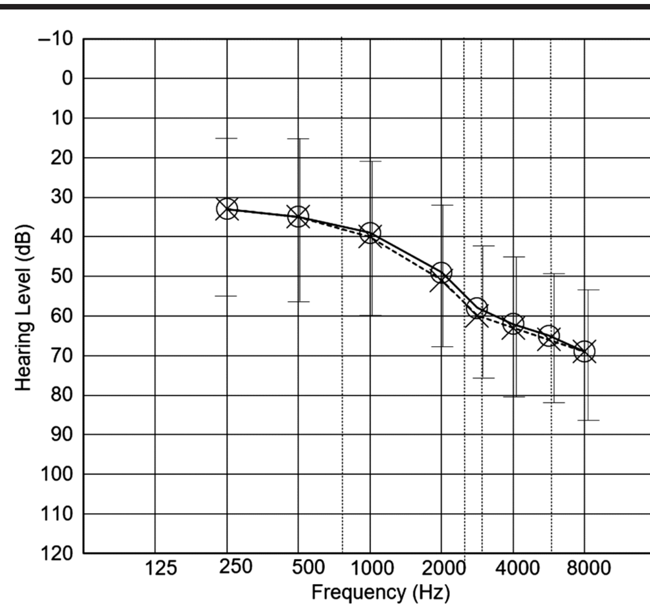
The right-ear PTA across participants was 40.7 dB HL (*SD* = 17.6), whereas the left-ear PTA across participants was 41.9 dB HL (*SD* = 19.5). A two-sample paired *t* test showed that there was no statistically significant difference between ears: $t(106) = -1.6$, $p = .12$. Table 1 includes the better ear PTA for all participants (M = 38.9 dB HL, SD = 71.2) and categorizes these characteristics into hearing status based on the World Health Organization (WHO) classification: Normal: $\times \leq 25$ dB HL; mild: 25 dB HL < $\times \leq 40$ dB HL; moderate: 40 dB HL < $\times \leq 60$ dB HL; severe: 61 dB HL < $\times \leq 80$ dB HL; profound: 81+ dB HL (World Health Organization, 1991). Most participants had a mild sensorineural hearing loss based on these categories of PTA. The right- and left-ear HF-PTAs across participants were also determined, and an average of 48.2 dB HL (*SD* = 15.5) was calculated. A two-sample paired *t* test showed that there was no statistically significant difference between ears, $t(107) = -1.9$, $p = .06$.

Figure 1 shows the average air-conduction thresholds across frequencies for both right and left ears with ±1 *SD* for the right ear only among all participants. Word recognition scores in quiet were obtained in each ear for all participants, except one for whom the data were not available. An average score of 75.9% (*SD* = 20.3%) was determined for the right ear, and an average score of 73.8% (*SD* = 25.1%) was calculated for the left ear. A two-sample paired *t* test showed that there was no statistically significant difference between ears: $t(106) = 1.2$, $p = .23$, for word recognition in quiet.

Clinical Measure of Speech-in-Noise

Based on previous normative data, the QuickSIN scores for older adults (49–94 years) with hearing loss typically range between 2.6 and 10 dB SNR loss, with an average of 6.3 dB SNR loss (Walden & Walden, 2004). See Table 2 for the distribution of the QuickSIN scores in this study (M = 7.0 dB SNR loss, SD = 5.6, range = −1.50–25 dB SNR loss) across degree of speech-in-noise difficulty categories. A Pearson's correlation coefficient

Figure 1. Average air-conduction pure-tone thresholds for right (o) and left (x) ears among all 107 participants. Error bars indicate +/– 1 *SD* for the right ear thresholds only.



was calculated to determine the linear relationship between the better ear PTA and performance on the QuickSIN test (see Figure 2A). A moderate positive correlation was determined, $r(105) = .68$, $p < .001$ (Schober et al., 2018). A subsequent Pearson's correlation coefficient was calculated to evaluate the relationship between QuickSIN performance and the better ear HF-PTA. A strong positive correlation was determined, $r(105) = .73$, $p < .001$ (see Figure 2B).

Hearing Loss Management: Amplification and HAT

The distribution of amplification settings and assistive technology availability can be found in Table 2. All of the top hearing aid manufacturers were represented in this sample with the majority wearing Phonak, Starkey, or Oticon hearing aids. Two participants used devices from different manufacturers between ears. For these two participants, two manufacturers were recorded rather than one each. Adaptive hearing aid technology was the most common directionality setting programmed by the clinician.

Table 2. Speech recognition in noise abilities and hearing loss management characteristics.

Characteristic, # of participants	Cohort (n = 107)
Speech in noise difficulty[a]	
Near normal/normal	31 (29%)
Mild	35 (33%)
Moderate	28 (26%)
Severe	13 (12%)
Hearing aid manufacturer[b], n = 109	
GN ReSound	9 (8%)
Oticon	26 (24%)
Phonak	30 (27.5%)
Signia/Siemens	3 (3%)
Starkey	28 (25.5%)
Unitron	6 (5.5%)
Widex	5 (5.5%)
Other (Bernafon)	1 (1%)
Directionality[c], n = 106	
Omnidirectional	17 (16%)
Fixed	23 (22%)
Adaptive	66 (62%)
Digital noise reduction[d], n = 106	
On	93 (88%)
Off	13 (12%)
Hearing assistive technology	
Yes	26 (24%)
No	81 (76%)

[a]Degree of speech-in-noise difficulty defined by using the QuickSIN test manual categories. Near normal/normal: $x \leq 3$ dB SNR; mild: 3 dB SNR $< x <$ 7 dB SNR; moderate: 7 dB SNR $\leq x <$ 15 dB SNR; severe: $x \geq 15$ dB SNR. [b]Two participants had different manufacturers between ears, and both were counted. [c]One participant was removed due to missing directionality information. [d]One participant was removed due to missing digital noise reduction information.

One participant was excluded from the directionality analyses due to missing data. The large majority (88%) had DNR activated to some degree. Again, one participant was removed from the DNR analyses due to missing information. Less than a quarter of the 107 participants used HAT.

Hearing Aid Features Compared to Degree of Speech-in-Noise Difficulties

Directionality

There was a statistically significant association between the distribution of type of directionality used and the degree of speech-in-noise difficulty, $X^2(6, N = 106) = 23.31$, $p = .0007$. To determine which groupings contributed the most to this significant finding, the Pearson's residuals were visualized using the corrplot function in the corrplot package in R (Wei & Simko, 2017). The residual numbers represent the contribution to the magnitude of the chi-square result. That is, the larger the number (percentage), the more of an impact it has on the chi-square. This visualization is shown in Figure 3. The bigger the circle, the more significant of a contribution was made. Furthermore, the darker the circle, the more significant the positive relationship is, whereas lighter circles indicate negative relationships.

The degree of speech-in-noise difficulties and omnidirectional settings together that contributed the most to the total chi-square score were mild (10%) and severe losses (7.5%). Specifically, omnidirectional settings were negatively associated with mild degrees of speech-in-noise difficulty but positively associated with severe degrees of speech-in-noise difficulty. Increased utilization of fixed directionality settings was seen as the degree of speech-in-noise difficulty increased. Adaptive directionality settings were positively associated with mild losses, whereas they were negatively associated with moderate and severe losses. From this calculation, it can be noted that the most contributing cells to the chi-square are omni/mild (9.98%), fixed/moderate (12.56%), fixed/severe (15.37%), adaptive/mild (10.23%), and adaptive/severe (13.75%). These combinations of type of directionality and severity of loss contribute about 61.89% of the total chi-square score and thus account for most of the significance.

DNR

The percentage of DNR use across degree of speech-in-noise difficulty is displayed in Figure 4. Of the participants in the near-normal/normal, mild, and moderate categories, 83 of 93 (89%) had DNR activated. In the severe SNR loss category, the percentage of participants that had DNR activated was 77% (10 of 13). A chi-square test of independence was conducted to determine the relationship between degree of speech-in-noise difficulty and

Figure 2. Scatterplots representing the relationship between better pure-tone average between ears (Panel A), better high-frequency pure-tone average between ears (Panel B), and binaural QuickSIN score. Panel A: a moderate positive correlation $r = .68$, $p < .001$. Panel B: a strong positive correlation $r = .73$, $p < .001$. QuickSIN = Quick Speech-in-Noise Test.

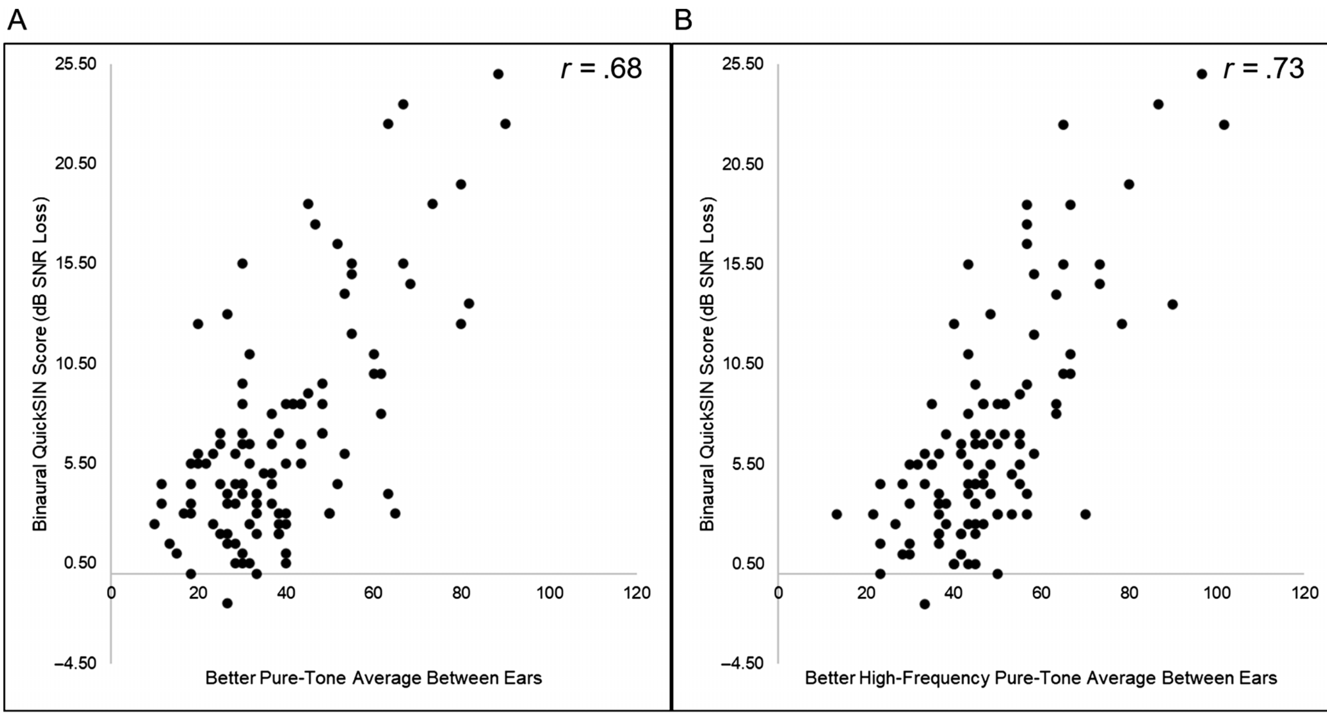


Figure 3. Pearson's residuals representing the contribution to the magnitude of the chi-square tests of independence comparing types of directional amplification (omnidirectional, fixed, adaptive) with degree of speech in noise difficulty by QuickSIN categories (near normal/normal, mild, moderate, severe). Larger percentages (numerated and shown as larger circles) indicate larger contributions. Black circles indicate a positive relationship, while white circles indicate a negative relationship. QuickSIN = Quick Speech-in-Noise Test.

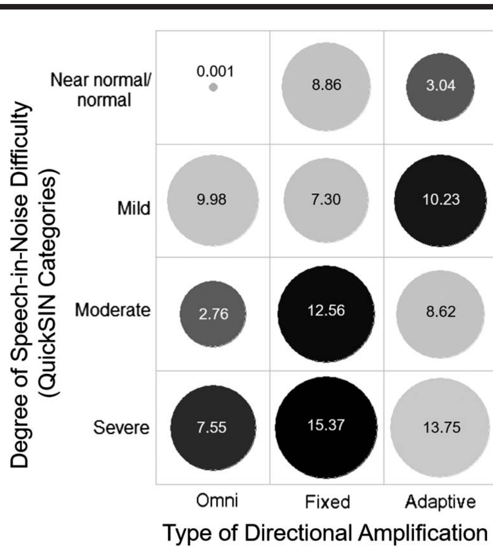


Figure 4. Bar graph representing the percentage of participants (n = 106) with digital noise reduction settings active (black bars) or not (white bars) categorized by their degrees of speech-in-noise difficulty (Quick Speech-in-Noise Test score in dB SNR Loss).

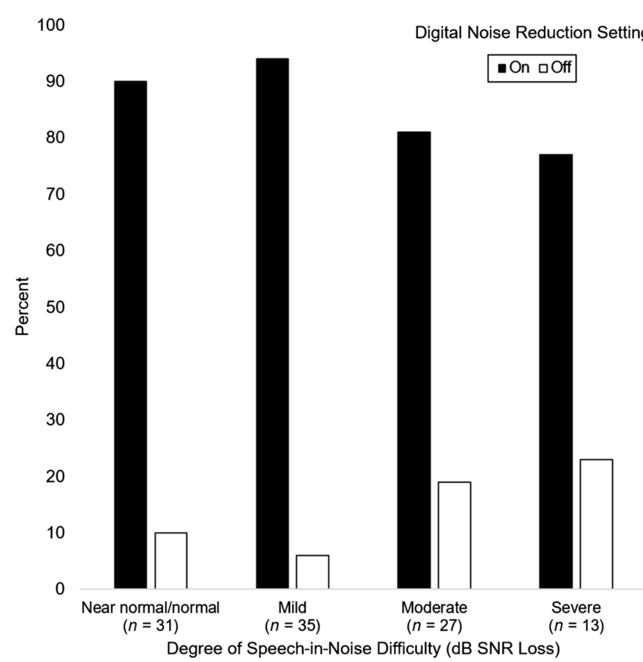
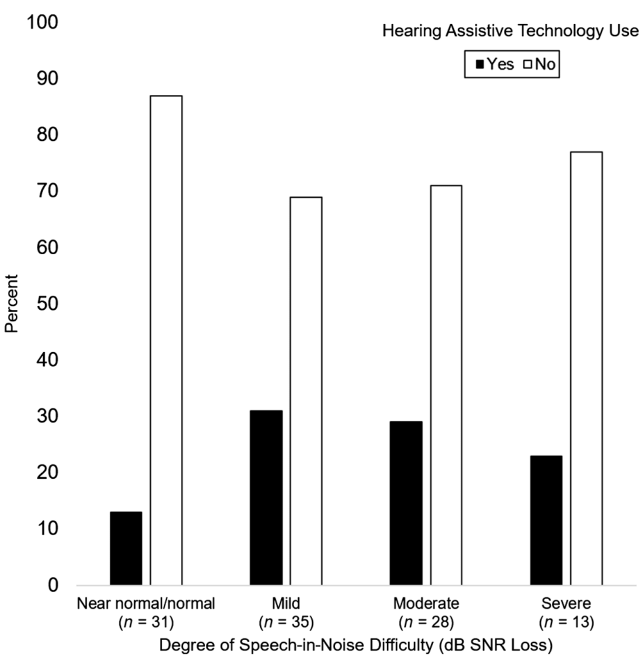


Figure 5. Bar graph representing the percentage of participants (n = 107) who used hearing assistive technology (black bars) and who did not (white bars) categorized by their degrees of speech-in-noise difficulty (Quick Speech-in-Noise Test score in dB SNR Loss).



DNR turned on or off. A statistically significant relationship was not determined, $X^2(3, N = 106) = 3.98, p = .26$.

HAT

Any assistive hearing technology additional to the hearing aids was considered for this analysis (e.g., remote microphones, television streamer, and FM system). The percentage of use of HAT among participants is illustrated in Figure 5. Regardless of the degree of speech-in-noise difficulty, HAT use was low (no more than 31%). To determine if QuickSIN performance was related to HAT use, as would be expected given that a score > 15 indicates the need for HAT, a chi-squared test of independence was conducted. The test found that there was no significant pattern between HAT use and this clinical measure of speech-in-noise scores, $X^2(3, N = 107) = 3.44, p = .33$.

Discussion

The study goal was to determine the relationship between specific advanced feature settings and a clinical speech-in-noise measure (QuickSIN; i.e., the extent to which the audiologist's setting choices agreed with the degree of speech-in-noise difficulty recommendations; Killion et al., 2004). The data are drawn from cohorts of community-dwelling older adults who were clinically fit with amplification by hearing care professionals outside the context of a research study, thus representing a natural experiment. While these fittings may not be fully representative of hearing aids fit nationally, they do include participants from different geographical locations in the United States (Arizona and Illinois). The majority of participants were fit with hearing aids at a university clinic, which is a unique population because students oftentimes allot more time to appointments and this additional time may afford further opportunities to discuss HATs.

Results suggest that speech recognition in noise abilities are not strongly related to the choice of advanced features in clinically fit devices. While there are many ways to evaluate speech recognition in noise abilities, there is no consensus on which measure to use in a clinical setting. Specific test aside, research has shown that clinical measures of speech-in-noise may be important when fitting hearing aids (Gioia et al., 2015; Ricketts, 2005), especially when evaluating outcomes (Davidson, Marrone, et al., 2021; Davidson, Musiek, & Marrone, 2021). In fact, Best et al. (2017) showed that setting optimal configurations of hybrid beamformer hearing aid microphones would depend on the listener and their individual abilities. However, in order to make clinical recommendations for an effective personalized management plan, objective testing and subjective testing are advised to evaluate the extent of each patient's needs. Data from comprehensive assessment may inform the need for a management plan that involves more than just hearing aids, such as HAT use and/or group aural rehabilitation. The following sections discuss the implications of results found for each of the advanced features in the current data set. The primary emphasis will be on directionality, as recommendations on how to generally set this feature are available from at least one common speech-in-noise test like the QuickSIN (Etymotic Research, 2001).

Directional Amplification

The most important clinically relevant finding was for fixed directionality settings. In line with the recommendations from the QuickSIN user manual, participants with moderate and severe losses were more likely to be fitted with directional settings, specifically fixed directionality. Additionally, those with near-normal/normal to mild losses were less likely to be fitted with fixed directional settings, as seen by the negative associations. There was a negative association between those with moderate and severe losses and adaptive directional settings. Although the finding for fixed directional settings is in line with the QuickSIN recommendations for those with moderate to severe losses, other results showed contradiction to the recommendations. That is, omnidirectional amplification was also shown to be a positive contributor to moderate and severe SNR losses (based on the chi-square test residual contributions).

For patients with moderate and severe SNR losses, an improvement in SNR is needed to improve communication. Although outside of the scope of this study, it would be of interest to compare hearing aid outcomes in those set with omnidirectional in the moderate to severe loss group and those set with directional technology in the moderate to severe loss group to determine the impact from directionality settings. It is unclear whether clinicians used the QuickSIN performance score to select these settings, if it was based on self-reported difficulties and specific needs, or if it was based on a combination. The AAA guidelines recommend using adaptive directional microphone technology for patients with speech understanding in noise difficulty. However, the results from this study did not show a trend for using adaptive amplification based on speech-in-noise performance. In fact, a negative association was seen between moderate to severe degrees of speech-in-noise difficulty and adaptive directionality. That is, someone with a mild SNR loss was nearly as likely to be set with adaptive directionality compared to someone with a moderate to severe SNR loss. That is not to say, however, that their hearing aid outcomes would be the same. This will be an important area of research for the development of evidence-based guidelines for hearing loss management.

It can be argued that the hearing aid style may not allow for directional settings and thus were set to omnidirectional by default. This could be the case for custom hearing aids that may not have two microphones built into the devices. To determine if the results for omnidirectional settings were confounded by this possibility, the numbers of in-the-ear (ITE), in-the-canal (ITC), and other custom styles were evaluated separately for their directionality settings. Of the 106 participants that had directionality settings available for analysis, seven had ITE (n = 6) or ITC (n = 1) devices. These hearing aids were set to either fixed directionality (n = 5) or adaptive directionality (n = 2). Thus, all custom devices in this study had directional technology capabilities, and it was concluded that hearing aid style did not play a role in setting this feature.

DNR and HAT

DNR

The findings from this data set suggest that participants had DNR activated the majority of the time, regardless of individual ability in speech recognition in noise. DNR was not found to be significantly related to degree of speech-in-noise difficulty. However, the lack of an observed relationship was likely a result of DNR settings being turned on in most participants (93/106 participants). No specific recommendations or guidelines are provided in the literature on when to have DNR turned on or off based on speech recognition in noise abilities. There are, however, suggestions that DNR should be set to different degrees based on the Acceptable Noise Level Test results to enhance sound quality and comfort (Ricketts et al., 2019).

HAT

The results of this study did not detect an association between speech recognition in noise abilities, as measured by the QuickSIN, and use of HAT. These findings were not in agreement with the QuickSIN recommendations or the AAA guidelines that if a patient has a severe degree of speech-in-noise difficulty, HAT should be utilized. The lack of associations between these measures may be partly explained by the low uptake of HAT among this cohort (24% use). Comparable to the current findings, Souza et al. (2018) found that 25% of their participant cohort used HAT. These results also reflect those of Hartley et al. (2010) who found that older individuals reported a low usage of HAT. In this study, the majority of participants did not use HAT and are likely experiencing increased difficulty in challenging listening environments.

Limitations and Future Directions

One limitation of this study was the lack of information on the hearing care professional and their insight into feature fitting strategy. It would have been beneficial if information were provided in the retroactive chart review on the clinician's level of training and why a clinician chose specific advanced feature settings (fitting protocol). For example, the feature selection could have been based on patient self-report during a needs assessment instead of their speech-in-noise performance or some combination of the two information. This type of decision making would be interesting to evaluate in a nationwide survey to practicing clinicians and patient perspectives of the selection process.

Another limitation stems from when participant's degree of speech-in-noise difficulties were evaluated for the purpose of the study. There may be variation between QuickSIN performance at the time of fitting (prefitting by a hearing care professional) compared to the time it was used for comparison purposes (postfitting by a researcher). However, one study evaluating the Words-in-Noise Test (Wilson & McArdle, 2007) found that retesting speech perception in noise abilities after 12 months did not show significant differences. Although these are different measures, they both utilize a similar scoring procedure and assess similar abilities, thus the results may be generalizable to the QuickSIN as well. Subsequently, McClannahan et al. (2021) did not find significant differences between QuickSIN performance, although only tested 14 days apart. Although further research is needed on the long-term test retest reliability of the QuickSIN, it appears that it is likely a relatively stable measure.

HAT use was low among all participants in this study. This finding, in agreement with other studies, opens the door to other future topics for research. Barriers to using these assistive devices should be explored to understand who will receive the most benefit from and should be recommended to try these management strategies. It is a limitation of this study that the reasons for low uptake were not inquired upon through follow-up, but it is probable that cost was one contributing factor.

Hearing loss management is a necessary part of an audiologist's responsibilities. Providing the clinician with evidence-based research to help inform patient-centered clinical decisions is still very much needed. The conclusions drawn from this study provide the rationale needed to continue research into how prefitting measures of speech recognition in noise abilities may play a role in managing hearing loss within hearing aid selection and fitting. A clinician's reasoning behind selection of advanced features would be an informative next step. This would provide information on whether individualized choices are superior to fitting schemes based on performance on speech recognition tests. It would also be of interest to determine if findings from this study are related to hearing aid outcomes. Future studies should focus on determining if performance on speech-in-noise tests and specific hearing aid feature settings are related to objective and subjective hearing aid outcomes.

Author Contributions

Alyssa Davidson: Conceptualization (Equal), Data curation (Equal), Formal analysis (Lead), Funding acquisition (Equal), Methodology (Equal), Validation (Lead), Visualization (Lead), Writing – original draft (Lead), Writing – review & editing (Supporting). **Nicole Marrone:** Conceptualization (Equal), Methodology (Equal), Resources (Equal), Supervision (Equal), Writing – review & editing (Supporting). **Pamela Souza:** Conceptualization (Equal), Data curation (Equal), Funding acquisition (Equal), Methodology (Equal), Resources (Equal), Supervision (Equal), Writing – review & editing (Supporting).

Acknowledgments

The authors would like to acknowledge the graduate student and research assistant contributions from both Northwestern University and The University of Arizona for their help with data collection, as well as the support of Tanyha Zepeda with data management and REDCap. Research reported in this publication was supported by the National Institute on Deafness and Other Communication Disorders of the National Institutes of Health under Award No. R01 DC012289-09 (Pamela Souza). Partial funding support was also provided by the Royal Arch Research Assistance (Alyssa Davidson) and the Graduate and Professional Student Council from The University of Arizona (Alyssa Davidson).

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