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BINAURAL SOUND FIELD PRESENTATION OF THE QUICKSIN: EQUIVALENCY ACROSS LISTS AND SIGNAL-TO-NOISE RATIOS

A Thesis in

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ABSTRACT

The purpose of this study was to evaluate the 12 standard test lists of the Quick Speech-in-Noise test (QuickSIN) for equivalency of across list and signal-to-noise ratio (SNR) and for test-retest reliability for binaural soundfield listening. The results of the QuickSIN were compared with word recognition scores for Northwestern University No. 6 (NU-6) word Lists 1A and 2A presented in the QuickSIN babble. Further, the relation between the QuickSIN results and the Abbreviated Profile of Hearing Aid Benefit (APHAB) scores were evaluated.

Two groups of adults (N = 36 per group), with normal hearing sensitivity (NH) and with mild to moderate sensorineural hearing impairment (HI), participated in a test and retest session separated by one to two weeks. Each participant completed the APHAB, received the 12 QuickSIN standard test lists in counterbalanced order, and the NU-6 List 1A (test) and 2A (retest) in the QuickSIN babble at a SNR based on the participant's mean QuickSIN SNR-50 score for the session.

Seven of the 12 QuickSIN standard test lists (Lists 1, 4, 5, 6, 8, 10, and 12) maintained equivalency across group and test session and resulted in a mean SNR-50 score of 2.7 dB (SD = 1.6 dB) for the NH and 5.5 dB (SD = 3.1) for the HI group. Mean NU-6 scores were 35 rau and could not be predicted by the presentation SNR. Low non-significant correlations were found between the QuickSIN SNR-50 scores and the APHAB results.

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Chapter 1

Introduction and Review of the Literature

As part of an audiologic test battery, audiologists commonly test a person's ability to understand speech using a list of monosyllabic words such as the Central Institute for the Deaf (CID) W-22 or the Northwestern University Auditory Test Number 6 (NU-6). Historically, these tests were developed based on the theory that if the "sounds" in the test words occurred with the same frequency of occurrence as normally occurs in English, a person's test score would reflect their "real-world" speech understanding ability. However, even though research has shown this not to be the case, audiologists routinely use the results of speech recognition tests in quiet to predict real world communication performance in order to counsel, plan, implement, and evaluate audiologic rehabilitation.

Subjective Assessment of Hearing Performance

Overall, it has long been recognized that the results of speech recognition tests in quiet do not reflect real-world listening. In part, this occurs because speaker and listener variables (e.g. word familiarity, linguistic competence, motivation, and internal state) dynamically interact with listening environmental variables (e.g., signal-to-noise ratio, type of background noise, reverberation, and distance). The evaluation of a person's understanding of speech must incorporate real-world variables in order to improve an

audiologist's ability to plan and evaluate audiologic intervention. In an effort to do this one approach has been to develop a subjective test to determine a person's hearing disabilities in different listening environments. One of the more common tests following this approach is the Abbreviated Profile of Hearing Aid Benefit (APHAB; Cox & Alexander, 1995).

The Abbreviated Profile of Hearing Aid Benefit

The APHAB was designed to evaluate the effect of hearing impairment on daily life. The self-report scale is composed of four subscales including Ease of Communication (EC), Reverberation (R), Background Noise (BN), and Aversiveness (AV). The respondent reads statements such as, "19. I can communicate with others when we are in a crowd." The respondent then provides subjective agreement to the statement via a Likert scale that provides a range of A. Always (99%) to G. Never (1%). The scores on the subscales and the global score can be compared to normative data and also can be used pre- and post-amplification to evaluate benefit. Cox, Alexander, and Gray (2003) evaluated the relationship between unaided APHAB scores and audiometric results to determine if moderate correlations would be found similar to those found for other subjective measures such as Hearing Handicap Inventory for the Elderly (Weinstein & Ventry, 1983). The audiometric measures used included three pure tone average formulae, speech recognition threshold, word recognition in quiet assessed with the NU-

6, and performance measures for the Revised Speech-in-Noise test (RSIN; Cox, Gray, & Alexander, 2001) at the 70 dB HL presentation level.

The results of the Cox et al (2003) study were consistent with similar studies for other subjective measures. Moderate correlations were found between the self-report scores for the EC, R, and BN subscales and the audiometric measures. The correlations with the BN scores were weaker than the other two subscales. Further, correlations between the BN scores and the RSIN performance were of similar strength to the BN scores and PTAs. Using the signal-to-noise ratio (SNR) needed for 50% correct on the RSIN did not show a stronger correlation with subscale scores than performance in rationalized arcsine units based on percent correct at the RSIN presentation SNRs. Although an individual's perceptions are important in the rehabilitative process, the typically moderate correlations indicate the need for additional objective outcomes measures.

Objective Evaluation of Speech Intelligibility in Noise

Another approach has been to develop objective tests to predict a person's speech understanding ability in real-word settings using a speech-in-noise test. The development of speech-in-noise tests reflects a movement toward incorporating real-world listening situations into clinical assessment. Pearson, Bennett, and Fidell (1977) measured speech and background noise levels in everyday listening environments including suburban and urban homes, hospital settings, classrooms, a department store, trains, and airplanes. The

noise levels ranged from 41 dBA in a suburban home to a mean level of 79 dBA in airplanes. Comparing the speech with the noise levels, they found speech to noise ratios (SNRs) ranging from -2 to –1 dB in the airplane and train settings to 5 to 15 dB in the more common settings such as the home and the department store (Olsen, 1998). Low SNRs typically contribute to reduced speech intelligibility (Beattie, Barr, & Roup, 1997; Bradley, Reich, & Norcross, 1999), reduced ability to follow conversation (Hygge,Ronnberg, Larsby, & Arlinger 1992; Larsby & Arlinger, 1994), and secondary effects such as frustration and feelings of social isolation as a result of difficult communicative situations (Hallberg, 1999; Hallberg & Carlsson, 1993; Hetu, Lalonde, & Getty, 1987; Resnick, Fries, &Verbrugge, 1997).

The primary complaint of hearing-impaired listeners is difficulty understanding speech in noise. Further, hearing aid users typically are the least satisfied with their hearing aid performance in noise conditions (Kochkin, 2000). Also, it is very well known that at the same SNR hearing-impaired listeners have poorer speech recognition abilities than normally hearing listeners (Beattie et al., 1997; Dubno, Dirks, & Morgan 1984; Pekkarinen, Salmivalli, & Suonpaa, 1990). The requirement for a more favorable SNR in order to perform equally well as compared to normal listeners has been referred to as SNR-loss and, as a comparison measure, is largely independent of speech material (Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004). It naturally follows, then, that the evaluation of a hearing-impaired listener's speech intelligibility in noise, as an area of primary complaint and increased difficulty, should be included in audiologic intervention. Indeed, the use of speech in noise tests has been recommended in the audiologic

evaluation (Divenyi & Haupt, 1997), audiologic rehabilitation (Tyler, 1994) and as part of the multifaceted measure of hearing aid outcome (Humes, 1999).

Objective Speech-in-Noise Tests

Speech-in-noise tests have tremendous potential to more accurately predict speech intelligibility in real-world listening environments because noise commonly occurs in those listening environments and because hearing-impaired listeners experience disproportionately decreased speech intelligibility in noise. The inclusion of a speech-in-noise test is important because an individual's ability to hear in noise cannot be predicted from the pure tone audiogram or from word recognition tests in quiet (Duquesnoy, 1983; Ferman, 1993; Killion, & Christensen, 1998; Wilson & Weakly, 2005). In fact, decreased speech understanding in noise may be found in people who have normal hearing sensitivity (audiograms) and/or normal word recognition in quiet (Ferman, Verschure, & van Zanten, 1993; Saunders & Haggard, 1992).

Speech recognition in quiet can be estimated from the amount of audibility provided by the level of the speech signal and the individual's hearing sensitivity using an audibility index. However, the prediction of speech recognition in noise for hearing-impaired listeners requires a factor adjustment beyond speech and noise levels and hearing thresholds (American National Standards Institute, 1997; Pavlovic, Studebaker, & Sherbecoe, 1986; Sherbecoe & Studebaker, 2003). Although the difficulty understanding speech in noise may be largely a result of reduced audibility (Humes, Watson, Christensen, Cokely, Halling, & Lee, 1994) other factors such as reduced

frequency or temporal resolution may contribute to the problem (Bacon, Opie, & Montoya, 1998; Crandall, 1991; Killion, 1997; Peters, Moore, & Baer, 1998; Thibodeau, 1991).

At the current time, because of the inability to predict speech intelligibility in noise from speech intelligibility in quiet and the lack of clinically available tests to account for distortion factors, speech-in-noise tests probably provide the best solution for objective assessment of a person's speech recognition ability in noise. This is supported by the inclusion of speech-in-noise tests into a best practices hearing aid evaluation protocol (Kochkin, 2003). The development of speech-in-noise tests requires rigorous evaluation to allow for valid and reliable assessment. Bilger (1984) presented a protocol for test development and standardization. The protocol includes seven stages: 1) test definition, 2) collection of a large number of possible test items, 3) evaluation of items with a large number of target population members, 4) psychometric evaluation of the items with a subgroup of those participants, 5) construction of test forms, 6) test form evaluation with a distinct participant subgroup, and 7) validation of the test with a new sample from the target population. Further, the validity of the instrument must be addressed especially if the results are to be used for predictive information (Walden, 1984) and the standard error of measurement needs to be known for clinical applications of the instrument (Demorest, 1984). Unfortunately, not all speech in noise tests have been developed and standardized using the Bilger (1984) protocol.

The development of a test to assess speech intelligibility in noise requires consideration of a number of factors. These factors include, but are not limited to, the presentation and response modes, type of speech stimuli, type of masker, and SNR.

Currently, several speech-in-noise tests are commercially available and include the Connected Speech Test (Cox, Alexander, & Gilmore 1987), the Hearing in Noise Test (Nilsson, Soli, & Sullivan, 1994), the Speech in Noise Test (Etymotic Research, 1993), and the Quick Speech-in-Noise Test (Etymotic Research, 2001). These tests vary somewhat as to their purpose, design, and development.

The Connected Speech Test

The Connected Speech test (CST; Cox, et al 1987) was designed as an assessment of hearing aid benefit using stimuli reflective of everyday speech situations. Connected, meaningful speech presented in a background of multitalker babble was chosen to simulate typical conversational situations. The test consists of 57 (48 test and 9 practice) passages of conversational speech, where each passage is approximately 10 sentences in length. The passages relate to a common topic identified prior to presentation and a topic key word is spoken during the first several sentences. Each passage contains 25 key words for scoring. The target speech passage is presented at an everyday conversational level, defined by Pearsons, et. al. (1977) as 55 dBA outside the listener's ear, in a background of babble. One sentence is presented at a time. The listener's task is to repeat the sentence. The resulting percentage correct score is transformed into a rationalized arc-sine unit (rau) (Studebaker, 1985).

The CST development protocol included an initial pool of 72 passages that were presented to 30 normally hearing listeners. Each listener heard the passages in one signal-

to-babble ratio (SBR, -3 dB through –8 dB in 1 dB steps). The listeners' responses were evaluated in reference to a level of key word intelligibility (in rau), the distribution of key word intelligibility in each passage over 5 levels of intelligibility (7.5-25%, 25.5-42%, 42.5-60%, 60.5-77%, and 77.5-95%), and the overall intelligibility of the passage. Of the initial pool of 72 passages, 57 contained at least five key words in each of the five levels of intelligibility. The passages then were assessed by key word comparisons within intelligibility levels until the overall passage intelligibility scores were 50% ± 1%. Then, correlation coefficients were determined between the grand mean and the passage mean scores for each participant. The 48 passages with the highest positive correlations (ranging from r = 0.88 to 0.97) were chosen as test passages. The remaining 9 passages became practice passages and the corpus of test passages became the CST version 1 (CSTv1).

The CSTv1 was then evaluated with a new group of 10 participants at one SBR (-4 dB). The group mean score for all passage presentations fell within the expected range based on the standard error estimate from the prior test development phase. A correlation matrix between participants and passage scores did not reveal a systematic passage difference. The CST development data were analyzed to provide a 95% critical difference score, 13 rau for 4 CST passages, and the performance-intensity function, 12 rau/dB for the material.

Following the CSTv1 development with normally hearing subjects, the CSTv1 was evaluated with hearing-impaired listeners (Cox, Alexander, Gilmore, & Pusakulich, 1988). Forty adults with sensorineural hearing loss were divided into four groups based on the degree of hearing loss. A speech recognition threshold (SRT) and the slope of the

hearing loss from 500 to 4,000 Hz were used to categorize the hearing loss. The categories were: 1) SRT < 40 dB HL with a slope of 6-14 dB HL per octave, 2) SRT < 40 dB HL with a slope > 14 dB HL per octave, 3) SRT 40-60 dB HL with a slope of 0-5 dB HL, and 4) SRT of 40-60 dB HL with a slope of 6-14 dB HL. All of the test passages were presented to each listener at a sensation level equal to 61 dB SPL. This occurred because this was the level of a Kemar recording in diffuse soundfield in reference to the Pearsons et. al. (1977) measurement of everyday conversational speech of 55 dBA plus one-half of their SRT as an approximation of hearing aid gain. The participants listened monaurally in the soundfield. Practice passages were used to determine an SBR (0 dB to 7 dB) at which the listener scored in the range of 50% to 80%. The SBR remained constant for each listener over test passage presentations.

The CSTv1 passages did not maintain equivalence with the hearing-impaired listeners. Several passages proved to be more difficult in terms of intelligibility for these listeners. Also, in comparison with the normally hearing listeners, the hearing-impaired listeners showed greater variability. Based on the results of the study, the passages were paired to equate for intelligibility and became the CST version 2 (CSTv2). CSTv2 was subsequently evaluated with a new group of hearing-impaired listeners to provide the paired-passage 95% critical difference (15.5 rau) and the SBR function slope (8.5 rau/dB).

The development of the CST demonstrates the necessity of evaluating the tool with the target population. Although the development data for normally hearing listeners provides a reference for test result expectations for a normal population, the inter-passage equivalence was not maintained when presented to a sample from the intended

population, hearing-impaired individuals. Overall, these findings demonstrated that test development required several stages prior to readiness for clinical use.

The Hearing in Noise Test

The Hearing in Noise Test (HINT; Nilsson et al., 1994) was developed specifically as a measure of speech intelligibility in noise, using an adaptive threshold procedure during which the level of background noise was held constant and the sentence presentation level was varied based on the correctness of the listener's response. The adaptive procedure results in a sentence speech reception threshold (sSRT) that is not limited by ceiling or floor effects that occur when a listener's response is scored in percent. The HINT was based on the sSRT procedure used in other countries (Hagerman, 1982; Plomp & Duquesnoy, 1982) and was developed to provide American English sentence stimuli. The HINT consists of a corpus of 25 lists. Two steady state noises are available as maskers. Each noise was chosen for the ability to match spectrums to the speech stimuli for a steep performance-intensity function and to provide a level SNR through the speech frequency region.

The development of the HINT followed several steps. Initially, Bamford-Kowal-Bench (BKB) sentences were edited to sound natural to American English speakers. The sentences were recorded in spectrally-matched noise. Groups of listeners responded to the BKB sentences at several SNRs. Individual word scoring was then used to adjust the mean root-mean-square (rms) amplitudes of the sentences in the noise to equate overall

sentence intelligibility. This procedure, of presenting the sentences and adjusting rms amplitudes, was continued for seven rounds until the resulting sentence intelligibility scores were within a standard deviation of 25.1%.

This resulted in 252 BKB sentences which were then placed into 21 twelve-sentence phonemically-balanced lists. The lists were presented to 18 normally-hearing participants to determine inter-list equivalency. Four blocks of list presentation were counterbalanced for quiet and for background noise at 72 dBA. Each block contained 5 lists. The list order was counterbalanced and the sentences within the lists were presented randomly. The mean SNR required for 50% intelligibility of the sentences (sSRT) was –2.92 dB with a standard deviation of 0.78 dB. In quiet, the mean sSRT was 23.91 dBA with a standard deviation of 3.45 dBA. No significant list differences were noted. Further evaluation of the HINT included inter-list equivalency with an older (60-70 year old) listener group (Hanks & Johnson, 1998).

The Speech-in-Noise Test

The Speech-in- Noise test (SIN) (Etymotic Research, 1993) was originally used in a study to compare the compression circuitry of hearing aids (Fikret-Pasa, 1993). The Institute of Electrical and Electronic Engineers (IEEE, 1969) sentence corpus was used to form nine lists of 40 sentences for the investigation. The nine lists then became commercially available as the SIN test. Key words are embedded in sentences for scoring. Real-world listening is further reflected in the use of a four-talker babble as

competitor. A formula using key-word scoring determines a score called the SNR-50. The SNR-50 is the SNR required for 50% intelligibility of the key words.

A SIN test includes a group of sentences that are presented at two levels (70 dB HL and 40 dB HL) in four SNRs (15, 10, 5, and 0 dB). The presentation levels were chosen to reflect casual and raised vocal effort in a range of naturally occurring SNRs. Five sentences, each containing five key words, are presented at each SNR beginning at the most favorable SNR (15 dB). The presentation order (5 sentences per SNR) is then replicated at the lower presentation level (40 dB HL).

Bentler (2000) evaluated the inter-list equivalency and test-retest reliability of the SIN. Participants consisted of 20 normally hearing and 20 hearing-impaired individuals. Each participant received the SIN test in a soundfield at 0º azimuth using 4 randomly selected lists over 3 different sessions. This design allowed for inter-list equivalency data for all lists and test-retest data for 3 of the lists per participant. The lists were tested for equivalence using the SNR-50 score and also percentage correct. Ceiling and floor effects were present in the data. Some individuals never scored below 50% and extrapolation from the performance-intensity functions was used. Inter-list equivalency was not maintained across all lists. Two subgroups of lists were found to be equivalent with the overall list score and over each presentation level: Lists 1, 2, and 9 and Lists 3, 4, and 5. The first grouping resulted in slightly higher average percentage correct scores than the second grouping. Bentler concluded that revisions should be made to future test versions to improve inter-list equivalency and to improve the possibility of achieving a 50% performance level.

Subsequently, a revision of the SIN was devised to increase inter-list equivalence by Cox, Gray, and Alexander (2001) using the data from the equivalency study conducted by Bentler (2000). The Revised Speech-in-Noise Test (RSIN) combined lists into modified dual blocks using data from the hearing-impaired group at the 5, 10, and 15 dB SNRs and from the normally hearing group at the 0 dB SNR to avoid effects of the ceiling and floor data. The modified dual blocks then were presented to 2 groups of older normally hearing listeners. One group received the sentences in their original, unfiltered manner and the second group received the stimuli in a 9 dB per octave (250 Hz through 4,000 Hz) low pass filtered condition. The filtered condition was used to evaluate inter-list equivalency with reduced audibility, simulating a mild sloping high-frequency hearing loss. The presentation of stimuli differed in format from the SIN in two ways. First, practice sentences were provided at the beginning of each change in SNR. Further, all sentences were presented at a comfortable listening level to control for audibility and the possibility of distortion at uncomfortably loud levels. Multivariate pairwise comparisons based on key word rau scores revealed that not all of the modified dual blocks were equivalent at all SNRs. Each modified dual block was then weighted to optimize block equivalence based on the 50 rau score. The RSIN provides inter-list equivalence increasing the confidence with which audiologic intervention or outcomes assessment decisions can be made. However, the RSIN was not based on evaluation with listeners with hearing impairment and requires additional test administration time that does not lend itself well to clinical use.

Development of the Quick Speech-in-Noise Test

The Quick Speech-in-Noise (Quick SIN) Test Version 1.3 (Etymotic Research, 2001) became commercially available in April, 2001. The primary purpose of the Quick SIN was to assess an individual's ability to hear in noise by determining the SNR at which 50% of the key words are identified. The SNR-50 is then corrected by minus 2 dB to account for expected normal performance. The corrected score is known as the SNR-loss and is an indication of the person's degree of difficulty hearing speech in noise. The greater the SNR-loss the poorer the listener's ability is to hear in noise.

The QuickSIN was developed to overcome some of the difficulties noted with the SIN, specifically to shorten the test administration time and to delete the lower presentation level (40 dB HL) that had been noted to be too difficult for many hearing-impaired listeners. The test provides three practice and 12 six-sentence lists in the standard version presented at 70 dB HL for listeners with a PTA ≤45 dB HL or at a 'loud but comfortable' level for greater degrees of hearing loss. Five key words are embedded in each sentence for scoring. The sentences are presented in a four-talker babble (3 females, 1 male). One sentence per SNR is presented beginning at a SNR of 25 dB and then another sentence is presented at a SNR of 20 dB. This is continued in decreasing steps of 5 dB until the last sentence is presented at a SNR of 0 dB. The number of key words repeated correctly in each sentence is used in the following formula to establish a person's SNR Loss. The formula is SNR Loss = 25.5 – the total number of the key words repeated correctly.

The SNR-loss formula is based on the Tillman-Olsen (1973) statistical spondee threshold method to determine the 50% correct level and on the SNR-50 expected for normal performance for the QuickSIN task. The QuickSIN SNR-50 and the Tillman-Olsen spondee threshold formulae are based on the Spearman-Kärber equation by Kinney (1952) (Wilson, Morgan, & Dirk, 1973). The formula, provided below, is used to derive the 50% correct point ($T_{50\%}$).

$$T_{50\%} = i + ½(d) – d(r)/n$$

Whereas i represents the initial test presentation level, d the dB decrement between presentation levels, r the number of correct responses overall and n the number of test items presented at each level. Therefore, the formula is simplified if the number of items per presentation level is the same as the decrement size.

The number of test items per level for the QuickSIN is the same as the decrement size (5). Each key word can be thought of as representing 1 dB. First, the SNR-50 is determined by adding one-half step size or 2.5 dB to the initial presentation level of 25 dB SNR (27.5). SNR-50 is calculated by subtracting the number of key words repeated correctly from 27.5. Most speech recognition scores provide a percent-correct score or the SNR required for the 50% correct point. The QuickSIN allows the opportunity to compare to normal performance. Therefore, the resultant value provides an individual's SNR loss. The SNR required for normally-hearing listeners to correctly repeat 50% of words in sentences is 2 dB (Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004) The normal performance value is subtracted from the formula (25.5). This value is then used from which to subtract the number of key words correct. The QuickSIN test manual provides adjective descriptors corresponding to the SNR-Loss score where a SNR-Loss

score of 0 to 2 dB is normal, 2 to 7 dB is mild, 7 to 15 dB is moderate, and >15 dB is severe.

The QuickSIN uses SNR-loss as the outcome score rather than the SNR-50 because it is independent of test material. One would expect a different normal value for different combinations of speech material and background competitors. Therefore, expected scores or performance for the specific test by a group of listeners with normal hearing needs to be known. The SNR-loss is then referenced to average normal performance.

Although it has been long recognized that hearing-impaired individuals require more favorable SNRs than normally hearing individuals require, the use of SNR-loss is somewhat new. Killion and Christensen (1998) and Killion and Niquette (2000) proposed the use of SNR loss to refer not to the loss of audibility but to a distortion factor. Pure tone thresholds provide audibility information but SNR-loss, with performance for normally-hearing individuals as the reference, provides additional important information for audiologic management including counseling and outcomes measurements related to listening in unfavorable situations.

Killion et al. (2004) presented Quick SIN development and normative values based on a series of experiments. In the first experiment, the IEEE sentences that were not used in the SIN Test and that were judged "to sound contemporary" were each recorded in a time-locked sequence of the four-talker babble at nominal -1, 2, and 5 dB SNRs based on the calibration tones of each set of material. This 360-sentence corpus was referred to as the Alpha 1 recording. It was noted that the sentences in quiet are not of equivalent difficulty. The sentences then were presented in staircase manner to 16

adults with normal hearing sensitivity through 4000 Hz. The stimuli were presented at 70 dB HL via ER-3A insert earphone, monaural presentation for 12 participants and binaural to the remaining 4 participants. The Tillman-Olsen (1973) method of scoring for spondee thresholds was used to determine the SNR-50, the SNR at which 50% of the sentence key words would be repeated correctly. The key words were given 1 point if correct and ½ point if close, i.e. missing pluralization. The number of words correctly repeated was subtracted from the sum of the best SNR (5) and ½ the step size (1.5). The derived SNR-50 scores for the IEEE sentences ranged from -1.3 to 5.9 dB with a mean of 2.5 dB. The results indicated variability across sentences due to the combination of sentence and babble sequence and the level of difficulty of the sentence.

The second experiment involved a rerecording of the sentences in the time-locked sequences of babble to adjust the SNR to produce results equivalent to the SIN Test mean score (2 dB SNR for normal listeners at a presentation level of 70 dB HL). The level of the babble was adjusted based on the mean data from the first experiment. These 'Alpha 2' sentences were then recorded at SNRs of 0, 5, 10, and 15 dB nominally set by calibration tones. The sentences were presented monaurally in a staircase manner at the 0 and 5 dB SNR for 6 normally-hearing adults. Eight adults with hearing impairment participated. The presentation level was set at an individually perceived 'loud but okay' level', 7 received monaural presentation and 1 binaural presentation. Results of SIN test list blocks determined which 2 SNRs a hearing-impaired participant would receive by bracketing the SNRs around the SIN score. The mean SNR-50 was 2.4 dB (SD = 1.6 dB) for the normally-hearing group and 7.4 dB (SD = 2.9 dB) for the hearing-impaired group.

The data from this and the previous experiment were used to determine the stimuli for the next experiment.

The purpose of the third experiment was to assess equivalence of sentence combinations in the QuickSIN format of six sentences in descending order of SNRs, 25 to 0 dB in 5 dB steps. Five criteria were used for selection. The data from experiment 2 was used to select sentences that had a standard deviation less than 1.5 dB and an SNR-50 score within 1.5 dB of the grand mean for the 6 normally-hearing participants, and an SNR-50 score within 2 dB of the grand mean for the 8 hearing-impaired participants. Further, the range of SNR-50 scores for the key words in the sentence needed to exceed 2 dB. This was determined by randomly selecting 5 participants from the normally-hearing group in experiment 1.

The criteria resulted in the inclusion of 89 sentences. The standard deviation criterion then was expanded to 2 dB for the inclusion of additional sentences to increase the list corpus. Twenty-one lists were recorded as the Beta version. As further indicated, the Beta version lists were assessed for equivalence and test-retest reliability using 26 normally-hearing individuals and 18 hearing-impaired individuals. The across list grand average SNR-50 for normally-hearing individuals was reported to be 1.9 dB.

The Beta lists were low-pass filtered at 750, 850, 1100, 1400, and 2000 Hz to assess the equivalency of the lists by simulating hearing loss. Twenty-five normally-hearing individuals received a staircase presentation of the filtered lists. The SNR-50 of all filtered conditions for 12 lists fell within the 2.2 dB of the grand mean for lists. These 12 lists comprise the QuickSIN standard lists. Three practice lists and 3 pairs of lists also

are provided. The list pairs are reported to average to the equivalence standards of the 12 lists.

Evaluation and Use of the Quick Speech-in-Noise Test

The Quick SIN test has potential advantages over the other speech-in-noise tests. The list administration time is one-minute providing clinical efficiency. Additionally, the four-talker babble is more realistic of typical listening environments. Individuals with hearing impairment are less able to make use of temporal gaps in background noise than normally hearing individuals. Greater variability in the speech recognition abilities of hearing-impaired listeners is noted with fluctuating noise versus steady-state noise (Hagerman, 2001) and, therefore, provides additional information for audiologic intervention.

The QuickSIN has been recommended for use in clinical protocols (Taylor, 2003), and has been used in research. Recently, Walden and Walden (2004) chose the QuickSIN as one of a battery of measures to predict successful hearing aid use in daily life. The study included 50 adult males, most of whom were not first time hearing aid users. The relationship between 10 predictors and 2 outcomes measures were examined. The International Outcome Inventory for Hearing Aids (IOI-HA) and Hearing Aid Usefulness Scale (HAUS) were used to measure the participants' subjective benefit from amplification. The IOI-HA is a seven item inventory designed as an outcomes measure for collaboration across research centers. Norms are provided for the American English version of the IOI-HA for individuals with self-reported mild to moderate hearing

problems without amplification and for moderately-severe and greater self-reported unaided hearing difficulty (Cox, Alexander, & Beyer, 2003). The HAUS is a self-rating from one to 100 of the benefit received from amplification. The audiometric measures of audibility included pure-tone average, unaided and aided articulation indices, and the NU-6 score for the better ear presented in quiet at 80 dB HL. Two QuickSIN lists were presented for an unaided and aided condition. Of these predictive audiometric measures, the QuickSIN lists were the only measure that incorporated a more realistic measure of speech-in-noise and were the only audiometric measure that significantly correlated with the self-assessment scales. The factor of age also showed a statistically significant correlation with these outcomes measures (Walden & Walden, 2004).

Walden and Walden (2005) also used the QuickSIN to assess unilateral versus bilateral hearing aid fittings for 28 patients, most of whom were experienced users of bilateral amplification. The QuickSIN was presented at 70 dB HL in a soundfield at 0º azimuth. Two QuickSIN lists were presented and averaged in each of four randomized conditions: unaided bilaterally, aided left, aided right, and aided bilaterally. The Dichotic Digit Test also was used as a measure of binaural separation. The majority of participants (23) performed better on the QuickSIN with unilateral amplification, challenging to assumption of bilateral amplification for the majority of individuals, especially for older individuals. These studies support the use of speech-in-noise tests clinically.

Evaluation of the Northwestern University No. 6 CNC Word Lists in Noise

Consonant-nucleus-consonant word lists presented in quiet are often the only speech intelligibility test used in the standard audiologic evaluation (Martin , Champlin, & Chambers, 1998; Wiley , Stoppenback, Feldhake, Moss, & Thordardottir, 1995). The Northwestern University No. 6 CNC word lists (NU-6) are one of the most commonly used word intelligibility tests. Word intelligibility derived from various recorded versions of the NU-6 has also been studied extensively for presentation in noise and degraded conditions (Stuart, Green, Phillips, & Stenstrom, 1994; Wilson, Preece, Salamon, & Sperry & Bornstein, 1994). Most recently, the female speaker version of the NU-6 test (Department of Veterans Affairs, 1998) was evaluated in multitalker babble in a series of studies to develop a clinical speech-in-noise task.

Wilson (2003) determined the psychometric functions for 70 NU-6 words for a group of normally-hearing and mild-moderate sensorineural hearing-impaired listeners in a 6-speaker babble (3 female, 3 male) at a fixed level of 70 dB SPL. The mean SNR required for 50% intelligibility derived by the Spearman-Kärber equation was 3.6 dB for the normally hearing and 10.6 for the hearing-impaired group. Performance on the NU-6 in the multitalker babble also was assessed at higher presentation levels and for monaural and binaural listening conditions. Mean performance was consistent across the presentation levels. Additionally, mean performance was similar (within 1 dB) for monaural and binaural presentation. The researchers suggested that the contralateral masking during monaural testing may have caused a central masking effect and, therefore, the binaural advantage typically seen in quiet was not elicited.

Wilson, Burks and Weakley (2005) compared word recognition results for the NU-6 words in the 6-speaker multitalker babble using descending presentation versus a random order presentation. Ten words were presented at 7 SNRs, 24 dB to 0 dB in 4 dB decrements, with the babble fixed at 80 dB SPL. The words were presented monaurally to the better ear. No significant difference in mean performance was noted for the group of hearing-impaired listeners between presentation modes although the descending approach required less administration time. The listeners were also asked to rate hearing difficulties in quiet and noise. No relationship between subjective report and objectively measured word recognition in noise was noted. This result reiterated the need to objectively measure speech-in-noise clinically.

McArdle, Wilson, and Burks (2005) examined speech recognition performance in the babble for digits, words, and sentences for a group of normally-hearing and hearing-impaired listeners. The female speaker version of the NU-6 was again used. The NU-6 was presented in quiet and in the six-speaker babble. Lists 3 and 4 from the QuickSIN were used for the sentence stimuli. The psychometric functions for the stimuli followed what would be expected for the varying linguistic context and each type of stimuli separated normal from hearing-impaired performance. The mean 50% correct points (dB SNR) derived by the Spearman-Kärber equation were lowest, best, for the closed set digit stimuli. The QuickSIN sentences were more difficult than the digits and easier than the NU-6 words. Moderate Spearman rho correlation coefficients collapsed across group were noted between a self-report rating of difficulty with speech in noise on a scale from 1 to 10 and results for all test conditions. A greater number of hearing-impaired listeners performed outside of the range of normal performance for the QuickSIN than for the NU-

6 in quiet. Of note, performance on the QuickSIN Lists 3 and 4 was significantly different at an alpha level of .05 and a small, but clinically insignificant, practice effect of 0.7 dB was found in test-retest analysis.

The significant difference noted for the QuickSIN lists but not for the digit or NU-6 lists in babble prompted McArdle and Wilson (2006) to examine QuickSIN list homogeneity. Two practice lists and then the 18 QuickSIN lists, the 12 standard lists and 3 list pairs, were presented monaurally in random order to 24 young normally-hearing listeners and 72 older listeners with high frequency sensorineural hearing loss. Use of the Spearman-Kärber equation, the Quick SIN SNR-50, to determine the 50% point revealed a range of 2.8 to 4.3 dB SNR for the normally-hearing listeners and 10.0 to 14.3 dB SNR for the hearing-impaired listeners. Greater variability in the psychometric function was seen for the hearing-impaired group across the lists. List homogeneity was determined by rank ordering mean performance for the hearing-impaired group and eliminated the three easiest (Lists 4, 5, and 13) and the three most difficult (Lists 7, 14, and 16). Next, the lists with irregular psychometric functions were eliminated (Lists 3, 9, and 18). Mean performance for the remaining lists (Lists 1, 2, 6, 8, 10, 11) was within 1 dB (SD = 0.5 dB). The mean performance across the remaining lists for this group of hearing-impaired listeners using better-ear monaural presentation was 12.2 dB SNR.

Summary

The primary complaint of hearing-impaired listeners is understanding speech in a background of noise. Subjective and objective information should be incorporated in

rehabilitation. Speech-in-noise tests provide the opportunity to objectively measure speech-in-noise performance in a controlled environment to counsel, plan rehabilitative measures, and evaluate those measures that is not afforded by conventional audiometric measures including speech recognition in quiet. In order to use a speech-in-noise test to predict real-world performance or as an outcomes measure for amplification; binaural listening would best be suited to the task. Therefore, the QuickSIN should be evaluated in the soundfield for binaural listening and also in terms of test-retest reliability for all lists. The NU-6 remains popular clinically and has been shown to separate normal from impaired performance when presented in a six-speaker babble. Performance was compared between the NU-6 and the QuickSIN. However, the babble was different. A four-talker babble will exhibit different temporal characteristics than a six-talker babble. Performance on both tests in the same babble should be evaluated, especially given the commercial availability of the QuickSIN babble. Further, no correlational strength difference was noted between audibility measures (PTAs) or the RSIN with unaided APHAB scores. These issues are addressed in the current study.

Research Objectives

The current investigation sought to evaluate the inter-list equivalency, test-retest reliability and the standard error of measurement of the QuickSIN, and to explore clinical applications and relation to a common self-assessment tool and word recognition test. The APHAB was chosen due to the subscale design that includes a category related to hearing in background noise, applicability to all adult ages, availability of normative data

for adults with hearing impairment and young adults without hearing impairment, and the previous comparison to the RSIN test. The NU-6 lists were chosen because of the popularity of the test, and extensive study of NU-6 performance in a six-talker babble. Specifically, the research objectives of this study were to:

1) Determine the inter-list equivalency of the 12 Quick SIN test lists across list and SNR for normally hearing and hearing impaired subjects for binaural listening in a soundfield,

2) Determine test-retest reliability for the Quick SIN lists for normally hearing and hearing impaired subjects,

3) Determine the critical difference values for the QuickSIN list presentations

4) Describe listeners' performance on a standard clinical word recognition test list, the NU-6, presented in the Quick SIN four-talker babble at the listener's average Quick SIN SNR-50 score, and

6) Evaluate the relation between the listeners' Quick SIN SNR-50 score and their score for the Abbreviated Profile of Hearing Aid Benefit.

Chapter 2

Method

Overview

A group of participants with normal hearing (NH, N = 36) and with hearing impairment (HI, N = 36) completed a test and a retest session. In each session each participant received the three practice and then the 12 standard QuickSIN test lists presented at 70 dB HL in a sound field. Then each participant was given the NU-6 monosyllabic word List 1A in the test and List 2A in the retest session presented in the QuickSIN multitalker babble at a signal to noise ratio (SNR) equal to their QuickSIN SNR-50 score averaged over all 12 lists. During the test session each participant also completed the Abbreviated Profile of Hearing Aid Benefit (APHAB).

Participants

Thirty-six participants with normal hearing (15 males and 21 females) and 36 participants with hearing impairment (20 males and 16 females) were recruited and nominally compensated ($10.00) for their participation in this study. The participants in the NH group ranged in age from 18 to 44 years old having a mean age of 24.3 years and a standard deviation of 6.5 years. The participants in the HI group ranged in age from 22 to 79 years old having a mean age of 61.7 years and a standard deviation of 13.1 years.

The NH participants were recruited from the undergraduate and graduate student population at The Pennsylvania State University. Each NH participant had pure-tone air conduction thresholds between -5 dB HL and 15 dB HL from 250 Hz to 8,000 Hz, no air conduction inter-ear threshold differences ≥15 dB HL, normal tympanograms, present ipsilateral acoustic reflexes at 1,000 Hz, (Margolis & Heller, 1987), and was a fluent native speaker of American English.

The HI participants were recruited from Pennsylvania Audiology Clinics after receiving a complete audiologic evaluation. Each HI participant had a bilateral, symmetric, sensorineural hearing loss with a pure tone average of ≤45 dB HL, no air-conduction inter-ear threshold difference ≥15 dB HL, no air-bone gaps ≥15 dB HL at more than one frequency, and a word recognition in quiet score ≥80%. Further, each HI participant had normal tympanograms, present ipsilateral acoustic reflexes at 1000 Hz, and was a fluent native speaker of American English. HI participants varied as to use of and experience with amplification.

Table 2.1 shows the mean pure-tone air conduction thresholds and standard deviations for each ear of each participant group. Inspection of Table 2.1 reveals the mean thresholds for the HI group were consistent with a mild to moderate sloping hearing loss. Mean thresholds and standard deviations increased as frequency increased. Further, the mean thresholds for the HI group left ear were slightly better than the right ear thresholds. The pure-tone air conduction thresholds for each participant are provided in Appendix A.

Table 2.2 provides a summary of demographic data for each group. The categories for Ethnicity and Occupation were based on the U.S. census data collection

procedures. The ethnicity category 'Other' incorporated multiple listings and no responses. Inspection of Table 2.2 reveals a majority of White participants for both groups. The NH group was comprised mainly of University students which is consistent with the lower mean age for this group. The HI group was older with a wider age range and showed a majority of participants in the management/professionals occupational category. Participants within each group indicated exposure to noise; however no military noise exposure was reported by participants in the NH group.

Table 2.1. Mean Pure-tone Air Conduction Thresholds and Standard Deviations (SD) for the Normal Hearing (NH; N = 36) and Hearing Impairment (HI; N = 36) Group re: ANSI S3.6-2004.

			Audiometric Frequency (Hz)							
Group	Ear		250	500	1,000	2,000	3,000	4,000	6,000	8,000
NH	Right	mean	6.1	4.2	5.6	4.6	3.6	2.6	8.9	9.6
		SD	3.6	4.1	4.7	5.0	4.9	5.7	5.5	5.2
	Left	mean	6.8	6.0	4.4	4.2	2.8	3.8	6.9	9.6
		SD	4.5	4.8	3.9	5.7	6.1	6.0	6.0	5.8
HI	Right	mean	18.1	22.8	29.4	38.1	45.4	51.1	57.2	59.6
		SD	7.6	7.3	7.6	10.4	12.1	14.4	14.1	14.4
	Left	mean	17.9	21.1	29.3	37.8	45.3	50.1	58.8	58.0
		SD	8.2	7.7	8.9	10.8	11.6	14.0	15.9	17.7

Table 2.2. Demographic Information for the Group with Normal Hearing (NH) and the with Hearing Impairment (HI) Showing Age Data in Years and the number of participants by Ethnicity, Occupation, and Reported Noise Exposure at Home (H), Work (W), and in the Military (M)

Group	Age		Ethnicity		Occupation		Noise Exposure	
NH	Mean	24.8	Black or African American	0	Management/ Professional	5	Home	21
	SD	6.9	Asian	1	Service	0	Work	2
	Minimum	18	Native American/Alaskan	0	Sales	1	Military	0
	Maximum	44	Native Hawaiian	0	Construction	0	H/W	11
	Range	26	Hispanic	2	Student	18	H/M	0
			White	29	Other	12	H/W/M	0
			Other	5			None	2
HI	Mean	61.7	Black or African American	0	Management/ Professional	18	Home	14
	SD	4.9	Asian	0	Service	6	Work	6
	Minimum	22	Native American/Alaskan	0	Sales	4	Military	1
	Maximum	76	Native Hawaiian	0	Construction	1	H/W	6
	Range	44	Hispanic	0	Student	1	H/M	2
			White	34	Other	6	H/W/M	1
			Other	2			None	6

Test Materials

QuickSIN

The QuickSIN test materials were those contained on a commercially available QuickSIN compact disc (Etymotic Research, 2001). Overall, the QuickSIN test contains three practice lists and 12 standard lists (shown in Appendix B). The practice and test

lists were mixed with four-talker (1 male, 3 females) speech babble to create SNRs ranging from 25 to 0 dB in 5 dB-steps. Each practice and test list contains six sentences where the first sentence is presented at a SNR of 25 dB, the next at a SNR of 20 dB, the next at a SNR of 15 dB, the next at a SNR of 10 dB, the next at a SNR of 5 dB, and the final sentence at a SNR of 0 dB. Each sentence contains five key words that were scored as correct or incorrect depending on the participant's response.

The QuickSIN was administered by presenting the instructions (shown in Appendix C), the practice lists, and then a counterbalanced order of each test list. The participant's score for each test list, known as the SNR-50, was determined by subtracting the number of key words correctly identified from 27.5. The participant's SNR-50 score for each list represents the SNR at which 50% of the key words were correctly identified.

NU-6

The Northwestern University Auditory Test No. 6 (NU-6) test materials were the female speaker version of Lists 1A and 2A (shown in Appendix D) available on compact disc from the Department of Veteran's Affairs (1998). Each list contained 50 monosyllablic words. The NU-6 lists and the QuickSIN four-talker babble were recorded on separate channels of a compact disc via Cool Edit Pro 2.0 software for presentation to the participants. In addition, each list was preceded by 12 practice words to reflect the percentage of practice items for the QuickSIN lists.

Abbreviated Profile of Hearing Aid Benefit

The self-assessment measure of hearing handicap was the Abbreviated Profile of Hearing Aid Benefit (APHAB; Cox & Alexander, 1995) (shown in Appendix E). The APHAB was completed by each participant for the 'without amplification' scale prior to the test session. The APHAB consists of 24 Likert scale questions divided into four subscales called: (a) Ease of Communication (EC), (b) Background Noise (BN), (c) Reverberation (RV), and (d) Aversiveness to Sound (AV).

Instrumentation

Three sites were used for data collection. In each site all testing was conducted in a sound-field of a sound-treated room having ambient noise levels suitable for ears open testing from 125 to 8,000 Hz (re: ANSI S3.1-1999, R-2003). In the first and second site, the QuickSIN and NU-6 CD were played by a laboratory computer having a 16-bit sound card, routed through a clinical audiometer (Madsen, OB 822) and then to a coaxial loudspeaker (Evergreen, 15A) located in an adjacent sound-treated room. In the third site the QuickSIN and NU-6 CD were played by a CD player routed though a clinical audiometer (Grason-Stadler, GSI 61) and then to the same loudspeaker used in first and second site that was located in an adjacent sound treated room. In each site, the participant's talk-back response was picked up via a microphone. The microphone output was directed into the control room, amplified, and played through a loudspeaker so that the experiment could score the participant's responses. In the first test site, the participant's responses were also recorded on cassette tape for later analysis. The

instrumentation in each site was calibrated before, during, and after data collection using the sound-field calibration procedures reported in ANSI S3.6-2004 and remained stable throughout data collection.

Procedure

Each participant completed a test and retest session where the retest session was separated by a minimum of seven days from the test session. For the NH group 31 participants and for the HI group 28 participants were retested within two weeks. However, due to extenuating circumstances such as illness and travel, the time between the test and retest sessions for five participants in the NH group and eight participants in the HI group was a maximum of 35 days.

Prior to the test session each participant read and signed two Informed Consent forms (Provided in Appendix F) indicating an understanding of the procedures and willingness to participate. Then each participant completed the APHAB in pen and paper format. Following the APHAB, each participant was seated in the sound-treated room and a tympanogram and an ipsilateral acoustic reflex at 1,000 Hz was obtained for each ear. The tympanograms and ipsilateral acoustic reflexes were also obtained prior to the retest session to insure that each participant had normal middle ear function prior to the retest session. Following this, pure tone air conduction thresholds were obtained from 250 to 8,000 Hz using TDH-49 earphones (ANSI S3.6-2004).

In each session, each participant was seated 1.5 m from the loudspeaker at 0º azimuth and a talkback microphone was placed within 10 cm of the participant's mouth.

Each participant was then tested according to an experimental schedule (shown in Appendix G) listing a counterbalanced order for the 12 QuickSIN lists and NU-6 List 1A in the test and List 2A in the retest session. In each session, the investigator provided the participant with a written copy of the QuickSIN instructions (shown in Appendix B) and read the instructions aloud stressing that the participant should guess if necessary. The 3 QuickSIN practice lists were then presented followed by the 12 QuickSIN standard test lists in the order indicated on the experimental schedule. Both the 3 practice and 12 QuickSIN lists were presented at 70 dB HL. As HI participants varied in regard to personal amplification use, all were tested in the unaided condition. The experimenter recorded the participant's responses and entered their scores in an Excel spreadsheet to determine the QuickSIN SNR-50 for each list. This was necessary for setting the SNR for the NU-6 test. Following the presentation of all of the QuickSIN lists, each participant was given a 5-minute break. Following the break, the participant was re-seated in the soundfield and given oral instructions concerning the task for the NU-6 test again stressing that guessing was encouraged. The NU-6 List 1A was presented for the test and list 2A for the retest session. When the NU-6 test was presented one channel of the audiometer containing the NU-6 word list was set to 70 dB HL and the other channel containing the QuickSIN 4-speaker babble was set at a SNR relative to 70 dB that equaled the participant's QuickSIN SNR-50 averaged across the 12 test lists for that test session. The participant's responses for the NU-6 Lists 1A and 2A were scored as correct or incorrect. The percent correct score for each list was then transformed into rationalized arcsine units (rau) This transform was completed to alleviate difficulties associated with

the ceiling and floor effects of the percentage scale and to more appropriately meet the requirements of interval data (Studebaker, 1985).

As reported above, each participant's response to the key words in each QuickSIN test list and the words on the NU-6 lists were scored as correct or incorrect as the test was being administered. In test site 1 the participant's responses were also tape recorded. This was done to verify the experimenter's scoring. Ten percent of the recorded responses were later reviewed by an independent judge. The agreement between the experimenter and the independent judge was 95%. The typical time commitment for each participant was 45 minutes for the test session and 30 minutes for the retest session.

Chapter 3

Results and Discussion

Experimental Objectives

In order to complete the experimental objectives of this study, two groups consisting of 36 participants with normal hearing (NH) and 36 participants with hearing impairment (HI) completed a test and retest session during which they completed the Abbreviated Profile of Hearing Aid Benefit (APHAB; Cox & Alexander, 1995) and were given the 3 practice and 12 standard QuickSIN lists (Etymotic Research, 2001) and the NU-6 word recognition List 1A in the test and 2A in the retest session (Department of Veteran's Affairs, 1998) in the QuickSIN babble at a SNR corresponding to their SNR-50 score averaged over the 12 QuickSIN standard lists. Recall, the research objectives were to:

1. Determine the equivalency across the 12 Quick SIN standard test lists and SNR for the NH and HI groups for binaural listening in a soundfield,
2. Determine test-retest reliability for the Quick SIN lists for the NH and HI groups,
3. Determine the critical difference values for QuickSIN test list presentations,
4. Describe listeners' performance on NU-6 Lists 1A and 2A presented in the Quick SIN four-talker babble at the listener's average Quick SIN test list SNR-50 score, and
5. Evaluate the relation between the listeners' Quick SIN SNR-50 score and their score on the APHAB

Data Analysis

Practice Effect

A practice effect is an improvement in performance due to increased familiarity with the task. As such, a practice effect extending beyond the 3 practice lists needed to be ruled out prior to analyzing the equivalency of the 12 QuickSIN standard test lists. Otherwise any improvement in the participant's score could not solely be attributed to a list difference but also possibly to the participant knowing what to expect in terms of the test task. Therefore, the QuickSIN SNR-50 scores (27.5 dB minus the number of key words correctly identified) for the practice and standard test lists were evaluated by the order the participants heard the lists according to the experimental schedule (shown in Appendix G). Recall, each participant received the practice Lists A, B, and C followed by a counterbalanced presentation order for the 12 standard lists. Data for two participants in each group for the test session were excluded from the analysis due to their lack of response to the first practice list. Additionally, data for one participant from each group in the retest session were excluded because these participants did not respond to the second practice list. In these instances the participants simply reported that they 'missed the sentences' or that they were not ready. Lists were not replayed because they had already heard a part of the stimuli. The data (SNR-50 scores) were categorized by the order that the lists were presented and a two-way analysis of variance (ANOVA) for each session was completed where the independent variables were group and list presentation order and the dependent measure was the SNR-50 score.

The results of the two-way ANOVA for the test [$F(14,990)=1.05$, $p>0.05$]and for the retest session [$F(14,1020)=1.70$, $p>0.05$] did not reveal a significant interaction between group and list presentation order. However, expected significant differences between the NH and HI groups were present for the test [$F(1,990)=308.31$, $p<0.05$] and retest session [$F(1,1020)=308.22$, $p<0.05$]. For the test session the mean NH group performance for their SNR-50 scores across the three practice lists and 12 QuickSIN standard lists was 2.6 dB (SD = 1.9 dB) and 5.4 dB (SD = 3.1 dB) for the HI group. The mean SNR-50 scores for the retest session across all lists was 2.1 dB (SD = 1.8 dB) for the NH group and 4.7 dB (SD = 2.8 dB) for the HI group.

A significant difference for QuickSIN lists by list presentation order [$F(14, 990)=1.94$, $p<0.05$] was found for the test but not the retest session. The mean SNR-50 score for the test session averaged across the NH and HI groups was 5.4 dB (SD = 3.8 dB) for the first practice list (List A) and 3.8 dB (SD = 2.7) for the second practice list (List B). This mean SNR-50 score for practice List B fell within the range of mean SNR-50 scores for the counterbalanced standard test lists (3.8 – 4.1 dB). The lowest mean SNR-50 score (3.3 dB) was found for Practice List C, the third list presented.

The main effect of the list presentation order was evaluated using a one-way ANOVA with Tukey's pairwise comparisons for each group in each session (shown in Appendix H). The order of presentation for the lists was only significant for the HI group in the retest session [$F(14,510)=2.09$, $p<0.05$]. Tukey's pairwise comparisons revealed several significantly different ($p<0.05$) list pairs by group in the test and retest sessions. Table 3.1 provides the list pairs that were significantly different for each group and session. Inspection of Table 3.1 shows the involvement of the first list presented (Practice

List A) in each list pair. No significant main effect for list presentation order was found when the practice lists were removed from the analysis. Therefore, a practice effect extending beyond the practice lists could be ruled out.

Table 3.1. List Presentation Order Pairs Found to be Significantly Different ($p<0.05$) by Tukey's Pairwise Comparisons for the Normal Hearing (NH) and the Hearing Impairment (HI) Group in the Test and Retest sessions. Practice Lists A, B, and C were Presented in Order (1-3). Standard Test Lists 1-12 were Counterbalanced (4-15).

Group	Session	List Pair
NH	Test	1,3
		1,6
		1,11
HI	Test	1,2
		1,3
		1,13
	Retest	1,2
		1,3
		1,4
		1,6
		1,7
		1,8
		1,9
		1,10
		1,11
		1,13
		1,14
		1,15

Equivalency Across the QuickSIN Standard Test Lists

A primary purpose of this study was to determine the equivalency across the 12 standard QuickSIN lists. Recall, the QuickSIN standard test lists were given to two participant groups (NH and HI) in two sessions (test and retest). The raw data for each group and session are shown in Appendix I. Table 3.**2** shows the descriptive statistics for each QuickSIN standard test list (SNR-50) for each participant group for the test and retest session. Inspection of Table 3.2 reveals that the NH group had overall lower (better) mean SNR-50 scores and less variability (smaller standard deviation) than the HI group for each test list and session. However, the mean SNR-50 scores for both groups across list were lowered (improved) for the retest than the test session (NH test 2.6, SD = 1.9; NH retest 2.2, SD = 1.8; HI test 5.4, SD = 3.3; HI retest 4.6, SD = 2.7). The mean improvement across lists of <1 dB was consistent with the results of McArdle and Wilson (2006). The lowest mean SNR-50 scores were obtained with List 9 (NH retest 0.7 dB, HI retest 3.4 dB). Whereas, the highest mean SNR-50 scores were obtained for List 11 for the NH group in the test session (3.7 dB) and List 3 for the HI group in the test session (6.7 dB). The range of SNR-50 scores was the same between groups averaged across session for List 9 (7.5 dB). Other lists resulted in range differences averaged across session from 4.5 dB (NH, List 12) to 16.5 dB (HI, List 6). Perfect SNR-50 scores (the lowest possible SNR-50 score of -2.5) were obtained for four list presentations (Lists 6 retest, 8 retest, 9 test, and 9 retest) for the NH group. The maximum (worst) SNR-50 score for the NH group for each list surpassed the normal performance score of 2 dB SNR-50 as reported by Killion et. al (2004) by 1.5 to 10.5 dB. The HI group SNR-50

scores for the standard lists were higher than the NH group SNR-50 scores by 1.1 dB to 3.8 dB. This separation between listeners with normal hearing and hearing impairment was less than the separation reported by McArdle and Wilson (2006).

Table 3.2. Descriptive Statistics for QuickSIN SNR-50 Scores for the Standard Test Lists for the Test and Retest Sessions for the Normal Hearing (NH) and Hearing Impairment (HI) Group.

List	Group	Session	Mean	Median	Standard Deviation	Minimum	Maximum	Range
1	NH	Test	2.6	2.5	1.4	-1.5	5.5	7.0
		Retest	2.6	2.5	1.5	-1.5	7.5	9.0
	HI	Test	5.5	4.5	3.6	1.5	13.5	12.0
		Retest	4.6	3.5	2.8	1.5	13.5	12.0
2	NH	Test	1.9	2.0	1.8	-1.5	5.5	7.0
		Retest	1.4	1.5	1.6	-1.5	4.5	6.0
	HI	Test	4.9	4.5	3.1	-0.5	14.5	15.0
		Retest	4.6	3.5	3.1	-1.5	13.5	15.0
3	NH	Test	3.2	2.5	1.6	0.5	9.5	9.0
		Retest	2.8	2.5	1.5	-0.5	8.5	9.0
	HI	Test	6.7	6.5	4.5	0.5	18.5	18.0
		Retest	5.6	4.5	3.3	1.5	15.5	14.0
4	NH	Test	2.6	2.5	1.4	-1.5	6.5	8.0
		Retest	2.9	2.5	1.5	-0.5	6.5	7.0
	HI	Test	5.4	5.5	1.8	1.5	8.5	7.0
		Retest	4.8	4.5	1.9	2.5	9.5	7.0
5	NH	Test	3.3	2.5	1.3	0.5	7.5	7.0
		Retest	3.1	2.5	1.4	0.5	8.5	8.0
	HI	Test	5.1	4.5	2.6	2.5	12.5	10.0
		Retest	4.0	3.5	1.8	1.5	9.5	8.0
6	NH	Test	2.1	2.5	1.1	-0.5	4.5	5.0
		Retest	1.9	2.5	1.7	-2.5	5.5	8.0
	HI	Test	5.3	4.5	4.2	-1.5	18.5	20.0
		Retest	4.3	3.5	3.3	0.5	13.5	13.0

Table 3.2. continued.

List	Group	Session	Mean	Median	Standard Deviation	Minimum	Maximum	Range
7	NH	Test	2.1	2.0	2.0	-0.5	6.5	7.0
		Retest	1.8	1.5	1.7	-1.5	5.5	7.0
	HI	Test	5.9	4.5	4.1	1.5	19.5	18.0
		Retest	4.3	4.0	2.9	0.5	14.5	14.0
8	NH	Test	2.9	3.5	2.0	-1.5	8.5	10.0
		Retest	1.9	2.5	2.0	-2.5	6.5	9.0
	HI	Test	6.4	6.5	3.0	0.5	12.5	12.0
		Retest	5.2	5.0	2.5	0.5	12.5	12.0
9	NH	Test	1.7	2.0	2.3	-2.5	5.5	8.0
		Retest	0.7	1.0	2.0	-2.5	4.5	7.0
	HI	Test	4.0	3.5	2.2	0.5	8.5	8.0
		Retest	3.4	2.5	2.2	0.5	7.5	7.0
10	NH	Test	2.7	2.5	2.0	-1.5	8.5	10.0
		Retest	2.2	2.5	1.9	-1.5	7.5	9.0
	HI	Test	5.1	4.0	3.0	1.5	14.5	13.0
		Retest	4.6	3.5	2.7	1.5	13.5	12.0
11	NH	Test	3.7	3.5	2.4	-0.5	12.5	13.0
		Retest	2.4	2.5	2.4	-0.5	8.5	9.0
	HI	Test	5.6	5.5	2.8	0.5	13.5	13.0
		Retest	5.3	5.0	2.6	0.5	11.5	11.0
12	NH	Test	2.6	2.5	1.6	0.5	6.5	6.0
		Retest	2.3	2.5	1.0	0.5	3.5	3.0
	HI	Test	4.7	4.5	2.5	-0.5	13.5	14.0
		Retest	4.4	4.5	2.4	0.5	13.5	13.0

Table 3.2. continued.

	Group	Session	Mean	Median	Standard Deviation	Minimum	Maximum	Range
Totals	NH	Test	2.6	2.5	1.9	-2.5	12.5	15.0
		Retest	2.2	2.5	1.8	-2.5	8.5	13.0
	HI	Test	5.6	4.5	3.6	-1.5	19.5	21.0
		Retest	4.6	4.5	2.7	-1.5	15.5	17.0

The SNR-50 scores for each group over the test and retest session were used to conduct a three-way repeated measures ANOVA to evaluate equivalency across lists (shown in Appendix J). The participants were nested in groups (the between-group factor) and designated as a random factor. The within-participants factors were the 12 QuickSIN standard test lists and the two sessions (test and retest). The ANOVA revealed a significant group main effect based [$F(1,770)=38.29$, $p<0.05$]. This finding was expected and is consistent with results from other speech-in-noise studies (e.g. Cox, Alexander, Gilmore, & Pusakulich 1988; Larsby, 1994) reporting that higher SNRs were needed for groups with hearing impairment to score similarly to groups with normal hearing for speech recognition in noise tasks. This occurs because of the decreased audibility and a distortion factor most likely due to reduced frequency and temporal resolution. The main effect for list [$F(11,770)=10.60$, $p<0.05$] was indicative of the non-equivalency of the SNR-50 scores between the QuickSIN test lists. A main effect for test session [$F(1,770)=50.39$, $p<0.05$] was indicative of a difference in QuickSIN SNR-50 scores across session. A three-way interaction between group, QuickSIN list, and session [$F(11,770)=2.75$, $p<0.05$] was also present. The mean QuickSIN SNR-50 scores varied

depending upon group, list, and session which creates difficulty in the interpretation of QuickSIN SNR-50 scores clinically. In order to further evaluate the individual QuickSIN lists, four one-way ANOVAs separating the group and session effects were conducted.

One-way ANOVAs and Post Hoc Analyses for QuickSIN List Effect

The SNR-50 scores by group for each session were analyzed by conducting several one-way ANOVAs and Tukey's multiple comparisons at a 95% confidence interval to determine pairs of lists that were significantly different from each other. The list involved in the most list pair combinations was then removed and another one-way ANOVA with Tukey's multiple comparisons and evaluation of the list pair differences was repeated. This statistical procedure continued until no further significant list pairs were found.

In total, six ANOVAs with post hoc analyses were conducted until no significant effect for QuickSIN list was present. For the HI group, the list effect was only significant for the initial ANOVA with all lists included. This was due to the larger variability for the HI group (standard deviation and range values) than for the NH group, For the NH group, significant effects for the QuickSIN lists were present until the final series of ANOVAs. In order to form a corpus of equivalent lists, the results from both groups needed to be used. Clinically, the corpus should be available for use with individuals who have hearing categorized as normal and impaired based on their pure-tone air and bone conduction thresholds.

For the initial one-way ANOVAs (shown in Appendix K) a significant QuickSIN list effect was present for both the test [$F(11,420)=4.05$, $p<0.05$] and retest sessions [$F(11,420)=5.58$, $p<0.05$] for the NH group and for the test session for the HI group [$F(11,420)=1.86$, $p<0.05$]. Table 3.3 shows the significant list pair differences following the first ANOVA. List 9 was involved in 12 of the 18 pairs. Also, List 9 differed from at least one other list in each group and session. Figure 3.1 illustrates the mean SNR-50 scores for the NH and HI group for each session. Inspection of Figure 3.1 shows that the mean SNR-50 scores for List 9 were lower than for the other lists for each group and session. Figure 3.1 also shows the separation in the mean SNR-50 scores between the groups and the larger difference between sessions for the HI group than for the NH group for almost every list.

Table 3.3. Tukey's Multiple Comparisons at a 95% Confidence Interval for QuickSIN List Differences by Group and Session for the Normal Hearing (NH) and Hearing Impairment (HI) Group in the Test (T) and Retest (R) Session.

Group	Session	List Pair Differences
NH	T	9,3
		9,5
		9,11
		11,2
		11,6
		11,7
	R	2,3
		2,4
		2,5
		9,1
		9,3
		9,4
		9,5
		9,10
		9,11
		9,12
HI	T	9,3
	R	9,3

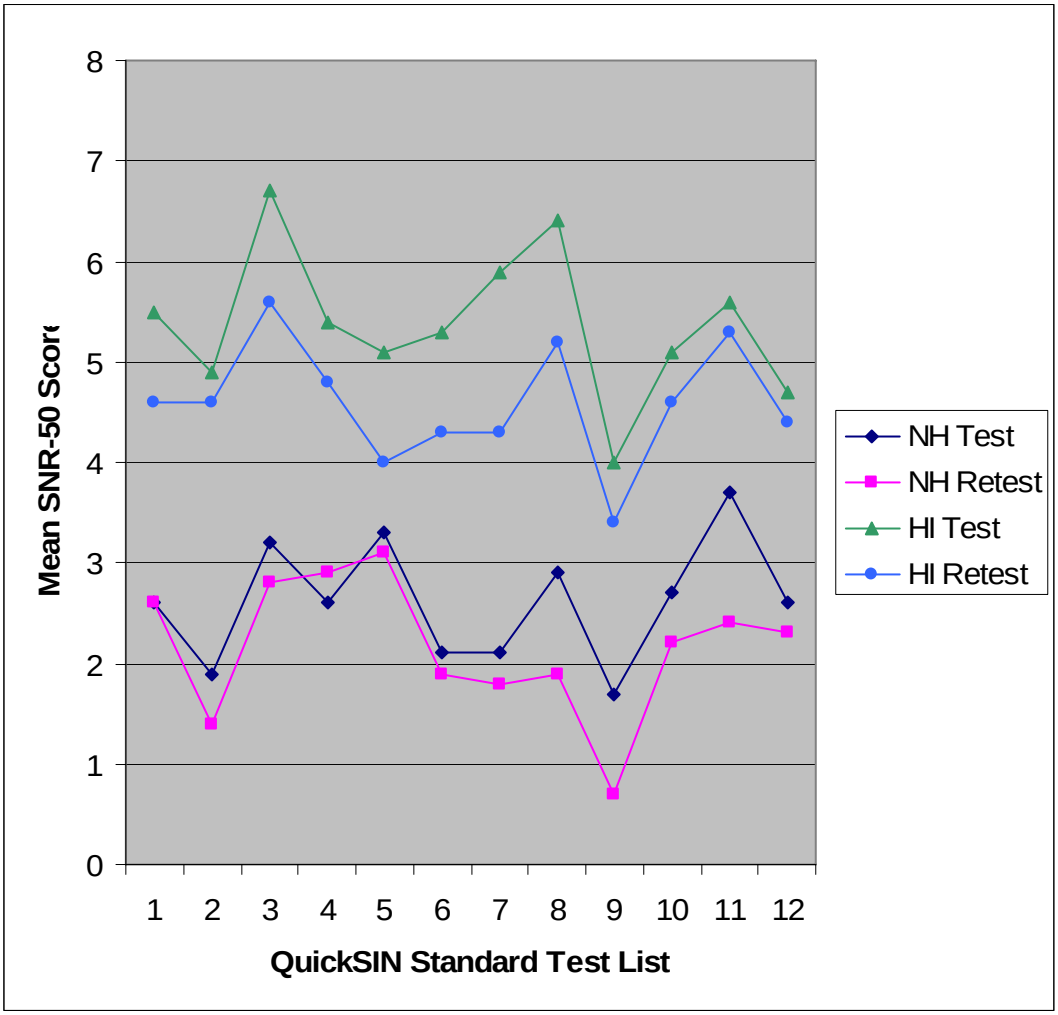

Figure 3.1. Mean SNR-50 Scores for Each QuickSIN Standard Test List for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the Test and Retest Session

List 9 was removed from the analyses for the second series of one-way ANOVAs (shown in Appendix L). Table 3.4 shows the significant list pair differences following the second ANOVA by group and session at the 95% confidence interval for Tukey's comparisons. Inspection of Table 3.4 reveals significant differences for the comparisons involving List 2 for just the NH group. Table 3.2 shows and Figure 3.1 illustrates that

lower mean SNR-50 scores (shown in Table 3.2) were obtained for List 2 for the NH group then for the other lists, except List 9 that was excluded from the analysis. Therefore List 2 was chosen for exclusion.

Table 3.4. Tukey's Multiple Comparisons at a 95% Confidence Interval for QuickSIN List Differences for the Hearing Impairment Group in the Test (T) and Retest (R) Sessions with List 9 Excluded.

Group	Session	List Pair Differences
NH	T	2,11
		7,11
	R	2,3
		2,4
		2,5
		5,7

The third series of one-way ANOVAS (shown in Appendix M) and Tukey's multiple comparisons resulted in significant list pair differences for the NH group in the test (List pairs 6, 11 and 7, 11) and the retest session (List pair 5, 7). Lists 7 and 11 were included in 2 of the 3 pairs. However, List 7 contributed to a significant difference in each NH group session.

Subsequently, the fourth series of ANOVAS (shown in Appendix N) was conducted following removal of List 7. Tukey's pairwise comparisons revealed a difference between List 6 and List 11 for the NH group in the test session. The mean SNR-50 scores and standard deviations shown in Table 3.2 indicated a larger difference in SNR-50 scores between the NH and HI group for list 6 compared with the remaining

lists. Additionally, a greater improvement in the mean SNR-50 score from the test to the retest session for the NH group was noted for List 11. Therefore, List 11 was chosen for exclusion.

The fifth series of one-way ANOVAs (shown in Appendix O) for list effect across group and session again indicated a significant effect for the NH group in both the test [$F(8,280)=2.13$, $p<0.05$] and retest [$F(8,280)=2.90$, $p<0.05$] session. Inspection of the significant pair differences revealed that Lists 3 and 6 and 5 and 6 were significantly different from each other in the test session and Lists 5 and 6 and 5 and 8 were significantly different from each other in the retest session. Inspection of Table 3.2 for the NH group shows List 5 resulted in better SNR-50 scores than the other remaining lists for the NH group. Further, there was a greater a greater difference between mean SNR-50 scores for List 6 between the test and the retest session for the NH group.

Both Lists 5 and 6 were subsequently removed from the final series of ANOVAS (shown in Appendix P). No significant list effect was noted for the remaining six lists (Lists1, 3, 4, 8, 10, and 12). Figure 3.2 shows the mean SNR-50 scores for the equivalent lists (Lists1, 3, 4, 8, 10, 12) for each group and session. Inspection of Figure 3.2 shows lower test and retest SNR-50 scores for the NH group. Further, Figure 3.2 reveals that the SNR-50 scores improved from the test to the retest session for all of the remaining lists for the HI group and for List 3, 8, 10, and 12 for the NH group. The range of mean SNR-50 scores for the remaining lists were 0.6 dB for NH test, 1.0 dB for NH retest, 2.0 dB for HI test, and 1.2 dB for HI retest. Removal of Lists 2, 5, 6, 7, 9, and 11 contributing to a main effect for list in the ANOVAs potentially provides a core of equivalent lists to determine an accuracy, or critical difference, table for clinical use based on the

equivalency across list SNR-50 scores for NH and HI listeners. However, for clinical use the lists also needed to be equivalent across SNRs.

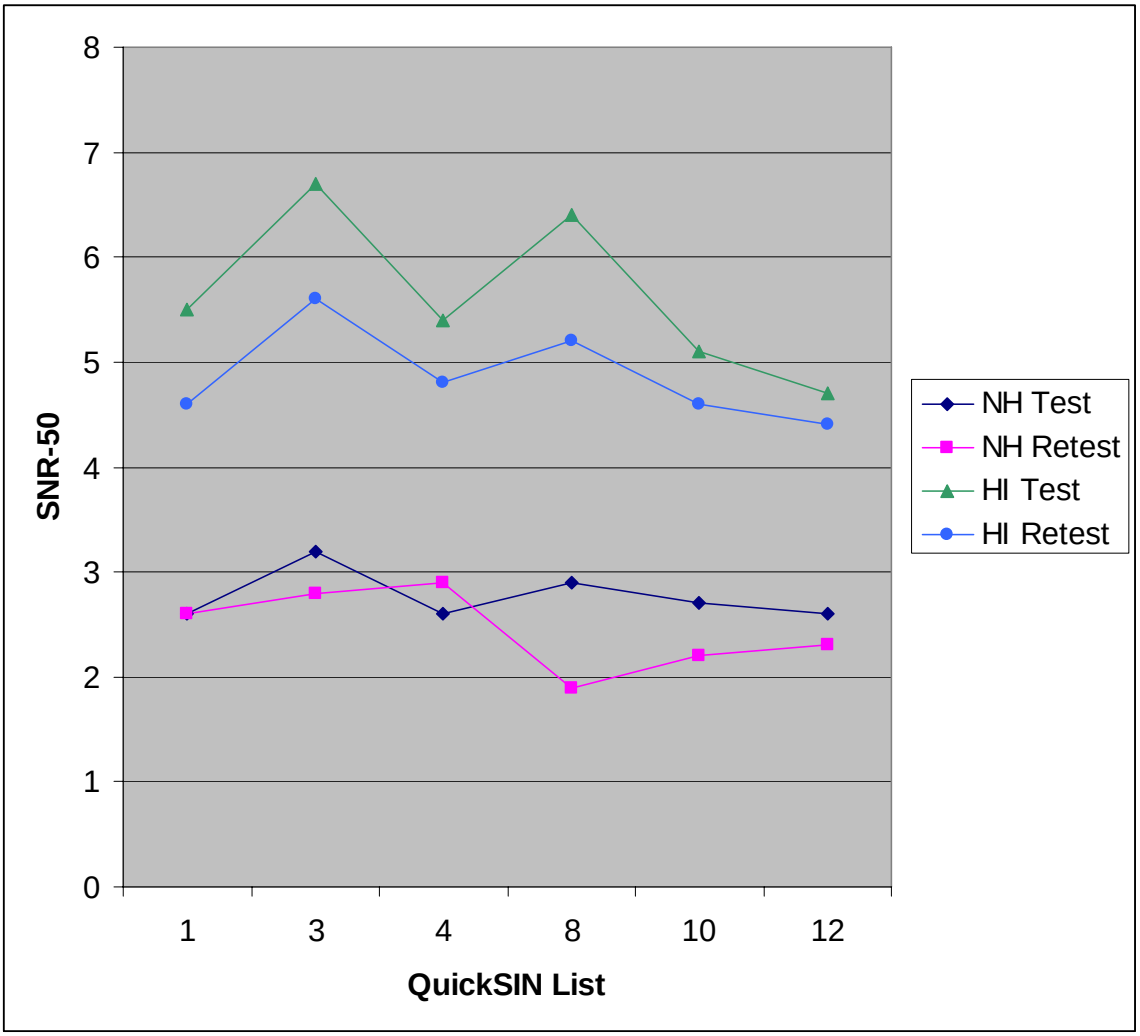

Figure 3.2. Mean SNR-50 Scores for each QuickSIN Lists for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the Test and Retest Session for the Six Lists (1, 3, 4, 8, 10, and 12) remaining following Post Hoc Analyses

QuickSIN List Equivalency across SNR

The QuickSIN lists were further evaluated to determine list equivalency across SNRs. If overall list scores were equivalent and the lists were not equivalent across SNRs, a factor other than speech-in-noise abilities may confound results obtained clinically. For example, if key words at a more favorable SNR were missed but key words at the difficult SNRs were repeated, unfamiliarity with the missed key words, not difficulty with speech-in-noise, may be the contributing factor.

To evaluate the list equivalency across the SNRs, four two-way ANOVAs (shown in Appendix Q) were conducted, one for each group in the test and retest session. The list by SNR interaction was significant for the NH group for the test [$F(55,2520)=8.24$, $p<0.05$] and for the retest session [$F(55,2520)=6.24$, $p<0.05$] and for the HI group for the test [$F(55,2520)=4.88$,$p<0.05$)] and retest session [$F(55,2520)=5.19$, $p<0.05$]. These results indicated non-equivalency across the lists by SNR.

The non-equivalency across the list by the SNRs was further examined by determining the percent of correct key word scores for each group by each SNR using whole word scoring as noted in the QuickSIN instruction manual. Appendix Q provides the number of keyword errors and percent incorrect for the NH and HI groups by SNR. Further, Appendix R provides an error count for the keywords. It should be noted that some of the keyword errors for each group were grammatical. For example, for List 8 at a SNR of 20 dB in the sentence "The stale smell of old beer lingers," 20 out of 22 errors for

the keyword ‘lingers’ the word ‘lingered’ was substituted across groups in the test session.

Figure 3.3 illustrates the mean percent of correct keywords for each QuickSIN list and SNR for the NH group in the test session. Inspection of Figure 3.3 reveals that the mean percent of keywords correctly identified decreased as the SNR decreases, as would be expected. Few keyword errors were found for the 25 and 20 dB SNRs. A slight decrease in mean percent correct keyword score at the 20 dB SNR as compared to the 15 dB SNR was found for Lists 7 and 8. Whereas the errors for List 8, previously mentioned, were grammatical, two keywords for List 7 contributed to the difference. Seven errors occurred for the keyword ‘droned’ with six errors being substitutions with the word ‘drowned’. Additionally, three errors occurred for the keyword ‘June’. Further, few keyword errors were exhibited for the 15 dB SNR except for Lists 11 and 6. The final keyword for List 11 at the SNR 15 dB accounted for the difference in this condition. Thirty-three of the 36 NH participants did not correctly repeat the keyword ‘rum’ for List 11 at the SNR of 15 dB. For List 6 at the SNR of 15 dB the two final keywords, ‘grain’ and ‘farmer’ were frequently missed. Greater variability for the mean keyword percent correct scores occurred for the SNRs 5 and 0 dB. The range of the mean keyword percent correct was 71% (List 11) to 100% (List 6) at 5 dB SNR and 3% (List 5) to 37% (List 7) at 0 dB SNR. Recall, Lists 11, 6, 5, and 7 having the extreme mean percent keyword scores at these two SNRs were removed during the list equivalency procedure.

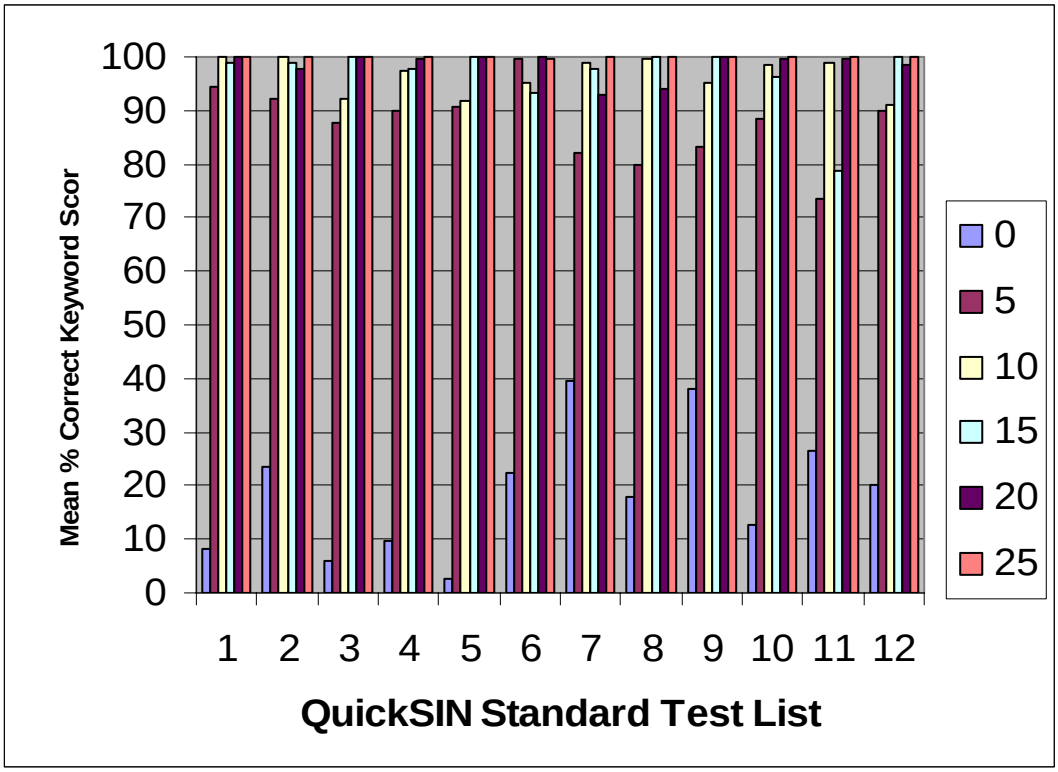

Figure 3.3. Mean Keyword Score in Percent Correct for the QuickSIN Lists by SNR for the Normal Hearing Group for the Test Session

Figure 3.4 illustrates the mean percent of correct keywords for each QuickSIN list and SNR for the HI group for the test session. Figure 3.4 shows a decrease in the mean percent correct keyword scores for all of the SNRs as would be expected for a group with hearing impairment compared with a group with normal hearing. Mean percent of correct keywords were lower and the range of scores narrower for the HI group at the 5 dB and 0 dB SNR. The range for the 5 dB SNR was 48% (List 8) to 69% (Lists 3 and 6). And for the 0 dB SNR the range was 1% (Lists 1, 5, and 10) to 17% (List 9). The mean percent correct keyword scores for the 10, 15, 20, and 25 dB SNRs showed greater variability for the HI than for the NH group (see Figure 3.2). Whereas mean percent correct scores for the NH group across all lists for the 10 dB and higher SNRs

(except list 11 at a SNR of 15 dB due to the previously noted error rate for the keyword 'rum') were higher than 90%, at least 1 list per SNR of 10 dB and higher fell below 90% for the HI group. Twenty-three of the 60 SNR by list conditions for the greater than or equal to 5 dB SNR for the NH group had a 100% correct keyword score. For these same conditions for the HI group, only five 100% correct keyword scores were obtained. Although the mean percent of correct keywords decreased as the SNR decreased seven of the lists for the HI group showed an increase in the mean percent of correct keywords for at least one SNR decrement. The finding that the mean percent of keywords correctly identified for some lists for at least one SNR decrement for the HI group in the present study is consistent with the findings of McArdle and Wilson (2006).

A common method to describe the percent of keywords correctly identified as a function of SNR employs the use of a psychometric function. That is, a psychometric function illustrates the percent of keywords correctly identified as the SNR increases or decreases. In addition, the shape and/or slope of the psychometric function provides an indication of whether or not keyword identification increases or decreases in a regular (smooth) or irregular manner as a function of SNR. Eight of the 12 standard lists exhibited an irregular psychometric function for the majority of hearing-impaired listeners in the present study. That is, their mean percent of correctly repeated keywords increased for at least one SNR decrement. This may, in part, be due to the increased difficulty for listeners with hearing impairment to use temporal gaps in the noise to gain information from the target speech. This inability to make use of the temporal gaps in

noise may be related to their poorer than normal frequency and/or temporal resolution (e.g. Baer & Moore, 1994; Eisenberg, Shannon, Schaefer Martinez, Wygonski, & Boothroyd, 2000; Helfer, 1990; Peters, 1998).

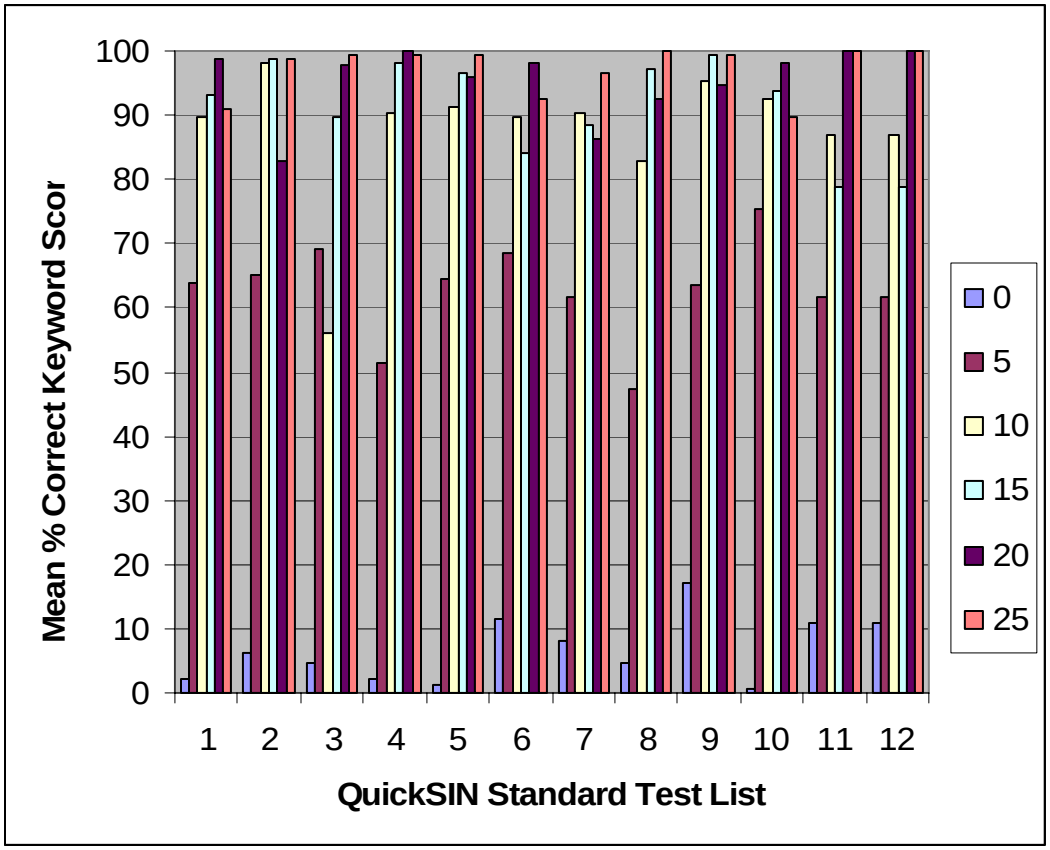

Figure 3.4. Mean Keyword Score in Percent Correct for the QuickSIN Lists by SNR (0-25 dB SNR) for the Hearing Impairment Group for the Test Session

The irregular psychometric functions for some lists for the HI group may also be due, in part, to the Quick SIN test construction. As found in the NH group, several key words were more often missed or repeated correctly in comparison to other keywords at the same SNR. Consistent with the NH group, 32 of the 36 HI participants missed the

keyword ‘rum’ in the final position of List 11 at the SNR of 15 dB. The error pattern for List 6 at a SNR of 15 dB for the HI group was consistent with the NH group. The two final keywords, ‘grain farmer’, were most frequently repeated incorrectly. Also, the keywords ‘droned’ and ‘June’ for List 7 at the SNR of 20 dB and the keyword ‘lingers’ for List 8 at the SNR of 20 dB were most often repeated incorrectly for the HI group as well as the NH group.

List 9 which was the first list eliminated during equivalency had the fewest keyword errors for both groups at the 0 dB SNR. This can be attributed to the first keyword ‘night’ which occurred during a temporal gap in the multitalker babble. For the keyword ‘night’ in List 9 at the 0 dB SNR only 7 of the 36 NH and 9 of the 36 HI participants had an incorrect response. For the 60 keywords (12 lists * 5 keywords per sentence) that occurred at the 0 dB SNR, all 36 HI participants had errors on 31 and all NH participants had errors on seven of the 60 keywords.

The sentence in List 3 at the 10 dB SNR was “Dimes showered down from all sides.” The keywords in this sentence, which was noted to be more difficult at the 10 dB SNR for the HI than the NH group, had a total of 82 out of a possible 180 keyword errors dispersed across the keywords. Although this list maintained overall equivalency, it differs from the other lists at the 10 dB SNR condition. The range for the percent incorrect keyword responses at the 10 dB SNR was 7-20% for the other five lists (Lists 1, 4, 8, 10, 12) deemed equivalent. List 3 had a 46% incorrect response rate and, therefore, should be considered non-equivalent.

Using psychometric functions, McArdle and Wilson (2006) reported the variability across list as a function of SNR but noted the variability seemed to be random.

Their findings are consistent with this study for the difficulty of List 3 at a SNR of 10 dB. However, this was not the case for other lists as a function of SNR. For example, List 11 at a SNR of 15 dB resulted in the most errors for the HI group in the present study but was the third most difficult of the 12 standard lists according to the data from McArdle and Wilson (2006). As another example for List 11 at a10 dB SNR, the HI participants repeated the keywords correctly over a range from 54-98%. However, for the same list and SNR the HI group used by McArdle and Wilson (2006) was 22-73%. These differences between the present study and McArdle and Wilson (2006) may be due binaural versus monaural listening, participant age differences, audiometric differences, or the increased number of HI participants (N = 72) in the McArdle and Wilson (2006) study.

Comparison of Equivalency to McArdle and Wilson (2006) QuickSIN Homogeneity Study

In addition to similar yet better ranges of percent keyword correct scores in the study, the overall performance for both the NH and HI participants was better than reported by McArdle and Wilson (2006). McArdle and Wilson (2006) reported mean SNR-50 scores for the 12 standard lists that ranged from 2.8-4.2 dB for their NH listeners compared with 1.7-3.7 dB in the current study using test session data. For their HI participants the mean SNR-50 scores for the 12 standard test lists ranged from 10.1 to 13.7 dB as compared with 4.0 to 6.7 dB for the present study using test session data. Recall, their previous study used monaural listening via an earphone while the present study used binaural soundfield listening. However, even if a binaural summation of 2 to

3dB occurred in the present study, it remains doubtful that this amount of improvement would bring the results of the HI group of McArdle and Wilson (2006) into the range of performance for the HI group noted in the present study. Further, McArdle and Wilson (2006) found a greater separation in the mean SNR-50 scores between the NH and HI participants compared with the present study. These group differences may be due, in large part, to air-conduction threshold differences between groups. The mean air conduction thresholds for the HI group in the present study were approximately 20 dB better at 3,000 and 4,000 Hz than the HI participants used by McArdle and Wilson (2006).

McArdle and Wilson (2006) also used a different procedure to determine list equivalency between the 12 standard QuickSIN Lists and the three QuickSIN List pairs. Their procedure consisted of rank ordering the mean SNR-50 scores per list for the HI group. The three easiest (Lists 4, 5, 15) and the three most difficult lists (Lists 7, 14, and 16) were then excluded using sequential blocking of the standard deviations. Psychometric functions were then examined and the lists that were the most irregular were eliminated (Lists 3, 9, and 18). As a result, McArdle and Wilson (2006) reported that Lists 1, 2, 6, 8, 10, 11, and 12 (and Lists 15 and 17 from the list pairs) were equivalent. It should be noted that their equivalency procedure did not include their NH participants and only used test session data because they did not do a retest.

Table 3.7 provides a rank ordering of the 12 lists by the mean SNR-50 scores for the NH and HI groups for the present study and those reported by McArdle and Wilson (2006). Even though there were differences in methodology and the air-conduction thresholds for the HI groups, there are some trends in the rank-order performance

between the studies. For example, six of the nine lists ranked in the easiest third are ranked accordingly in more than one condition. Four of the eight lists ranked in the most difficult third maintain that categorization in more than one condition. The rank order changed between the NH and HI groups for both studies. This result is not surprising and supports the need to evaluate test material for both normal and targeted hearing-impaired populations.

Table 3.8 shows the change in the list rank order position for each study. This was done by subtracting the list rank order for the NH from the rank order for the HI group as shown in Table 3.5. For example, in the McArdle and Wilson (2006) study list 1 was ranked 12th for the NH and 6th for the HI participants yielding a change in rank between the NH minus the HI group of +6. The change in rank order for each study was similar for the direction of change and the mean change in position. The change in rank order position complicates the decision to eliminate lists based on rank order of difficulty alone as done by McArdle and Wilson (2006). It should be noted, however, that the ranges of the mean SNR-50 scores were similar between the studies (NH 1.4 dB for M & W, 1.6 for the present study; HI 3.6 for M & W, 2.7 dB for the present study). Further, the ranges of mean SNR-50 scores for each group in each study fall within the reported QuickSIN 95% critical difference of 3.9 dB for comparison between 1 pair of lists.

The mean SNR-50 scores for the present study were closer to the normal performance across lists (1.9 dB) reported by Killion et al (2004) than reported by Wilson and McArdle (2006). The present study and Killion et al (2004) study used binaural listening. Killion et al (2004) also used ER-3A insert earphones and TDH headphones. However, the SNR-50 scores from the HI participants with hearing impairment in the

Killion et al. study (2004) was not used for determining list equivalency due to the variability in results from the 18 HI participants. Rather, list equivalency was based on SNR-50 scores obtained with the QuickSIN lists presented via a low-pass filter at cut-off frequencies of 750, 850, 1100, 1400, and 2000 Hz, to simulate a hearing loss, presented to NH participants. The use of low-pass filtering reduces audibility but does not simulate the distortion created by a cochlear hearing loss. As such, the equivalency of the test lists is not known until the lists are assessed with the target population (e.g. Bilger, 1984; Cox et al., 1988).

McArdle and Wilson (2006) and the present study eliminated four of the same standard QuickSIN lists (Lists3, 5, 7, and 9) while Lists 1, 8, 10, and 12 were maintained as equivalent. Of the four remaining lists (Lists 2, 4, 6, and 11), Lists 2, 6, and 11 were found to be equivalent by McArdle and Wilson (2006) while only List 4 was found to be equivalent in the present study. List 4 was rank ordered as one of the easiest lists in the McArdle and Wilson (2006) study. However, in the present study list 4 ranked in the middle third for each group. Additionally, keyword errors by SNR did not exhibit an irregular psychometric function and the test-retest mean SNR-50 difference was 0.3 dB. Therefore, List 4 maintained equivalency categorization.

List 2 was the second list eliminated in the post hoc analyses because the list was a component in each pair listing found to be significantly different by Tukey's multiple comparisons. However, these pair differences were only noted for the NH group. Further, four of the five lists paired with List 2 were subsequently eliminated. The List 2 mean SNR-50 fell within the range of SNR-50 scores for the equivalent lists for the HI group. The mean SNR-50 for the NH group was 0.7 dB better than the equivalent lists but within

a clinically acceptable difference. However, an irregular pattern for keyword errors was noted for the HI group. The highest percentage of incorrect responses across lists at the 20 dB SNR was found for List 2. The sentence, "A cruise in warm waters in a sleek yacht is fun" does not sound contemporary. The SNRs 15 through 0 dB were relatively easier in comparison to the other lists. Thus, the categorization of List 2 as non-equivalent was not changed.

The irregularity of SNR-50 scores for List 11 was discussed previously. Recall, list 11 had the highest error rate (21%) at a favorable SNR of 15 dB for the NH group. The highest error rate across lists was also noted for List 11 at the 5 dB SNR. The 0 dB SNR presentation level was ranked third easiest. The highest error rate (21%) at the 15 dB SNR was also noted for the HI group. Thus, list 11 also maintained the categorization of non-equivalent.

List 6 was removed from analyses during the same step as List 5. List 5 was also removed by McArdle and Wilson (2006) because of the low mean SNR-50. That is, list 5 was ranked second among the standard lists for their HI group but sixth for their NH group. In the present study, list 5 was ranked fourth for the HI group and 11th for the NH group. List 6 was ranked eighth among the standard lists for both groups in the McArdle and Wilson (2006) study, third for the NH group and sixth for the HI group in the present study. Across SNR, list 5 keyword error analyses did not show an irregular psychometric function, although all errors at the 10 dB SNR for both groups in the present study were attributed to the final keyword in, "The chair looked strong but had no bottom." The final two keyword positions contributed to the second highest keyword error rate for both groups for List 6 at the 15 dB SNR for the sentence, "Down that road is the way to the

grain farmer.” Test-retest mean SNR-50 scores for lists 5 and 6 were within 1 dB. Therefore, the categorization for Lists 5 and 6 was changed to equivalent.

At this point, the QuickSIN standard test lists deemed equivalent were Lists 1, 4, 5, 6, 8, 10, 12. The mean SNR-50 across these lists for the test session was 2.7 dB (SD = 1.6 dB) for the NH group, slightly above the reported normal performance (Etymotic Research, 2001) and is slightly better but within 1 dB of mean performance for monaural listening across the 9 lists deemed equivalent by McArdle and Wilson (2006). A slight separation in mean SNR-50 score between the NH and HI groups for this study was noted. The mean SNR-50 for the HI group in the present study was 5.5 dB (SD = 3.1), a difference + 2.8 dB as compared to the NH group mean SNR-50 score.

Table 3.5. Mean SNR-50 Scores Rank Ordered for the 12 Standard QuickSIN Test Lists for the Normal Hearing (NH) and Hearing Impairment (HI) Reported by McArdle and Wilson (2006) Study and the Present Study in the Test Session

	McArdle and Wilson (2006)				Present Study			
	NH		HI		NH		HI	
Rank Order	List	SNR-50	List	SNR-50	List	SNR-50	List	SNR-50
1 [a]*	7	2.8	4	10.1	9	1.7	9	4.0
2 [a]	12	2.9	5	10.1	2	1.9	12	4.7
3	9	2.9	8	11.6	6	2.1	2	4.9
4*	2	3.0	11	12.0	7	2.1	5	5.1
5*	10	3.0	2	12.0	1,4	2.6	10	5.1
6 [a]*	5	3.1	1	12.1	1,4	2.6	6	5.3
7	4	3.2	10	12.1	12	2.6	4	5.4
8 [a]*	6	3.5	6	12.4	10	2.7	1	5.5
9	8	3.9	9	12.4	8	2.9	11	5.6
10 [a]*	3	4.0	12	12.8	3	3.2	7	5.9
11 [a]	11	4.0	3	13.3	5	3.3	8	6.4
12 [a]*	1	4.2	7	13.7	11	3.3	3	6.7

[a] Indicates List Equivalency according to McArdle and Wilson (2006).

*Indicates List Equivalency in Present Study.

Table 3.6 Change in Rank Position for the Standard QuickSIN List Mean SNR-50 Scores Determined by Subtracting the Rank Order for the Hearing Impaired Group from the Rank Order for the Normally Hearing Group reported by McArdle and Wilson (2006) and in the Present Study for the Test Session

QuickSIN List	McArdle & Wilson (2006)	Current Study
1[a]*	+6	-3
2[a]	-1	-1
3	-1	-2
4*	+6	-2
5*	+4	+7
6[a]*	0	+3
7	-11	-6
8[a]*	+6	-2
9	-6	0
10[a*]	-2	+3
11[a]	+7	+3
12[a]*	-8	+5
Mean Absolute Rank Order Change	4.8	3.1

[a] Indicates List Equivalency according to McArdle and Wilson (2006).
*Indicates List Equivalency in Present Study through ANOVA Analyses.

Test-Retest Reliability of Seven Equivalent QuickSIN Test Lists

The mean SNR-50 scores for the test and retest session and the difference between the test minus the retest SNR-50 scores for the seven equivalent lists for each group are shown in Table 3.9. Inspection of Table 3.9 reveals that the SNR-50 scores improved for all lists for the HI group and all but two lists (Lists 1, 4) for the NH group. The range of improvement was .2 to 1.0 dB for the NH and .3 to 1.2 dB for the HI group. However, the improvement in mean SNR-50 score was closer to 1 dB for 5 of the 7 lists for the HI group.

Table 3.7. Mean SNR-50 Scores for the Normal Hearing (NH) and Hearing Impairment (HI) Group in the Test (T) and Retest (R) Session and Test Minus Retest for the Seven Equivalent QuickSIN Test Lists

Group	Session	QuickSIN List							
		1	4	5	6	8	10	12	Mean
NH	T	2.6	2.6	3.3	2.1	2.9	2.7	2.6	2.7
	R	2.6	2.9	3.1	1.9	1.9	2.2	2.3	2.4
	T-R	0.0	-0.3	0.2	0.2	1.0	0.5	0.3	0.3
HI	T	5.5	5.4	5.1	5.3	6.4	5.1	4.7	5.5
	R	4.6	4.8	4.0	4.3	5.2	4.6	4.4	4.6
	T-R	0.9	0.6	1.1	1.0	1.2	0.5	0.3	0.9

The test-retest SNR-50 scores were evaluated for each group with paired t-tests. The paired t-tests across the seven equivalent lists were significant for the NH ($t= 3.05$, $p<0.05$) and HI groups ($t = 5.37$, $p<0.05$). Table 3.7 shows that each group demonstrated an improvement in the SNR-50 scores. Across the lists the improvement was 0.3 dB for the NH and 0.8 dB for the HI group. Table 3.8 shows the results for the paired t-tests for

each equivalent list and across all equivalent lists for each group. (Appendix S shows the paired t-tests for each list and across lists for each session.) Inspection of Table 3.10 reveals a significant difference for Lists 1, 4, 5, 6, and 8 for the HI group but only for List 8 for the NH group. Even though the test versus retest SNR-50 scores were significantly different for several lists especially for the HI group, the differences of approximately 1 dB in test-retest score are not considered clinically significant. If, however, a more sensitive measure were required, Lists 10 and 12 which were not significantly different could be used for hearing-impaired individuals. Further, because a QuickSIN test list requires one minute for administration it would be feasible to present more than one list during a clinic session.

Table 3.8. Paired t-Test Results for Test-Retest Performance of the Seven Equivalent QuickSIN Lists

Group	Quick SIN List	T-Value	p-Value
NH	1	-0.13	0.895
	4	-1.28	0.210
	5	0.76	0.454
	6	0.61	0.549
	8	2.93	0.006*
	10	1.83	0.076
	12	1.00	0.324
	Across Lists	3.05	0.003*
HI	1	2.50	0.017*
	4	2.50	0.017*
	5	3.50	0.001*
	6	2.37	0.023*
	8	2.88	0.007*
	10	1.60	0.119
	12	0.91	0.369
	Across Lists	5.37	<0.001*

* Significant at the p< 0.05 level

Critical Difference Table for the Seven Equivalent QuickSIN Test Lists

Multiple list administrations of the QuickSIN are feasible clinically and will decrease the interval between scores needed to conclude a clinical change. Due to the clinically small yet statistically significant difference in the test-retest SNR-50 scores, only the test session data was used for the critical difference table. A critical difference table can be determined based on the standard deviation across the remaining lists. The QuickSIN manual provides a critical difference table for the 95% and 80% confidence intervals based on data from normally-hearing listeners with auditory filtering to simulate hearing loss. Table 3.11 provides critical difference information based on the NH and HI test session data from this study. The values from the Quick SIN manual (Etymotic Research, 2001) are provided for comparison. The formula to determine the confidence interval is based on the z-value for a normal distribution, the pooled standard deviation across list, and the number of lists used for testing; where

$$95\%\ \text{C.I.+}: \frac{1.96 \times pooledSD}{\sqrt{No.of\ lists}} \qquad 80\%\ \text{C.I.+}: \frac{1.28 \times pooledSD}{\sqrt{No.of\ lists}}$$

The pooled standard deviation for the seven equivalent lists was 1.579 dB for the NH group and 3.056 dB for the HI group. Inspection of Table 3.11 shows better accuracy intervals for the NH than the HI group due to the increased variability among HI participants. The accuracy values for the NH group compared to the QuickSIN model are nearly the same at for both confidence intervals. Due to the increased variability in SNR-50 scores, the confidence intervals derived from the HI group scores are wider. For most clinical applications, administration of more than one test list is desirable.

Table 3.9. Accuracy Table at the 95% and 80% Confidence Intervals (CI) in dB for the Number of Lists Presented for the Normally-Hearing (NH) and Hearing-Impaired (HI) Groups and According to the QuickSIN Manual (Etymotic Research, 2001)

Group	CI (%)	Number of QuickSIN Lists						
		1	2	3	4	5	6	7
NH	95	3.1	2.2	1.8	1.5	1.4	1.3	1.2
	80	2.0	1.4	1.2	1.0	0.9	0.8	0.8
HI	95	6.0	4.2	3.5	3.5	2.7	2.4	2.3
	80	3.9	2.8	2.3	2.0	1.7	1.6	1.5
QuickSIN	95	2.7	1.9	1.6	1.4	1.2	1.1	1.0
Manual	80	2.2	1.6	1.3	1.1	1.0	0.9	0.8

Comparison of Mean QuickSIN and NU-6 Performance

Recall the NU-6 List 1A and List 2A were presented in the test and retest session respectively in a time-locked sequence of the QuickSIN babble at a SNR equal to the participant's individual mean SNR-50 score across the 12 standard test lists. The NU-6 lists were scored as a percent correct and transformed into rationalized arcsine units (rau). Table 3.12 shows descriptive statistics related to the NU-6 rau scores (shown in Appendix T). Inspection of Table 3.12 reveals similar performance across groups for the NU-6 lists presented at the individual SNR-50 scores. Repetition of keywords embedded in sentences is an easier task than repetition of keyword following a carrier phrase due to the linguistic context in the former task.

The mean SNR-50 scores and the raus were evaluated by session to investigate the relationship between test performances. In order to determine the ability to predict the NU-6 score by the mean SNR-50 score, an ANCOVA model was used. The dependent measure was rau. Fixed factors were session and group, both with two levels. Subject was designated as random and nested within group. The interaction term, group by mean SNR-50 score was included. The mean SNR-50 score was also entered as a covariate. The complete results are shown in Appendix U. The following regression model was obtained:

$$\mathbf{Rau = b_0 + b_1 mean\ SNR\text{-}50 + b_2 Group*SNR}$$

For the test session, the group by SNR interaction was not significant at the $p<0.05$ level and was disregarded in the equation. The terms derived from the coefficients of the constant and SNR provided the following model:

$$\mathbf{Rau = 13.052 + 5.977 SNR\text{-}50}$$

The model was unsuccessful in predicting the rau score for the NU-6 lists. No trend was apparent in the predicted versus residuals plots. The inability to use the mean SNR-50 score to predict NU-6 performance was further shown in the linear regression analyses by session (shown in Appendix U). The mean SNR-50 scores were not significant at the $p<0.05$ level for either the test session and NU-6 List 1A or the retest session and NU-6 List 2A data.

Another way to evaluate the mean SNR-50 scores and NU-6 raus is to determine the correlation between scores. If the SNR-50 score is a representation of the 50% point on a performance-intensity (PI) function, then it is possible that the NU-6 rau scores would cluster around one score. This clustering would represent the corresponding point

on a PI function for single words rather than key words embedded in sentences for the same background noise. Further, if the individual mean SNR-50 scores represent a single point on the PI function, then a low correlation would be expected. The Pearson product-moment correlation was not significant at an alpha level of .05 for either NU-6 List 1A $r(70) = 0.192$, $p = 0.107$ or List 2A $r(70) = -0.95$, $p = 0.426$. This result was consistent with expected mean performance but probably occurred due to individual variability. Overall, these findings are consistent with the performance-intensity functions presented by McArdle et al. (2005) for digits and NU-6 words in a 6 speaker-babble and QuickSIN sentences. The 50-percent correct point for the QuickSIN sentences equated to approximately 20-30% correct for the NU-6 words for monaural presentation.

Table 3.10. Descriptive Statistics for the Northwestern University No. 6 Word List rau Scores in the QuickSIN Babble at the QuickSIN Derived Signal-to-Noise Ratio and SNR-50 Scores across 12 Standard Test Lists for the Normal Hearing (NH) and Hearing Impairment (HI) Group

Group	Session	Test	Mean	Median	s.d.	Minimum	Maximum	Range
NH	Test	NU-6 1A	35.1	35.2	9.4	10.9	55.5	44.6
		QuickSIN	2.5	5.6	1.0	0.8	5.2	4.4
	Retest	NU-6 2A	35.9	36.2	6.3	23.0	50.0	27.0
		QuickSIN	2.2	2.3	1.0	.03	4.5	4.2
HI	Test	NU-6 1A	35.3	35.2	8.8	16.1	51.8	35.7
		QuickSIN	5.4	5.2	2.6	1.7	12.3	10.6
	Retest	NU-6 2A	32.4	33.2	8.3	5.0	48.2	43.2
		QuickSIN	4.6	4.3	2.1	1.8	10.9	9.1

Relation between QuickSIN and APHAB Results

Recall, all of the participants completed the APHAB for the unaided condition (shown in Appendix V). A summary of the descriptive statistics for the Global APHAB and subscales scores and the SNR-50 scores across the equivalent lists (Lists 1, 4, 5, 6, 8, 10, 12) by group are shown in Table 3.13. Inspection of Table 3.13 shows lower (better) global and subscale scores and less variability for the NH compared with the HI group as would be expected. When compared with the 1995 APHAB norms (Hearing Aid Research Lab, 2004) the NH group was within the 80th percentile for Ease of Communication and hearing in Background Noise and within the 65th percentile for hearing in Reverberation and sound Aversiveness. The HI group scores when compared to unaided hearing aid users indicated less reported self-difficulty. The HI group fell within the 20th percentile for Ease of Communication and hearing in Background Noise, the 5th percentile for hearing in Reverberation, and the near the 65th percentile for the sound Aversiveness subscale. The APHAB subscale scores for the HI group were consistent with the better QuickSIN SNR-50 scores found in the present study than reported by Walden and Walden (2004) and McArdle and Wilson (2006).

The relation between the mean QuickSIN SNR-50 score averaged over the equivalent lists for the test session and the global and each subscale score of the APHAB were examined through a Pearson Product-Moment correlation analysis shown in Table 3.14. Inspection of Table 3.14 reveals low non-significant ($p<.05$) correlations for both the NH and HI groups for the relations between the APHAB scores and the SNR-50 scores. These results are not consistent with the moderate correlations found by Cox,

Alexander, and Gray (2003) between the APHAB subscales and rau scores for the 0, 5, 10, and 15 dB SNR levels of the Revised SIN test. The Cox et al. (2003) study incorporated three groups of listeners with hearing impairment; mild, moderate, and moderately-severe. The mean unaided APHAB scores in the present study appear to best match their group with mild hearing impairment.

Table 3.11. Descriptive Statistics for the Abbreviated Profile of Hearing Aid Benefit (APHAB)[a] Global and Subscale Scores and SNR-50 Scores over the Equivalent QuickSIN Lists[b] for the Normal Hearing (NH) and Hearing Impairment (HI) Group

Group	Test	Mean	Median	Standard Deviation	Minimum	Maximum	Range
NH	Global	16.5	16.0	7.0	5.0	30.0	25.0
	Background Noise	17.3	14.5	11.6	3.0	64.0	61.0
	Ease of Communication	6.3	5.0	5.4	1.0	25.0	24.0
	Reverberation	12.9	12.0	7.2	1.0	31.0	30.0
	Aversiveness	29.8	28.0	7.1	1.0	75.0	74.0
	eqSNR-50	2.8	2.9	1.0	0.9	6.2	5.3
HI	Global	36.3	34.0	14.1	4.0	70.0	67.0
	Background Noise	44.5	44.0	15.2	3.0	85.0	82.0
	Ease of Communication	33.2	25.0	20.4	5.0	79.0	74.0
	Reverberation	43.0	44.0	15.2	1.0	66.0	65.0
	Aversiveness	24.9	21.0	22.0	1.0	87.0	86.0
	eqSNR-50	5.4	4.8	2.6	1.8	12.2	10.4

[a] APHAB scores in %.
[b]Equivalent QuickSIN Lists 1, 4, 5, 6, 8, 10, 12.

Table 3.12 Pearson Product-Moment Correlations between Global and Each Subscale APHAB Score with the Mean SNR-50 Scores for the Equivalent QuickSIN Test Lists for the Normally-Hearing (NH) and Hearing-Impaired (HI) Groups. All of the Correlations were not Significant at an Alpha Level of 0.05.

	APHAB				
Group	Global	Background Noise	Ease of Communication	Reverberation	Aversiveness
NH	0.031	0.322	-0.032	0.174	-0.206
HI	0.184	0.203	0.137	0.095	0.140

Chapter 4

Conclusions and Future Research

Within the experimental constraints of this study, the following conclusions may be drawn:

1. The 12 standard QuickSIN test lists presented at 70 dB HL at 0º azimuth in a sound field were evaluated for equivalency for 36 participants with normal hearing (NH) and 36 participants with sensorineural hearing impairment (HI). The test list equivalency was determined through a series of ANOVAs by group with the QuickSIN SNR-50 score as the dependent variable and QuickSIN list as the independent variable. In addition, Tukey's multiple pairwise comparisons were used to determine list differences. The QuickSIN lists were further evaluated across SNR through ANOVAs and descriptive statistics. As a result, QuickSIN Lists 1, 4, 5, 6, 8, 10, and 12 were found to be equivalent The mean SNR-50 score across the equivalent lists was 2.7 dB (SD = 1.6) for the NH group and 5.5 dB (SD = 3.1) for the HI group. The mean SNR-50 score for the NH group was slightly higher (+.7 dB) than reported by Killion et al. (2005) but lower (-.8 dB) than reported by McArdle and Wilson (2006) for monaural listening. The mean SNR-50 score for the HI group was also lower than reported for older listeners with greater degrees of hearing impairment by Walden and Walden (2004; 2005) and McArdle and Wilson, (2006).

2. The test-retest QuickSIN SNR-50 scores for the seven equivalent lists revealed that both groups had slightly higher scores for the test compared with the retest session, especially for the HI group. However, the small test-retest difference for each of the seven equivalent lists across group was typically < 1.0 dB. This finding is consistent with McArdle and Wilson (2006).

3. Critical difference values for the number of lists administered have been determined for the NH and HI group for the 95% and 80% confidence interval. These values enable the audiologist to judge whether or not the difference in SNR-50 scores is clinically significant and can be used pre and post amplification fitting.

4. NU-6 List 1A and 2A scores obtained in the QuickSIN babble could not be predicted by the specific SNR derived from the SNR-50 scores averaged across the 12 standard test lists for the NH nor the HI group. In theory, the mean SNR-50 score represents the 50% correct point on a performance-intensity function. A lower score would be expected for the NU-6 lists. The SNR level was held constant but the task difficulty was increased by using words preceded by a carrier phrase rather than embedded in a sentence. Descriptive statistics indicated that NU-6 list 1A and 2A rau scores will cluster around 35 rau, however, with very wide variability.

5. Very low non-significant correlations ($p > 0.05$) were obtained between the QuickSIN SNR-50 scores and the global and subscale APHAB scores for the NH and HI group. This finding was inconsistent with other studies that have found moderate correlations between speech-in-noise tests and subjective measures (Cox, Alexander, and Gray, 2003; McArdle, 2004).

Future Research

The QuickSIN speech-in-noise test has gained widespread popularity in the audiology community especially for determining the effectiveness of noise-reduction hearing aids. In part, this is due to the fact that the QuickSIN is easy to administer and can be completed in less than five minutes. Unfortunately, the development of the QuickSIN test lists lacked extensive research concerning list equivalency and reliability. More unfortunately, audiologists are using the QuickSIN on a daily basis and making judgments on a person's ability to hear in noise and the effectiveness of hearing aids not knowing if the test lists are equivalent and reliable.

The present study, as well as other recent studies Walden and Walden (2004; 2005) and McArdle and Wilson, (2006) have found that all of the 12 QuickSIN test lists are not equivalent for normal and hearing impaired listeners. As such, the present study and other studies have reported that some of the QuickSIN lists are equivalent while other lists are not equivalent and should not be used. However, there is disagreement as to which lists are equivalent.

There are many ways to determine list equivalency and the possibility exists that methodology differences between studies is an important factor for determining which QuickSIN lists are both equivalent and reliable. These methodological differences including mode of presentation (monaural versus binaural, earphones versus sound field), presentation levels, age, type and configuration of hearing loss, cause of hearing loss, and duration of hearing loss have to be researched to determine if they are contributing

factors for both list equivalency and reliability. Further, future studies should include a diversified participant population to research the possible contribution of factors such as linguistic and cultural background. Until this occurs the results of the present study were interpreted to indicate that for normally hearing and hearing impaired persons with a mild to moderate bilateral symmetric sensorineural hearing loss tested in a sound field at 0° azimuth and when presented at 70 dB HL, QuickSIN Lists 1, 4, 5, 6, 8, 10, and 12 are equivalent and reliable.

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Appendix A

Pure-tone Air Conduction Thresholds

Puretone air conduction thresholds by group and by ear are provided in the tables below.

Table A.1. Audiometric Thresholds Provided in dB HL re: ANSI S3.6-2004 for the HI Group Right Ear.

ID	Audiometric Frequency (Hz)							
	250	500	1000	2000	3000	4000	6000	8000
H1	15	25	25	35	45	40	50	55
H2	35	35	40	45	50	50	65	70
H3	15	20	30	35	40	50	55	60
H4	30	30	30	50	60	60	80	85
H5	20	30	30	35	50	50	80	65
H6	20	25	35	35	35	35	50	50
H7	15	10	15	25	45	65	65	55
H8	20	25	35	40	50	60	60	65
H9	15	15	20	35	40	50	50	55
H10	10	15	25	30	35	50	55	60
H11	25	25	20	35	40	55	65	75
H12	15	25	35	50	65	60	80	55
H13	20	25	35	55	60	70	75	75
H14	30	35	40	45	45	55	65	65
H15	15	20	35	45	55	60	70	65
H16	5	10	10	20	30	40	50	50
H17	10	10	25	25	25	25	40	45
H18	25	30	25	20	10	20	30	45
H19	15	20	30	40	50	50	60	60
H20	10	15	30	30	50	60	55	85
H21	10	15	25	30	45	60	50	50
H22	15	30	30	45	55	65	65	70
H23	35	30	30	30	45	65	60	85
H24	20	25	45	60	60	55	50	55
H25	15	20	25	55	60	70	70	70
H26	10	15	35	45	50	55	40	45
H27	30	35	30	25	20	10	30	35
H28	20	25	35	45	40	45	60	65
H29	15	15	40	50	50	60	55	55
H30	20	30	40	45	60	65	70	65
H31	5	15	15	30	45	55	50	40
H32	20	25	25	30	35	25	30	25
H33	25	30	30	25	35	35	40	40
H34	10	15	25	35	45	50	65	75
H35	15	25	30	40	50	50	45	50
H36	20	25	30	50	60	70	80	80
Mean	18.1	22.8	29.4	38.1	45.4	51.1	57.2	59.6
SD	7.6	7.3	7.6	10.4	12.1	14.4	14.1	14.4

Table A.2. Audiometric Thresholds Provided in dB HL re: ANSI S3.6-2004 for the HI Group Left Ear.

ID	Audiometric Frequency (Hz)							
	250	500	1000	2000	3000	4000	6000	8000
H1	20	20	25	30	35	35	50	50
H2	35	30	40	40	45	45	50	75
H3	10	15	25	30	40	50	55	60
H4	25	20	25	40	50	60	65	80
H5	15	20	30	40	50	50	75	60
H6	25	20	35	40	35	40	50	50
H7	10	10	10	20	40	60	55	50
H8	20	25	30	40	50	55	60	55
H9	15	15	25	35	35	45	50	45
H10	10	10	25	35	40	45	50	65
H11	25	15	20	20	30	40	55	70
H12	10	25	45	55	65	65	65	55
H13	20	25	35	65	80	80	90	90
H14	30	30	35	40	45	45	55	65
H15	10	20	35	45	55	65	70	65
H16	5	10	15	25	35	35	55	60
H17	10	15	25	20	20	25	50	55
H18	25	25	25	30	30	20	35	25
H19	15	15	30	40	50	60	55	65
H20	10	10	15	20	40	50	65	85
H21	5	15	20	35	50	55	50	45
H22	20	30	35	45	50	60	70	65
H23	40	35	35	35	45	65	60	85
H24	15	20	40	50	55	60	75	70
H25	15	20	25	55	60	70	65	60
H26	10	15	35	45	50	50	55	55
H27	25	30	30	40	30	25	45	50
H28	15	25	40	45	45	45	55	60
H29	20	30	50	45	60	60	50	35
H30	25	35	35	45	50	55	55	65
H31	10	10	15	30	45	55	40	35
H32	25	25	25	30	35	30	35	35
H33	25	30	30	25	35	30	40	35
H34	10	10	20	35	45	55	60	70
H35	20	30	35	35	45	50	40	40
H36	20	25	35	55	60	70	35	85
Mean	17.9	21.1	29.3	37.8	45.3	50.1	55.1	58.8
SD	8.2	7.7	8.9	10.8	11.6	14.0	12.1	15.9

Table A.3. Audiometric Thresholds Provided in dB HL re: ANSI S3.6-2004 for the NH Group Right Ear.

ID	Audiometric Frequency (Hz)							
	250	500	1000	2000	3000	4000	6000	8000
N1	0	-5	-5	0	5	0	5	10
N2	10	0	0	0	0	0	5	5
N3	5	5	15	5	5	0	10	15
N4	0	0	5	5	5	5	15	15
N5	5	5	10	5	5	10	15	15
N6	5	10	10	15	15	15	15	20
N7	5	5	5	0	5	0	5	10
N8	5	5	0	0	5	0	10	10
N9	5	5	5	-5	5	0	10	10
N10	0	0	5	0	10	5	15	15
N11	10	0	5	5	5	15	15	15
N12	0	0	0	0	0	5	5	10
N13	5	0	0	5	5	0	10	15
N14	5	5	5	0	5	10	10	5
N15	5	0	0	5	5	5	10	10
N16	5	5	0	5	5	5	10	0
N17	5	5	5	-5	-5	5	5	0
N18	10	0	5	0	-5	-5	-5	5
N19	10	0	5	5	0	0	10	10
N20	10	5	5	10	10	5	5	10
N21	5	10	15	15	5	0	10	0
N22	10	10	10	5	10	5	5	10
N23	5	5	5	5	-5	-5	10	15
N24	15	15	15	15	10	10	15	15
N25	5	5	5	10	5	5	10	5
N26	5	5	5	10	5	0	15	10
N27	5	5	5	5	0	0	0	5
N28	0	0	0	0	-5	-5	5	0
N29	5	5	5	5	-5	-10	0	0
N30	10	10	10	5	0	0	15	10
N31	10	10	10	5	5	10	20	20
N32	10	5	10	10	0	-5	5	10
N33	5	5	10	5	5	5	15	15
N34	10	5	5	0	5	5	10	5
N35	5	0	0	5	0	-5	0	10
N36	10	5	10	10	10	5	5	10
Mean	6.1	4.2	5.6	4.6	3.6	2.6	8.9	9.6
SD	3.6	4.1	4.7	5.0	4.9	5.7	5.5	5.5

Table A.4. Audiometric Thresholds Provided in dB HL re: ANSI S3.6-2004 for the NH Group Left Ear.

ID	Audiometric Frequency (Hz)							
	250	500	1000	2000	3000	4000	6000	8000
N1	10	0	0	0	0	-5	0	0
N2	10	5	0	0	0	0	5	10
N3	15	15	10	10	10	10	10	20
N4	0	5	10	10	10	5	5	10
N5	10	10	10	5	5	10	15	10
N6	15	10	10	20	20	15	15	20
N7	15	15	0	0	5	5	0	5
N8	5	10	0	5	5	0	10	5
N9	10	15	5	0	-5	0	5	5
N10	0	0	0	0	0	0	10	15
N11	0	5	0	5	5	10	15	15
N12	0	0	0	0	-5	0	0	5
N13	0	5	0	0	0	5	10	15
N14	5	5	5	0	10	10	0	15
N15	10	10	5	5	5	5	5	10
N16	5	5	10	10	5	5	5	15
N17	10	0	0	-5	-5	5	10	10
N18	0	0	5	-5	-5	-5	-5	0
N19	5	0	10	5	0	5	15	15
N20	5	0	5	5	0	0	0	5
N21	5	5	10	15	5	5	5	5
N22	10	0	5	5	5	10	5	10
N23	5	10	5	5	-10	0	5	15
N24	10	10	10	15	10	5	15	15
N25	5	5	5	5	5	5	0	0
N26	5	5	5	5	0	-5	5	10
N27	5	10	0	0	0	0	10	15
N28	0	0	0	0	-5	-5	5	5
N29	5	5	5	10	5	0	10	0
N30	10	5	5	5	0	5	15	10
N31	10	10	10	5	15	20	20	20
N32	10	0	5	5	0	5	10	5
N33	10	10	5	0	5	5	5	10
N34	10	10	0	0	5	10	10	10
N35	5	5	0	-5	-5	-10	-5	5
N36	10	10	5	10	5	5	5	5
Mean	6.8	6.0	4.4	4.2	2.8	3.8	6.9	9.6
SD	4.5	4.8	3.9	5.7	6.1	6.0	6.0	5.8

Appendix B

Quick Speech-in-Noise (QuickSIN) Test Lists

Shown below are the QuickSIN practice (N=3) and standard test lists (N=12). Each list contains six sentences and each sentence contains five keywords (underlined). The lists were presented at 70 dB HL in a soundfield where the first sentence in each list is presented at a signal-to-noise ratio (SNR) of 25 dB and subsequent sentences are presented in 5 dB SNR decrements of 20, 15, 10, 5 and 0 dB.

Practice List A
1. The lake sparkled in the red hot sun.
2. Tend the sheep while the dog wanders.
3. Take two shares for a fair profit.
4. North winds bring colds and fevers.
5. A sash of gold silk will trim her dress.
6. Fake stones shine but cost little.

Practice List B
1. Wake and rise, and step into the green outdoors.
2. Next Sunday is the twelfth of the month.
3. Every word and phrase he speaks is true.
4. Help the weak to preserve their strength.
5. Get the trust fund to the bank early.
6. A six comes up more often than a ten.

Practice List C
1. One step more and the board will collapse.
2. Take the match and strike it against you shoe.
3. The baby puts his right foot in his mouth.
4. The pup jerked the leash as he saw a feline shape.
5. Leave now and you will arrive on time.
6. She saw a cat in the neighbor's house.

List 1 1. A white silk jacket goes with any shoes. 2. The child crawled into the dense grass. 3. Footprints showed the path he took up the beach. 4. A vent near the edge brought in fresh air. 5. It is a band of steel three inches wide. 6. The weight of the package was seen on the high scale.	List 2 1. Tear a thin sheet from the yellow pad. 2. A cruise in warm waters in a sleek yacht is fun. 3. A streak of color ran down the left edge. 4. It was done before the boy could see it. 5. Crouch before you jump or miss the mark. 6. The square peg will settle in the round hole.	List 3 1. Pitch the straw through the door of the stable. 2. The sink is the thing in which we pile dishes. 3. Post no bills on this office wall. 4. Dimes showered down from all sides. 5. Pick a card and slip it under the pack. 6. The store was jammed before the sale could start.
List 4 1. The sense of smell is better than that of touch. 2. He picked up the dice for a second roll. 3. Drop the ashes on the worn old rug. 4. The couch cover and hall drapes were blue. 5. The stems of the tall glasses cracked and broke. 6. The cleat sank deeply into the soft turf.	List 5 1. To have is better than to wait and hope. 2. The screen before the fire kept in the sparks. 3. Thick glasses helped him read the print. 4. The chair looked strong but had no bottom. 5. They told wild tales to frighten him. 6. A force equal to that would move the earth.	List 6 1. The leaf drifts along with a slow spin. 2. The pencil was cut to be sharp at both ends. 3. Down that road is the way to the grain farmer. 4. The best method is to fix it in place with clips. 5. If you mumble your speech will be lost. 6. A toad and a frog are hard to tell apart.

List 7	List 8	List 9
1. The kite dipped and swayed, but stayed aloft. 2. The beetle droned in the hot June sun. 3. The theft of the pearl pin was kept secret. 4. His wide grin earned many friends. 5. Hurdle the pit with the aid of a long pole. 6. Peep under the tent and see the clown.	1. The sun came up to light the eastern sky. 2. The stale smell of old beer lingers. 3. The desk was firm on the shaky floor. 4. A list of names is carved around the base. 5. The news struck doubt into restless minds. 6. The sand drifts over the sill of the old house.	1. Take shelter in this tent, but keep still. 2. The little tales they tell are false. 3. Press the pedal with your left foot. 4. The black trunk fell from the landing. 5. Cheap clothes are flashy but don't last. 6. At night the alarm roused him from a deep sleep.
List 10	**List 11**	**List 12**
1. Dots of light betrayed the black cat. 2. Put the chart on the mantel and tack it down. 3. The steady drip is worse than a drenching rain. 4. A flat pack takes less luggage space. 5. The gloss on top made it unfit to read. 6. Seven seals were stamped on great sheets.	1. The marsh will freeze when cold enough. 2. A gray mare walked before the colt. 3. Bottles hold four kinds of rum. 4. He wheeled the bike past the winding road. 5. Throw out the used paper cup and plate. 6. The wall phone rang loud and often.	1. The hinge on the door creaked with old age. 2. The bright lanterns were gay on the dark lawn. 3. He offered proof in the form of a large chart. 4. Their eyelids droop for want of sleep. 5. There are many ways to do these things. 6. We like to see clear weather.

Appendix C

Quick Speech-in-Noise (QuickSIN) Test Instructions

Imagine that you are at a party. There will be a woman talking and several other talkers in the background. The woman's voice is easy to hear at first, because her voice is louder than the others. Repeat each sentence the woman says. The background talkers will gradually become louder, making it difficult to understand the woman's voice, but please guess and repeat as much of each sentence as possible.

Appendix D. Northwestern University Auditory Test No. 6

List 1A		List 2A	
1. laud	26. love	1. pick	26. mill
2. boat	27. sure	2. room	27. hush
3. pool	28. knock	3. nice	28. shack
4. nag	29. choice	4. said	29. read
5. limb	30. hash	5. fail	30. rot
6. shout	31. lot	6. south	31. hate
7. sub	32. raid	7. white	32. live
8. vine	33. hurl	8. keep	33. book
9. dime	34. moon	9. dead	34. voice
10. goose	35. page	10. loaf	35. gaze
11. whip	36. yes	11. dab	36. pad
12. tough	37. reach	12. numb	37. thought
13. puff	38. king	13. juice	38. bought
14. keen	39. home	14. chief	39. turn
15. death	40. rag	15. merge	40. chair
16. sell	41. which	16. wag	41. lore
17. take	42. week	17. rain	42. bite
18. fall	43. size	18. which	43. haze
19. raise	44. mode	19. soap	44. match
20. third	45. bean	20. young	45. learn
21. gap	46. tip	21. ton	46. shawl
22. fat	47. chalk	22. keg	47. deep
23. met	48. jail	23. calm	48. gin
24. jar	49. burn	24. tool	49. goal
25. door	50. kite	25. pike	50. far

Appendix E

Abbreviated Profile of Hearing Aid Benefit

Instructions: Please circle the answers that come closest to your everyday experience. Notice that each choice includes a percentage. You can use this to help you decide on your answer. For example, is a statement is true about 75% of the time, circle 'C' for that item. If you have not experienced the situation we describe, try to think of a similar situation that you have been in and respond to that situation. If you have no idea, leave that item blank.

A	Always (99%)	E	Occasionally (25%)
B	Almost Always (87%)	F	Seldom (12%)
C	Generally (75%)	G	Never (1%)
D	Half-the-time (50%)		

1. When I am in a crowded grocery store, talking with the cashier, I can follow the conversation.	A	B	C	D	E	F	G
2. I miss a lot of information when I'm listening to a lecture.	A	B	C	D	E	F	G
3. Unexpected sounds, like a smoke detector or alarm bell are uncomfortable.	A	B	C	D	E	F	G
4. I have difficulty hearing a conversation when I'm with one of my family at home.	A	B	C	D	E	F	G

5. I have trouble understanding the dialogue in a movie or at a theater.	A	B	C	D	E	F	G
6. When I am listening to the news on the car radio, and family members are talking, I have trouble hearing the news.	A	B	C	D	E	F	G
7. When I'm at the dinner table with several people, and am trying to have a conversation with one person, understanding speech is difficult.	A	B	C	D	E	F	G
8. Traffic noises are too loud.	A	B	C	D	E	F	G
9. When I am talking with someone across a large empty room, I understand the words.	A	B	C	D	E	F	G
10. When I am in a small office, interviewing or answering questions, I have difficulty following the conversation.	A	B	C	D	E	F	G
11. When I am in a theater watching a movie or play, and the people around me are whispering and rustling paper wrappers, I can still make out the dialogue.	A	B	C	D	E	F	G
12. When I am having a quiet conversation with a friend, I have difficulty understanding.	A	B	C	D	E	F	G
13. The sounds of running water, such as a toilet or shower, are uncomfortably loud.	A	B	C	D	E	F	G
14. When a speaker is addressing a small group, and everyone is listening quietly, I have to strain to understand.	A	B	C	D	E	F	G
15. When I'm in a quiet conversation with my doctor in an examination room, it is hard to follow the conversation.	A	B	C	D	E	F	G
16. I can understand conversations even when several people are talking.	A	B	C	D	E	F	G
17. The sounds of construction work are uncomfortably loud.	A	B	C	D	E	F	G
18. It's hard for me to understand what is being said at lectures or church services.	A	B	C	D	E	F	G
19. I can communicate with others when we are in a crowd.	A	B	C	D	E	F	G
20. The sound of a fire engine siren close by is so loud that I need to cover my ears.	A	B	C	D	E	F	G
21. I can follow the words of a sermon when listening to a religious service.	A	B	C	D	E	F	G
22. The sound of screeching tires is uncomfortably loud.	A	B	C	D	E	F	G
23. I have to ask people to repeat themselves in one-on-one conversation is a quiet room	A	B	C	D	E	F	G
24. I have trouble understanding others when an air conditioner or fan is on.	A	B	C	D	E	F	G

Appendix F

INFORMED CONSENT FORM FOR SOCIAL SCIENCE RESEARCH

The Pennsylvania State University

Title of Project: **Inter-list equivalency and test-retest reliability of the Quick Speech-in-Noise Test** (Etymotic Research, 2001)

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1. **Purpose of the Study:** This study will evaluate a hearing test called the Quick Speech-in-Noise (QuickSIN) Test. The QuickSIN is used to test how well a person can hear speech in a noisy background and provides important information for a treatment plans for hard-of-hearing people. This study will look at the consistency and repeatability of the QuickSIN test results.
2. **Procedures to be followed:** Participation in this research will include completion of two test sessions about two weeks apart. A test of ear drum movement (tympanograms) and a hearing test will be completed. The tympanogram involves placing a rubber tip up to the outside of your ear canal. You will hear a low level tone and feel a slight change in pressure. The test takes less than a minute. The hearing test involves sitting in a closed quiet room. Earphones will be placed over your ears and you will be instructed to press a response button whenever you hear a beeping tone. The hearing test is done to determine the quietest levels you can hear different pitch tones for each ear. The hearing test will take less than 10 minutes. In the event that abnormal results are obtained for the tympanograms or hearing test, you will be told of the results immediately. It will then be

recommended that you contact your private medical provider for follow-up. If you have been asked to participate through the Penn State Speech and Hearing Clinic, your tympanograms and hearing test may be available. In that case, you will not complete this part of the study today. After the tests you will complete a 24-item questionnaire about your hearing. Some additional information is requested on the questionnaire. You may choose not to answer anything if you are not comfortable doing so. For the test, you will be seated in a sound-treated room in front of a loudspeaker and will be asked to sit still. The investigator will leave the room and close the door. You will be able to see the investigator through the window to the adjacent control room and to talk through a microphone. Your task will be to repeat sentences spoken by a female voice in a noise background of four people talking. Some sentences will be easier to hear than others. You will be asked to speak clearly because your responses will be tape-recorded. The tape recording may be heard later by an independent listener to judge the investigator's scoring of responses but will not contain any identifying information. Also, you will hear and repeat words heard in the same background of noise. The level of the noise will not change during the word testing. The second test session will include the tympanograms and the sentences and words in the background noise.

3. **Discomforts and Risks:** All of the testing in this study is typical to the testing that routinely occurs in audiology (hearing) clinics and the investigator is a licensed audiologist in Pennsylvania and New York. Sound levels are well within the range of normally occurring sounds in daily life. Some people may find the pressure change of the tympanogram or the earphones to be slightly uncomfortable. The discomfort, if any, is minimal.

4. **Benefits:**

a. The benefits to participants include a better understanding of their ability to hear speech in noise and the experience of being part of a research study.

b. The benefits to society include the evaluation of a speech in noise test that is easy to administer in clinic settings and has the potential to be used in the rehabilitation process for hard-of-hearing people. The QuickSIN is a fast, easy test that is designed to reflect listening in a common social setting where conversations often occur.

5. **Duration/Time:** The estimated time commitment for both the first session is one hour and for the second session is one-half hour.

6. **Statement of Confidentiality:** Your name and identifying information will remain confidential to the investigator. All test results obtained during the sessions will be coded with only the investigator having access to the code. The informed consent forms will be kept in a locked cabinet to which only the investigator has a key and will be maintained for three years after the study has ended. The acknowledgement of receipt of payment forms will remain within the Department of Communication Sciences and Disorders for financial records. The tape recordings will be used to check the reliability of the investigator's scoring of the test results. An independent listener will hear the tapes with no identifying information attached to the tapes. The tapes will be kept in a locked cabinet to which only the investigator has the key and will be erased upon completion of the study by the year 2005. Test results will not be presented in any form that identifies the individual participant in the study. The Office for Research Protections and the Biomedical Institutional Review Board may review records related to this project.

7. **Right to Ask Questions:** You have the right to ask questions and have those questions answered. All questions should be directed to the investigator at any time during the session. You may also contact Penn State's Office for Research Protections with questions about the rights of research participants (814) 865-1775.

8. **Compensation:** You will receive $10.00 upon the completion of the second test session and will be asked to sign a form to acknowledge your receipt of the payment.
9. **Voluntary Participation:** Participation is voluntary. You can withdraw from the study at any time by notifying the principal investigator and can decline to answer specific questions.

You must be 18 years of age or older to consent to participate in this research study. If you consent to participate in this research study and to the terms above, please sign your name and indicate the date below.

You will be given a copy of this consent form to keep for your records.

I consent to participate in this research study and to the best of my knowledge do not have any situations or difficulties that may increase my potential for risk in this study.

I understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided. I also understand that I am not waiving any rights that I may have against the University for injury resulting from negligence of the University or investigators.

_____ _____

Participant Signature Date

I, the undersigned, verify that the above informed consent procedure has been followed.

_____ _____

Investigator Signature Date

Appendix G

QuickSIN Standard Test List Experimental Schedule

Shown below is the counterbalanced schedule for the order in which the QuickSIN test lists were presented. The 36 participants in the normal hearing (NH) and the hearing impairment (HI) group followed the same counterbalanced schedule.

NH or HI Participant No.			QuickSIN List Order											
1	13	25	1	2	3	4	5	6	7	8	9	10	11	12
2	14	26	2	3	4	5	6	7	8	9	10	11	12	1
3	15	27	3	4	5	6	7	8	9	10	11	12	1	2
4	16	28	4	5	6	7	8	9	10	11	12	1	2	3
5	17	29	5	6	7	8	9	10	11	12	1	2	3	4
6	18	30	6	7	8	9	10	11	12	1	2	3	4	5
7	19	31	7	8	9	10	11	12	1	2	3	4	5	6
8	20	32	8	9	10	11	12	1	2	3	4	5	6	7
9	21	33	9	10	11	12	1	2	3	4	5	6	7	8
10	22	34	10	11	12	1	2	3	4	5	6	7	8	9
11	23	35	11	12	1	2	3	4	5	6	7	8	9	10
12	24	36	12	1	2	3	4	5	6	7	8	9	10	11

Appendix H

ANOVAs on QuickSIN Lists to Evaluate a Practice Effect

This appendix shows the results of the ANOVAs that were conducted on the data (SNR-50 scores) for the test and retest sessions to examine a practice effect. The QuickSIN SNR-50 score was the dependent measure. The results of any follow-up ANOVAS are listed immediately following the relevant factors. In the tables, PO = presentation order and G = group for collapsed data. For the factors of list presentation order and group and their interactions, the degrees of freedom and mean squares are shown.

Table H.1. Two-way ANOVA on Presentation Order of QuickSIN Practice and Standard Test Lists in the Test Session to Evaluate a Test Practice Effect.

Source	SS	df	MS	F	p
PO	179.95	14	12.85	1.94	0.020
G	2044.25	1	2044.25	308.31	0.000
PO x G	97.84	14	6.99	1.05	0.397
Error	6564.29	990	6.63		

Table H.2. Two-way ANOVA on Presentation Order of QuickSIN Practice and Standard Test Lists in the Retest Session to Evaluate a Test Practice Effect.

Source	SS	df	MS	F	p
PO	124.36	14	8.88	1.63	0.064
G	1674.55	1	1674.55	308.22	0.000
PO x G	129.08	14	9.22	1.70	0.051
Error	5541.71	1020	5.43		

Table H.3. One-way ANOVA on Presentation Order for the Group with Normal Hearing in Test Session

Source	SS	df	MS	F	p
PO	136.09	14	9.72	1.67	0.058
Error	3055.50	525	5.82		

Table H.4. One-way ANOVA on Presentation Order for the Group with Hearing Impairment in the Test Session.

Source	SS	df	MS	F	p
PO	226.4	14	13.2	1.49	0.109
Error	5692.6	525	10.8		

Table H.5. One-way ANOVA on Presentation Order for the Group with Normal Hearing in Retest Session

Source	SS	df	MS	F	p
PO	31.64	14	2.26	0.69	0.784
Error	1667.60	510	3.27		

Table H.6. One-way ANOVA on Presentation Order for the Group with Hearing Impairment in Retest Session

Source	SS	df	MS	F	p
PO	221.80	14	15.84	2.09	0.011
Error	3874.11	510	7.60		

Table H.7. Two-way ANOVA on Presentation Order of QuickSIN Standard Test Lists and Group for the Test Session

Source	SS	df	MS	F	p
PO	9.8	11	0.89	0.13	1.000
G	1507.21	1	1507.21	227.76	0.000
PO x G	19.10	11	1.74	0.26	0.992
Error	5241.03	792	6.62		

Appendix I

SNR-50 Scores for QuickSIN Standard Test Lists

Table I.1. QuickSIN Standard Test List SNR-50 Scores for the Normal Hearing Group for the Test Session

Participant	Standard Test List											
	1	2	3	4	5	6	7	8	9	10	11	12
1	5.5	1.5	2.5	1.5	2.5	2.5	3.5	4.5	3.5	2.5	1.5	2.5
2	3.5	2.5	3.5	3.5	2.5	2.5	2.5	4.5	1.5	2.5	2.5	0.5
3	2.5	3.5	2.5	0.5	3.5	3.5	4.5	4.5	5.5	2.5	4.5	5.5
4	-0.5	-0.5	1.5	1.5	2.5	1.5	-0.5	3.5	-1.5	0.5	4.5	2.5
5	2.5	1.5	2.5	3.5	2.5	2.5	1.5	3.5	0.5	2.5	3.5	1.5
6	2.5	-1.5	2.5	2.5	2.5	0.5	-0.5	-1.5	0.5	0.5	0.5	0.5
7	-1.5	-0.5	3.5	1.5	3.5	2.5	-0.5	1.5	0.5	3.5	2.5	2.5
8	2.5	3.5	2.5	3.5	3.5	2.5	2.5	3.5	0.5	2.5	4.5	4.5
9	3.5	0.5	2.5	2.5	4.5	2.5	5.5	4.5	2.5	3.5	4.5	2.5
10	2.5	1.5	2.5	2.5	2.5	1.5	1.5	0.5	-2.5	1.5	5.5	1.5
11	3.5	4.5	2.5	5.5	4.5	3.5	3.5	4.5	4.5	8.5	3.5	6.5
12	2.5	1.5	2.5	2.5	2.5	2.5	-0.5	2.5	4.5	4.5	4.5	4.5
13	2.5	1.5	0.5	1.5	0.5	2.5	1.5	1.5	1.5	1.5	1.5	0.5
14	1.5	2.5	2.5	4.5	2.5	1.5	0.5	4.5	3.5	2.5	-0.5	2.5
15	5.5	2.5	3.5	3.5	2.5	4.5	5.5	4.5	1.5	5.5	5.5	3.5
16	2.5	0.5	2.5	3.5	2.5	1.5	3.5	0.5	-2.5	-0.5	1.5	1.5
17	2.5	0.5	2.5	2.5	2.5	2.5	0.5	1.5	-0.5	2.5	2.5	0.5
18	2.5	3.5	7.5	2.5	7.5	2.5	3.5	8.5	4.5	7.5	12.5	3.5

Table I.2. continued.

Participant	Standard Test List											
	1	2	3	4	5	6	7	8	9	10	11	12
19	-0.5	-1.5	2.5	-1.5	2.5	0.5	5.5	3.5	2.5	-1.5	3.5	3.5
20	2.5	2.5	3.5	2.5	4.5	1.5	2.5	3.5	-0.5	4.5	5.5	4.5
21	2.5	0.5	1.5	1.5	4.5	0.5	0.5	-0.5	1.5	2.5	2.5	2.5
22	5.5	0.5	3.5	2.5	4.5	2.5	3.5	3.5	3.5	1.5	2.5	3.5
23	2.5	5.5	4.5	1.5	4.5	4.5	2.5	4.5	5.5	2.5	4.5	1.5
24	2.5	2.5	2.5	2.5	3.5	1.5	1.5	4.5	1.5	2.5	4.5	1.5
25	2.5	2.5	2.5	2.5	3.5	2.5	3.5	4.5	2.5	4.5	3.5	1.5
26	2.5	2.5	3.5	1.5	2.5	1.5	-0.5	1.5	-2.5	1.5	1.5	0.5
27	3.5	3.5	3.5	2.5	2.5	2.5	3.5	2.5	2.5	2.5	7.5	2.5
28	2.5	0.5	2.5	1.5	1.5	0.5	-0.5	-0.5	2.5	1.5	1.5	3.5
29	2.5	1.5	4.5	2.5	4.5	2.5	-0.5	-0.5	-0.5	2.5	4.5	1.5
30	2.5	4.5	9.5	2.5	5.5	2.5	6.5	2.5	5.5	6.5	8.5	5.5
31	1.5	5.5	3.5	6.5	3.5	2.5	3.5	2.5	3.5	1.5	4.5	2.5
32	2.5	1.5	3.5	4.5	2.5	3.5	1.5	2.5	3.5	1.5	4.5	4.5
33	2.5	-0.5	4.5	2.5	2.5	1.5	0.5	3.5	0.5	3.5	1.5	0.5
34	3.5	2.5	3.5	2.5	3.5	-0.5	-0.5	4.5	-2.5	3.5	2.5	3.5
35	2.5	3.5	4.5	3.5	3.5	0.5	0.5	3.5	2.5	2.5	2.5	3.5
36	2.5	3.5	1.5	4.5	2.5	0.5	2.5	3.5	2.5	0.5	3.5	0.5

Table I.3. QuickSIN Standard Test List SNR-50 Scores for the Normal Hearing Group for the Test Session

Participant	Standard Test List											
	1	2	3	4	5	6	7	8	9	10	11	12
1	2.5	2.5	2.5	2.5	3.5	3.5	3.5	2.5	2.5	2.5	-0.5	3.5
2	3.5	2.5	3.5	4.5	2.5	2.5	0.5	3.5	-0.5	2.5	3.5	2.5
3	2.5	1.5	2.5	2.5	3.5	4.5	2.5	2.5	4.5	3.5	5.5	2.5
4	1.5	1.5	2.5	1.5	2.5	0.5	0.5	-2.5	-0.5	-0.5	3.5	2.5
5	2.5	1.5	2.5	3.5	2.5	2.5	1.5	3.5	0.5	2.5	3.5	1.5
6	0.5	-1.5	2.5	2.5	3.5	0.5	-0.5	3.5	-2.5	2.5	-0.5	1.5
7	-1.5	0.5	2.5	1.5	4.5	-2.5	-0.5	0.5	-2.5	0.5	0.5	0.5
8	2.5	2.5	2.5	1.5	2.5	2.5	2.5	5.5	1.5	2.5	3.5	3.5
9	2.5	0.5	3.5	3.5	0.5	2.5	2.5	2.5	2.5	4.5	0.5	1.5
10	3.5	0.5	1.5	1.5	2.5	1.5	0.5	0.5	-2.5	-1.5	0.5	0.5
11	2.5	3.5	3.5	6.5	4.5	3.5	4.5	1.5	1.5	7.5	5.5	0.5
12	2.5	-1.5	3.5	2.5	2.5	2.5	3.5	0.5	2.5	2.5	2.5	3.5
13	2.5	2.5	1.5	4.5	0.5	1.5	0.5	-1.5	1.5	2.5	1.5	2.5
14	2.5	1.5	3.5	4.5	2.5	0.5	2.5	3.5	0.5	2.5	-0.5	2.5
15	4.5	1.5	3.5	2.5	5.5	4.5	3.5	3.5	-1.5	3.5	-0.5	3.5
16	2.5	0.5	0.5	1.5	1.5	1.5	1.5	1.5	0.5	2.5	0.5	1.5
17	2.5	-1.5	1.5	1.5	2.5	2.5	0.5	-0.5	-0.5	1.5	0.5	1.5
18	2.5	3.5	3.5	2.5	8.5	2.5	3.5	3.5	2.5	7.5	8.5	2.5

Table I.4. continued.

Participant	QuickSIN Standard Test List											
	1	2	3	4	5	6	7	8	9	10	11	12
19	-1.5	-1.5	-0.5	-0.5	3.5	1.5	0.5	2.5	1.5	-0.5	3.5	0.5
20	3.5	1.5	1.5	3.5	3.5	3.5	0.5	2.5	0.5	-0.5	2.5	1.5
21	2.5	2.5	2.5	1.5	3.5	0.5	1.5	1.5	3.5	1.5	2.5	1.5
22	4.5	1.5	3.5	1.5	3.5	0.5	3.5	2.5	3.5	1.5	0.5	2.5
23	2.5	2.5	4.5	2.5	4.5	2.5	4.5	3.5	1.5	4.5	1.5	2.5
24	2.5	-1.5	3.5	2.5	3.5	5.5	1.5	5.5	-1.5	2.5	2.5	2.5
25	3.5	1.5	2.5	3.5	2.5	2.5	3.5	6.5	1.5	2.5	5.5	1.5
26	1.5	2.5	3.5	2.5	2.5	0.5	0.5	-0.5	-2.5	-0.5	0.5	1.5
27	3.5	2.5	3.5	2.5	2.5	2.5	-0.5	2.5	-1.5	2.5	3.5	3.5
28	2.5	1.5	2.5	1.5	2.5	0.5	0.5	0.5	1.5	0.5	0.5	3.5
29	2.5	0.5	1.5	2.5	3.5	3.5	1.5	-1.5	-0.5	0.5	3.5	3.5
30	7.5	3.5	8.5	2.5	3.5	2.5	5.5	2.5	4.5	2.5	8.5	2.5
31	0.5	4.5	2.5	5.5	2.5	2.5	4.5	2.5	2.5	1.5	2.5	3.5
32	2.5	0.5	3.5	4.5	2.5	4.5	2.5	1.5	2.5	3.5	4.5	3.5
33	3.5	2.5	4.5	2.5	2.5	0.5	0.5	0.5	1.5	2.5	2.5	2.5
34	3.5	-1.5	1.5	2.5	3.5	-2.5	-1.5	-0.5	-1.5	1.5	-0.5	1.5
35	3.5	1.5	3.5	4.5	3.5	0.5	0.5	2.5	0.5	2.5	0.5	3.5
36	2.5	2.5	1.5	6.5	2.5	0.5	2.5	-0.5	-1.5	1.5	4.5	3.5

Table I.5. QuickSIN Standard Test List SNR-50 Scores for the Hearing Impairment Group for the Test Session

Participant	Standard Test List											
	1	2	3	4	5	6	7	8	9	10	11	12
1	3.5	2.5	7.5	3.5	4.5	-1.5	5.5	7.5	1.5	2.5	4.5	4.5
2	2.5	2.5	4.5	5.5	3.5	4.5	6.5	7.5	2.5	3.5	2.5	1.5
3	12.5	14.5	17.5	8.5	12.5	7.5	16.5	8.5	5.5	14.5	7.5	13.5
4	2.5	4.5	5.5	4.5	4.5	2.5	4.5	6.5	3.5	2.5	3.5	6.5
5	3.5	5.5	6.5	5.5	3.5	4.5	3.5	7.5	6.5	3.5	5.5	5.5
6	5.5	9.5	6.5	7.5	5.5	7.5	4.5	7.5	3.5	7.5	8.5	3.5
7	5.5	7.5	6.5	7.5	2.5	2.5	2.5	6.5	5.5	4.5	4.5	6.5
8	13.5	6.5	7.5	5.5	7.5	11.5	8.5	6.5	5.5	8.5	7.5	4.5
9	13.5	8.5	18.5	7.5	8.5	18.5	19.5	12.5	8.5	12.5	12.5	7.5
10	4.5	5.5	2.5	5.5	6.5	6.5	3.5	5.5	7.5	3.5	4.5	6.5
11	3.5	3.5	1.5	8.5	3.5	0.5	3.5	2.5	1.5	4.5	4.5	2.5
12	8.5	5.5	8.5	7.5	4.5	9.5	9.5	7.5	1.5	6.5	5.5	3.5
13	13.5	11.5	17.5	7.5	10.5	13.5	17.5	12.5	7.5	12.5	13.5	6.5
14	8.5	5.5	8.5	6.5	7.5	8.5	7.5	4.5	3.5	4.5	7.5	6.5
15	7.5	7.5	12.5	4.5	4.5	10.5	4.5	10.5	5.5	3.5	7.5	7.5
16	1.5	2.5	3.5	5.5	2.5	2.5	4.5	7.5	2.5	3.5	4.5	7.5
17	2.5	2.5	3.5	3.5	2.5	2.5	4.5	4.5	0.5	3.5	3.5	1.5
18	4.5	3.5	3.5	1.5	2.5	5.5	4.5	7.5	2.5	2.5	3.5	2.5

Table I.6 continued.

Participant	Standard Test List											
	1	2	3	4	5	6	7	8	9	10	11	12
19	2.5	0.5	3.5	4.5	2.5	2.5	3.5	3.5	3.5	1.5	5.5	2.5
20	2.5	1.5	0.5	5.5	2.5	0.5	2.5	2.5	2.5	3.5	0.5	1.5
21	5.5	4.5	7.5	6.5	2.5	3.5	7.5	4.5	3.5	6.5	7.5	3.5
22	1.5	1.5	2.5	3.5	2.5	0.5	1.5	0.5	2.5	2.5	1.5	-0.5
23	2.5	6.5	3.5	5.5	4.5	3.5	4.5	4.5	4.5	6.5	2.5	5.5
24	4.5	6.5	9.5	3.5	9.5	7.5	6.5	5.5	3.5	5.5	5.5	5.5
25	9.5	7.5	12.5	6.5	7.5	11.5	6.5	9.5	8.5	4.5	8.5	5.5
26	9.5	6.5	8.5	7.5	8.5	4.5	6.5	3.5	4.5	6.5	7.5	4.5
27	3.5	-0.5	0.5	2.5	2.5	2.5	1.5	1.5	2.5	3.5	2.5	2.5
28	4.5	1.5	7.5	8.5	5.5	1.5	6.5	11.5	1.5	5.5	8.5	4.5
29	2.5	3.5	6.5	5.5	3.5	3.5	3.5	6.5	4.5	2.5	5.5	3.5
30	4.5	4.5	8.5	4.5	4.5	1.5	2.5	8.5	3.5	3.5	4.5	3.5
31	3.5	5.5	7.5	4.5	7.5	7.5	7.5	8.5	4.5	5.5	8.5	4.5
32	3.5	3.5	4.5	5.5	4.5	5.5	4.5	3.5	6.5	3.5	6.5	8.5
33	3.5	2.5	2.5	2.5	2.5	2.5	3.5	2.5	1.5	2.5	3.5	3.5
34	7.5	2.5	2.5	4.5	7.5	8.5	3.5	9.5	7.5	6.5	4.5	4.5
35	2.5	5.5	3.5	3.5	4.5	1.5	4.5	2.5	2.5	3.5	2.5	2.5
36	8.5	4.5	7.5	4.5	4.5	6.5	6.5	8.5	1.5	4.5	5.5	5.5

Table I.7. QuickSIN Standard Test List SNR-50 Scores for the Hearing Impairment Group for the Retest Session

Participant	Standard Test List											
	1	2	3	4	5	6	7	8	9	10	11	12
1	2.5	2.5	6.5	2.5	2.5	1.5	4.5	5.5	2.5	3.5	4.5	5.5
2	2.5	6.5	3.5	7.5	2.5	5.5	6.5	4.5	2.5	3.5	3.5	3.5
3	10.5	9.5	15.5	9.5	9.5	12.5	9.5	8.5	7.5	13.5	11.5	13.5
4	2.5	2.5	2.5	4.5	3.5	3.5	3.5	6.5	2.5	2.5	4.5	4.5
5	3.5	7.5	5.5	3.5	3.5	2.5	2.5	3.5	6.5	2.5	6.5	4.5
6	5.5	6.5	4.5	3.5	5.5	4.5	6.5	5.5	3.5	3.5	8.5	6.5
7	2.5	9.5	4.5	3.5	2.5	2.5	3.5	3.5	3.5	4.5	2.5	5.5
8	10.5	6.5	7.5	5.5	5.5	6.5	5.5	7.5	3.5	7.5	7.5	5.5
9	13.5	8.5	13.5	7.5	9.5	12.5	14.5	12.5	7.5	13.5	8.5	8.5
10	6.5	3.5	6.5	3.5	3.5	3.5	4.5	4.5	1.5	3.5	6.5	4.5
11	1.5	5.5	3.5	8.5	4.5	3.5	2.5	3.5	2.5	2.5	4.5	4.5
12	3.5	7.5	7.5	6.5	4.5	6.5	7.5	4.5	1.5	6.5	6.5	3.5
13	9.5	13.5	9.5	6.5	8.5	9.5	9.5	4.5	7.5	5.5	9.5	8.5
14	4.5	5.5	9.5	7.5	2.5	4.5	4.5	5.5	1.5	5.5	6.5	4.5
15	3.5	5.5	8.5	5.5	3.5	13.5	6.5	7.5	2.5	5.5	8.5	7.5
16	5.5	3.5	1.5	5.5	2.5	2.5	1.5	7.5	0.5	2.5	2.5	4.5
17	2.5	3.5	4.5	2.5	4.5	1.5	4.5	4.5	2.5	3.5	2.5	1.5
18	2.5	2.5	3.5	3.5	3.5	4.5	0.5	2.5	0.5	2.5	3.5	3.5

Table I.8. continued.

Participant	QuickSIN Standard Test List											
	1	2	3	4	5	6	7	8	9	10	11	12
19	2.5	-1.5	1.5	2.5	3.5	2.5	0.5	2.5	2.5	2.5	0.5	2.5
20	2.5	0.5	2.5	4.5	4.5	3.5	0.5	4.5	2.5	2.5	2.5	0.5
21	6.5	3.5	3.5	4.5	3.5	3.5	3.5	4.5	2.5	3.5	5.5	2.5
22	4.5	0.5	2.5	4.5	1.5	1.5	1.5	0.5	1.5	2.5	0.5	2.5
23	4.5	3.5	4.5	3.5	2.5	1.5	3.5	5.5	0.5	3.5	7.5	3.5
24	4.5	6.5	10.5	2.5	3.5	4.5	4.5	6.5	6.5	6.5	4.5	2.5
25	4.5	6.5	5.5	7.5	4.5	7.5	5.5	5.5	7.5	5.5	7.5	2.5
26	8.5	4.5	7.5	3.5	4.5	4.5	4.5	3.5	4.5	8.5	5.5	4.5
27	2.5	0.5	1.5	2.5	2.5	2.5	2.5	2.5	2.5	1.5	3.5	1.5
28	3.5	1.5	6.5	6.5	3.5	0.5	3.5	7.5	1.5	4.5	5.5	3.5
29	2.5	2.5	3.5	4.5	2.5	0.5	1.5	0.5	4.5	2.5	3.5	2.5
30	2.5	8.5	5.5	5.5	3.5	2.5	7.5	9.5	7.5	5.5	10.5	4.5
31	3.5	4.5	8.5	3.5	4.5	1.5	3.5	8.5	4.5	2.5	4.5	5.5
32	6.5	3.5	7.5	4.5	4.5	5.5	4.5	3.5	5.5	5.5	5.5	3.5
33	2.5	0.5	2.5	2.5	2.5	0.5	0.5	2.5	0.5	2.5	1.5	3.5
34	3.5	3.5	3.5	4.5	4.5	4.5	3.5	5.5	4.5	4.5	5.5	5.5
35	2.5	3.5	2.5	4.5	3.5	1.5	2.5	5.5	2.5	3.5	4.5	4.5
36	4.5	3.5	2.5	3.5	3.5	4.5	4.5	7.5	1.5	4.5	4.5	3.5

Appendix J

ANOVAs on QuickSIN Main Effects and Interactions

This appendix shows the results of the ANOVAs that were conducted to examine inter-list equivalency of the QuickSIN lists for the normally-hearing (NH) and hearing-impaired (HI) groups across the test and retest sessions. The QuickSIN SNR-50 scores were the dependent measure. Three independent factors were fixed: Group (G;2 levels), QuickSIN lists (QL; 12 levels), and Test Session (TS; 2 levels). Participant (P) was designated as a random factor and was nested within Group. The results of any follow-up ANOVAS are listed immediately following the relevant factors. For the factors of group and participant, QuickSIN list, session, and their interactions, the degrees of freedom and mean squares are shown. Additionally, four separate one-way ANOVAS for QuickSIN list for each group and session are shown.

Table J.1. Three-way Repeated Measures ANOVA on Group (G), QuickSIN List (QL), and Test Session (TS).

Source	SS	df	MS	F	p
G	2919.28	1	2919.28	38.29	0.000
S(G)	5337.20	70	76.25	13.37	0.000[a]
QL	468.17	11	42.56	10.60	0.000
G*QL	125.83	11	11.44	2.85	0.001
QL*S(G)	3090.50	770	4.01	2.38	0.000
TS	170.00	1	170.00	50.39	0.000
G*TS	13.02	1	13.02	3.86	0.053
TS*S(G)	236.14	70	3.37	2.00	0.000
QL*TS	27.64	11	2.51	1.49	0.129
G*QL*TS	50.87	11	4.62	2.75	0.002
Error	1296.33	770	1.68		

[a]Not an exact F-test.

Table J.2. One-way ANOVA on QuickSIN List for the Group with Normal Hearing in the Test Session.

Source	SS	df	MS	F	p
QL	142.62	11	12.97	4.05	0.000
Error	1344.36	420			

Table J.3. One-way ANOVA on QuickSIN List for the Group with Normal Hearing in the Retest Session.

Source	SS	df	MS	F	p
QL	181.58	11	16.51	5.58	0.000
Error	1242.75	420			

Table J.4. One-way ANOVA on QuickSIN List for the Group with Hearing Impairment in the Test Session.

Source	SS	df	MS	F	p
QL	212.70	11	19.30	1.86	0.043
Error	4361.20	420			

Table J.5. One-way ANOVA on QuickSIN List for the Group with Hearing Impairment in the Retest Session

Source	SS	df	MS	F	p
QL	135.62	11	12.33	1.72	0.067
Error	3011.86	420			

Appendix K

ANOVAs on QuickSIN Lists Post Removal of List 9

This appendix shows the results of the ANOVAs that were conducted to examine inter-list equivalency of the QuickSIN lists excluding list 9 for the normally-hearing (NH) and hearing-impaired (HI) groups across the test and retest sessions. The QuickSIN SNR-50 scores were the dependent measure. For the factor QuickSIN list, the degrees of freedom and mean squares are shown.

Table K.1. One-way ANOVA on QuickSIN List Excluding List 9 for the NH Group in the Test Session.

Source	SS	df	MS	F	p
QL	111.10	10	11.11	3.71	0.000
Error	1154.14	385			

Table K.2. One-way ANOVA on QuickSIN List Excluding List 9 for the NH Group in the Retest Session.

Source	SS	df	MS	F	p
QL	99.90	10	9.99	3.49	0.000
Error	1102.53	385			

Table K.3. One-way ANOVA on QuickSIN List Excluding List 9 for the HI Group in the Test Session

Source	SS	df	MS	F	p
QL	136.70	10	13.70	1.25	0.255
Error	4194.20	385			

Table K.4. One-way ANOVA on QuickSIN List Excluding List 9 for the HI Group in the Retest Session

Source	SS	df	MS	F	p
QL	81.53	10	8.15	1.11	0.355
Error	2835.11	385			

Appendix L

ANOVAs on QuickSIN List Post Removal of Lists 9 and 2

This appendix shows the results of the ANOVAs that were conducted to examine inter-list equivalency of the QuickSIN lists excluding List 9 and List 2 for the normally-hearing (NH) and hearing-impaired (HI) groups across the test and retest sessions. The QuickSIN SNR-50 scores were the dependent measure. For the factor QuickSIN list, the degrees of freedom and mean squares are shown.

Table L.1. One-way ANOVA on QuickSIN List Excluding List 9 and List 2 for the NH Group in the Test Session

Source	SS	df	MS	F	p
QL	88.53	9	9.84	3.30	0.001
Error	1043.25	350			

Table L.2. One-way ANOVA on QuickSIN List Excluding List 9 and List 2 for the NH Group in the Retest Session

Source	SS	df	MS	F	p
QL	66.33	9	7.26	2.51	0.009
Error	1012.22	350			

Table L.3. One-way ANOVA on QuickSIN List Excluding List 9 and List 2 for the HI Group in the Test Session

Source	SS	df	MS	F	p
QL	122.40	9	13.60	1.23	0.275
Error	3865.40	350			

Table L.4. One-way ANOVA on QuickSIN List Excluding List 9 and List 2 for the HI Group in the Retest Session

Source	SS	df	MS	F	p
QL	8.123	9	9.03	1.26	0.255
Error	2497.56	350			

Appendix M

ANOVAs on QuickSIN List Post Removal of Lists 9, 2, and 7

This appendix shows the results of the ANOVAs that were conducted to examine inter-list equivalency of the QuickSIN lists excluding Lists 9, 2 and 7 for the normally-hearing (NH) and hearing-impaired (HI) groups across the test and retest sessions. The QuickSIN SNR-50 scores were the dependent measure. For the factor QuickSIN list, the degrees of freedom and mean squares are shown.

Table M.1. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, and 7 for the NH Group in the Test Session.

Source	SS	df	MS	F	p
QL	67.82	8	8.48	2.97	0.003
Error	898.36	315			

Table M.2. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, and 7 for the NH Group in the Retest Session.

Source	SS	df	MS	F	p
QL	51.72	8	6.47	2.24	0.025
Error	910.58	315			

Table M.3. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, and 7 for the HI Group in the Test Session

Source	SS	df	MS	F	p
QL	117.00	8	14.60	1.41	0.192
Error	3272.60	315			

Table M.4. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, 7 for the HI Group in the Retest Session

Source	SS	df	MS	F	p
QL	75.69	8	9.46	1.35	0.217
Error	2202.56	315			

Appendix N

ANOVAs on QuickSIN Test Post Removal of Lists 9, 2, 7, and 11

This appendix shows the results of the ANOVAs that were conducted to examine inter-list equivalency of the QuickSIN lists excluding Lists 9, 2, 7, and 11 for the normally-hearing (NH) and hearing-impaired (HI) groups across the test and retest sessions. The QuickSIN SNR-50 scores were the dependent measure. For the factor QuickSIN list, the degrees of freedom and mean squares are shown.

Table N.1. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, 7, and 11 for the NH Group in the Test Session

Source	SS	df	MS	F	p
QL	37.36	8	5.34	2.13	0.040
Error	700.14	280			

Table N.2. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, 7, and 11 for the NH Group in the Retest Session

Source	SS	df	MS	F	p
QL	51.67	7	7.38	2.90	0.006
Error	713.83	280			

Table N.3. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, 7, and 11 for the HI Group in the Test Session

Source	SS	df	MS	F	p
QL	116.80	7	16.70	1.56	0.148
Error	2999.00	280			

Table N.4. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, 7, and 11 for the HI Group in the Retest Session

Source	SS	df	MS	F	p
QL	63.05	7	9.01	1.29	0.256
Error	1958.92	280			

Appendix O

ANOVAs on QuickSIN List Post Removal of Lists 9, 2, 7, 11, 5, and 6

This appendix shows the results of the ANOVAs that were conducted to examine inter-list equivalency of the QuickSIN lists excluding Lists 9, 2, 7, 11, 5, and 6 for the normally-hearing (NH) and hearing-impaired (HI) groups the across test and retest sessions. The QuickSIN SNR-50 scores were the dependent measure. For the factor QuickSIN list, the degrees of freedom and mean squares are shown.

Table O.1. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, 7, 11, 5, and 6 for the NH Group in the Test Session

Source	SS	df	MS	F	p
QL	10.83	5	2.17	0.76	0.581
Error	600.50	210			

Table O.2. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, 7, 11, 5, and 6 for the NH Group in the Retest Session

Source	SS	df	MS	F	p
QL	25.69	5	5.14	1.99	0.082
Error	542.53	210			

Table O.3. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, 7, 11, 5, and 6 for the HI Group in the Test Session

Source	SS	df	MS	F	p
QL	106.90	5	21.40	2.11	0.066
Error	2129.40	210			

Table O.4. One-way ANOVA on QuickSIN List Excluding Lists 9, 2, 7, 11, 5, and 6 for the HI Group in the Retest Session

Source	SS	df	MS	F	p
QL	35.54	5	7.11	1.02	0.405
Error	1459.72	210			

Appendix P

ANOVAs for QuickSIN SNR Effect

This appendix shows the results of the ANOVAs that were conducted to examine inter-list equivalency of the QuickSIN lists for the normal hearing (NH) and hearing impairment (HI) groups across signal-to-noise ratio (SNR) in the test and retest sessions. The number of correct keywords was the dependent measure. The independent factors are fixed: QuickSIN lists (QL; 12 levels), and SNR (6 levels). For the factors of QuickSIN list, SNR, and their interactions, the degrees of freedom and mean squares are shown.

Table P.1. Two-way ANOVA for QuickSIN List (QL) and Signal-to-Noise Ratio (SNR) for the Normal Hearing Group in the Test Session

Source	SS	df	MS	F	p
QL	26.167	11	2.379	5.25	0.000
SNR	5440.727	5	1088.145	240.327	0.000
QL*SNR	205.218	55	3.731	8.24	0.000
Error	1141.000	2520	0.453		

Table P.2. Two-way ANOVA for QuickSIN List (QL) and Signal-to-Noise Ratio (SNR) for the Normal Hearing Group in the Retest Session

Source	SS	df	MS	F	p
QL	26.167	11	2.379	5.25	0.000
SNR	5440.727	5	1088.145	240.327	0.000
QL*SNR	205.218	55	3.731	8.24	0.000
Error	1141.000	2520	0.453		

Table P.3. Two-way ANOVA for QuickSIN List (QL) and Signal-to-Noise Ratio (SNR) for the Hearing Impairment Group in the Test Session

Source	SS	df	MS	F	p
QL	29.341	11	2.808	2.88	0.001
SNR	6692.812	5	1338.562	1372.37	0.000
QL*SNR	261.868	55	4.761	4.88	0.000
Error	2457.917	2520	0.975		

Table P.4. Two-way ANOVA for QuickSIN List (QL) and Signal-to-Noise Ratio (SNR) for the Hearing Impairment Group in the Retest Session

Source	SS	df	MS	F	p
QL	30.884	11	2.808	2.88	0.001
SNR	6692.812	5	1338.562	1372.37	0.000
QL*SNR	261.868	55	4.761	4.88	0.000
Error	2457.917	2520	0.975		

Appendix Q

Number and Percent Incorrect of Keyword Errors

Table Q.1. Number (#) and Percent Incorrect (%) Keyword Errors for Each Signal-to-Noise Ratio for Each List for the Normally Hearing (NH) and Hearing Impairment (HI) Group for the Test Session

List	Group	Signal-to-Noise Ratio												Overall	
		25		20		15		10		5		0			
		#	%	#	%	#	%	#	%	#	%	#	%	#	%
1	NH	0	0	0	0	2	1	0	0	13	7	167	93	182	17
	HI	18	10	3	2	12	7	18	10	70	39	178	99	299	28
2	NH	0	0	3	2	2	1	0	0	17	9	138	77	160	15
	HI	2	1	35	19	2	1	4	2	63	35	169	94	275	25
3	NH	0	0	0	0	0	0	15	8	21	12	167	93	203	19
	HI	2	1	4	2	18	10	82	46	56	31	172	96	334	31
4	NH	0	0	1	1	3	2	5	3	16	9	160	89	185	17
	HI	1	1	0	0	3	2	16	9	89	49	176	98	285	26
5	NH	0	0	0	0	0	0	14	8	16	9	174	97	204	19
	HI	1	1	7	4	6	3	14	8	64	36	178	99	270	25
6	NH	1	1	0	0	14	8	9	5	0	0	140	78	164	15
	HI	14	8	5	3	29	16	17	9	56	31	160	89	281	26
7	NH	0	0	10	6	4	2	3	2	28	16	114	63	159	15
	HI	8	4	25	14	19	11	17	9	71	39	156	87	296	27
8	NH	0	0	10	6	0	0	1	1	34	19	145	81	190	18
	HI	0	0	13	7	6	3	36	20	94	52	172	96	321	30
9	NH	1	1	0	0	0	0	12	7	29	16	115	64	157	15
	HI	1	1	9	5	0	0	9	5	69	38	149	83	237	22
10	NH	0	0	1	1	6	3	2	1	20	11	157	87	186	17
	HI	21	12	3	2	13	7	13	7	50	28	179	99	279	26
11	NH	0	0	2	1	37	21	1	1	52	29	136	76	228	21
	HI	0	0	0	0	38	21	26	14	70	39	163	91	297	28
12	NH	0	0	3	2	0	0	16	9	19	11	141	78	179	17
	HI	1	1	11	6	5	3	27	15	57	32	161	89	262	24

Appendix R

Number of Key Words Errors for Each Keyword at Each Signal-to-Noise (SNR) for the QuickSIN Standard Test Lists for the Normal Hearing and Hearing Impairment Group for the Test Session

Table R.1. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 1 for the Test Session

SNR	Group	Keyword					Total
25		white	silk	jacket	any	shoes	
	NH	0	0	0	0	0	0
	HI	6	11	1	18	0	36
20		child	crawled	into	dense	grass	
	NH	0	0	0	0	0	0
	HI	0	1	0	0	2	3
15		footprints	showed	path	took	beach	
	NH	0	0	0	0	0	0
	HI	0	9	0	3	0	12
10		vent	near	edge	fresh	air	
	NH	0	0	0	0	0	0
	HI	5	6	3	2	2	18
5		band	steel	three	inches	wide	
	NH	0	0	5	3	5	13
	HI	10	17	14	14	15	70
0		weight	package	seen	high	scale	
	NH	35	32	32	35	33	167
	HI	35	35	36	36	36	178

Table R.2. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 2 for the Test Session

SNR	Group	Keyword					Total
25		tear	thin	sheet	yellow	pad	
	NH	0	0	0	0	0	0
	HI	0	2	0	0	0	2
20		cruise	waters	sleek	yacht	fun	
	NH	0	0	2	0	1	3
	HI	3	10	12	7	3	35
15		streak	color	down	left	edge	
	NH	0	2	0	0	0	2
	HI	0	0	0	0	2	2
10		done	before	boy	see	it	
	NH	0	0	0	0	0	0
	HI	3	0	1	0	0	4
5		crouch	before	jump	miss	mark	
	NH	10	1	0	3	3	17
	HI	23	4	3	17	16	63
0		square	peg	settle	round	hole	
	NH	17	23	34	34	30	138
	HI	31	31	36	36	35	169

Table R.3. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 3 for the Test Session

SNR	Group	Keyword Errors					Total
25		pitch	straw	through	door	stable	
	NH	0	0	0	0	0	0
	HI	0	0	1	0	1	2
20		sink	thing	which	pile	dishes	
	NH	0	0	0	0	0	0
	HI	0	0	4	0	0	4
15		post	no	bills	office	wall	
	NH	0	0	0	0	0	0
	HI	3	4	4	3	4	18
10		dimes	showered	down	all	sides	
	NH	5	7	1	1	1	15
	HI	18	18	17	13	16	82
5		pick	card	slip	under	pack	
	NH	1	1	1	2	16	21
	HI	10	8	10	10	18	56
0		store	jammed	before	sale	start	
	NH	33	36	32	30	36	167
	HI	35	36	33	32	36	172

Table R.4. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 4 for the Test Session

SNR	Group	Keyword Errors					Total
25		sense	smell	better	than	touch	
	NH	0	0	0	0	0	0
	HI	0	0	0	1	0	1
20		picked	up	dice	second	roll	
	NH	0	0	0	1	0	1
	HI	0	0	0	0	0	0
15		drop	ashes	worn	old	rug	
	NH	0	0	3	0	0	3
	HI	0	0	3	0	0	3
10		couch	cover	hall	drapes	blue	
	NH	0	0	5	0	0	5
	HI	1	0	12	3	0	16
5		stems	tall	glasses	cracked	broke	
	NH	1	1	8	2	4	16
	HI	24	8	19	18	20	89
0		cleat	sank	deeply	soft	turf	
	NH	33	34	35	23	35	160
	HI	36	36	36	32	36	176

Table R.5. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 5 for the Test Session

SNR	Group	Keyword Errors					Total
25		have	better	than	wait	hope	
	NH	0	0	0	0	0	0
	HI	0	0	1	0	0	1
20		screen	before	fire	kept	sparks	
	NH	0	0	0	0	0	0
	HI	0	1	0	1	5	7
15		thick	glasses	helped	read	print	
	NH	0	0	0	0	0	0
	HI	2	1	3	0	0	6
10		chair	looked	strong	no	bottom	
	NH	0	0	0	0	14	14
	HI	0	0	0	0	9	9
5		told	wild	tales	frighten	him	
	NH	1	2	4	2	7	16
	HI	12	9	9	13	21	64
0		force	equal	would	move	earth	
	NH	32	35	36	36	35	174
	HI	34	36	36	36	36	178

Table R.6. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 6 for the Test Session

SNR	Group	Keyword Errors					Total
25		leaf	drifts	along	slow	spin	
	NH	0	0	0	0	1	1
	HI	2	4	1	4	3	14
20		pencil	cut	sharp	both	ends	
	NH	0	0	0	0	0	0
	HI	3	2	0	0	0	5
15		down	road	way	grain	farmer	
	NH	0	0	0	5	9	14
	HI	0	1	0	9	19	29
10		best	method	fix	place	clips	
	NH	0	4	1	0	4	9
	HI	1	1	3	3	9	17
5		if	mumble	your	speech	lost	
	NH	0	0	0	0	0	0
	HI	9	14	12	10	11	56
0		toad	frog	hard	tell	apart	
	NH	19	18	34	35	34	140
	HI	27	28	35	35	35	160

Table R.7. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 7 for the Test Session

SNR	Group	Keyword Errors					Total
25		kite	dipped	swayed	stayed	aloft	
	NH	0	0	0	0	0	0
	HI	1	4	1	1	1	8
20		beetle	droned	hot	June	sun	
	NH	0	7	0	3	0	10
	HI	0	15	0	9	1	25
15		theft	pearl	pin	kept	secret	
	NH	0	0	4	0	0	4
	HI	4	7	5	2	1	19
10		wide	grin	earned	many	friends	
	NH	1	1	1	0	0	3
	HI	4	4	5	2	2	17
5		hurdle	pit	aid	long	pole	
	NH	21	4	1	1	2	29
	HI	30	21	6	7	7	71
0		peep	under	tent	see	clown	
	NH	33	14	15	24	28	114
	HI	25	30	29	36	36	156

Table R.8. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 8 for the Test Session

SNR	Group	Keyword Errors					Total
25		sun	came	light	eastern	sky	
	NH	0	0	0	0	0	0
	HI	0	0	0	0	0	0
20		stale	smell	old	beer	linger	
	NH	0	0	0	0	10	10
	HI	0	0	1	0	12	12
15		desk	firm	on	shaky	floor	
	NH	0	0	0	0	0	0
	HI	0	4	0	2	0	6
10		list	names	carved	around	base	
	NH	0	0	0	0	1	1
	HI	6	5	5	7	13	36
5		news	struck	doubt	restless	minds	
	NH	1	1	8	13	11	34
	HI	13	7	19	29	26	94
0		sand	drifts	over	sill	house	
	NH	29	30	25	30	31	145
	HI	33	36	31	36	36	172

Table R.9. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 9 for the Test Session

SNR	Group	Keyword Errors					Total
25		take	shelter	tent	keep	still	
	NH	0	0	0	1	0	1
	HI	0	0	0	1	0	1
20		little	tales	they	tell	false	
	NH	0	0	0	0	0	0
	HI	0	3	1	2	3	9
15		press	pedal	with	left	foot	
	NH	0	0	0	0	0	0
	HI	0	0	0	0	0	0
10		black	trunk	fell	from	landing	
	NH	0	11	0	0	1	12
	HI	1	7		1	0	9
5		cheap	clothes	flashy	don't	last	
	NH	0	0	2	11	16	29
	HI	7	9	11	18	24	69
0		night	alarm	roused	deep	sleep	
	NH	7	25	30	26	27	115
	HI	9	32	36	36	36	149

Table R.10. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 10 for the Test Session

SNR	Group	Keyword Errors					Total
25		dots	light	betrayed	black	cat	
	NH	0	0	0	0	0	0
	HI	10	3	6	1	1	21
20		put	chart	mantel	tack	down	
	NH	0	0	0	1	0	1
	HI	1	1	1	0	0	3
15		steady	drip	worse	drenching	rain	
	NH	1	5	0	0	0	6
	HI	0	10	0	3	0	13
10		flat	pack	less	luggage	space	
	NH	0	2	0	0	0	2
	HI	2	5	1	1	4	13
5		gloss	top	made	unfit	read	
	NH	3	3	5	3	6	20
	HI	12	6	9	10	13	50
0		seven	seals	stamped	great	sheets	
	NH	26	34	28	35	34	157
	HI	36	36	35	36	36	179

Table R.11. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 11 for the Test Session

SNR	Group	Keyword Errors					Total
25		marsh	freeze	when	cold	enough	
	NH	0	0	0	0	0	0
	HI	0	0	0	0	0	0
20		gray	mare	walked	before	colt	
	NH	0	0	0	0	2	2
	HI	0	0	0	0	0	0
15		bottles	hold	four	kinds	rum	
	NH	1	1	1	1	33	37
	HI	2	2	1	1	32	38
10		wheeled	bike	past	winding	road	
	NH	0	0	1	0	0	1
	HI	10	1	10	2	3	26
5		throw	used	paper	cup	plate	
	NH	7	5	5	5	30	52
	HI	11	10	4	14	31	70
0		wall	phone	rang	loud	often	
	NH	20	20	34	26	36	136
	HI	31	30	36	30	36	163

Table R.12. Number of QuickSIN Keyword Errors for Each Keyword at Each SNR for the Normal Hearing (NH) and Hearing Impairment (HI) Group for the QuickSIN Standard Test List 11 for the Test Session

SNR	Group	Keyword Errors					Total
25		hinge	door	creaked	old	age	
	NH	0	0	0	0	0	0
	HI	0	0	1	0	1	2
20		bright	lanterns	gay	dark	lawn	
	NH	0	0	0	3	0	3
	HI	2	0	3	6	0	11
15		offered	proof	form	large	chart	
	NH	0	0	0	0	0	0
	HI	1	2	2	0	0	5
10		their	eyelids	droop	want	sleep	
	NH	1	0	15	0	0	16
	HI	3	2	16	3	3	27
5		many	ways	do	these	things	
	NH		9	2	4	4	19
	HI	1	9	7	20	20	57
0		we	like	see	clear	weather	
	NH	16	19	34	36	36	141
	HI	27	28	35	35	36	161

Appendix S

Paired t-tests for Equivalent QuickSIN Test Lists

Paired T-Test and CI: Test-Retest Session Across List NH Group

Paired T for NH T SNR-50 - NH R SNR-50

	N	Mean	StDev	SE Mean
NH T SNR-50	216	2.778	1.686	0.115
NH R SNR-50	216	2.440	1.626	0.111
Difference	216	0.338	1.629	0.111

95% CI for mean difference: (0.120, 0.556)

T-Test of mean difference = 0 (vs not = 0): T-Value = 3.05

P-Value = 0.003

Paired T-Test and CI: Test-Retest Session Across List HI Group

Paired T for HI T SNR-50 - HI R SNR-50

	N	Mean	StDev	SE Mean
HI T SNR-50	216	5.630	3.225	0.219
HI R SNR-50	216	4.852	2.637	0.179
Difference	216	0.778	2.130	0.145

95% CI for mean difference: (0.492, 1.063)

T-Test of mean difference = 0 (vs not = 0): T-Value = 5.37

P-Value = 0.000

Paired T-Test and CI: List 1 Test-Retest Session NH Group

Paired T for NH T SNR-50 - NH R SNR-50

	N	Mean	StDev	SE Mean
NH T SNR-50	36	2.556	1.393	0.232
NH R SNR-50	36	2.583	1.538	0.256
Difference	36	-0.028	1.253	0.209

95% CI for mean difference: (-0.452, 0.396)

T-Test of mean difference = 0 (vs not = 0): T-Value = -0.13

P-Value = 0.895

Paired T-Test and CI: List 1 Test-Retest Session HI Group

Paired T for HI T SNR-50 - HI R SNR-50

	N	Mean	StDev	SE Mean
HI T SNR-50	36	5.528	3.566	0.594
HI R SNR-50	36	4.583	2.802	0.467
Difference	36	0.944	2.267	0.378

95% CI for mean difference: (0.177, 1.712)

T-Test of mean difference = 0 (vs not = 0): T-Value = 2.50

P-Value = 0.017

Paired T-Test and CI: List 4 Test-Retest Session NH Group

Paired T for NH T SNR-50 - NH R SNR-50

	N	Mean	StDev	SE Mean
NH T SNR-50	36	2.639	1.417	0.236
NH R SNR-50	36	2.861	1.496	0.249
Difference	36	-0.222	1.045	0.174

95% CI for mean difference: (-0.576, 0.131)

T-Test of mean difference = 0 (vs not = 0): T-Value = -1.28

P-Value = 0.210

Paired T-Test and CI: List 4 Test-Retest Session HI Group

Paired T for HI T SNR-50 - HI R SNR-50

	N	Mean	StDev	SE Mean
HI T SNR-50	36	5.417	1.811	0.302
HI R SNR-50	36	4.778	1.876	0.313
Difference	36	0.639	1.533	0.256

95% CI for mean difference: (0.120, 1.158)

T-Test of mean difference = 0 (vs not = 0): T-Value = 2.50

P-Value = 0.017

Paired T-Test and CI: List 5 Test-Retest Session NH Group

Paired T for NH Test List 5 - NH Retest List 5

	N	Mean	StDev	SE Mean
NH Test List	36	3.250	1.251	0.208
NH Retest Li	36	3.111	1.358	0.226
Difference	36	0.139	1.099	0.183

95% CI for mean difference: (-0.233, 0.511)

T-Test of mean difference = 0 (vs not = 0): T-Value = 0.76

P-Value = 0.454

Paired T-Test and CI: List 5 Test-Retest Session HI Group

Paired T for HI Test List 5 - HI Retest List 5

	N	Mean	StDev	SE Mean
HI Test List	36	5.111	2.611	0.435
HI Retest Li	36	4.028	1.828	0.305
Difference	36	1.083	1.857	0.310

95% CI for mean difference: (0.455, 1.712)

T-Test of mean difference = 0 (vs not = 0): T-Value = 3.50

P-Value = 0.001

Paired T-Test and CI: List 6 Test-Retest Session NH Group

Paired T for NH Test List 6 - NH Retest List 6

	N	Mean	StDev	SE Mean
NH Test List	36	2.056	1.132	0.189
NH Retest Li	36	1.917	1.746	0.291
Difference	36	0.139	1.376	0.229

95% CI for mean difference: (-0.327, 0.605)

T-Test of mean difference = 0 (vs not = 0): T-Value = 0.61

P-Value = 0.549

Paired T-Test and CI: List 6 Test-Retest Session HI Group

Paired T for HI Test List 6 - HI Retest List 6

	N	Mean	StDev	SE Mean
HI Test List	36	5.333	4.246	0.708
HI Retest Li	36	4.278	3.305	0.551
Difference	36	1.056	2.672	0.445

95% CI for mean difference: (0.151, 1.960)

T-Test of mean difference = 0 (vs not = 0): T-Value = 2.37

P-Value = 0.023

Paired T-Test and CI: List 8 Test-Retest Session NH Group

Paired T for NH T SNR-50 - NH R SNR-50

	N	Mean	StDev	SE Mean
NH T SNR-50	36	2.944	1.978	0.330
NH R SNR-50	36	1.889	2.032	0.339
Difference	36	1.056	2.164	0.361

95% CI for mean difference: (0.323, 1.788)

T-Test of mean difference = 0 (vs not = 0): T-Value = 2.93

P-Value = 0.006

Paired T-Test and CI: List 8 Test-Retest Session HI Group

Paired T for HI T SNR-50 - HI R SNR-50

	N	Mean	StDev	SE Mean
HI T SNR-50	36	6.389	3.040	0.507
HI R SNR-50	36	5.222	2.480	0.413
Difference	36	1.167	2.432	0.405

95% CI for mean difference: (0.344, 1.990)

T-Test of mean difference = 0 (vs not = 0): T-Value = 2.88

P-Value = 0.007

Paired T-Test and CI: List 10 Test-Retest Session NH Group

Paired T for NH T SNR-50 - NH R SNR-50

	N	Mean	StDev	SE Mean
NH T SNR-50	36	2.722	2.030	0.338
NH R SNR-50	36	2.194	1.910	0.318
Difference	36	0.528	1.732	0.289

95% CI for mean difference: (-0.058, 1.114)

T-Test of mean difference = 0 (vs not = 0): T-Value = 1.83

P-Value = 0.076

Paired T-Test and CI: List 10 Test-Retest Session HI Group

Paired T for HI T SNR-50 - HI R SNR-50

	N	Mean	StDev	SE Mean
HI T SNR-50	36	5.056	2.971	0.495
HI R SNR-50	36	4.556	2.735	0.456
Difference	36	0.500	1.875	0.312

95% CI for mean difference: (-0.134, 1.134)

T-Test of mean difference = 0 (vs not = 0): T-Value = 1.60

P-Value = 0.119

Paired T-Test and CI: List 12 Test-Retest Session NH Group

Paired T for NH T SNR-50 - NH R SNR-50

	N	Mean	StDev	SE Mean
NH T SNR-50	36	2.611	1.617	0.270
NH R SNR-50	36	2.306	1.009	0.168
Difference	36	0.306	1.833	0.306

95% CI for mean difference: (-0.315, 0.926)

T-Test of mean difference = 0 (vs not = 0): T-Value = 1.00

P-Value = 0.324

Paired T-Test and CI: List 12 Test-Retest Session HI Group

Paired T for HI T SNR-50 - HI R SNR-50

	N	Mean	StDev	SE Mean
HI T SNR-50	36	4.694	2.539	0.423
HI R SNR-50	36	4.417	2.371	0.395
Difference	36	0.278	1.830	0.305

95% CI for mean difference: (-0.341, 0.897)

T-Test of mean difference = 0 (vs not = 0): T-Value = 0.91

P-Value = 0.369

Appendix T

Northwestern University Auditory Test No. 6 Scores in rau

Table T.1. Northwestern University Auditory Test (NU-6) Scores in rau as Presented in the QuickSIN Babble at a SNR Equal to the Participant's Individual SNR-50 Scores Averaged over the 12 Standard Test Lists

NH Participant	NU-6 List		HI Participant	NU-6 List	
	1A	2A		1A	2A
1	35.2	37.1	37	16.1	23.0
2	42.7	48.2	38	46.4	29.3
3	27.2	25.1	39	51.8	39.0
4	40.8	39.0	40	35.2	25.1
5	27.2	33.2	41	40.8	50.0
6	37.1	35.2	42	42.7	31.3
7	55.5	40.8	43	35.2	23.0
8	44.5	44.5	44	29.3	31.3
9	46.4	33.2	45	33.2	40.8
10	46.4	39.0	46	20.8	25.1
11	29.3	25.1	47	27.2	39.0
12	50.0	40.8	48	29.3	20.8
13	33.2	39.0	49	46.4	29.3
14	40.8	42.7	50	50.0	29.3
15	46.4	40.8	51	27.2	33.2
16	35.2	40.8	52	37.1	48.2
17	31.3	35.2	53	25.1	35.2
18	27.2	50.0	54	25.1	31.3

Table T.2. continued

NH Participant	NU-6 List		HI Participant	NU-6 List	
	1A	2A		1A	2A
19	10.9	27.2	55	48.2	42.7
20	29.3	37.1	56	29.3	40.8
21	27.2	31.3	57	35.2	35.2
22	33.2	37.1	58	31.3	35.2
23	40.8	35.2	59	37.1	40.8
24	39.0	42.7	60	42.7	35.2
25	35.2	35.2	61	35.2	29.3
26	29.3	29.3	62	37.1	31.3
27	44.5	39.0	63	42.7	33.2
28	20.8	35.2	64	37.1	42.7
29	29.3	37.1	65	46.4	33.2
30	42.7	37.1	66	35.2	42.7
31	40.8	35.2	67	20.8	37.1
32	29.3	35.2	68	40.8	35.2
33	25.1	25.1	69	29.3	33.2
34	27.2	29.3	70	46.4	31.3
35	40.8	31.3	71	31.3	31.3
36	20.8	23.0	72	35.2	16.1

Appendix U

ANCOVA to Evaluate the Ability to Predict NU-6 rau scores by the Mean QuickSIN SNR-50 score

General Linear Model: NU-6 1A rau versus Group, Sub

```
Factor       Type Levels Values

Group       fixed      2 0 1

Sub(Group) random

72  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

24 25 26 27 28 29 30 31 32 33 34 35 36 38 39 40 41 42 43 44 45 46 47 48

49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72

Analysis of Variance for NU-6 1A, using Adjusted SS for Tests

Source          Model DF   Reduced DF     Seq SS

Mean SNR               1            1    212.542

Group                  1            1     64.334

Sub(Group)            70           69+  5510.883

Group*Mean SNR         1            0+     0.000

Error                 -2            0      0.000

Total                 71           71   5787.760


+ Rank deficiency due to empty cells or collinearity.

  No storage of results or further analysis will be done.
```

General Linear Model: NU-6 1A rau versus Session, Group, Sub

```
Factor       Type Levels Values
Session     fixed      2 1 2
Group       fixed      2 0 1
Sub(Group) random
72  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54
55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72

Analysis of Variance for NU-6 1A, using Adjusted SS for Tests

Source           DF     Seq SS     Adj SS     Adj MS       F      P
Mean SNR          1      64.42     650.17     650.17   15.86  0.000
Session           1      37.29     106.90     106.90    2.61  0.111
Group             1     271.93     136.99     136.99    3.27  0.075 x
Sub(Group)       70    6664.52    6619.81      94.57    2.31  0.000
Group*Mean SNR    1       1.21       1.21       1.21    0.03  0.864
Error            69    2829.18    2829.18      41.00
Total           143    9868.55

x Not an exact F-test.

Term               Coef   SE Coef        T      P
Constant         13.052     5.175     2.52  0.014
Mean SNR          5.977     1.501     3.98  0.000
Mean SNR*Group
         0        0.213     1.235     0.17  0.864
```

Unusual Observations for NU-6 1A

Obs	NU-6 1A	Fit	SE Fit	Residual	St Resid
19	10.9000	20.4545	4.6126	-9.5545	-2.15R
38	46.4000	35.6257	4.6097	10.7743	2.42R
41	40.8000	24.1345	4.5726	16.6655	3.72R
91	27.2000	17.6455	4.6126	9.5545	2.15R
110	29.3000	40.0743	4.6097	-10.7743	-2.42R
113	5.0000	21.6655	4.5726	-16.6655	-3.72R

R denotes an observation with a large standardized residual.

Appendix V

Abbreviated Profile of Hearing Aid Benefit Data

This appendix provides the Global and subscale scores (Background Noise, Ease of Communication, Reverberation, and sound Aversiveness) of the Abbreviated Profile of Hearing Aid Benefit (APHAB) for the normal hearing and hearing impairment groups. Additionally, the raw data by APHAB item is provided for both groups.

Table V.1. APHAB Global and Subscale Scores for Background Noise (BN), Ease of Communication (EC), Reverberation (RV) and Aversiveness (A) for the Normal Hearing Group

Participant	Global	BN	EC	RV	AV
1	14.8	14.2	2.8	6.5	35.5
2	4.7	8.3	1.0	6.5	2.8
3	27.0	20.8	4.7	14.2	68.3
4	26.6	29.2	10.8	18.7	47.7
5	10.0	16.3	2.8	16.3	4.7
6	10.0	10.2	6.5	10.8	12.3
7	9.3	10.2	4.7	10.2	12.3
8	5.1	4.7	1.0	8.3	6.5
9	18.8	24.8	6.5	20.8	22.8
10	24.1	14.5	1.0	6.5	74.5
11	8.0	17.3	1.0	2.8	11.0
12	20.3	8.7	12.7	20.8	39.2
13	17.5	22.7	8.3	14.2	25.0
14	18.8	10.5	10.5	12.3	41.8
15	5.8	6.5	2.8	1.0	12.7
16	18.0	8.7	8.7	6.5	48.0
17	12.5	2.8	1.0	8.7	37.5
18	18.5	19.6	4.7	22.7	27.3
19	15.8	12.7	2.8	10.5	37.2
20	14.0	14.5	1.0	2.8	42.2
21	13.4	9.0	4.7	21.0	19.0
22	26.6	29.2	5.0	14.2	58.0
23	29.8	39.7	25.0	12.7	41.8
24	14.0	10.2	12.7	24.7	8.3
25	14.2	16.8	6.5	10.5	24.8
26	14.8	4.7	2.8	12.3	39.3
27	28.6	25.0	6.8	20.5	62.2
28	16.5	10.5	2.8	4.7	47.8
29	19.7	26.8	8.7	14.2	29.2
30	22.9	64.3	2.8	23.3	1.0
31	13.0	14.2	4.7	18.8	14.5
32	21.1	27.2	17.3	31.2	8.7
33	8.3	12.8	2.8	6.5	11.0
34	15.9	8.3	2.8	4.7	47.7
35	7.3	14.7	1.0	5.0	8.7
36	24.8	27.4	17.2	16.3	37.3

Table V.2. APHAB Global and Subscale Scores for Background Noise (BN), Ease of Communication (EC), Reverberation (RV) and Aversiveness (A) for the Hearing Impairment Group

Participant	Global	BN	EC	RV	AV
37	32.8	35.2	45.7	47.7	2.8
38	26.5	33.3	24.8	24.8	22.8
39					
40	28.7	47.8	24.5	41.5	1.0
41	23.1	26.8	25.2	37.5	2.8
42	55.6	58.3	72.7	49.8	41.5
43	69.5	68.5	62.3	60.2	87.0
44	52.3	66.5	25.0	54.0	66.2
45	64.4	85.0	78.8	64.5	29.2
46	27.1	43.7	27.2	31.2	6.5
47	35.3	54.0	12.0	66.3	8.7
48	33.0	54.2	35.3	39.5	2.8
49	34.3	60.3	18.5	45.0	15.3
50	31.1	29.0	37.5	47.8	10.2
51	20.8	23.0	16.3	29.2	14.8
52	13.6	28.8	4.7	16.3	4.7
53	3.6	2.8	9.2	1.0	1.0
54	30.6	37.5	20.7	50.0	14.2
55	31.1	22.8	24.8	37.3	39.5
56	31.1	37.5	29.0	43.7	14.2
57	55.9	56.0	59.8	58.2	49.7
58	38.5	62.5	24.8	45.8	20.7
59	46.8	41.7	50.0	52.0	43.7
60	28.8	29.2	21.0	41.7	23.2
61	29.7	33.3	37.5	37.5	10.5
62	20.1	18.8	25.0	35.0	1.0
63	53.0	58.0	77.0	64.2	12.8
64	39.5	35.3	43.7	43.7	35.3
65	42.8	60.3	45.8	60.3	4.7
66	50.0	43.7	68.7	62.5	25.3
67	18.8	29.0	8.3	12.0	24.8
68	36.8	45.7	10.2	29.0	62.2
69	35.6	55.8	16.3	27.0	43.3
70	45.0	47.9	21.8	41.7	68.7
71	43.7	68.7	33.3	50.0	22.7
72	39.0	52.0	20.7	50.0	33.2

Table V.3. Raw Data for APHAB Item Responses for the Participants (P) for the Normal Hearing Group

P	APHAB Item Number																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	12	1	50	12	1	12	12	75	12	1	12	1	1	1	1	12	25	1	12	50	12	12	1	25
2	1	12	1	1	1	12	12	1	1	1	12	1	1	1	1	12	12	12	1	1	1	1	1	12
3	12	12	99	1	12	12	50	25	25	12	12	1	1	1	1	25	99	12	25	99	12	87	12	1
4	1	25	87	12	50	87	25	12	12	1	1	25	12	1	1	25	75	12	25	75	12	25	25	12
5	12	25	1	1	25	25	12	12	12	1	12	12	1	1	1	25	12	12	12	1	12	1	1	12
6	1	1	12	12	1	12	12	25	25	12	12	12	12	1	1	12	12	1	12	12	25	1	1	12
7	1	12	25	12	12	12	12	12	12	1	1	1	1	1	1	12	12	12	12	12	12	12	12	12
8	1	12	12	1	1	12	1	1	12	1	12	1	1	1	1	1	1	1	12	12	12	12	1	1
9	1	25	25	1	1	25	12	12	50	12	25	12	1	1	1	12	12	12	87	75	12	12	12	12
10	1	1	99	1	12	25	12	75	12	1	12	1	12	1	1	12	87	1	12	87	1	87	1	25
11	1	1	50	1	1	1	1	1	1	1	12	1	1	1	1	99	1	1	1	12	1	1	1	1
12	1	87	99	25	12	25	12	25	12	1	1	12	12	12	1	12	75	12	1	12	1	12	25	1
13	12	12	75	12	12	50	12	12	12	12	25	12	1	1	1	25	25	12	25	25	12	12	12	12
14	1	12	75	12	12	25	12	25	12	1	1	12	1	25	1	12	50	12	12	75	25	25	12	1
15	1	1	12	1	1	12	12	25	1	1	1	1	1	1	1	12	25	1	1	1	1	12	12	1
16	1	1	75	12	12	25	1	25	12	1	12	12	1	1	1	12	87	1	1	75	1	25	25	12
17	1	1	50	1	25	12	1	12	12	1	12	1	1	1	1	1	25	1	1	87	1	50	1	1
18	12	12	75	1	12	50	12	12	12	1	1	1	1	12	1	12	50	12	12	25	87	1	12	

Table V.3 continued

P	APHAB Item Number																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
19	1	12	87	1	1	25	12	25	1	1	12	1	12	12	1	12	75	25	25	12	12	12	1	1
20	1	12	87	1	1	12	12		1	1	1	1	12	1	1	25	12	1	12	50	1	50	1	25
21	1	12	87	12	1	25	1	1	1	1	12	1	1	1	1	25	12	1	1	12	99	1	12	1
22	1	12	99	1	12	75	12	25	12	1	25	1	1	25	1	25	99	12	12	25	12	99	1	50
23	1	25	99	25	1	50	25	25	1	1	12	12	1	12	1	87	75	12	50	50	25	1	99	25
24	1	12	12	25	12	12	12	1	12	12	50	12	1	1	1	12	12	12	12	12	50	12	25	12
25	1	25	25	12	12	25	12		1	1	12	1	12	12	1	50	25	1	12	50	12	12	12	1
26	1	12	99	12	25	1	1	25	12	1	12	1	1	1	1	12	12	1	1	87	12	12	1	12
27	1	12	87	12	50	25	25	12	12	1	25	1	1	1	1	12	99	12	75	99	12	75	25	12
28	1	12	87	12	12	25	1	25	1	1	1	1	1	1	1	12	87	1	12	75	1	12	1	12
29	12	12	75	1	25	75	12	12	12	12	12	12	1	1	1	25	50	12	12	25	12	12	25	25
30	25	75	1	1	1	99	87	1	1	1	50	1	1	1	1	75	1	1	50	1	12	1	12	50
31	12	25	25	12	1	25	12	25	25	1	12	1	1	1	1	12	12	25	12	12	25	12	12	12
32	1	25	1	1	12	25	12	25	50	1	25	1	12	1	1	25	12	25	25	1	50	1	99	75
33	1	12	50	12	1	50	1	12	12	1	1	1	1	1	1	12	1	12	1	1	1	1	1	12
34	1	12	75	12	1	12	12	12	1	1	1	1	12	1	1	12	75	12	12	87	1	25	1	1
35	1	25	12	1	1	50	12	12	1	1	1	1	1	1	1	12	25	1	12	1	1	1	1	1
36	12	25	75	12	12		25	25	25		12	25	12	12	12	50	25	12	25	75	12	12	25	25

Table V.4. Raw Data for APHAB Item Responses for the Participants (P) for the Hearing Impairment Group

P	APHAB Item Number																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	12	75	12	12	75	50	50	1	87	87	12	1	1	87	12	12	1	25	12	1	12	1	75	75
2	25	25	25	50	12	25	25	12	50	25	25	25	1	12	12	25	75	25	25	12	12	12	25	75
3																								
4	25	25	1	87	12	75	25	1	87	12	50	12	1	12	12	87	1	50	25	1	25	1	12	50
5	12	25	12	25	50	50	50	1	50	1	25	12	1	87	1	12	1	50	25	1	25	1	25	12
6	25	87	25	87	25	75	75	50	25	87	25	75	25	75	25	50	87	87	50	12	50	50	87	75
7	25	75	87	87	87	99	75	87	12	50	87	50	87	87	75	75	75	75	50	87	25	99	25	87
8	25	25	99	25	87	75	75	50	25	25	87	25	25	25	25	87	99	75	50	99	25	25	25	87
9	75	50	50	87	75	87	87	75	25	75	75	50	12	87	87	87	25	87	87	1	75	12	87	87
10	12	25	1	25	25	75	25	12	12	25	75	12	1	75	1	50	12	25	50	12	25	1	25	50
11	25	75	12	12	87	87	87	25	50	12	87	12	1	12	12	1	12	87	99	1	12	1	12	25
12	25	12	1	75	75	75	50	12	25	25	25	25	1	50	12	75	1	50	75	1	50	1	25	25
13	87	25	1	25		50	50	87	25	25	75	12	1	12	12	50	1	50	50	1	50	1	25	75
14	25	50	12	75	50	12	50	12	87	25	25	25	12	50	25	50	12	50	12	1	25	12	25	25
15	1	25	25	25	25	12	25	25	25	12	25	12	1	12	12	25	25	50	50	1	25	12	25	25
16	12	12	12	1	12	12	50	12	12	1	25	12	1	12	1	75	1	25	12	1	12	1	1	12
17	1	1	1	50	1	1	1	1	1	1	1	1	1	1	1	12	1	1	1	1		1	1	1
18	25	50	12	25	25	50	50	12	75	25	50	25	12	12	12	25	25	75	25	12	25	12	25	50

Table V.4 continued

P	APHAB Item Number																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
19	12	87	50	50	12	25	25	25	50	12	25	25	12	25	12	25	50	25	25	25	25	75	25	25
20	25	25	12	25	25	75	25	12	50	25	50	12	12	50	12	50	25	25	25	12	87	12	50	25
21	50	50	50	99	99	87	75	87	25	12	25	50	12	99	12	12	87	75	25	50	75	12	87	87
22	50	25	12	50	25	75	25	75	50	12	50	25	12	12	25	75	12	50	75	1	75	12	25	75
23	25	50	25	75	25	50	50	25	50	50	50	25	12	50	25	25	50	87	50	75	50	75	75	50
24	25	25	75	25	50	25	25	25	25	25	50	25	1	25	1	50	25	50	25	12	50	1	25	25
25	25	25	1	50	25	25	50	12	50	25	50	50	25	50	25	50	12	25	25	1	50	12	25	25
26	1	25	1	25	25	25	12	1	25	25	75	25	1	25	25	25	1		25		25	1	25	25
27	25	87	25	75	87	99	75	1	25	75	87	75	1	87	75	50	24	87	12	25	12	1	75	87
28	12	25	75	75	12	25	25	25	50	25	75	50	12	50	12	50	50	50	50	25	50	25	50	50
29	50	25	12	75	75	75	75	1	50	25	87	50	1	50	25	25	12	75	87	1	50	1	50	50
30	12	75	25	75	75	50	50	75	75	25	50	75	25	87	75	50	25	50	50	1	50	1	75	50
31	12	12	1	1	12	25	25	12	12	1	12	12	12	12	12	75	25	12	25	12		87	12	12
32	12	25	87	12	25	50	25	12	12	12	75	12	1	12	1	25	87	25	87	99	12	87	12	75
33	12	12	99	12	25	87	87	25	50	12	25	25	12	12	12	87	25	25	12	87	25	12	25	50
34	25	37.5	87	25	50	50	37.5	75	25	18.5	37.5	25	25	25	12	50	75	50	50	75	50	75	25	75
35	50	50	25	25	75	75	75	25	25	50	25	25	12	50	25	75	50	50	87	12	75	12	25	50
36	25	50	75	25	50	75	50	25	50	25	50	25	12	12	12	87	25	50	25	12	50	50	25	50

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Presentations and Publications

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