The Australian SpIN™ speech in noise test

Peter J. Blamey[1,2], Maryam Zargarbashi[1,2], Jeremy K. Blamey[1,2], and Elaine Saunders[1,2]

[1] Blamey and Saunders Hearing Pty Ltd, Australia
[2] Department of Audiology and Speech Pathology, The University of Melbourne, Australia
[3] Faculty of Science Engineering and Technology, Swinburne University of Technology

peter.blamey@blameysaunders.com.au, mzargarbashi@student.unimelb.edu.au, jeremy.blamey@blameysaunders.com.au, elaine.saunders@blameysaunders.com.au

Abstract

An Australian recording of the QuickSIN sentences was tested with 12 normally hearing adults and 12 adults with impaired hearing to determine the signal-to-noise ratio at which 50% of words were recognised (SNR50). Speech was presented from the front and four-talker babble was presented from behind the listener. Eight of the 12 lists gave equivalent SNR50 values (–3.8 to –4.8 dB) for listeners with normal hearing. SNR50 for listeners with impaired hearing averaged 10.3 dB unaided and 2.7 dB in the aided condition, indicating an average 7.6 dB benefit from the use of hearing aids with adaptive directional microphones.

Index Terms: speech, noise, signal-to-noise-ratio, hearing loss, hearing aid, directional microphone

1. Introduction

A problem commonly reported by hearing aid (HA) users is difficulty understanding speech in noise [1]. In 1970, Carhart and Tillman [2] emphasized the importance of measuring speech recognition in the presence of background noise, suggesting speech-in-noise tests be included in the standard audiometric test battery. Several tests have been developed for this purpose, including the HINT (Hearing In Noise Test) [3] and the QuickSIN (Quick Speech In Noise) Test [4]. In 1978, Plomp [5] proposed a model of hearing impairment comprised of two independent components: an attenuation component and a distortion component which was equivalent to a signal-to-noise-ratio (SNR) component. In keeping with Plomp's model, the QuickSIN estimates an SNR50 value which is the SNR at which a listener recognises 50% of words in sentences correctly and compares it with the SNR50 for normally hearing people to estimate the SNRloss [4]. If Plomp's model is correct then the SNRloss and the audiogram together will provide a better characterization of an individual's hearing loss than either measure on its own.

The QuickSIN can also be used to estimate the SNR50 with HAs fitted to find the HA benefit as the difference between the aided and unaided SNR50 values. It is common these days for digital HAs to provide substantial benefits in background noise as a consequence of the use of directional microphones. Depending on the directions of the speech and noise, the benefits can be as great as 8 deciBels (dB) increase in the effective SNR [6]. Being able to experience this effect and demonstrate the size of the benefit in background noise can be an important factor in convincing people of the benefit of wearing HAs.

The original QuickSIN test materials [7][8] were recorded with an American speaker. Twelve equivalent QuickSIN sentence lists were developed. Each QuickSIN list consisted of six Institute of Electrical and Electronics Engineers (IEEE) phonetically balanced sentences, to provide subtle semantic cues with strong syntax cues [9]. Each sentence contained five key words presented at a fixed level in multi-talker babble. The multi-talker babble level was increased by 5 dB for successive sentences to produce SNR values from 25 dB to 0 dB to accommodate the performance of normal to severely hearing-impaired individuals [7][8]. Killion et al. [4] found normal hearing participants' SNR50 was +2 dB SNR and used this value to calculate SNRloss. The American QuickSIN has been widely used, but is not ideal for Australian listeners because of the American accent of the speaker.

A new Australian recording of the QuickSIN sentences was available and the purpose of this study was to test the equivalence of the 12 lists in the new recording, and to provide an SNR50 value for young Australian adults with normal hearing in order to calculate SNRloss in an equivalent manner to the original QuickSIN. The experiments were designed to test the three hypotheses that the 12 Australian lists would be of equivalent difficulty, that the SNR50 value for the normally-hearing participants would be 2 dB as for the American test, and that the benefit of HAs would be about 7 dB as measured for adaptive directional microphones in a previous study [6] using a different speech in noise test.

2. The Australian SpIN™

2.1. Recordings

Twelve SpIN lists, consisting of six sentences per list with five key words per sentence, were recorded by an Australian female speaker together with babble for 4 Australian talkers at the correct SNRs in separate channels. For hearing impaired listeners the SNR range was 20 to –5 dB and for normal hearing listeners the SNR range was 15 to –10 dB, with 5 dB decrements from one sentence to the next. The SNR ranges chosen for the Australian SpIN in order to include the possibility of negative SNR50 values as shown in previous studies [The method used to measure and equalize the levels of sentences and babble was to estimate the intensity in 20 ms windows, discard all estimates with intensity below a threshold of 30 dB and then use the 95th percentile of the remaining estimates as the intensity for the sentence or noise. The goal of this process was to ignore periods of silence before, after, or during the sentences.

2.2. Presentation

Each participant was provided with the following 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." Each sentence in noise was presented by a computer program when the participant was ready. The test was routed through two speakers in the free field of a sound-proof booth. One speaker presented the sentences at 0˚ azimuth, with the multitalker babble noise played by a second speaker at 180˚ azimuth. The front and back locations of speech and noise were chosen to demonstrate the benefit of directional microphones to HA users. The sentences were presented at a fixed level of 65 dBA and multitalker babble was increased by 5 dB increments, to span a 25 dB SNR range. The participant repeated the words in each sentence and the experimenter indicated on the computer screen which key words were correctly repeated by the participant. One point was scored for each of the five key words correctly recognized in each sentence

3. Participants

Twenty four people participated in this study, one group of twelve young adults with normal hearing, and a second group of twelve experienced adult HA users.

3.1. Audiometric screening

All participants were tested with an audiometer to establish hearing thresholds from 250 Hz to 6 kHz. Normal middle ear function, nil communication problems, and native English speaking backgrounds were also established prior to testing.

3.2. Cognitive and memory screening

All participants were screened for cognitive deficits [10] using the Mini Mental State Examination (MMSE) [11] and the Wechsler forward and reverse digit span (DS) test [12]. A minimum score of 24 on the MMSE, a forward digit-span of 5 or more, and a reverse digit-span of 4 or more [13] were required for study participation. These criteria were required because poor auditory working memory and reduced cognition can result in poorer speech recognition performance, particularly for older adults with a hearing loss [14].

4. Standardisation with normally-hearing listeners

Twelve volunteers with hearing thresholds of ≤ 15 dB HL were recruited from the 2014 Melbourne University M. Aud. student cohort. Ages ranged from 21 to 31 years with a mean of 23.8 years. Participants listened to the 12 SpIN lists within a latin square experimental design to avoid bias effects of order, participant, and list. The SNR for the six sentences started at 15 dB and reduced by 5 dB per sentence down to –10 dB. If the actual SNR50 was 0 dB, the expected number of key words correct would be 17.5 per list. The number of key words recognized correctly was totaled for the 6 sentences of each list and the SNR50 was estimated for each list using the formula:

$$SNR50(normal\ hearing) = 17.5 - (words\ correct) \qquad (1)$$

A three-factor balanced ANOVA of the 144 SNR50 values indicated significant differences between SpIN lists {F(11,110) = 8.0, p<0.001} and participants {F(11,110) = 4.4, p<0.001} but order of list presentation {F(11,110) p=0.252} had no significant effect.

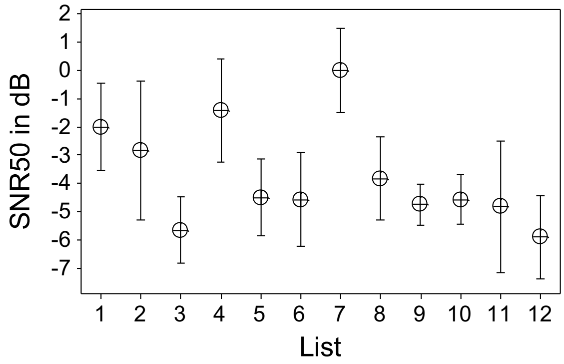

Figure 1. *Mean SNR50 scores and 95% confidence intervals for normal hearing participants (n=12) for 12 SpIN lists.*

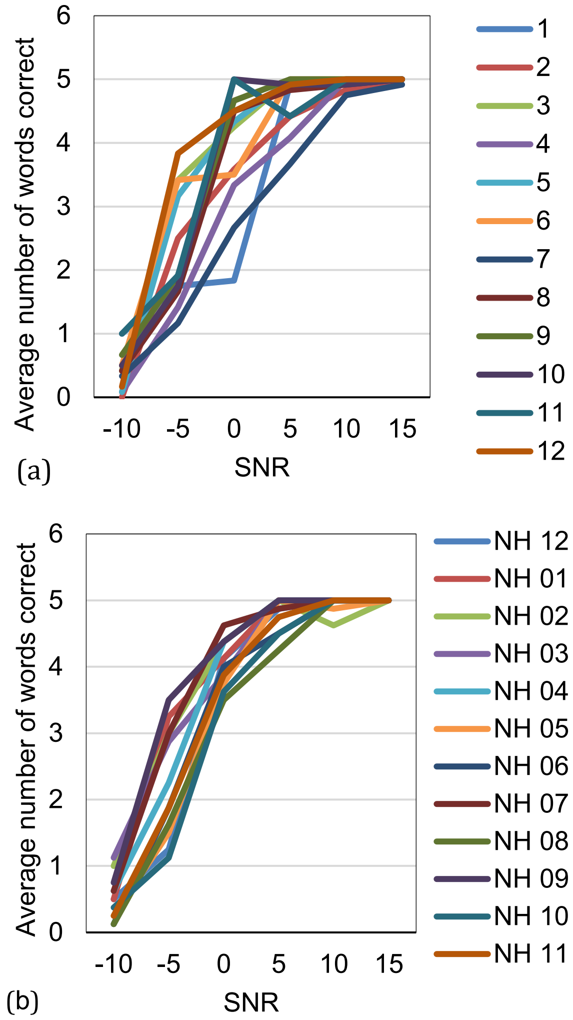

Figure 2. *Number of words correct per sentence a) averaged across participants for each list, and b) averaged across lists for each participant*

Bonferroni post hoc comparisons of the means in Figure 1 showed that lists 3, 4, 7 and 12 were different from the rest and that there was no significant difference between the remaining

8 lists. The across-subject SNR50 average for the 8 equivalent SpIN lists was –4.0 dB (± 2.7 dB st. dev.).

Figures 2 a) and 2 b) indicate that the eight balanced lists and the twelve participants produced similarly shaped performance versus SNR curves. Note that the first sentence in each list was at +15 dB SNR and every participant scored 5 words correct for every list. The last sentence in every list was at –10 dB SNR and the average number of words correct was between 0 and 1 for every list and for most participants.

5. Investigation of the SpIN with HA users

Twelve adult HA users with mild, moderate, or severe symmetrical high frequency sensorineural hearing loss were recruited from the Blamey Saunders Clinic. Their average age was 65.2 years and individual age ranged from 26 to 88 years. They were binaurally fitted with Blamey Saunders HAs which they had used for between 6 weeks and 5 years at the time the SpIN was carried out. All but one participant (11) reported using their HAs for at least 8 hours per day. The HAs all incorporated automatic adaptive directional microphone technology [6].

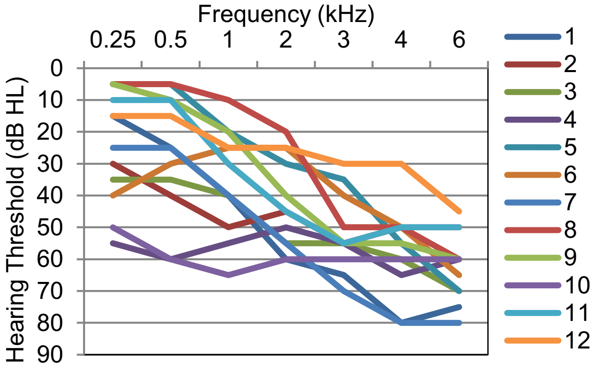

Figure 3. *Audiograms in the better ear for each participant in Group 2.*

Each participant was tested with three SpIN lists in the unaided and aided conditions. Three pairs of lists of equal difficulty were used (8 and 5, 6 and 10 and 9 and 11). One list from each of these pairs was administered in the aided and the other in the unaided condition randomly to ensure equal difficulty of sentence lists in aided and unaided conditions across participants. The condition presented first was randomly chosen. SpIN sentences in each list were presented at SNRs ranging from 20 dB to −5 dB with 5 dB decrements (ie 5 dB greater SNR than for the normally hearing participants). If the actual SNR50 was 0 dB, the expected number of key words correct would be 22.5 per list. The SNR50 for hearing impaired participants was calculated using the equation:

$$SNR50(hearing\ impaired) = 22.5 - (words\ correct) \quad (2)$$

SNR50(unaided) and SNR50(aided) were calculated by averaging over 3 lists each. SNRloss was calculated as

$$\begin{aligned} SNRloss &= SNR50(unaided) - SNR50(normal) \\ &= SNR50(unaided) + 4.0 \quad (3) \end{aligned}$$

SNRbenefit for each participant was calculated as

$$SNRbenefit = SNR50(unaided) - SNR50(aided) \quad (4)$$

The SNR50 for hearing impaired participants ranged from –3.2 to 11.2 dB in the aided condition and –0.5 to 21.2 dB in the unaided condition. SNRloss ranged from 0.8 to 15.2 dB, and SNRbenefit ranged from 0.0 to 18.3 dB.

Figure 4 shows that the shapes of the performance versus SNR curves for the HA users were less steep than the corresponding curves for the normally hearing participants in Figure 2b. Participants 1, 2, 3, 4, 7, and 10 scored 2.5 words correct or less on average in the unaided condition at 20 dB SNR. These were the participants with the greatest hearing loss in Figure 2, and their poor scores were caused by poor audibility of the sentences at the high SNR values. In this case, the formula used to estimate the unaided SNR50 value for these participants was invalid because there was no SNR tested at which the percentage of words correct was greater than 50%. The SNR50 values estimated for these participants in the unaided condition should be treated with caution. If these six participants are ignored, the unaided SNR50 for the remaining HA users ranged from – 0.2 to + 8.5 dB, SNRloss ranged from 3.8 to 12.5 dB, and SNRbenefit ranged from 0 to 9.3 dB. The mean SNR benefit was 4.1 dB. All of the HA users scored higher than 50% at 20 dB SNR in the aided condition, and so the aided SNR50 estimates are valid.

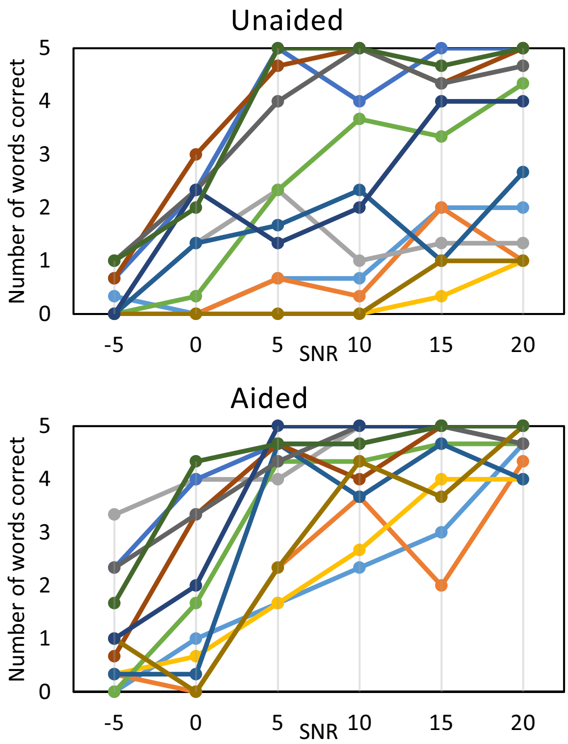

Figure 4. *Number of words correct per sentence averaged across lists for each participant in the unaided and aided conditions.*

6. Discussion

The two hypotheses based on the American QuickSIN were both disproved by this study (a) that the 12 lists would be equivalent, and (b) that the SNR50 for normal listeners would be 2 dB SNR on average.

The Australian SpIN differs from the American QuickSIN in a number of ways that had a strong influence on the results, even though the actual sentences and key words were identical.

- The sentences and babble were recorded by Australian speakers

- The sentences and noise levels were normalised in a specific manner that may have been different from the method used for the American QuickSIN
- The sentences were presented from in front of the listener (0° azimuth) and the noise was presented from behind (180° azimuth).
- Performance of normally hearing individuals was determined without filtering the sentences in Australia, and using high pass filtered speech in America.
- The Australian lists were normalised using a 15 dB to –10 dB range of SNRs while the American lists were normalised using a range from 25 dB to 0 dB SNR. In the American study, normal listeners made errors only at the 5 and 0 dB SNRs so there may have been a floor effect in their data.
- In the current study normal hearing was defined as thresholds of ≤ 15 dB across the 0.25 to 6 kHz frequency range, whilst normal hearing was defined as thresholds ≤20 dB for the same frequency range by Killion et al [4].

The mean SNR50 for normally hearing listeners was –4.0 dB in Australia and +2 dB for the American version. The differences listed above are more than sufficient to account for this. It should be noted that the Australian SpIN SNR50 is in accord with the value of –4 dB measured by Miller, Heise, and Lichten [15] for words in sentences in white noise and the value of –6.4 dB reported by Bronkhorst and Plomp [16] for sentences in speech shaped noise modulated by the envelope of 4-talker babble.

Interpretation of the unaided SNR50 estimates was complicated by the fact that half of the participants with impaired hearing did not have sufficiently good thresholds to be able to score above 50% on the sentences even when the SNR was +20 dB. When these six participants were excluded from the analysis, the data analysis was more straight-forward. Both the SNRloss values and the SNR benefits were more moderate and more in line with expectations. The mean and maximum SNR benefit of 4.1 and 9.3 dB respectively were reasonably in accord with the expected benefit of 7 dB expected from the adaptive directional microphone [6] under these testing conditions.

Although the unaided SNR50 estimates were not valid for the six HA users with the greatest hearing loss, the raw scores from the SpIN were still valid and they show that these participants were the ones who actually benefited most from their HAs in background noise. The reason for this is that there was an audibility benefit from the HAs in addition to the SNR benefit from the adaptive directional microphones.

7. Conclusion

The Australian SpIN test gave different results from the American QuickSIN from which it was derived, but in some ways, the Australian SpIN results were more in accord with the published literature on speech perception in noise. Eight of the twelve lists were chosen as being reasonably equivalent, and a study of twelve listeners with impaired hearing showed that there was a significant improvement in Australian SpIN scores between the unaided and aided conditions. Valid measurements (in dB) of SNRloss and SNRbenefit could be derived for 50% of listeners with the least degree of hearing loss. The test is useful clinically to demonstrate the benefits of HA use in background noise for clients across a wide range of hearing loss types and degrees.

8. Acknowledgements

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