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Instructions for Use – EN

BKB-SIN

Speech-in-noise test

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Interacoustics

Table of Contents

1. BKB-SIN Speech-in-noise test

1.1 Quick start (standard version)

- Activate your license key to get access to the BKB-SIN Speech-in-noise test.
- Present the test via earphones or in a sound field with attenuator dial set to 70 dB HL. For subject with 3F PTA hearing losses greater that 45 dB HL, set the attenuator dial to a level that is" Loud, But OK".
- When testing in a sound field, have the patient speak into the talkback microphone so that responses are clearly audible to the tester.
- Instruct the patient to repeat the sentences spoken by the main talker and to ignore the background talkers.
- A verbal 'ready' cue precedes each sentence.

1.2 Scoring

- IMPORTANT: The BKB-SIN Test contains 18 List Pairs that are equated for difficulty. Each List Pairs has two lists; *both* lists of the pair (A&B) must be administered for valid scoring. Each List Pair takes approximately three minutes to administer and score.
- The first sentence in each list has four key words, and the remaining sentences each have three. Give one point for each key word repeated correctly (key words are underlined on the score sheets). Write the number of correct words for each sentence on the line provided.
- Add the number of correct words for each list, putting the sum in the space provided. Subtract the total correct from 23.5 to obtain the SNR-50 (signal-to-noise ratio for 50% correct).
- Score each list, then average the two scores for the List Pair using the space provided on the score sheets (see Figure 1). When administering more than one List Pair, average the SNR-50 scores across List Pairs. As in any measure, reliability is influenced by the number of items presented. See Table 4 to determine the desired number of List Pairs.
- Calculate SNR Loss by subtracting the SNR-50 score from the group-average value (see Table 2).

Figure 1 Scoring example

LIST PAIR 2

List 2A		Key Words	#Correct	SNR
1	The cat is sitting on the bed.	4	4	+21 dB
2	They had a lovely day.	3	3	+18 dB
3	The ~~thin~~ dog was hungry.	3	2	+15 dB
4	~~They~~ are watching the ~~train~~.	3	1	+12 dB
5	The dog played with a ~~stick~~.	3	2	+9 dB
6	The ~~farmer~~ ~~keeps~~ a ~~bull~~.	3	0	+6 dB
7	The lady ~~wore~~ a ~~coat~~.	3	1	+3 dB
8	The ~~boy~~ is ~~running~~ ~~away~~.	3	0	0 dB
9	The room is ~~getting~~ ~~cold~~.	3	0	-3 dB
10	The ~~wife~~ ~~helped~~ her ~~husband~~.	3	0	-6 dB
	Total Key words correct:		13	
	SNR-50 = (23.5) – (#Correct) =		10.5	dB

List 2B		Key Words	#Correct	SNR
1	The lady went to the store.	4	4	+21 dB
2	A tree fell on the house.	3	3	+18 dB
3	The fruit came in a box.	3	3	+15 dB
4	The husband brought some flowers.	3	3	+12 dB
5	A man ~~told~~ the police.	3	2	+9 dB
6	Potatoes ~~grow~~ in the ~~ground~~.	3	1	+6 dB
7	The ~~big~~ ~~dog~~ was ~~dangerous~~.	3	0	+3 dB
8	The ~~strawberry jam~~ was ~~sweet~~.	3	0	0 dB
9	The ~~boy~~ has ~~black~~ ~~hair/tie~~.	3	0	-3 dB
10	The ~~mother~~ ~~heard~~ the ~~baby~~.	3	0	-6 dB
	Total Key words correct:		16	
	SNR-50 = (23.5) – (#Correct) =		7.5	dB
	Average SNR-50, Lists 2A and 2B=		9	dB

10.5 + 7.5 = 18

18 ÷ 2 = 9

1.2.1 Interpretation (Adults)

SNR LOSS	DEGREE OF SNR LOSS	EXPECTED IMPROVEMENT WITH DIRECTIONAL MICROPHONES
0-3 dB	Normal/near normal	May hear better than normals hear in noise.
3-7 dB	Mild SNR loss	May hear almost as well as normals hear in noise.
7-15 dB	Moderate SNR loss	Directional microphones help. Consider array microphone.
>15 dB	Severe SNR loss	Maximum SNR improvement is needed. Consider FM system.

Table 1 General guideline for SNR Loss interpretation for adults.

1.2.2 Interpretation (Children)

Interpreting test results for children should be done on a case-by-case basis. Results should not be interpreted in isolation, but rather be integrated with other information regarding a child's speech/language abilities, educational performance and ability to function in the classroom. For additional information, refer to Test Interpretation.

1.3 What is included in BKB-SIN Speech-in-noise test

Th Speech-in-noise test contains recordings of 18 BKB-SIN List Pairs (BKB sentences in four-talker babble). It also includes the target talker and background babble recorded on the same channel at pre-recorded signal-to-noise ratios (SNRs). As well as the target talker and background babble recorded.

1.3.1 Standard BKB-SIN

List Pairs 1-18
Track 21: Speech Spectrum Noise Recorded at 0 VU re: Cal Tone on Track 2.

List Pairs 1-8 have ten sentences in each list, with one sentence at each SNR of: +21, +18, +15, +12, +9, +6, +3, 0, -3 and -6 dB. The level of the target talker remains constant, and the level of the background babble increases by 3 dB for each sentence, to the 0 dB SNR level (sentence 8). In the last two sentences in these lists (sentences 9 and 10) the level of the background babble remains constant (the same level as at the 0 dB SNR sentence) and the level of the target talker *decreases*. This was done to reduce the SNR without increasing the relative constant overall presentation level.

List Pairs 9-18 have eight sentences in each list, with one sentence at each SNR of: +21, +18, +15, +12, +9, +6, +3 and 0dB. The level of the target talker remains constant, and the level of the background babble increases by 3 dB for each sentence.

1.3.2 Split Track BKB-SIN

Split Track 1, List Pairs 1-18
Split Track 2, List Pairs 9-14
Track 28: Speech Spectrum Noise Recoded at 0 VU re: Cal Tone on Track 2

Split Track 1
In these recordings the target talker and background babble are recorded on separate channels (Channel 1= target talker, Channel 2 = background babble) so the speech and babble can be presented through separate loudspeakers in the sound field. When the audiometer attenuators are set correctly (both attenuators set to identical presentation levels) these tracks maintain the same signal-to-noise ratios as on the standard recording; that is, the signal-to-noise ratio automatically changes by 3 dB for each sentence.
Note: Results obtained using Split Track 1 recordings (target and babble directed to separate loudspeakers) will be improved compared to results obtained using the Standard recordings (target and babble directed to a single loudspeaker). When the target talker and background babble are spatially separated, performance improves several dB over that of a single loudspeaker presentation. To avoid a test floor effect when using the Split Track 1 recordings with normal-hearing listeners, the SNRs need to be adjusted in the initial setup by decreasing the attenuator setting of the target talker (Channel 1) by 6 dB.

Example:
Default setup: Set both attenuators (target talker and background babble channels) to 70 dB HL. The resulting SNRs for the Split Track 1 lists are: +21, +18, +15, +12, +9, +6, +3, 0, -3 and -6 dB. SNR-50 = 23.5 - Total Correct.

Adjusted setup for normal-hearing listeners: Set the attenuator the target talker (Channel 1) to 64 dB HL. Set the attenuator for the background babble (Channel 2) to 70 dB HL. The resulting SNRs for the Split Track 1 lists are: +15, +12, +9, +6, +3, 0, -3, -6, -9 and -12 dB. In this case, SNR-50= 17.5 – Total Correct.

Split Track 2
These Split Track recordings were designed for research and special applications. Both channels of these tracks (Channel 1 = target talker, Channel 2 = background babble) were recorded at a constant overall level. The signal-to-noise ratios do not change automatically after each sentence; the tester must manually adjust the level of the target talker and/or the background babble to change the signal-to-noise ratio.

1.4 Test Instructions

1.4.1 Test instructions (Adult)

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

1.4.2 Test Instructions (Child)

You will hear a man talking to you through the earphones (or loudspeaker). He is going to say "Ready" and then he'll say a sentence. Repeat the sentence the man says. You will hear other talkers in the background. Don't pay any attention to them; just repeat what the man says. The background talkers will get louder, and then it will be hard for you to hear the man's voice. When that happens, it is OK to guess; repeat anything you think you heard the man say.

1.4.3 List Pairs

The BKB-SIN Test contains 18 List Pairs that are equated for difficulty. Each List Pair has two lists; both lists of the pair must be administered, and the scores averaged, for valid results. Use of individual lists (e.g., 1A, 2A, etc.) invalidates the equivalence of the List Pairs. Each List Pair takes approximately three minutes to administer and score.

List Pairs 1-8 can be used with all listeners. The range of SNRs on these lists (+21 dB to -6 dB) makes them appropriate for a wide range of SNR losses, as well as for normal-hearing listeners.

List Pairs 9-18 encompass a smaller range of SNRs (+21 dB to O dB). These provide ten additional equivalent List Pairs that can be used for cochlear implant patients and those with significant SNR loss. These List Pairs are not recommended for normal- hearing listeners, since a test floor effect will occur.

1.4.4 Practice

To familiarize the listener with the task, administer one list (half of a List Pair) as a practice list. Since List Pairs 1-8 will be used most often for routine clinical testing, one of the remaining lists (any list from 9A to 18B) can be used as a practice list.

1.5 Scoring

The first sentence in each list has four key words, and the remaining sentences each have three. Key words are underlined on the score sheets. One point is given for each key word repeated correctly. The number of correct words for each sentence should be written in the space provided at the end of the sentence, and the total number correct calculated for each list. The total correct is subtracted from 23.5 to obtain the SNR-50 (signal-to-noise ratio for 50% correct). See Appendix B.

SNR-50 = 23.5 - Total Correct

The SNR-50 scores for both lists of the List Pair must be averaged to obtain the List Pair score. When administering more than one List Pair, the List Pair scores are averaged.
To calculate SNR Loss, locate the appropriate subject category in Table 2 (e.g., Adult, Child, Adult Cochlear Implant User).

SNR Loss = Subject's SNR-50 - Average SNR-50 for that Subject Category

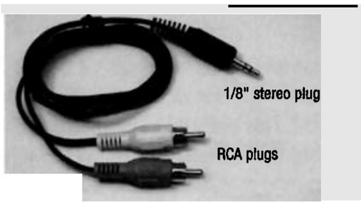
Table 2 BKB-SIN Test Norms (List Pairs 1-8)

	Adults		Children by age		
	Normal Hearing	CI Users	Ages 5-6	Ages 7-10	Ages 11-14
Mean SNR-50	-2.5	*	3.5	0.8	-0.9
Standard Deviation	0.8	1.6	2.0	1.2	1.1

*Compare to normal-hearing adult value to determine SNR Loss

Example: If you are testing a 6-year old child and the SNR-50 score is 8.5, the SNR Loss = 8.5 (subject score) - 3.5 (average value for a normal-hearing 5-6 year old) = 5 dB. This child needs 5 dB greater SNR than the average normal-hearing 5-6 year old child for equivalent performance on this task. If performance is compared to the average adult value (-2.5 dB), this child needs 11 dB greater SNR than the average normal-hearing adult for equivalent performance on this task.

Note: An interesting phenomenon occurs in five sentences when the Standard and Split Track recordings are compared: normal-hearing listeners perceive a different word on the Standard recording than on the Split Track recordings. For example, when the target talker and background babble are presented from a single source using the Standard recording (earphone or loudspeaker presentation), sentence nine of List 28 is heard as "The boy has black tie." When the target talker and background babble are spatially separated using the Split Track recordings (target talker from one loudspeaker and background babble from another loudspeaker), sentence nine of List 28 is heard as "The boy has black hair." In the first instance, the word "tie" (spoken by one of the babble talkers) masks the word "hair" (spoken by the target talker). For this reason, two possible correct answers are shown on the score sheet (see Figure 1). Sentences containing a key word with two possible correct answers are: **List 2B, sentence 9; List 8A, sentence 5; List 8B, sentence 9; List 15B, sentence 5; and List 18A, sentence 7.**



1.5.1 Presentation Mode

The Standard recording is presented via earphones or through a single loudspeaker in the sound field. When using earphones (inserts or TDH) the test may be presented either monaurally or binaurally. Testing each ear separately provides ear-specific information but takes twice as long. Testing binaurally provides an overall estimate of a person's ability to hear in noise. Normative data were collected using binaural presentation.

Split Track

Use of the Split Track recordings requires a calibrated sound field. The speech spectrum noise on Track 27 can be used to verify presentation levels at the listener's position.

Testing can be conducted using speakers at 0 and 180 degrees or 45 and 135 degrees. In some cases (e.g., testing directional microphone hearing aids) results will be somewhat influenced by loudspeaker location. An inexpensive alternative that can be implemented in most clinical settings is a ceiling-mounted speaker that provides a neutral location for presentation of the competing signal (Mueller and Sweetow, 1978).

Presentation Level

The choice of presentation level depends on the purpose of testing.

1.5.2 Standard SNR Loss Testing

For standard SNR Loss testing the BKB-SIN Test should be presented at a relatively high level (Loud, But Below Discomfort). A relatively high presentation level is recommended for two reasons:

1. To maximize audibility. SNR Loss is a measure of the hearing in noise deficit beyond that caused by a lack of audibility; in other words, after making as much of the speech signal audible as possible, the SNR Loss reflects the remaining deficit that would likely be experienced by the user, even after being appropriately fitted with hearing aids.
2. To represent the sound levels found in most typical social gatherings [commonly 65 to 85 dB SPL (Killion, 2004)) and schools [65 to 72 dB for occupied classrooms (Jamieson et. al., 2004) and 75 to 86 dB A for occupied school cafeterias and gymnasiums (Ross, 1992)).

Other presentation levels may be chosen based on the purpose for testing (see "Other Uses"). Normative data on normal-hearing adults and normal-hearing children were collected using binaural presentation via insert earphones, at a presentation level of 70 dB HL (83 dB SPL). Normative data on adult cochlear implant users were collected using a 65 dB SPL presentation level in sound field (equivalent to 50 dB HL at O degrees azimuth).

If a 70 dB HL presentation level is uncomfortably loud for the listener, the presentation level may be decreased to a level the listener judges as "Loud, But OK" (see Appendix A). A previous experiment with the SIN Test revealed no significant differences in scores for fourteen normal-hearing adults at presentation levels of 50, 60 and 70 dB HL (Niquette, 1998). Since average conversational speech levels are typically in the range of 60 to 70 dB SPL (Cox and Moore, 1988; Pearsons et. al., 1977) the presentation level for basic SNR Loss testing should never be lower than 50 dB HL. For individuals with greater than a mild hearing loss, presentation level should be greater than 70 dB HL.

Table 3 Suggested Presentation Levels for Standard SNR Loss Testing

	Hearing Loss:	**Set Dial To:**
Adult	Normal hearing or mild loss 3F PTA > 45 dB HL	70 dB HL* Loud, But OK (See Appendix A)
Child	Normal hearing or mild loss 3F PTA > 45 dB HL	50 to 70 dB HL Loud, But OK (See Appendix A)
CI User	Aided with Cochlear Implant	50 to 70 dB HL

*At this level the frequent peaks of the talker are at approximately 83 dB SPL for insert earphones, 85 dB SPL at O degrees azimuth in sound field, and 90 dB SPL with TOH earphones (ANSI S3.6 Specification for Audiometers, 1996).

1.6 Test Interpretation

1.6.1 Adults

Knowing the SNR Loss allows the hearing professional to recommend the appropriate technology (e.g., omni-directional microphones, directional microphones, array microphones, FM systems) required for the listener to function in common noisy situations.
Just as important, knowing the SNR Loss enables the hearing professional to give patients realistic expectations for their potential improvement in noise with a given amplification technology. Measuring SNR Loss also increases clinical efficiency; the results of several minutes of testing can be used for counselling patients appropriately and guiding their expectations, which often reduces unnecessary visits for hearing aid re-adjustments.

The table below provides a general guideline for SNR Loss interpretation for adults.

SNR LOSS	DEGREE OF SNR LOSS	EXPECTED IMPROVEMENT WITH DIRECTIONAL MICROPHONES
0-3 dB	Normal/near normal	May hear better than normals hear in noise.
3-7 dB	Mild SNR loss	May hear almost as well as normals hear in noise.
7-15 dB	Moderate SNR loss	Directional microphones help. Consider array microphone.
>15 dB	Severe SNR loss	Maximum SNR improvement is needed. Consider FM system.

Table 1 (repeated from section 1.2.1)

1.6.2 Children

The effects of SNR Loss are more pronounced for children than adults. Adults possess linguistic proficiency and world knowledge that facilitates speech perception, whereas children are in the process of acquiring linguistic and world knowledge through audition. While hearing aids with directional microphones can reduce the difficulties experienced by an adult with a 5 dB SNR Loss, typical classroom factors (distance from the teacher, high levels of background noise, and reverberation) can degrade the incoming speech signal so much that a 5 dB improvement may be inadequate to meet a child's listening needs. A child with a 5 dB SNR Loss may need hearing aids and/or a wireless or infrared assistive listening device plus classroom modifications to function optimally in the typical classroom.

Interpreting test results for children should be done on a case-by-case basis. Factors such as the student's speech, language and academic skills, as well as the learning environment (class size, acoustic properties of the room, and teaching style) should be considered. For example, a 5 dB SNR Loss may have less impact on a child who has strong communicative and academic skills than one who is struggling in those areas. Similarly, classroom environments that are instructionally and acoustically hospitable can sometimes reduce the adverse impact of the SNR Loss, while those that are not may increase the impact of the SNR Loss. Consultation with a child's educational audiologist, classroom teacher, and/or speech-language pathologist may be necessary to identify pertinent factors in the child's learning environment and to make appropriate recommendations for amplification and classroom management. As the BKB-SIN Test becomes widely used with children, published reports should improve the ability to interpret test results for different age groups and special populations.

1.7 Other Uses For The Bkb-Sin Test

The BKB-SIN Test is a flexible tool that can be applied clinically in a variety of ways by adjusting the presentation level or the presentation mode. When using the BKB-SIN Test in ways other than the Standard SNR Loss protocol, the normative data do not apply.

Clinicians should set the test parameters based on their purpose for testing, and develop their own set of local norms for this purpose.

1.7.1 Demonstrating the Benefits of Amplification

Scores for unaided and aided presentation are compared to demonstrate aided benefit (Sweetow, in Mueller, 2001). See "Comparing Two Conditions" to determine significant differences for two scores.

Procedure: Present List Pairs through a single loudspeaker in the sound field at a low presentation level (45 dB HL).

1.7.2 Predicting Performance with Hearing Aids In Loud, Noisy Environments

Scores for unaided and aided presentation are compared (see "Comparing Two Conditions") to determine significant differences for two scores. Decreased performance in the aided condition merits further investigation. Possible causes include narrow bandwidth, clipping distortion and overload distortion (all of which are possible even in high-end digital hearing aids). Testing at 70 dB HL also provides a way to verify that the maximum output level of the hearing aids is set appropriately; if loudness discomfort occurs at this level, the output of the hearing aids should be reduced.

Procedure: Present List Pairs through a single loudspeaker in the sound field, using a relatively high presentation level (70 dB HL). Performance in the aided condition should not decrease compared to the unaided condition.

1.7.3 Assessing Directional Microphone Performance

Scores for omni and directional conditions are compared (see "Comparing Two Conditions" to determine significant differences for two scores). Keep in mind that sound- treated booths do not provide a perfect representation of the real world, and test results may be influenced by the interaction of loudspeaker location and the null of the directional microphones. An inexpensive alternative that provides a better representation of the effects of real-world noise is a ceiling-mounted loudspeaker that provides a neutral location for presentation of the background babble (Mueller and Sweetow, 1978). The BKB-SIN Split Track recordings should be used as a general, rather than absolute, estimate of omni/directional performance differences.

Procedure: Present List Pairs from Split Track 1 through two loudspeakers in the sound field, with the target talker (Channel 1) directed to one loudspeaker and the background babble (Channel 2) directed to the other loudspeaker (any typical speaker setup is acceptable, e.g., 0/180 or 45/135). Set both attenuators to 70 dB HL. The signal-to-noise ratios will automatically change for each sentence.

1.7.4 Estimating Children's Performance for Soft Speech

Scores for unaided and/or aided presentation are compared to local norms (see "Comparing Two Conditions" to determine significant differences for two scores). Results can be used in conjunction with questionnaires [e.g.,I.I.F.E. (Anderson and Smaldino, 1998) or S.I.F.T.E.R. (Anderson, 1989)] and consultation with school personnel to estimate how well a child will function in the typical classroom (Madell, 1990; Elkayam, 2004). Local norms can be established by calculating the average SNR-50 across List Pairs for either the Standard recording or the Split Track recordings, using at least ten normal-hearing children in each of the three age groups (5-6; 7-10; and 11-14).

Procedure:

- Standard recordings: Present List Pairs through a single loudspeaker in the sound field at 35-40 dB HL.
- Split Track recordings: Present List Pairs through separate loudspeakers in the sound field (target talker through one loudspeaker and background babble through the other loudspeaker). Attenuators should be set to reflect desired signal-to-noise ratios.

1.7.5 Screening for Auditory Processing Disorders In Children

Compare the results from Standard BKB-SIN List Pairs to the BKB-SIN norms (see Table 2) to identify possible auditory figure-ground problems. If the result is 1.5 standard deviations poorer than the mean (average normal performance) the child may be considered at risk for an auditory processing disorder and referral for a complete APO test battery is indicated. If the result is more than two standard deviations from the mean there is a greater likelihood that the child has an APO and referral for a complete APO test battery is necessary (Keith, 2005).

The educational significance of SNR Loss will vary depending on the child's speech, language and academic skills, as well as the learning environment (see Test Interpretation for Children). Results of this test may help the audiologist determine optimal classroom modifications and assistive listening device requirements. As the BKB-SIN Test is used with children with suspected or known APO, its usefulness in APO evaluation will be identified.

Procedure: Present List Pairs using the Standard recording through earphones at 50 to 70 dB HL, testing each ear separately. Compare results to BKB-SIN Test norms (Table 2).

1.8 Statistics

1.8.1 Reliability

A basic mathematical principle governs the statistics of test reliability: The greater the number of test items administered, the greater the test reliability. This principle holds to a certain level at which point adding more test items results in minimal increases in reliability. As such, there is a test time/reliability tradeoff.
Example: In Table 4, when testing an adult subject and desiring a 95% confidence interval, when the number of List Pairs administered increases from one to three, reliability improves by 0.7 dB (from +/- 1.6 dB for one List Pair to +/- 0.9 dB for three List Pairs). Each List Pair takes approximately three minutes to administer, so test time increases by 6 minutes (from 3 minutes to 9 minutes) when adding two List Pairs. In contrast, reliability only improves by 0.2 dB (from +/- 0.9 dB to +/- 0.7 dB) when increasing the number of List Pairs administered from three to five. In this case, adding more List Pairs results in a longer test time without a big improvement in reliability.
Reliability is also related to age and cochlear implant use. In normal-hearing subjects, reliability improves with age, from the 5–6-year-old category to the adult category.
Cochlear implant users, who typically have a 10 dB or greater SNR Loss, exhibit higher test variability.

Table 4 Reliability

		Test										
AGE GROUP	Number of Lists=		2	3	4	5	6	7	8	9		STDEV TEST
Adults	95%C.I. Test+/-	1.6	1.1	0.9	0.8	0.7	0.6	0.6	0.6	0.5	dB	0.8
	80%C.I. Test+/-	1.3	0.9	0.7	0.6	0.6	0.5	0.5	0.5	0.4	dB	
Adult CI Users	95%C.I. Test+/-	3.1	2.2	1.8	1.6	1.4	1.3	1.2	1.1	1.0	dB	1.6
	80%C.I. Test +/-	2.6	1.8	1.5	1.3	1.1	1.0	1.0	0.9	0.9	dB	
Children by Age												
5-6	95%C.I. Test+/-	3.9	2.7	2.2	1.9	1.7	1.6	1.5	1.4	1.3	dB	2.0
	80%C.I. Test +/-	3.1	2.2	1.8	1.6	1.4	1.3	1.2	1.1	1.0	dB	
7-10	95%C.I. Test +/-	2.5	1.8	1.4	1.2	1.1	1.0	0.9	0.9	0.8	dB	1.2
	80%C.I. Test +/-	2.0	1.4	1.2	1.0	0.9	0.8	0.8	0.7	0.7	dB	
11-14	95%C.I. Test +/-	2.3	1.6	1.3	1.1	1.0	0.9	0.9	0.8	0.8	dB	1.1
	80%C.I. Test+/-	1.9	1.3	1.1	0.9	0.8	0.8	0.7	0.7	0.6	dB	

1.8.2 Comparing Two Conditions

Table 5 Critical Difference for Comparisons indicates the magnitude of difference that can be reliably measured when comparing two conditions, based on the number of List Pairs administered in each condition.

Table 5 Critical Difference for Comparisons

	Critical Difference for Comparisons										
	Number of lists =		2	3	4	5	6	7	8	9	
Adults	95%C.D.Test+/-	2.2	1.6	1.3	1.1	1.0	0.9	0.8	0.8	0.7	dB
	80%C.D. Test+/-	1.8	1.3	1.0	0.9	0.8	0.7	0.7	0.6	0.6	dB
Adult CI Users	95%C.D. Test+/-	4.4	3.1	2.6	2.2	2.0	1.8	1.7	1.6	1.5	dB
	80%C.D. Test+/-	3.6	2.6	2.1	1.8	1.6	1.5	1.4	1.3	1.2	dB
Children by Age											
5-6	95%C.D.Test+/-	5.4	3.9	3.1	2.7	2.4	2.2	2.1	1.9	1.8	dB
	80%C.D.Test +/-	4.4	3.1	2.6	2.2	2.0	1.8	1.7	1.6	1.5	dB
7-10	95%C.D. Test +/-	3.5	2.5	2.0	1.8	1.6	1.4	1.3	1.2	1.2	dB
	80%C.D. Test+/-	2.9	2.0	1.7	1.4	1.3	1.2	1.1	1.0	1.0	dB
11-14	95%C.D.Test+/-	3.2	2.3	1.9	1.6	1.5	1.3	1.2	1.1	1.1	dB
	80%C.D. Test+/-	2.6	1.9	1.5	1.3	1.2	1.1	1.0	0.9	0.9	dB

Adults When testing an adult using one List Pair in each of two conditions (e.g.,omni mic vs. directional mic), the difference in scores must be greater than 2.2 dB to be significant at the 95% confidence interval, or greater than 1.8 dB to be significant at the 80% confidence interval. To reliably measure a smaller difference than 2.2 or 1.8 dB, two or more List Pairs are required for each condition.

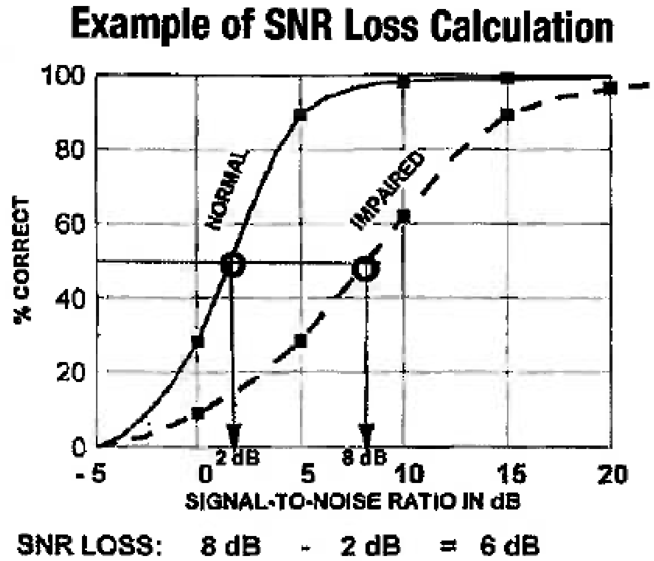
Adult CI Users When testing an adult cochlear implant user, using one List Pair in each of two conditions (e.g., omni mic vs. directional mic), the difference in scores must be greater than 4.4 dB to be significant at the 95% confidence interval, or greater than 3.6 dB to be significant at the 80% confidence interval. To reliably measure a smaller difference than 4.4 or 3.6 dB, two or more List Pairs are required for each condition.

Children BKB-SIN Test results on children revealed critical differences that varied according to the child's age. For example, when testing a 5- to 6-year-old child using one List Pair in each of two conditions, the difference in scores must be greater than 5.4 dB to be significant at the 95% confidence interval, or greater than 4.4 dB to be significant at the 80% confidence interval. When testing a 7- to 10-year-old child using one List Pair in each of two conditions, the critical difference is 3.5 dB at the 95% confidence interval, and 2.9 dB at the 80% confidence interval. Critical differences for the 11–14-year-old age group are smaller: 3.2 dB at the 95% confidence interval and 2.6 dB at the 80% confidence interval when using one List Pair in each of two conditions. The age-related trends indicate that because of the increased variability inherent in young children's responses, more List Pairs are required in each condition in order to reliably measure smaller differences.

1.9 SNR Loss

Understanding speech in background noise is the biggest problem reported by adult hearing aid users (Kochkin: 1992, 1993, 1995, 1996, 2000, 2002), and the most recent MarkeTrak survey revealed that only 30% of hearing aid wearers were satisfied with their hearing aids in noisy situations (Kochkin, 2002).
By analogy with hearing loss, "SNR Loss" (Signal-to-Noise Ratio Loss) refers to the increase in signal-to-noise ratio required by a listener to obtain 50% correct words, sentences, or words in sentences, compared to normal performance. Performance on any speech-in-noise test is affected by a number of factors, including: speech materials (sentences, spondees, etc.); background noise (shaped noise, multi-talker babble); test setup (combined speech and noise vs. separated speech and noise); audibility of the signal; reverberation; knowledge of the language; and age. Due to these factors, absolute scores (SNR-50, for example) will vary for an individual subject across different speech-in-noise tests.
By comparing test results to age-derived norms, an estimate of SNR Loss can be obtained. If a normal-hearing subject requires a +2 dB SNR to obtain 50% correct on a speech-in-noise test, and a hearing-impaired subject requires a +8 dB SNR to obtain 50% correct on the same test, the SNR Loss for the hearing-impaired subject is 6 dB (see Figure 4). SNR Loss is substantially independent of calibration and test material.
Published reports indicate a wide range of SNR Loss in persons with similar pure tone hearing losses; the measurement of SNR Loss is important because it cannot be reliably predicted from the pure tone audiogram (Lyregaard, 1982; Dirks et. al.,1982; Killion, 1997; Killion and Niquette, 2000; Taylor, 2003). One person with a 50 dB pure tone average hearing loss but little or no SNR Loss may report little or no difficulty hearing in noise with hearing aids, while another person with the same pure tone average loss but severe SNR Loss may require an FM system in order to understand speech in noise. Similarly, word recognition in quiet is not a reliable predictor of performance in noise.

Figure 4 **Example of SNR Loss Calculation**



1.10 BKB-SIN Test Methodology

The BKB-SIN Test uses the Bamford-Kowal-Bench sentences (Bench and Bamford, 1979; Bench, Kowal and Bamford, 1979) spoken by a male talker in four-talker babble (Auditec of St. Louis, 1971). The BKB-SIN contains 18 List Pairs. Each List Pair consists of two lists of eight to ten sentences each. The first sentence in each list has four key words, and the remaining sentences each have three. A verbal "ready" cue precedes each sentence. The key words in each sentence are scored as correct or incorrect. The sentences are presented at prerecorded signal-to-noise ratios that decrease in 3-dB steps. List Pairs 1-8 have ten sentences in each list, with one sentence at each SNR of: +21, +18, +15, +12, +9, +6, +3, 0, -3 and -6 dB. List Pairs 9-18 have eight sentences in each list, with one sentence at each SNR of: +21, +18, +15, +12, +9, +6, +3 and 0 dB. Each list in the pair is individually scored, and the results of the two lists are averaged to obtain the List Pair score. Results are compared to normative data to obtain the SNR Loss.

1.10.1 Choice of Speech and Babble

Sentence Materials

In any speech-in-noise test, the choice of speech and background noise presents a compromise between realism and reproducibility. Monosyllabic words, recorded and played back at uniform, controlled intensity levels, are not representative of speech in the real world. Sentences spoken with natural dynamics have greater dynamic range than monosyllabic words, and are thus a more valid representation of real speech (Villchur, 1982).

The Bamford-Kowal-Bench sentences consist of 21 lists, each containing 16 sentences (336 total sentences). The sentences were derived from language samples elicited from young hearing-impaired children (Bench and Bamford, 1979; Bench, Kowal and Bamford, 1979) and are at approximately a first grade reading level (Soli and Nilsson, 1994).

According to Bench et al. (1979) the vocabulary and grammar should be familiar to children because the sentences were produced by children, and in constructing the sentences, the investigators gave preference to the words produced by the younger and more hearing-impaired children. Sentence length is seven syllables or less for most of the sentences.

Background Babble

A constant-level background noise, while easy to control and reproduce, is not typical of that encountered by most people in their everyday lives. Fikret-Pasa (1993) examined the intensity variations as a function of time of the background noise in shopping malls and crowded restaurants. She found level variations with standard deviations of 2.8 to 8.4 dB, for maximum and minimum sound level meter readings, respectively. In contrast, she measured zero variation in level in available speech-spectrum-noise maskers, and only a 1-dB variation in level in two examples of multitalker babble, both of which contained so many talkers that the result was a constant-level hum. She found that the Auditec four- talker babble (Auditec of St. Louis, 1971) had more level variations than any of the other commercially available noises, presumably because the babble talkers were instructed to speak naturally (Carver, 1991). Use of a background noise with level variations is particularly important when testing patients whose amplification utilizes compression (common in hearing aids and cochlear implant processors) so that the compression circuits are not locked in a fixed-gain setting by the noise. The Auditec four-talker babble represents a realistic simulation of a social gathering, in which the listener may tune out the target talker and tune in one or more of the other nearby talkers using what Broadbent (1958) labelled "selective listening." More subtly, the use of constant-level noise in speech perception research eliminates the temporary gaps in the noise of real talkers, gaps that normal hearing persons use when listening in noise (Bacon et al., 1998).

1.11 BKB-SIN Test Development

The QuickSIN™ Test (Etymotic Research, 2001; Killion et al., 2004) was designed to provide a quick estimate of SNR Loss and is appropriate for use with most adults. The IEEE sentences used in the QuickSIN are at approximately a high school language level, making the test too difficult for use with young children. Additionally, clinicians reported the sentence length caused difficulty when testing some cochlear implant users and elderly adults with auditory memory deficits.

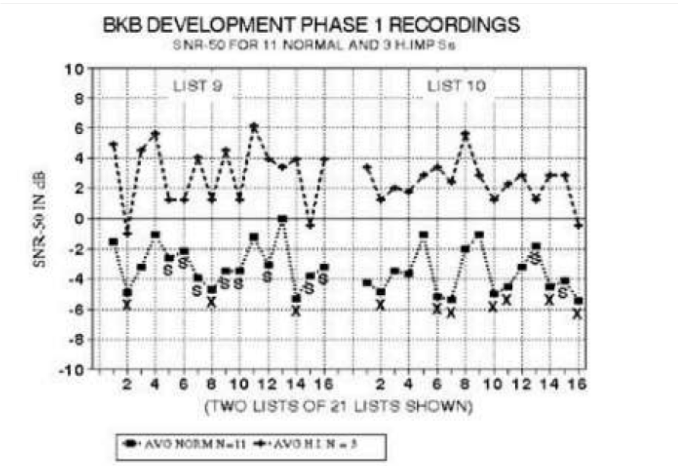
In October 2000, Etymotic Research and Cochlear Americas began collaboration on a project to create a speech-in-noise test that could be used as part of the test protocol for a binaural cochlear implant study on adults and children (Litovsky et al., 2004). The audiologists designing the study at Cochlear preferred the QuickSIN to other speech-in--noise tests because of its ease of use, speed, and realistic four-talker babble; however, they believed the QuickSIN sentences would be too difficult for many subjects participating in their study. The Bamford-Kowal-Bench (BKB) sentences have been used for many years in cochlear implant testing and research. Cochlear Americas proposed recording the BKB sentences in the Auditec four-talker babble to create a new speech-in-noise test that would be appropriate for use with cochlear implant patients. The digital recording of the BKB sentences used in the BKB-SIN Test was commissioned by Margaret Skinner under NIOCD Grant #R01 DC00581.This recording was made using an "Americanized version" of the BKB sentences,with the rms level of each sentence made equal (Skinner, 2000). The sentences were spoken by audiologist Jon Shallop, with a verbal "ready" cue preceding each sentence. The sentences were then re-recorded against the Auditec four-talker babble at Etymotic Research by Larry Revit, Revitronix. Prior experience with the SIN and QuickSIN tests suggested that rms equivalence is not sufficient to ensure sentence equivalence when the sentences were recorded in the Auditec four-talker babble. The instantaneous levels of both the BKB sentences and the babble talkers ebb and flow at any presentation level; as a result, the SNR required for 50% correct in a given sentence depends on the babble segment with which it is paired.

1.11.1 Phase 1: Sentence Equivalence Testing

The 336 BKB sentences were recorded in the Auditec four-talker babble at four SNRs: +8, +3, -2 and -7 dB. In the master recording of the sentences and babble, each sentence-babble pair was time-locked, meaning that the time relationship between each sentence and its corresponding babble segment was fixed. The master recording was made so that all subsequent re-recordings of a given sentence had the same time-locked relationship between speaker and babble segments.

A pilot test suggested that the -7 dB SNR was too difficult for normal-hearing listeners. Subsequently, sentences were tested for equivalence on 11 normal-hearing adults at the -2 and +3 dB SNRs. Data were also obtained on three hearing-impaired adults at the -2, +3 and +8 dB SNRs. The signal-to-noise ratio for 50% correct was calculated for each sentence across all subjects in both subject groups. Results indicated that the rms equivalence did not translate to SNR equivalence for the sentence-babble combinations, as shown in Figure 5.

Figure 5



1.11.2 Phase 2: Sentence Equivalence Testing

Based on the results from Phase 1 testing, 160 sentences were compiled into 16 "high standards" lists of 10 sentences each, with one sentence at each SNR of: +21, +18, +15, +12, +9, +6, +3, o, -3 and -6 dB.

Sentences were chosen based on two criteria:

1. The standard deviation of the sentence was 2 dB or less from the grand average value across sentences and subjects.

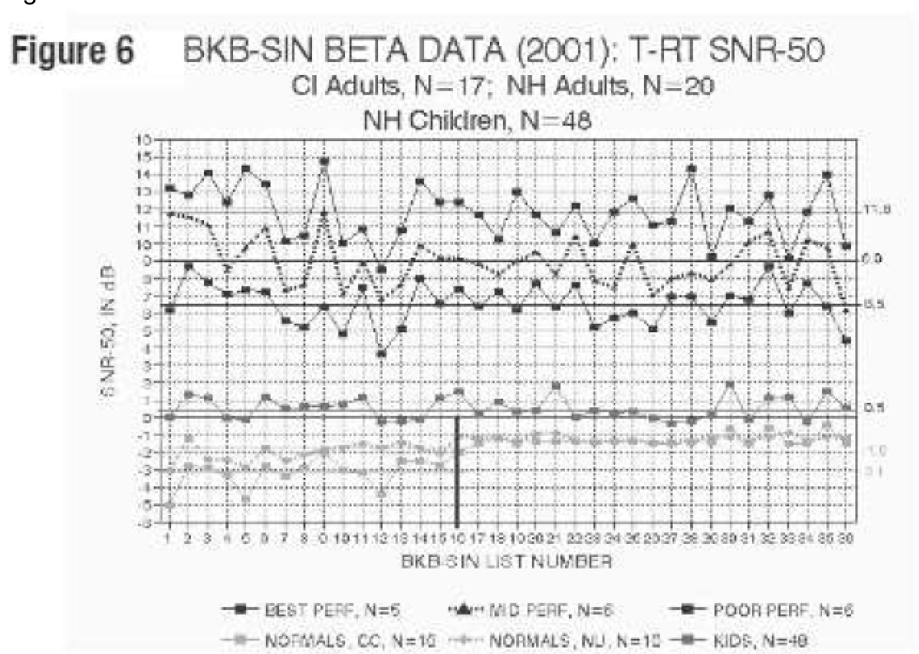
2. The SNR-50 value for the sentence was greater than -4.5 dB (values at or below -4.5 dB indicated a test floor effect since they were below the reliable range for the -2 and +3 dB SNRs used).

Since more than 16 lists were needed for the binaural cochlear implant test protocol, 160 of the remaining sentences were compiled into 20 lists of 8 sentences each, with one sentence at each SNR of: +21, +18, +15, +12, +9, +6, +3 and 0 dB. These sentences did not meet the criteria indicated above, and the most questionable sentences were placed at the +21 dB SNR (the easiest SNR at which almost all subjects should get all the words correct) and the 0 dB SNR (the most difficult level on these lists, where it was unlikely that cochlear implant subjects would get any words correct). The time interval between all sentences in all lists was increased from 4 seconds to 6 seconds. Because it was imperative to maintain each time-locked sentence-babble segment, the gaps between sentences were filled by splicing other babble segments into the gaps.

The BKB SIN includes these recordings: one with speech and babble on the same track (Standard recordings)and one with speech and babble on separate tracks (Split Track recordings). All equivalence data were obtained with the Standard recording, and the binaural CI study was performed using the Split Track recording.

Data on list equivalence were obtained from 19 cochlear implant users (monaural implant), 20 normal-hearing adults, and 48 normal-hearing children, ages 5 to 14. The cochlear implant users were separated into three groups based on average performance across lists: Best performers (N=5), mid-level performers (N=6) and poor performers (N=6). Two subjects did not fit into any of these groups. Figure 6 shows test-retest average SNR-50 scores for all lists for the 17 adult cochlear implant users, 20 normal-hearing adults and 48 normal-hearing children.

Figure 6



1.11.3 Phase 3: Constructing Equivalent List Pairs

Based on Phase 2 results, the lists were grouped into equivalent List Pairs. This was accomplished by pairing the most difficult lists with the easiest lists, and the more equivalent lists with each other, to balance the difficulty between List Pairs. Equivalence criterion for the cochlear implant subjects was that the average value for each List Pair could not deviate from the all-list grand average value by more than 1 dB. This criterion was met for four groups of cochlear implant subjects: best performers (N=5), average performers (N=6), poor performers (N=6), and the CI group as a whole (N=19). The List Pairs were also equivalent based on performance of the normal-hearing adults and children (Figures 7 and 8).

Figure 7

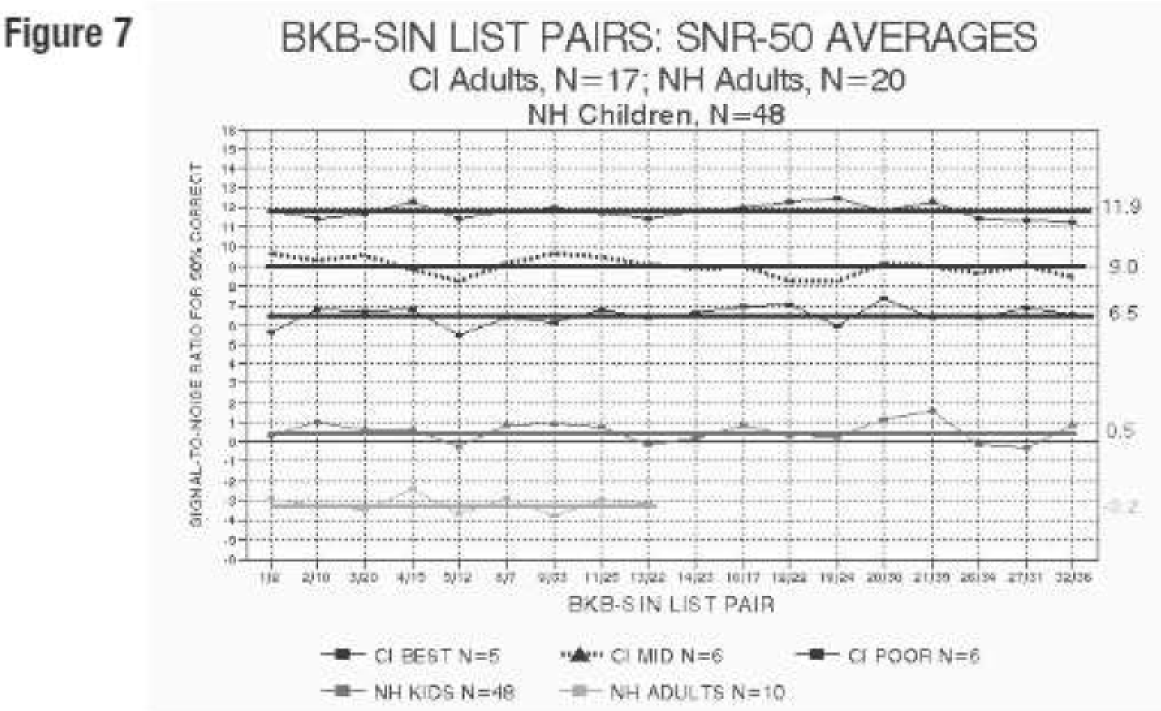
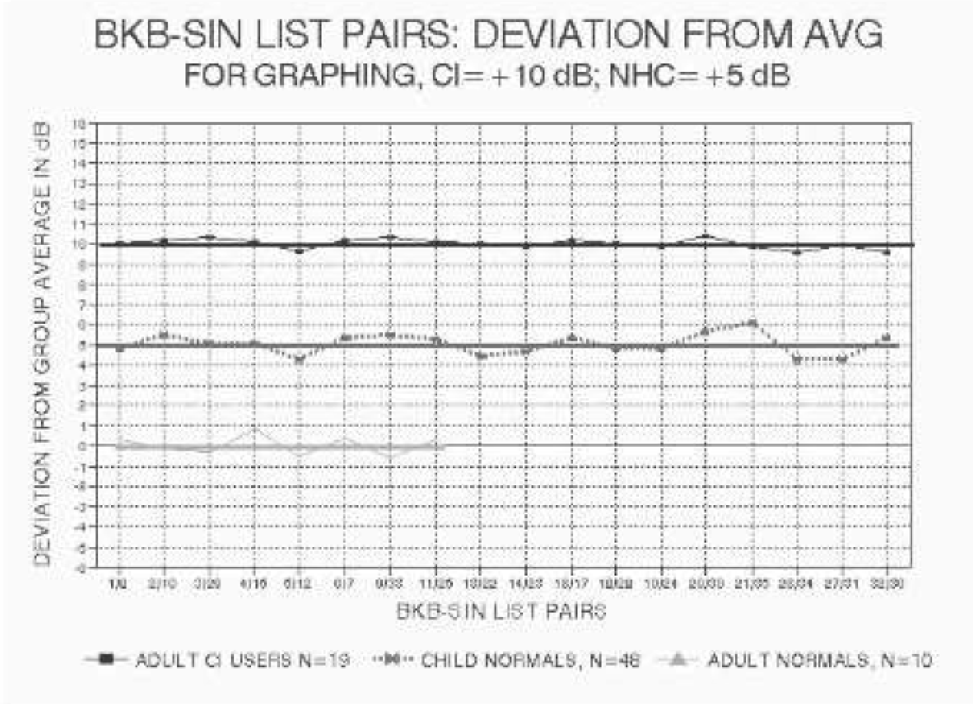


Figure 8

Figure 8



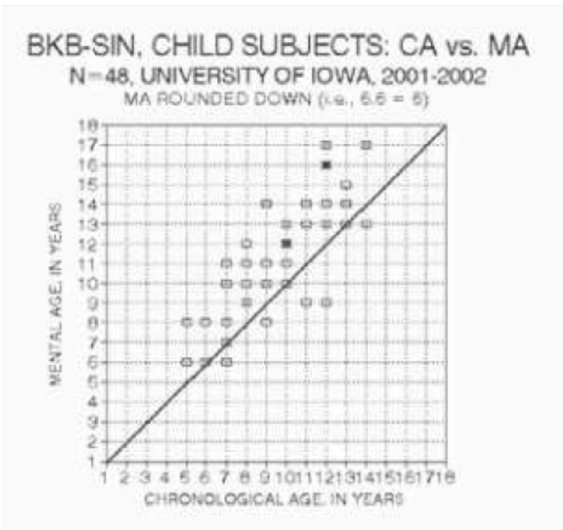
1.11.4 Phase 4: Confirmation of Child Norms

Statistical analysis of the data on 48 normal-hearing children revealed age-related performance differences. Scores fell into three groups, each significantly different from the other two:

- Ages 5-6
- Ages 7-10
- Ages 11-14

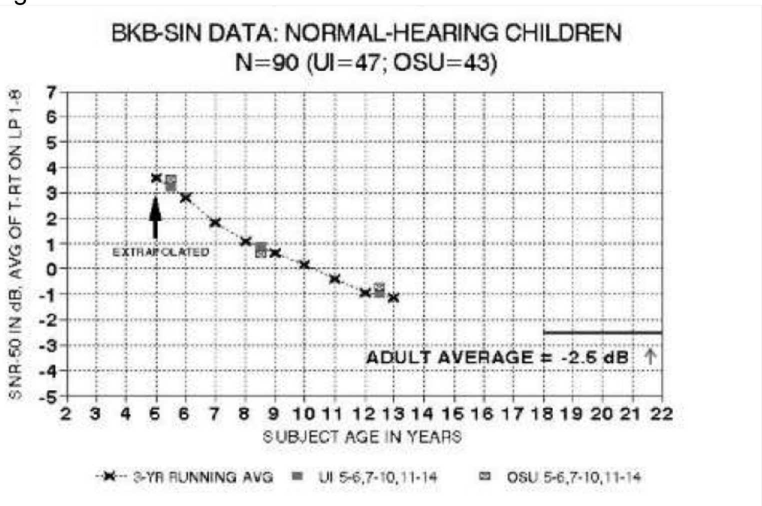
The sample of 48 normal-hearing children was taken from a demographic with a highly educated population. The vocabulary subscale of the Wechsler Intelligence Scale for Children (Third Edition) was used to provide an estimate of "mental age" (based on language ability) vs. chronological age. Results indicated that the majority of these 48 children had mental ages exceeding their chronological ages, even after mental age scores were rounded down to whole ages (e.g., 6.6 = 6.0). See Figure 9.

Figure 9



To provide a more representative sample for the age-related child norms, a second data set was obtained with the children being drawn from an area with families of lower educational and socioeconomic status than the first sample. Test and retest data were obtained on 44 normal-hearing children, and results indicated no significant differences in SNR-50 scores as compared to the first child data set (see Figure 10). In the 7-10 age group, the best and worst scores appeared to be outliers, and those two scores (out of the 33 in that age group) were removed prior to plotting the data.

Figure 10



Appendix A: Categories Of Loudness

7. Uncomfortably Loud
6. Loud, But Ok
5. Comfortable, But Slightly Loud
4. Comfortable
3. Comfortable, But Slightly Soft
2. Soft
1. Very Soft

Valente and Van Vliet (1997)

Appendix B: Scoring Formula

The scoring formula used in the BKB-SIN Test (SNR-50 =23.5 - Total correct) was derived from the Tillman-Olsen recommended method for obtaining spondee thresholds (1973). The Tillman-Olsen procedure provides a simple method for estimating SNR-50 using the total number of words repeated correctly. In this method, two spondees are presented at each level, starting at a level where all spondees are repeated correctly, then decreasing in 2-dB steps until no response is obtained for several words. The starting level plus half of the step size (1 dB), minus the total number of words repeated correctly, is the spondee threshold. The simple arithmetic comes from the use of 2-dB steps and two words per step.

The BKB-SIN Test uses three key words per sentence (except for the first sentence of each list, which has four). The SNR steps are 3 dB starting at 21 dB SNR, so the starting point (21 dB) plus half of the step size (1.5), plus the extra word in the first sentence (1) equals 23.5. SNR-50 is 23.5 minus the total number of words repeated correctly.

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Margaret Skinner and Steven Staller initiated this project. The project was coordinated at Etymotic Research by Patty Niquette and Mead Killion, and at Cochlear Americas by Jennifer Arcaroli, Aaron Parkinson and Steven Staller. All re-recording work was done by Larry Revit of Revitronix. Audiologists at cochlear implant centers throughout the US provided data on cochlear implant patients under the direction of Jennifer Arcaroli. Data on normal-hearing children were collected at the University of Iowa by Donna Devine, Hope Jones and Darcia Dierking under the direction of Ruth Bentler. The second data set on normal-hearing children was collected at The Ohio State University by Gail Whitelaw and Christine Valdez. Catherine Palmer assisted with statistical analysis on the first child data set. Judith Elkayam consulted on use of the BKB-SIN Test to estimate children's performance for soft speech. Robert Keith consulted on use of the BKB-SIN Test in screening for auditory processing disorders. He was a constant source of encouragement throughout the test development process.

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