Practice Guidance

Assessment of speech understanding in noise in adults with hearing difficulties

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General foreword

This document presents Practice Guidance by the British Society of Audiology (BSA). This Practice Guidance represents, to the best knowledge of the BSA, the evidence-base and consensus on good practice, given the stated methodology and scope of the document and at the time of publication. This is to allow for a greater range of evidence to be included.

Although care has been taken in preparing this information, with reviews by national and international experts, the BSA does not and cannot guarantee the interpretation and application of it. The BSA cannot be held responsible for any errors or omissions, and the BSA accepts no liability whatsoever for any loss or damage howsoever arising.

Stakeholder consultation was undertaken in September 2018. The draft document was available via the BSA website. An electronic copy of this draft, the full list of those invited to comment on the draft and the spreadsheet of comments supplied during the consultation are available on request.

Comments on this document are welcomed and should be sent to:

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1. Introduction

1.1 Development of the practice guidance

Unless stated otherwise, the principles described here represent the consensus of expert opinion and received wisdom as interpreted by the Professional Guidance Group (formerly the Education Committee and the Professional Practice Committee of the British Society of Audiology) in consultation with its stakeholders. The document was developed in accordance with BSA guidance development protocols.

This document is practice guidance on the assessment of speech understanding in noise in adults with hearing difficulties, and as such provides broad principles on the topic rather than providing a standard for the conduct of a specified audiological technique typically found in the BSA's recommended procedures. Clinicians are therefore advised to use this document to inform their own clinical decisions rather than providing a ridged method when undertaking a specific speech in noise test.

For this document speech in noise tests are defined as sentence tests presented in the presence of background noise (characteristically this noise is multi-speaker babble) rather than focusing on the more traditional speech audiometry using single words or phonemes.

This document aims to provide clinicians with information to equip them in undertaking speech in noise assessments whenever improving speech understanding in noise is a desired outcome, this is likely to reduce clinical time and minimise the need for repeated visits.

1.2 Background and scope

Speech testing can be applied in a variety of ways throughout a care pathway. In this practice guidance document, we focus exclusively on speech in noise (SiN) testing for adults.

For some professionals, SiN testing may already be a routine practice, and for others it may be an unknown or untried aspect of audiology practice. Although SiN test materials have been available for several decades, anecdotal evidence suggests many clinicians do not routinely use them due to concerns about choosing an appropriate test, test duration and the understanding of testing and scoring procedures. The test materials now available can assist clinicians in undertaking assessments of speech understanding in noise to enhance auditory rehabilitation planning in addition to providing diagnostic information.

This practice guidance is intended to familiarise clinicians with the underlying fundamentals of conducting these tests clinically for adults. These include part of a diagnostic assessment or in the pre- and post-fitting evaluation of any amplification, or the need for complementary technologies and/or listening strategies.

Cochlear Implantation programmes across the UK currently use a range of SiN tests, primarily as pre- and post-implantation assessment; this document is relevant to those services too.

The document does not include any screening tests and all those included use sentences rather than single words or phonemes. Monosyllabic word lists presented in quiet conditions are limited in terms of reliability and lack validity in relation to real-world simulations (Walden et al, 1983; Nilsson et al, 1994; Beattie et al, 1997; Taylor, 2003; Killion et al, 2004).

This document intends to address variations in current practice and to highlight to the clinical audiological community the relevance of SiN testing for hearing aid amplification and rehabilitation, including how it can provide further information for both individual listeners and clinicians about the progress service users are making with their amplification. However, advice on adjustments to hearing aids in response to speech-in-noise testing is outside the scope of this document.

Most of the tests covered in this guidance require minimal additional clinical time, so that the appointment can still focus on rapport building, needs assessment, treatment options, improved device and setting selection and expectations management. The inclusion of a SiN assessment, whenever improving speech understanding in noise is a desired outcome, is most likely to reduce overall clinical time and minimises the need for repeated visits.

1.3 Shared Decision-Making

It is implied throughout this document that the service user should be involved in shared decision-making about whether a SiN test should be undertaken, what information it provides and how it will impact on the personalisation of care. Individual preferences should be considered, and the role of the clinician is to enable a person to make a meaningful and informed choice. Each test brings a variety of information for both the clinician and the service user which can be used for counselling and decision-making regarding technology and anticipated outcomes.

Person-centred care is much more than simply educating service users, it is about providing guidance from their healthcare provider in the context of full and unbiased information. It is important to fully consider SiN testing in terms of the benefits and harms as well as the goals and preferences of your service user.

It is important that clinicians address any emotional content in what service users say. This emotional content often communicates the service user's preferences. Clinicians need to employ counselling and health coaching skills in shared decision-making (Elwyn et al, 2012). Informed decision-making can also lessen any fears service users have around a procedure, reduce overtreatment, reduce health inequalities and improve health outcomes (Malhotra et al, 2015). Shared decision-making does not guarantee lower resource use (Walsh et al, 2014); greater involvement of service users in deciding their care will require a new set of consultation skills as well as an improved range of decision aids. This is an

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important principle to consider so that healthcare systems are not wasteful and service users can make informed decisions about whether they consider this test to be of value to them.

2. Guiding Principles - Why Speech in Noise tests are used

2.1 General considerations

Most people who seek help for their hearing have difficulty understanding conversations in background noise, particularly when there are several people speaking simultaneously (Kochkin, 2000; Gatehouse, 1999). One of the main aims of auditory rehabilitation is to improve communication skills and participation in everyday life by reducing activity limitations and participation restrictions (Boothroyd, 2007). The most common form of treatment for hearing loss in adults is the provision of a hearing aid system. However, acceptance and adoption of hearing aids remains low, even with the advances in technology and improvements in hearing aid fitting practices (Chien & Lin, 2012). In a scoping review of why people did not use their hearing aids, five of the ten articles identified noisy situations/background noise as being the reason (McCormack & Fortnum, 2013).

Although these limitations can be reported by the service user through history taking, the scale of this cannot be predicted from conventional audiometric measures such as pure-tone audiometry (PTA) or from word recognition scores in quiet, with or without amplification (Grant & Walden, 2013). If a listener presents with a good word recognition-in-quiet score, this does not indicate their performance for word recognition in background noise. A words-in-noise task adds significant cognitive load, compared to a similar task without noise. SiN testing may be considered as the “stress test” of auditory function (Wilson, 2011). However, if the word recognition score in quiet is poor, it would generally indicate that performance in noise will be poorer (McArdle et al, 2005).

There are evidence-based reasons why SiN testing can be beneficial when used at clinically appropriate times. The results obtained through SiN tests can provide some valuable insights into what the most appropriate amplification strategy might be. They may indicate if someone needs a particular signal processing to try to manage the effects of background noise, or the results indicate that these do not need to be consider at all. Perhaps most importantly, it may offer precision in the way in which we counsel service users about realistic expectations (Taylor, 2003; Taylor, 2011) and allows valid, post-fitting measurement to evaluate intervention and to quantify improvement. SiN tests can provide information throughout the entire hearing aid selection and fitting process (Beck & Nilsson, 2013).

2.2 Compensation for the limitations of pure-tone audiometry

The pure-tone audiogram (PTA) has been used as the “gold standard” for hearing ability since the 1940s and is a good measure of impairment. However, the audiogram is a poor indicator of speech recognition in noise (Vermiglio et al, 2012). It is a diagnostic tool to measure hearing sensitivity and provides no information about the auditory processing of complex real-world signals, such as speech (Musiek et al,

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2017). It is the basis for hearing aid prescriptive fitting algorithms and probe microphone verification but its limitations for insight into functional hearing are recognised. There is generally a poor correlation between audiometric thresholds and difficulty understanding speech in background noise although a good correlation has been found between pure-tone audiometry (PTA) and the Digit Triplets Test (Moore et al, 2014).

An individual's hearing sensitivity as assessed by pure-tone audiometry can only partly explain the listener's experience of hearing in background noise (Thornton & Raffin, 1978; Heinrich et al, 2015). More specifically, Jerger (1992) reports that the performance on sentence identification in noise cannot be explained by peripheral hearing sensitivity. Wilson et al (2005) found that word recognition in multi-speaker babble had an unsubstantiated relationship to PTA thresholds and Vermiglio et al (2012) stated that ability to recognise speech in steady-state noise cannot be predicted from the audiogram and is a distinct function of the auditory system.

The audiogram should not serve as the primary foundation upon which hearing aid selections or counselling are based (Beck, 2013). Through implementing SiN testing with a listener, regardless of the PTA configuration, this would further inform the clinician for future management options (Beck, 2013). If a person's primary complaint is about hearing in background noise, adding SiN testing will give additional information when considering appropriate treatment options.

Assessing older adults only using pure-tone audiometry may not be enough to address their hearing needs. Such a narrow approach does not take into account the higher-level impairments contributing to hearing and listening problems. Use of speech-in-noise tests, together with audiometry and potentially other tests, can help to identify and understand more comprehensively older adults' hearing difficulties and to inform their management plan (Spyridakou & Bamiou, 2015).

In terms of diagnostic examples, SiN assessment could be used for:

a) Suspected Auditory Processing Disorder (BSA Position Statement: Auditory Processing Disorder (APD), 2011 & BSA Position Statement and Practice Guidance: Auditory Processing Disorder (APD), 2018)

b) Cochlear implantation criteria (NICE, 2019)

c) Noise Induced Hearing Loss

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2.3 Increasing the relevance of the hearing assessment procedure to individuals' real-world problems in understanding speech

When listeners undergo hearing assessments, a test which simulates their real-world conditions is more relatable for both the person being assessed and the assessing professional.

2.3.1 Age

On an individual level, there is a relationship between age and understanding speech in noise. The effects of ageing on the auditory system have been studied extensively over the last three decades and it is clear from the literature that, as hearing thresholds worsen, whether due to ageing effects or noise damage, the ability to understand speech in background noise also declines (Akeroyd, 2008; Walden & Walden, 2004). This decrease in understanding occurs for syllables[1], words[2] and for sentences[3].

2.3.2 Cognition

A listener's ability to understand speech in noise depends on both peripheral and central processing factors. Both types of processing are influenced by hearing loss and age-related cognitive deficits (Desjardins and Doherty, 2013). The clinician should also be aware that cognition, and particularly working memory and attention can relate to speech intelligibility, particularly using sentence testing (Rudner et al, 2008; Grant & Walden, 2013; Heinrich et al, 2015). The SiN tests chosen for each listener need to be considered both prior to joint decision-making and the testing itself.

The SiN tests listed in Section 3 highlight the flexibility in speech materials, audio-visual options, memory, comprehension and audibility. Section 3 covers a comprehensive but not exhaustive choice of tests, even an audio-visual option for an assessment of audibility, comprehension and, to some extent, memory. Each test focuses on speech intelligibly in noise when listening to speech.

2.4 Relevance before hearing aid fitting as part of hearing aid selection procedure and determination of the rehabilitation strategy

During the pre-rehabilitation strategy discussion, the clinician should cover expectations of any suggested treatment. When Kochkin (2000) evaluated the primary reasons why those who were good candidates for amplification returned their hearing aids, the second most stated reason for not wearing them (25.3%) was the limitations in background noise.

[1] Gelfand et al, 1986; Humes & Christopherson, 1991; Humes & Roberts, 1990.
[2] Souza & Turner, 1994; Stuart & Phillips, 1996; Studebaker et al, 1997; Summers & Molis, 2004; Wiley et al., 1998; Wilson, 2011.
[3] Bacon et al, 1998; Dubno et al, 1984; Gordon-Salant & Fitzgibbons, 1995.

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A logical conclusion is that when a listener is struggling unaided in background noise, it would be clinically useful to have a reliable test to measure their ability, or their inability, to hear in those kinds of situations to prevent non- or under-use of amplification technologies (Taylor, 2011). As stated earlier, this cannot be predicted from the pure-tone audiogram or their speech-in-quiet test results.

For the clinician to know the severity of the effect background noise is having on speech recognition for the service user and any potential benefits of amplification, measures can be undertaken at two moments in time: pre-treatment and post-treatment. Of note, pre-treatment might simply be an unaided SiN measurement, but could also be an aided measurement obtained with the listener's previous hearing aid system, if used, thus comparing the previous system to the proposed new replacement (Beck & Nilsson, 2013).

Measurements that can predict success with amplification and identify any distortion component of hearing are supra-threshold measures such as temporal and frequency resolution or intolerance of noise. However, these measures are not typically measured clinically, but can be combined with measures of audibility in some SiN tests. (Killion & Niquette, 2000; Grant & Walden, 2013).

Rehabilitative examples of where SiN assessments could be undertaken prior to any treatment include:

a) Where a patient presents with thresholds on a pure-tone audiogram falling within normal limits but reports difficulties in background noise. In this case SiN test results could be used to counsel the listener regarding options and expectations

b) In pre-cochlear implantation; SiN tests are often used to reduce ceiling effects

c) With hearing aid options; where a range of quality of hearing aids are available including analogue aids and those with minimal features. SiN tests can be used to guide listeners around the benefits from specific features, for example directional microphones. They can also be used in expectation counselling pre-fitting.

2.5 Relevance after hearing aid fitting verification and validation of the effectiveness of the fitting and any subsequent changes at follow-ups

Traditionally, hearing aid fitting protocols have been based on PTA thresholds determining the hearing aid prescription. The chosen prescription should be verified using probe microphone measurements (BSA, Guidance on the verification of hearing aids using probe microphone measurements, 2018). This type of verification, though, only indirectly addresses hearing better in background noise, through matching prescription targets. Speech in noise tests are estimated to occur in fewer than ten percent of all audiometric evaluations (Beck, 2017).

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Using both verification and validation of the hearing aid system to evaluate performance minimises reports of a less than optimum fitting and unacceptable degree of benefit, thereby reducing the number of repeat visits a person requires (Kochkin, 2011).

SiN tests can be used to assess baseline performance and to validate many service user's primary complaint, and then can be re-tested after a period of acclimatisation to demonstrate improvements in aided performance, attributable to the fitted hearing aid system. If the hearing aid fitting or the rehabilitative strategies are found not to deliver improved SiN performance for the listener then they should be revaluated (Beck & Nilsson, 2013).

Rehabilitative examples of where SiN assessments could be undertaken after treatment include:

a) In post-cochlear implantation; SiN tests are often used to reduce ceiling effects and alongside aided audiometry in assessing benefit and processor levels

b) With hearing aid options; where a range of quality of hearing aids are available including analogue aids and those with minimal features. SiN tests can be used to guide listeners around the benefits from specific features, for example directional microphones

d) As part of post-fitting verification either undertaken immediately or as part of a follow up later where it can be used as counselling tool for the patient to be able to demonstrate difficulty reported, to counsel expectations, to look at other options for amplification, or other assistive listener devices such as external microphones

3. Examples of SiN procedures

Despite a clinician's best efforts, many service users still do not hear well in background noise, even with digital hearing aids with directional microphones. It therefore appears to be reasonable to design and incorporate a simple-to-administer, statistically meaningful and real-life SiN test to evaluate a listener's baseline ability to understand speech in noise which, as a minimum, will enable realistic expectations to be set (Beck, 2017).

SiN testing should ideally involve commercially available test materials (most of the following tests are available commercially in the UK at the time of publishing), that have been standardised and are sensitive to changes in individual's performance. The test materials should come from a recording, rather than live voice to reduce variability in presentation. The SiN stimuli should involve sentences that are simple and relatively equal in context and equal in difficulty to assure sensitive and repeatable measurements. This guidance covers the following: -

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- The Quick Speech in Noise Test (*QuickSIN*™)
- Hearing in Noise Test (HINT)
- Bamford-Kowal-Bench SIN Test (BKB-SIN)
- City University of New York Sentences (CUNY)

Most of the tests referred to in this practice guidance are quick both to administer and to score, with an average of around 5 minutes per test unless indicated below (Mueller et al, 2010).

There are several contra-indications for testing with speech in noise and these should be considered on a case by case basis in addition to the joint decision-making with your service user:

- Service users with limited or no English language
- Service users with additional complexities such as dementia, reduced cognitive function or intellectual disabilities
- Service users who have been unable to cooperate fully during other hearing assessment procedures or who have produced unreliable results
- Occlusion of ear canals which cannot be removed prior to testing
- Service users who do not consent.

There are two principal ways of measuring speech perception in noise: -

1. Keeping the noise at a fixed level and varying the speech signal. This establishes the signal to noise ratio (SNR) prior to testing and remains unchanged throughout the test. These tests provide a straightforward percentage score, typically for amplification benefit or comparison with normal hearing results. The limitations are that, depending on the SNR selected, floor or ceiling effects might be present which could underestimate or overestimate the true amplification benefit. Use of a percentage score approach with fixed SNR is common in the context of assessment pre- and post- cochlear implantation, particularly as this reduces the ceiling effect found with speech in quiet testing and is appropriate for use in such practice.
2. The second option is through testing with adaptive SNR, e.g. the QuickSIN and the BKB-SIN tests, where the speech signal is fixed and the noise level varies (Taylor, 2003; Vlaming et al, 2011).

3.1 The Quick Speech in Noise Test (*QuickSIN*™)

3.1.1 Overview

The QuickSIN test was developed by Etymotic Research and became commercially available in 2001. It is the most widely quoted SiN test in the literature when referring to practice-based rather than laboratory-based tests. It was designed to provide a quick method of expressing a listener's ability to understand speech in noise as a SNR loss rather than as a percent correct score (Killion, 1997). The QuickSIN test is one of the most sensitive tests for measuring speech recognition performance in

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background noise (Wilson et al, 2007). It has a short test duration and quantifies the real-world SNR loss. As noted above, this is not reliably inferred from the audiogram and helps clinicians identify amplification options for individuals (Etymotic Research, 2001; Killion et al, 2004).

There is a total of 18 unique, 6-sentence lists, one sentence per SNR level, designed to provide limited contextual cues to aid in understanding (Etymotic Research, 2001). The sentences are spoken by a female talker and are presented at a constant level in a background of 4-talker babble (one male and three females). Four-talker babble is reportedly more representative of the noise typically encountered in social situations than speech-weighted noise (Killion & Villchur, 1993; Sperry et al, 1997). There is also high frequency emphasis (HFE) lists available for assessing benefits of higher frequency amplification.

There are two presentation modes: -

- Standard mode presents both target sentences and multitalker babble through one loudspeaker; this would normally be the mode for aided assessment.
- Split track mode spatially separates the target sentences and multitalker babble by presenting each through one of two loudspeakers.

QuickSIN uses an adaptive SNR method, recorded with 6 different SNRs. The babble level in each list increases in its level in 5 dB steps from +25 to 0 dB in order to vary the SNR (Etymotic Research, 2001; Killion et aI, 2004). The test may be administered in a sound field with the signal and noise presented from the same speaker at 0° azimuth. As an alternative, the test can be administered under insert earphones (Etymotic Research, 2001) or using a standard earphone; however, this is not practical when evaluating hearing aids. The presentation level is 70 dB HL for listeners with a pure-tone average (PTA) of 45 dB HL or less. The presentation level should be set to "loud but OK" (Cox, 1995; Valente & Van Vliet, 1997) for listeners with a PTA greater than 45 dB HL (Etymotic Research, 2001). The listener's task is to repeat the sentences presented. Each sentence has five key words; see the underlined words in sample scoring list below.

List 1		**Score**
1. A white silk jacket goes with any shoes.	S/N 25	________
2. The child crawled into the dense grass.	S/N 20	________
3. Footprints showed the path he took up the beach.	S/N 15	________
4. A vent near the edge brought in fresh air.	S/N 10	________
5. It is a band of steel three inches wide.	S/N 5	________
6. The weight of the package was seen on the high scale.	S/N 0	________
25.5 - TOTAL =________ SNR Loss	**TOTAL**	________

Figure 1: Sample QuickSIN scoring list

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3.1.2 Advantages and limitations of the test

The QuickSIN test material is easily available and there is a selectable option in some software-based test equipment. It is also easy to set up and administer. There are six different SNRs which are pre-recorded on a single channel, so calibration for each presentation is not an issue. It does not require that clinics obtain their own sound field norms before using the test. However, it should be noted that certain lists are not appropriate for use in the UK as these contain words used only in American English.

The test is quickly completed, even with need to do a practice test, but 2-3 lists need to be used to obtain an average test score. The scoring method is straightforward and identifies the SNR where communication in noise breaks down. The test is adaptable for assessing benefit of directional microphones in the clinic if the separate speech and noise tracks are presented from different loudspeakers.

3.1.3 Nature of results

Each correctly repeated word is awarded one point out of a total possible score of 30 points per list. The score is determined by use of the formula 25.5 minus the score of total words correct = SNR loss. The SNR loss score represents the SNR which a listener with hearing loss requires above the SNR which a normally hearing listener requires to achieve 50% correct sentence identification; this is called the SNR-50. Normally hearing people on average require +2 dB SNR, i.e. target talker 2 dB louder than background babble talkers, to correctly repeat 50% of the key words on the QuickSIN test (see Figure 2 below from Killion et al, 2004). As an example, a hearing-impaired person who requires the target speech to be 12 dB higher than the noise to achieve a 50% correct score would have a 10 dB SNR loss.

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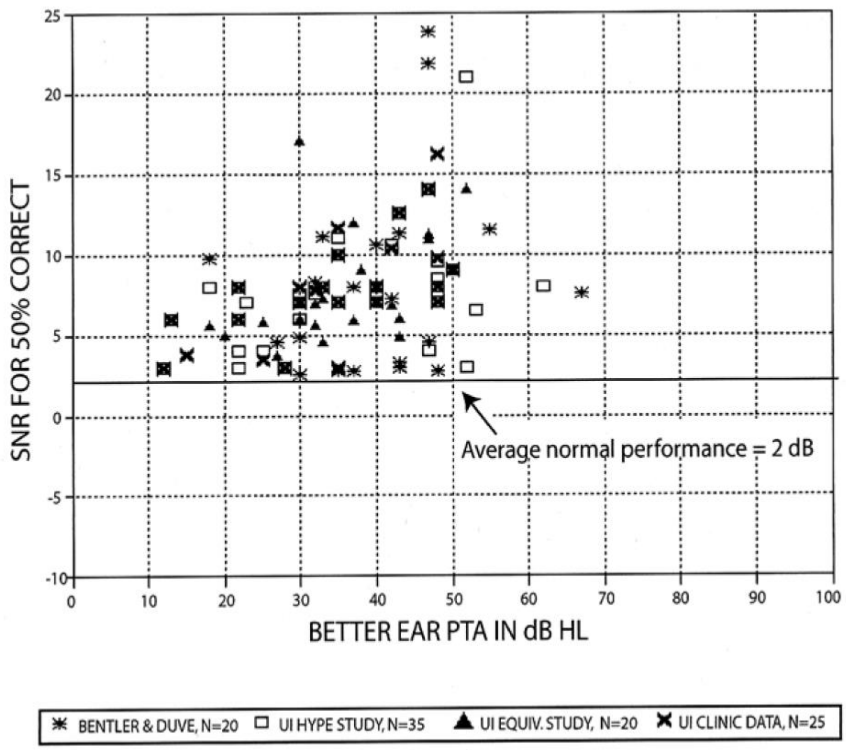

Figure 2: Signal-to-noise ratio for 50% correct on the SIN test (70 dB HL presentation level) versus three-frequency average pure-tone hearing loss in the better ear (average of 0.5, 1 & 2 kHz). Four data sets obtained at the University of Iowa Speech and Hearing Clinic (Killion & Niquette, 2000).

3.1.4 Interpretation

The QuickSIN user manual provides guidelines for interpreting performance on the QuickSIN test based on adjectives that describe the amount of SNR loss: -

- Normal 0-2dB SNR loss
- Mild 3-6dB SNR Loss
- Moderate 7-12dB SNR Loss
- Severe >12dB SNR loss (see appendix A for more details)

These categories of SNR loss (normal, mild, etc.) and their associated recommendations are only suggestions. There is no formally recognised scale of SNR loss categories each with their appropriate intervention (Killion & Niquette, 2000).

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3.1.5 Practical application of the results

The QuickSIN SNR loss score is relative to normal performance rather than a percentage correct score. That is, the QuickSIN score represents the SNR a listener with hearing loss requires above the SNR needed by a normally- hearing listener to achieve 50% correct sentence identification (Killion, 1997). The results can be used to make specific recommendations about the nature of the most appropriate intervention for an individual. The test result is especially useful for counselling service users regarding realistic expectations and additionally provides guidance for further rehabilitation support through auditory training or onward referral to hearing therapy. Of note, when evaluating AIDED results, as the step-size of the QuickSIN test is 5 dB, advantages of 1, 2, 3, or 4 dB may not be apparent, although a 3 or 4 dB SIN improvement may be significant to the hearing aid wearer (Beck, 2017).

3.2 Hearing in Noise Test (HINT)

3.2.1 Overview

The HINT first became commercially available on CD in the early 1990s and in a hardware and software system (HINT for Windows) some years later. Both were developed at the Hearing Aid Research Laboratory in the Department of Human Communication Sciences at the House Ear Institute (Maico Diagnostics, 2003; Nilsson et al, 1994). The HINT was created because of the shortcomings in speech tests at the time (Nilsson et al, 1990) such as poor representation of natural speech provided by spondees and the floor and ceiling effects associated with percentage-correct scoring (Hanks & Johnson, 1998). Unfortunately, the HINT test has now ceased to be easily available commercially. However, it is still included in the practice guidance as it is frequently referred to in the literature being widely used for research purposes & is included for those centres that have access to this already.

The HINT consists of 250 Bench-Kowal-Bamford (BKB) sentences (Bench & Bamford, 1979) which were equalised in length, difficulty, intelligibility and phonemic distribution to ensure equivalency (Hanks & Johnson, 1998). The sentences, spoken by a male talker, are phonemically matched and balanced and are 5-7 syllables in length. The sentence lists are used adaptively, as with the QuickSIN test, to determine the thresholds at which sentences are correctly identified in a background of speech-shaped noise. Also, as with QuickSIN, the HINT produces a SNR score.

In the standard HINT protocol, there are three test conditions: Quiet and Noise from the Front (NF), from the right (NR) and from the left (NL). The noise may be presented from any of three speaker locations (0° azimuth or Front, 90° azimuth or Right, and 270° azimuth or Left) when using the CD version of the HINT, and from speakers or earphones when the Windows version is used. Prior to test administration, the transducers must be calibrated to determine the dB HL dial reading associated with a competing noise presentation level of 65 dB(A). For the CD version, loud speakers are used and their height and distance from the listener for all speaker locations are specified. In addition to the main goal

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of finding a person’s SNR-50, the HINT is used to determine the advantage of binaural directional hearing by obtaining the listener's thresholds for sentences in quiet and in noise coming from any of three directions. Listeners are required to repeat all words in each sentence with some minor variations allowed, e.g. "a" for "the". The noise presentation level is held constant at 65 dB(A). Initially an ascending approach is used to determine the presentation level at which the first sentence is correctly repeated. The presentation levels of the next three sentences are adaptively increased or decreased in 4 dB steps. The presentation level of subsequent sentences are adaptively increased or decreased in 2-dB steps.

3.2.2 Advantages and limitations of the test

The HINT is no longer as readily available when compared to the other SiN tests discussed here and it has more complicated set-up requirements, test administration and scoring as well as requiring clinics to obtain their own sound field norms before using the test. The HINT is more commonly used in research rather than in clinical practice even though the HINT is acknowledged as an excellent tool for differentiating small differences amongst people and products (Taylor & Mueller, 2017); it is also one of the most researched speech tests. It should be noted that the listener must repeat all the words in a sentence correctly for the sentence to be scored as correct. The HINT identifies the SNR at which communication in noise breaks down.

3.2.3 Nature of results

The adaptive procedure of the HINT is used to obtain a Reception Threshold for Sentences (RTS). The RTS is the level of the sentences at which the listener can correctly repeat 50% of the sentences. The scoring formula is RTS minus dB Noise = dB SNR. The resulting score is the SNR needed to reach 50% correct performance (Nilsson & Soli, 1994; Nilsson et al, 1994). In one study for listeners with hearing loss, the mean RTS was 8.9 dB (Wilson et al, 2007). This average value varies from study to study depending on the population tested.

3.2.4 Interpretation and practical application of the results

HINT thresholds can be expressed either in terms of the actual SNR threshold or as the deviation from the average RTS for normally hearing individuals. By comparing with the norms for the normally hearing population, the degree of SNR loss can be used in pre-fitting counselling and unaided HINT measures can serve as a baseline for later hearing aid verification. The sensitivity of the HINT makes it better than many other speech tests for detecting differences in hearing aid performance (Mueller et al, 2014).

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3.3 Bench-Kowal-Bamford Speech in Noise Test (BKB-SIN)

3.3.1 Overview

The BKB sentences used in this test were published in 1979 as a protocol for testing hearing impaired children and developed as a SiN test by Niquette et al, 2003. The BKB-SIN test is commercially available (www.etymotic.com) as a CD with a comprehensive user manual describing calibration and scoring methods. It uses a simple vocabulary by a male speaker. The sentences are shorter than in other SiN tests.

There are 10 sentences in each list with 18 equivalent list pairs and the multi-talker babble ranges from +21 to -6 dB in 3 dB steps for the 10 sentences. Each sentence has three or four words, and both lists in a pair must be administered and scored. The four-talker babble and general scoring method are the same as with the QuickSIN. It uses a pre-recorded, adaptive test protocol to establish the SNR at which a listener can identify the test sentences with 50% accuracy and requires administration of two lists and use of an audiometer or other device with a volume unit (VU) meter for output adjustment. Recognition of the words in the sentences for each list becomes progressively more difficult by 3 dB increases in the noise for each sentence; a verbal “Ready?” cue precedes each sentence.

There are two presentation modes: -

- Standard mode presents both target sentences and multi-talker babble through one loudspeaker; this would normally be the mode for aided assessment.
- Split track mode spatially separates the target sentences and multi-talker babble by presenting each through one of two loudspeakers.

The goal is to be able to track improvements in SNR at which a listener can achieve 50% sentence recognition.

BKB-SIN Test List 4A

1.	A mouse ran down the hole.	4	+21	4
2.	The light went out	3	+18	3
3.	They wanted some potatoes	3	+15	3
4.	The little girl is shouting	3	+12	3
5.	The cold milk is in a pitcher	3	+ 9	3
6.	The paint dripped on the ground	3	+ 6	2
7.	Mother stirred her tea	3	+ 3	1
8.	The father is coming home	3	0 dB	0
9.	She had her spending money.	3	- 3	0
10.	He is bringing his raincoat	3	-6	0
	SNR 50%= 23.5 – 19 = 4.5 dB			19

Figure 3: Example of a completed test score sheet

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3.3.2 Advantages and limitations of the test

- Although it takes a little longer than other SiN tests, it is quick and easy to administer and score.
- There is less normative data for the BKB-SIN than for other tests (such as the QuickSIN), including norms for children and cochlear implant users.
- There are also separate lists for cochlear implant users and those with severe hearing loss or significant SNR loss.
- With its simpler vocabulary, BKB-SIN can be used for all adults including those who might find the other tests too demanding, thus making it appropriate for adults with auditory memory difficulties or other significant cognitive issues.
- As has been said about the QuickSIN and HINT, the BKB-SIN identifies the SNR where communication in noise breaks down.

3.3.3 Nature of results

The number of key words in each sentence is subtracted from 23.5 to determine the SNR-50, the SNR at which a listener understands 50% of the words. So, the formula is 23.5 minus Correct Key Words = SNR loss. For an overall SNR-50, calculate a SNR-50 for each list and then average the values for both lists. The BKB-SIN provides normative values to calculate the SNR loss. Although from only one study, it is worth noting that, for listeners with hearing loss, the mean SNR-50 is 5 dB (Wilson et al, 2007).

3.3.4 Interpretation

- 0-3 dB SNR loss: Normal/near normal. With hearing aids, may hear better in noise than those with normal hearing.
- 3-7 dB SNR loss: Mild SNR loss. May hear almost as well in noise as those without hearing loss.
- 7-15 dB SNR loss: Moderate SNR loss.
- >15 dB SNR loss: Severe SNR loss. Maximum SNR improvement is needed.

3.3.5 Practical application of the results

The BKB-SIN can be used to assist in selection of hearing aid systems with appropriate signal processing features, to demonstrate the benefits of amplification and to evaluate directional microphone effectiveness. In common with other speech-in-noise tests, the BKB-SIN can inform realistic expectations for counselling.

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3.4 City University of New York Sentences (CUNY)

3.4.1 Overview

The CUNY sentences test was originally developed to be used in assessing speech-reading ability and to assess understanding when other sensory cues were added. The CUNY sentences (Boothroyd et al, 1985) were used, as adapted by the Royal National Throat, Nose, and Ear Hospital Cochlear Implant team, (Peasgood et al, 2003).

Twenty-four sentences by a male UK speaker are provided in each of the 12 lists available with no semantic content. The sentences vary in length from 3 to 14 words and are balanced throughout each list. There is a visual component to the test which allows lip-reading and limited information from restricted facial expressions. There is a prompt on the audio-visual sentences by "Prepare yourself" but this is absent on the audio-only sentences.

The test can be used aided or unaided and is most often employed in cochlear implant (CI) assessment and evaluations (Craddock et al, 2016; Peasgood et al, 2003; Hay-McCutcheon et al, 2009, Leigh et al, 2016). SNR during testing is presented at +10dB (Flynn et al, 1998) to represent an environment more typical of everyday listening conditions. It uses a fixed SNR and results are a straightforward percentage score. Amplification benefit is therefore easy to explain and, to help create realistic expectations, you can compare to someone with normal hearing.

3.4.2 Advantages and limitations of the test

The CUNY sentence test is easy to score, expressed as a percentage. It has an audio-visual component not found in other SiN tests which can make the test more easily accepted by service users with a severe / profound hearing loss where speech testing can be daunting. However, ceiling effects are common and, with developments in cochlear implant technologies, some consider that the CUNY sentences are too easy and ceiling effects may be demonstrated too early in the rehabilitation process (Lawson & Peterson, 2011). It is a lengthy test (with 24 sentences per list) especially with different conditions for testing e.g. with lipreading in quiet, without lipreading in quiet, with lipreading in noise.

3.4.3 Nature of results

Three results are recorded for each list: the number of words, key words and full sentences repeated correctly (although you can choose to reduce these for local protocols).

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List 1

Would you roast a joint for tomorrow?
Are your sisters still single or are they married?
Do you think the secretary can make the arrangements for the business meeting?
Get your trousers cleaned or you won't be able to wear them on Saturday.
We went to the children's zoo and saw the animals.
The central heating needs repairing.
The crowds in the stadium cheered when the team won the game.
Did you hear the wind howl?
Go to the doctor and get some advice.
Lend me that paperback.
Pay the bill.
They always buy tickets to both the opera and the ballet.
Do you want to have a barbecue this evening?
When was the last time that you went to visit your parents?
What time do you finish work today?
Please don't put too much powder in the machine when you do the washing.
The cows are grazing in the big field.
The house is for sale.

Figure 4

3.4.4 Interpretation

Each list contains 102 words and a score is given for how many words, keywords and full sentences are correctly identified. There has not been any previous work completed on categorising the results of the CUNY sentences for further interpretation.

3.4.5 Practical application of the results

The CUNY has been historically used as an assessment tool within Cochlear Implant clinics to assess the ability of lip-reading and is often used in addition to BKB sentences (without lipreading) as part of the test battery. Some Severe and Profound clinics (for service users not being managed on a Cochlear Implant Clinic) also use the CUNY sentence test to help determine CI assessment criteria as set out by the National Institute for Health and Care Excellence (NICE, 2019). It is also used to help compare pre- and post-fitting information with service users, including lipreading ability and therefore additional rehabilitative strategies to amplification.

4. Summary and Recommendations

This document aims to provide clinicians with information to equip them in undertaking a speech in noise assessment whenever improving speech understanding in noise is a desired outcome, this is likely to reduce clinical time and minimise the need for repeated visits.

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SiN tests can enhance the service user experience of their treatment and overall service when one of their primary complaints is not hearing well in background noise. SiN tests can significantly compensate for the limitations of pure-tone audiometry and are normally accepted by service users as they increase the relevance of the hearing assessment in simulating the real-world conditions in which individuals experience the problems they describe in their history. SiN assessments can be used diagnostically with many service users, for example, those who have suspected auditory processing disorder, in cochlear implantation assessments and with noise induced hearing loss.

They can be a useful rehabilitative tool with service users, for example, when a service user presents with pure tone audiogram thresholds within normal limits but reports of difficulties in background noise, in pre- and post-amplification (including hearing aids and cochlear implantation). SiN testing is equally helpful at the post-fitting stages to help verify and validate the effectiveness of the fitting and, when used in conjunction with probe microphone measurements, it can reduce the amount of clinical time spent in post-fitting rehabilitation support. More broadly SiN assessments can help in considering wider treatment options for additional listening equipment, hearing therapy, auditory training programmes and expectations counselling.

It is recommended that all professionals in adult audiology consider the range of SiN tests available and the feasibility of using these, as part of their care pathway, with all service users who report that they struggle with understanding speech in background noise.

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Appendix A: Terminology specific to speech-based tests

Signal to Noise Ratio (SNR) is a measure that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise.

Signal to Noise Ratio Loss - When testing SiN, some of the types of tests below can diagnose Signal to Noise Ratio (SNR) loss, which is a quantified measure of how well a service user will understand speech in noise when compared to someone who hears normally in noise.

SNR loss – defined as the dB increase in signal-to-noise ratio required by a person with hearing loss to understand speech in noise as well as a person with normal hearing. (Christensen, 2000). SNR loss is not reflected in the pure-tone audiogram. (Thornton & Raffin, 1978).

Table 1 summarises the degrees of SNR loss.

SNR loss	**Degree of SNR loss**
0-2dB	Normal
2 – 7dB	Mild SNR loss
7 – 15dB	Moderate SNR loss
>15dB	Severe to profound SNR loss

Table 1 – Degree of SNR loss (Killion & Niquette, 2000)

Speech Recognition Threshold (SRT) / Speech Detection Threshold (SDT) The SRT is defined as the lowest hearing level at which the service user correctly repeats 50% of a list of spondaic words whilst the SDT is the lowest hearing level at which speech can barely be recognised or understood.

Word Recognition Scores (WRSs) is the ability of a listener to recognise words presented through earphones or speakers correctly. It is sometimes referred to as "Isolated Word Recognition" because it is without the benefit of surrounding words for contextual help.

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