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Speech-in-noise tests: a review of tests available in Spanish

Marlene Rodríguez-Ferreiro[1]; **Valeria Serra**[2, 3]
[1] Centro Auditivo OE+, A Coruña, Spain / [2] Clínica Universitaria de Navarra, Spain / [3] Universidad Católica de Santa Fe, Argentina

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Edited by:
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Correspondence
Marlene Rodríguez-Ferreiro
c/Ramón Ferreiro nº5 bajo, 15680 Ordes, A Coruña, Spain
email: marlenerofe@gmail.com

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Abstract

People with hearing loss or of an older age often complain of difficulty understanding speech in the presence of background noise. This complaint is one of the main reasons for audiology consultations in this population and it helps explain why speech-in-noise hearing tests are a useful tool in the assessment, diagnosis and intervention of patients with hearing loss.

The aim of this study was to describe the main characteristics of speech-in-noise hearing tests, as well to identify the different tests available for the Spanish-speaking population. We performed a literature review by searching the *Web of Science* and *Google Scholar* databases for the terms "speech-in-noise test" and "Spanish" in both Spanish and English.

The search produced 12 speech-in-noise tests for the Spanish-speaking population, 11 of which were for adults. These tests show differences in the defining characteristics of speech-in-noise tests, as well as in their usability.

Keywords

Speech-in-noise test, speech-in-noise discrimination, speech-in-noise recognition, Spanish, Spanish-speaking, hearing loss.

Clinical implications

Speech-in-noise tests have many different applications in diagnoses and interventions and therefore audiology professionals in Spanish-speaking countries must be familiar with them. Knowledge of these tests will allow professionals to guide clinical practice and improve diagnostic processes and therapeutic interventions, not only selecting the most appropriate hearing aid for a patient but also ensuring correct fitting together with subsequent auditory training or rehabilitation.

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Introduction

Speech-based communication often occurs in noisy environments, which affects speech intelligibility and makes it hard to understand a spoken message (Shannon & Weaver, 1949). This situation mostly affects the communication of older adults and individuals with hearing loss. They regularly complain of poor speech discrimination and recognition in noisy environments (Goossens *et al.*, 2017; Smith *et al.*, 2012).

The two diagnostic tests currently performed in hearing clinics are speech and tonal audiometry. Tonal audiometry is used to measure the minimum intensity levels at which an individual is able to perceive acoustic stimuli delivered in the form of pure tones, and it can establish the existence or absence of possible hearing loss, the degree of hearing loss, and the initial site of the causal lesion (Spanish Audiological Society AEDA, 2002). Speech audiometry qualitatively assesses an individual's hearing by measuring the ability to discriminate, identify, recognize and audibly understand the spoken word (Huarte & Girón, 2014). However, there is no correlation between performance in these tests and real-life settings, where background noise is present (Killion & Niquette, 2000; Taylor, 2003; Vermiglio *et al.*, 2012; Wilson & Weakley, 2005), because there is no direct relationship between pure-tone audiometry and an individual's discrimination ability. This lack of relationship is because mechanisms of perception are much more complex than the sensorineural function measured in pure-tone audiometry (Huarte & Girón, 2014).

Furthermore, recent studies by Fitzgerald *et al.* (2023, 2024) have concluded that speech-in-noise (SIN) test measurements provide more information than those obtained in word-recognition in quiet (WRQ) tests and may even be able to replace WRQ in clinical practice. Moreover, both the degree of hearing loss and the results obtained in SIN tests have been found to be predictive of scores on the *Speech, Spatial and Qualities of Hearing Scale* (SSQ12; Noble *et al.*, 2013), while the WRQ was not predictive. Overall, these findings corroborate the hypothesis that the measurements obtained in SIN tests are of greater clinical utility than those obtained in WRQ tests. The only two factors that appear to predict performance in SIN perception tasks are age (Decambron *et al.*, 2022; Goderie *et al.*, 2020; Goossens *et al.*, 2017; Holder *et al.*, 2018; Pronk *et al.*, 2013; Ross *et al.*, 2021) and degree of hearing loss (Fitzgerald *et al.*, 2024; Killion, 1997; Rodríguez-Ferreiro *et al.*, 2024; Walden & Walden, 2004), such that the greater the age or degree of hearing loss, the greater the influence of noise on speech recognition. However, these data are insufficient to predict the magnitude of effect. Therefore, word-in-noise perception limitations can be demonstrated only by using a diagnostic SIN test.

Although the first recommendations to introduce these tests into hearing assessments date back to 1970 (Carhart & Tillman, 1970), only recently have they become among the most widely requested tests because of the amount of information they deliver. Such information is used during the initial assessment phase and for diagnosis as well as at later therapeutic decision-making phases, when performing hearing aid fitting, auditory training and rehabilitation, and with complementary hearing support techniques (Chen *et al.*, 2021; Davidson *et al.*, 2021; Davidson *et al.*, 2022; Gohari *et al.*, 2023).

After observing the benefits of incorporating these tests into routine hearing test batteries, several international societies now endorse the use of SIN tests in their recommendations, guidelines and standards. For example, the Société Française d'Audiologie together with the Société Française d'ORL et de Chirurgie Cervico-Faciale include SIN audiometry for adults in their recommendations (Joly *et al.*, 2022), as does the British Society of Audiology (2019). The International Hearing Society (IHS) also includes it in *Good Practices Recommendation for Fitting and Dispensing Hearing Aids* (2020), as does the American Academy of Audiology (AAA) in *Standards of Practice for Audiology* (2023) and the American Speech-Language-Hearing Association (ASHA) in *Clinical Practice Guideline on Aural Rehabilitation for Adults with Hearing Loss* (Basura *et al.*, 2023).

However, in most countries, including Spain and other Spanish-speaking countries, these tests are not in widespread use and are yet to form part of the battery of hearing tests performed in daily clinical practice. In fact, the hearing protocols published in these countries in recent years do not include these tests, and therefore their importance is not acknowledged (Collazo *et al.*, 2009; Pla *et al.*, 2014; García-Valdecasas *et al.*, 2009; Lassaletta *et al.*, 2023). Although several SIN tests have been adapted to or developed in Spanish, the assessment of speech recognition abilities in noise is still not widespread in audiological clinical practice. Possible reasons for their poor uptake are a lack of dissemination (preventing them from having the effect and impact expected of them), shortage of time, lack of availability of the different tests and even doubts about which SIN test to use.

The aim of this study is to review SIN tests validated in Spanish, based on the principal defining characteristics of these tests. The ultimate aim is to help guide clinical practice, leading to an increased use of this type of test.

Defining characteristics of SIN tests

Although all SIN tests have the common denominator of assessing an individual's ability to process speech in noise, they differ in several other characteristics, which should be taken into consideration when selecting the most appropriate SIN test for each person, as follows:

- Verbal material: this must be semantically, syntactically and phonologically representative of the language in question. Since it is not recommended to use isolated words, recorded and played back at uniform intensity levels, because this is not representative of real speech (Cox *et al.*, 1987; Killion *et al.*, 2004; Villchur, 1973), tests may vary in terms of length and syntactic structure, as well as type of words used.
- Speaker: the speaker may be male or female, although the International Collegium of Rehabilitative Audiology (ICRA; Akeroyd *et al.*, 2015) recommends a female speaker with a neutral accent (without regional or cultural intonations that could hinder speech discrimination), who is able maintain constant vocalization effort during the recording session. In the specific case of Spanish, it has been found that American Spanish dialects have substantial phonemic and lexical differences that can significantly affect listener performance in clinical word recognition tests, and therefore dialect features should be considered in the assessment (Shi & Cañizales, 2013).
- Speech type: SIN tests tend to have flat speech characterized by the absence of intonation patterns (e.g., exclamatory, questioning intonation) and without the effects that occur when speaking in a noisy environment to enhance the speaker's intelligibility. This type of speech is known as the Lombard effect and is characterized by increased volume, as well as increased spectral energy at higher frequencies and decreased speaking rate; and clear speech characterized by increased articulation (Godoy *et al.*, 2014; Saba & Hansen, 2022). Despite referring to this characteristic speech production in noisy environments, few SIN tests incorporate it (Marrero-Aguiar, 2015; Rodríguez-Ferreiro *et al.*, 2023). Equally scarce are SIN tests that incorporate casual speech, which features a more relaxed tone with contractions, or conversational speech in noisy environments (Miles *et al.*, 2023; Weisser & Buchholz, 2019). Finally, technological advances in speech type should be mentioned, permitting speech to be generated from text (text-to-speech [TTS]) and incorporating deep learning techniques to transform speech type and improve intelligibility, especially in noisy environments (Novitasari *et al.*, 2022; Paul *et al.*, 2020). These TTS synthesis systems already exist in speech audiometry (Génin *et al.*, 2024; Nuesse *et al.*, 2024).
- Masking noise used: following ICRA recommendations again (Akeroyd *et al.*, 2015), noise should provide energetic masking with a long-term spectrum similar to that of speech. Most SIN tests opt for multitalker babble or speech-shaped noise, which has speech-like spectral characteristics. In the case of multitalker babble, which provides energetic as well as informational masking, consideration should be given to the number of speakers, their gender and the proportion of male and female voices in the recording.
- Signal-to-noise ratio (SNR): this defines the ratio between signal intensity and noise intensity, expressed in dB. Several aspects should be taken into account for the SNR ratio. First, the difference between each SNR presented for each verbal stimulus should be considered, since smaller step sizes between SNRs provide more information (for example, in the case of the QuickSIN test [Killion et al., 2004] the SNRs are +25, +20, +15, +10, +5 and 0 dB, with a step size of 5 dB, while in the BKB-SIN test [Etymōtic Research, 2005] the steps are 3 dB, from 21 dB SNR to 0 dB SNR). Second, it should be noted whether the speech intensity remains fixed while the noise intensity varies or whether, on the contrary, the noise intensity remains fixed while the speech presentation intensity varies. Although this aspect should be taken into consideration, it appears that no significant differences are seen in test results (Wilson & McArdle, 2005). SNR adaptivity is another variable to be taken into account in SIN tests. Adaptivity refers to the possibility of modifying the different SNR values depending on an individual's test response patterns, which is the case, for example, in the Matrix Test (Hagerman, 1982), but not in tests with sentences that have fixed predefined SNRs, such as the QuickSIN test. Finally, although stimuli volume does not influence SNRs, this aspect is,

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however, covered in the evaluation protocols of each test (for example, in the QuickSIN test, a presentation level of 70 dB HL [hearing level] is established for hearing losses of ≤45 dB HL, while fixed volumes are not established for losses >45 dB HL, simply indicating that presentation levels should be "loud but OK").

- Test duration: tests should be administered in a relatively short time, while ensuring that as much information as possible is obtained. It should be noted that these tests are usually performed after other auditory tests, such as pure-tone audiometry and WRQ tests. Extremely long or complex tests may cause fatigue and attention decline, which might introduce bias in the results.
- Performance calculation method: although all tests seek to provide information about speech recognition in noise, they do not all produce the same outcome. Thus, a hearing assessment can result in outcomes such as 1) the SNR50, understood as the SNR required to recognize 50% of the spoken message, 2) SNR loss, which refers to the dB increase in the SNR required by a person with hearing loss to identify 50% of SIN compared to a person with normal hearing, 3) the speech reception threshold (SRT) in noise, understood as the SNR required to correctly recognize a certain percentage of the presented speech material, such as SRT50 or SRT80 (recognition of 50% or 80% of the speech material, respectively), 4) reference psychometric curves, which reflect the number of keywords or percentage of speech correctly identified at each presented SNR. In addition, it should be considered whether each of these outcome measures is provided with standardized reference values.
- Mode of presentation: stimuli may be presented through headphones or loudspeakers, which marks another difference in SIN tests. Headphones allow for both monaural and binaural assessment, which may help diagnose certain pathologies characterized by interaural asymmetry (Qian *et al.*, 2023). Although most tests were initially developed for presentation through headphones, the option of loudspeakers in a free-field setting has since appeared, as is the case, for example, with the BKB-SIN, QuickSIN, AzBio and Matrix tests (Holder *et al.*, 2018; Spahr *et al.*, 2012). Loudspeakers not only permit SIN assessment, but also have a place in hearing aid fitting. Despite this, there is no standard criteria for using loudspeakers in a free-field setting in terms of choice of the number of loudspeakers, their distribution in the azimuth (horizontal) plane or even use of a single loudspeaker at 0° azimuth to present the verbal stimulus and noise (Holder *et al.*, 2018).

Materials and methods

We performed a systematic literature search in the *Web of Science* database for the terms "*speech-in-noise test*" and "*Spanish*" in articles published from 1981 to October 2024 in external peer-reviewed journals. We repeated the same search using *Google Scholar*. We included articles only if they had a description of the SIN test, the target population and the procedure followed for its development or adaptation and validation, and if the test was in Spanish or a Spanish variant.

Results

The systematic literature search on the *Web of Science* platform yielded 165 articles. Selection by title and abstract ruled out 155 articles (SIN tests in another language, evaluations in bilingual populations, evaluations with non-validated tests, paediatric reports). The Google Scho*lar* search yielded 922 articles and selection by title and abstract eliminated 901 articles. A total of 31 articles remained that met the study objective, 12 of which were identified as SIN tests in Spanish.

Although various SIN tests started to be developed in the English-speaking world back in the 1980s, it was not until 2008 that the first Spanish adaptations and other new Spanish tests were published. The tests that are currently available in Spanish are cited and described below. Table 1 shows the main distinguishing features of each of these tests, although some tests had missing information for some of these features. Although all the SIN tests are in Spanish, the speaker's accent differs depending on the country or region for which the tests were adapted or developed.

The tests listed in Table 1 are explained below:

- Adaptation of the Hearing in Noise Test (HINT; Nilsson *et al.*, 1994) by Huarte (2008): the verbal material was translated and adapted from the original 714 sentences comprising the American English version of HINT. The test consists of 20 lists of 10 short, simple sentences that are phonemically balanced and do not require memory effort. A professional native male speaker was used for the recording. The SNRs in this test are 5 dB and −10 dB, with a spectrally matched noise. The pilot test, with individuals with normal hearing aged 20–50 years showed

Table 1. Principal SIN tests in Spanish, with their main characteristics

SIN test	Verbal material	Speaker	Noise	SNR	Approximate test duration	Outcome objective and measure	Existing standard values or reference curves	Availability
Spanish adaptation of HINT (Huarte, 2008)	20 lists of 10 short, simple sentences	Male	Spectrally matched noise	Variable sentence intensity with fixed noise intensity at 65 dBA. Presentation −5 and −10 dB SNR These data can be varied	Variable depending on the SNRs used	SRT50 calculation	Yes	For research purposes only
Latin American Spanish adaptation of HINT (LA-HINT; Barón *et al.*, 2008)	24 lists of 10 sentences of 5–8 words	Male		-7, -4 and −2 dB SNR		SRT50 calculation	Yes	
SPIN adaptation: Spanish Sentence Lists (LFE; Cervera & González-Álvarez, 2011) and its short version (vr-LFE; Cervera, 2014).	Six lists of 50 sentences (LFE) or 5 lists of 12 sentences (vr-LFE)	Female	Multitalker babble with 12 people (6 men and 6 women)	0, 5 and 10 dB SNR	10 minutes (LFE) and 4 minutes (vr-LFE)	Percentage of correct word recognition	Yes	Yes
Sentence Matrix Test for Spanish speakers: Matrix Test (Hochmuth *et al.*, 2012)	Lists of 20 short, simple sentences	Female	Spectral masking	Adaptive SNR with noise at fixed intensity and speech at variable intensity or vice versa.	3 minutes per ear or binaural setting	Calculation of SRT50 and SRT80	Yes	Yes, on payment
Digit triplet identification (Pérez-González *et al.*, 2014).	100 digit triplets	Male and female	Multitalker with 32 voices	+10, 0 and −10 dB SNR	24 minutes (full test); 6 minutes (*female speaker version*)	Reference psychometric curves for each SNR	Yes	
Speech-in-Noise Audiometry Test (PAVER; Marrero-Aguiar, 2015)	10 lists of 6 sentences with 4 keywords.	Female	Child multitalkers with 2 boys and 2 girls	+30, +10, +5, 0, −5 y −10 dB SNR at fixed speech intensity	4–5 minutes	Reference psychometric curves for each SNR	Yes	Yes
Consonant recognition in noise (Moreno-Torres *et al.*, 2017).	80 consonant-vowel syllables	Male	Multitalkers with 8 voices (4 female and 4 male).	+2, -2 and −6 dB SNR		Reference data for 35% of syllables.	Yes	No
Adaptation of QuickSIN in Rioplatense Spanish (Cristiani *et al.*, 2020).	8 lists of 6 sentences with 5 keywords	Female	Multitalkers with 3 female voices and 1 male voice	+17, +12, +7, +2, −3 and −8 dB SNR	5 minutes	SNR50 calculation	Yes	Yes, upon request to authors
AzBio in Spanish (Rivas *et al.*, 2021)	42 lists of 20 sentences	Male and female	Multitalkers with 10 voices	+10, +5, 0, −5 and −10 dB SNR	5 minutes	Percentage of correct word recognition	Yes	Yes, on payment
Spanish-language spatial release from masking task in a Mexican population (Lelo *et al.*, 2023).	256 sentences combining 8 names, 4 colours and 8 numbers	Male	Multitalkers with 4 male and 4 female voices	+8 to −10 dB in steps of 2 dB SNR		Percentage of correct word recognition	Yes	Yes
Speech-in-Noise Discrimination test in Colombian Spanish (Buitrago *et al.*, 2023)	Lists of 10 words and lists of 10 sentences with 5 keywords	Female speaker in a loud voice	White noise	−5 and −10 dB SNR	15 minutes	Percentage of correct word recognition	No, test	No
Noise-in-Speech Auditory test in Spanish (PAHRE; Rodríguez-Ferreiro *et al.*, 2023).	Lists of 12 short sentences.	Female	Multitalkers with 3 female voices and 1 male voice	+12, +6, +3, 0, −3 y −6 dB SNR at fixed speech intensity	3 minutes per ear or binaural setting	Reference SNR curves and SRT50	Yes	Pending

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an intelligibility of 65% with an SNR of −5 dBA ±2 dB. Despite the specific characteristics of this test adapted for Spanish, other studies conducted on the same test in Spanish have used modified noise types and SNRs values. For example, a study by Zhang *et al.* (2024) in cochlear implant subjects used a noise with similar spectral characteristics to speech and an initial SNR of 30 dB with 3 dB and 2 dB steps between each SNR presented. Adaptivity has also been addressed, for example in the study by Desouki & Mendel (2023) where SNR steps were adapted by between 2 dB and 4 dB. All these variations in the HINT test make it difficult to obtain data on test duration. At present, the test is available only for research purposes with prior authorization for use. In 2015, a software tool was also developed to apply different types of everyday noises, but this version is not available either (Rodríguez, 2015).

- Latin American Spanish adaptation of HINT (LA-HINT), by Barón *et al.* (2008): this version uses a total of 24 phonemically balanced lists of 10 sentences comprising four to eight words each. The sentences were developed from children's books and from translating the US-English HINT sentences for children. The material was recorded by a professional male speaker. The SNRs used are −2, −4 and −7 dB. We found information only about the test development, and no publications regarding its validation. Furthermore, we found no information about noise type, test duration or test availability.
- Spanish Sentence Lists (LFE; Cervera & González-Álvarez, 2011): a test comprising six lists of 50 sentences distributed into 25 sentences of high predictability in which the final word can be predicted to a certain extent from the preceding context, and 25 sentences of low predictability in which the final word cannot be predicted by the context. The same final word appears both in the high-predictability sentences and in the corresponding low-predictability sentence so that the final word of each sentence matches in the lists. The predictable and non-predictable sets are also equivalent in terms of sentence length, phonemic content and final word frequency. The verbal material was recorded by a female speaker and the masking noise was multitalker babble with 12 people (six male and six female). The test uses only three SNRs with 5 dB steps in between. The SNR presentation values are 0, +5 and +10 dB. The test consists of repeating the last word of each sentence presented. Test duration is approximately ten minutes. Due to the length of the test, a short version (vr-LFE; Cervera, 2014) was then developed, consisting of five lists of 12 sentences each (six predictable and six non-predictable), while maintaining the reliability and validity characteristics of the original test. This version is considerably shorter in duration. Unlike other SIN tests, it does not provide reference SRT data, but mean values and confidence intervals for each of the presented SNR conditions for the high- and low-predictability sentences. Although the test is supposed to be available and presented on CD, we were unable to source it.
- Matrix test: a test with a matrix of 10 names, verbs, numerals, nouns and adjectives from which lists of 20 random sentences are formed. Each sentence is composed of five words with the same syntax but in a semantically unpredictable presentation, representing the distribution of phonemes in the Spanish language. The verbal material was recorded by a female speaker while the stationary masking noise was generated by superimposing all the synthesized sentences to achieve the same long-term spectrum as the speech, ensuring spectral masking. The SNRs presented are adaptive according to the individual's response, adjusting the size of the SNR steps starting from > 5 dB to < 1 dB SNR in some cases, allowing a fairly accurate SRT to be obtained. The test can be presented using fixed noise intensity and variable speech intensity, or vice versa. The test duration is approximately 3 minutes per ear or binaural setting. The test provides reference SRT values for normal-hearing individuals in the range of −6.2 ± 0.8 dB SNR for the open-set format and −7.2 ± 0.7 dB SNR for the closed-set format. Furthermore, the study concluded that, based on the results, the test is applicable to Spanish listeners in Spain and Latin America alike. The test is validated for headphones and for a free-field setting and is available for use upon purchase.
- Digit triplet identification (Pérez-González *et al.*, 2014): a test involving the identification of 100 digit triplets (from 0 to 9). The digits were recorded by three men and one woman such that each speaker recorded 25 triplets. Therefore, 25% of the triplets are pronounced by a different speaker. The noise is composed of a 32-talker babble. The SNR values presented are +10, 0 and −10 dB SNR. The test consists of repeating the triplets by entering the answer on a numeric keypad. The response is marked as correct only if each of the three digits are identified in the order in which they were presented. The test is provided with reference psychometric curves for a young normal-hearing population, with SRT values of 6.1, 7.2 and 32.2 dB SL for SNR levels of +10, 0 and −10 dB, respectively. The test takes eight minutes for each SNR condition presented, making a total test time of approximately 24 minutes. The time can be reduced

to a quarter by using the 25 digit triplets recorded by a single speaker only – in this case the female speaker. However, this could lead to an increased margin of error. We were unable to verify if the test is available.

- Speech-in-Noise Audiometry Test (PAVER; Marrero, 2015): a paediatric test for children aged 6−7 years and over. The test comprises ten lists of six sentences each; the lists are grouped in series of three lists for application purposes. Each sentence presents four keywords with semantic content. As it is a paediatric test, the lexical and grammatical structure is adjusted for primary school stage one [children aged 6–8 years], and for Spanish phoneme frequency. The sentences were recorded by a speaker specialized in imitating children's voices, once in quiet and then with conversational noise through the speaker's headphones to provoke the Lombard effect in her utterance. Each series therefore presents two lists of sentences spoken in quiet and one list of sentences spoken in noise. The masking noise used was child multitalkers composed of two boys and two girls. The SNRs used for each of the sentences in each list were +30, +10, +5, 0, −5 and −10 dB SNR. The test takes approximately four to five minutes for a binaural presentation in a free-field setting. The test provides reference values for each SNR in normal-hearing children aged 6−8 years. The test is available through PIP (Phonak Children's Programme).
- Consonant recognition in noise (Moreno-Torres *et al.* 2017): a test with a set of 80 consonant-vowel syllables (16 consonants and 5 vowels). The material was recorded by two speakers. The noise used was multitalker babble with four women and four men. The test initially offered reference data for the recognition of 35% of syllables for the normal-hearing adult population, and subsequently for paediatric cochlear implant users. There is no information about test duration. The test is not available.
- Adaptation of QuickSIN in Rioplatense Spanish (Cristiani *et al.*, 2020): a SIN test with the same structure as the QuickSIN test, consisting of eight lists of six sentences with five keywords each. The verbal material was taken from the Sharvard Corpus (Aubanel *et al.*, 2014) and was recorded by a female Argentinian speaker. The noise used was multitalker babble with three women and one man. The different SNRs are presented with a 5 dB step decrease with each consecutive sentence: +17, +12, +7, +2, −3 and −8 dB SNR. The test provides reference values for SNR50 of −4.88 dB and +4.98 dB SNR for the normal-hearing and hearing-loss populations, respectively. The test is available on request to the authors.
- AzBio in Spanish (Rivas *et al.*, 2021): a test composed of 30 lists of 20 sentences with an average of 142 words per list. The verbal material was recorded by two men and two women, and the noise was a multitalker babble composed of ten speakers. The different SNRs presented are +10, +5, 0, −5 and −10 dB SNR (Holder *et al.*, 2018). The test is intended for free-field presentation and assessment, and for use in the clinical assessment of hearing-impaired listeners and cochlear implant users, for whom validated data are provided. The test takes approximately five minutes to perform and can be purchased for use.
- Spanish-language spatial release from masking task (Lelo *et al.*, 2023): this test is designed for self-administration using an app. It comprises 256 sentences combining eight names, four colours and eight numbers. The task involves listening for a name, and reporting the colour and number by responding on a grid in the app. The verbal material was recorded by four men and four women, although the male voice recordings were chosen. All the recorded sentences can be used as targets or maskers. The sentences are presented at a fixed intensity of 65 dB and the masker starts at 57 dB SPL in 10 consecutive 2-dB step increments. The validation in normal-hearing individuals was performed in two spatial conditions with 0, 45 and −45° azimuth simulated spatial locations. The specific test time is not stated, since it forms part of a one-hour test battery covering the detection of frequency modulation, temporal gaps and modulated broadband noise in the temporal, spectral and spectrotemporal domains, all self-administered via the PART (Portable Adaptive Rapid Testing) app. The test has been validated in the Mexican population.
- Noise-in-Speech Auditory test in Spanish (PAHRE; Rodríguez-Ferreiro *et al.*, 2023): a test based on the QuickSIN test, but with several distinguishing features. It consists of lists of six sentences, each presenting five keywords with semantic content. The lists are grouped in sets of two for administration. The verbal material developed is representative of Spanish in terms of lexical and syntactic structure, as well as phonemic and syllabic distribution. As in the PAVER test, two types of recordings were carried out, one in quiet and the other with multitalker babble presented to the speaker through headphones to generate the Lombard effect in her utterance. Thus, each set has two lists of sentences, one spoken in silence and the other in noise. The noise used was multitalker babble with three women and one man. The SNR values decreased as the sentences in each list were presented, maintaining speech intensity fixed

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at +12, +6, +3, 0, −3 and −6 dB SNR. The test provides reference values for each SNR as well as for the SRT in the age-dependent hearing-impaired and normal-hearing populations. The reference values used were those obtained in the young normal-hearing population, with reference SRT values of 1.99 and −2.95 dB SNR for the non-Lombard and Lombard lists, respectively (Rodríguez-Ferreiro *et al.*, 2024). Test availability for clinical use is currently pending.

- Speech-in-noise discrimination test in Colombian Spanish (Buitrago *et al.*, 2023): a test comprising lists of 10 words and lists of 10 sentences with 5 keywords each. The verbal material was taken from the Sharvard Corpus (Aubanel *et al.*, 2014) and the Quirós and Morgante Corpus (Quirós & D'Elia, 1974) and was reproduced in a loud voice by a female speaker. The noise used is white noise presented at a fixed intensity, from which speech intensity is regulated for presentation at −5 and −10 dB SNR. The test allows the noise to be applied ipsilaterally or contralaterally to the speech presentation. Each presentation option yields discrete clinical data on auditory processing and discrimination ability, with significant interaction between them. The test time is 15 minutes. Validated data are not yet available because the study data refer to a pilot test.

Discussion

The aim of this article is to provide information about Spanish-language SIN tests to promote and increase their use in clinical assessments as part of routine audiological practice. To date, 12 SIN tests have been adapted to or developed in Spanish, 11 of which are for adults. Despite the variety of tests reviewed here, it should be noted that not all can be used in the general Spanish-speaking population, since nuances and differences exist in Spanish variants, particularly regarding differences between Spanish in Spain and Spanish in Latin America. Despite these differences, some tests state they are feasible across the entire Spanish-speaking population, such as the case of the Matrix Test (Hochmuth *et al.* 2012). However, the adaptation of QuickSIN in Rioplatense Spanish (Cristiani *et al.*, 2020) and the speech-in-noise discrimination test in Colombian Spanish (Buitrago *et al.*, 2023) both specify that they are feasible for the geographical area for which they have been adapted. The Spanish-language spatial release from masking task (Lelo *et al.*, 2023) does not specify geographical feasibility, although being validated in a Mexican population only hinders its application in the rest of the Spanish-speaking population.

Based on the characteristics of SIN tests for adults in Spain, and following the ICRA recommendations for developing these tests in terms of speaker and noise characteristics (Akeroyd *et al.*, 2015), it appears that the tests that meet these criteria best are the LFE and vr-LFE (Cervera & González-Álvarez, 2011; Cervera, 2014), the Matrix Test (Hochmuth *et al.*, 2012), AzBio (Rivas *et al.*, 2021) and PAHRE (Rodríguez-Ferreiro *et al.*, 2023). The digit triplet identification test should not be ruled out (Pérez-González *et al.*, 2014), although the time it takes to administer makes it less practical. In addition, if the aim is to assess speech-in-noise discrimination under the most realistic conditions possible, it is preferable to use tests with sentences rather than digits as the verbal material (Cox *et al.*, 1987; Killion *et al.*, 2004; Villchur, 1973). It should be noted that the loud-voice reproduction of the speech-in-noise discrimination test in Colombian Spanish (Buitrago *et al.*, 2023) hinders its reproduction, reliability and feasibility. In the case of the LA-HINT, its low complexity may not adequately assess true communication difficulties experienced daily by individuals (Velandia *et al.*, 2024).

Although a number of specific measures were applied when these tests were developed or adapted to Spanish, such as noise type, range of SNR values and mode of presentation, some of these variables were further modified, for example, in the HINT test. These subsequent modifications are sometimes made because researchers are exploring possible differences or broader applicability across diverse populations, such as in cochlear implant users (Desouki & Mendel, 2023; Zhang *et al.*, 2024). All these modifications show how complex a SIN test is and how changing their characteristics has an impact on the outcome, which in turn makes it difficult to standardize these tests in the clinic.

Considering the different SNR values presented in each of the aforementioned tests, it appears that tests offering more specific values in terms of measured outcomes are the ones that have smaller fixed or variable steps between each SNR value. Such tests include the LA-HINT, the Matrix Test, the spatial release from masking task and the PAHRE, in which the SNR steps are 3 dB maximum.

Although test presentation mode is beyond the scope of this review, this variable deserves a mention because it is one of the easiest to adjust in daily clinical practice when research is not involved, simply to assess the effect of SIN discrimination in different settings, especially with and without hearing aids. Two aspects relevant to free-field presentation should be noted: on the one hand, the lack of consensus on free-field presentation means that data comparisons cannot be made reliably, but on the other hand, free-field presentations are still an option to assess hearing aid fitting performance, because speech can be presented in one loudspeaker, while noise can be presented in the same loudspeaker or in the other loudspeakers in the free-field setting. A free-field presentation mode can therefore corroborate the benefit of a hearing aid, compare the benefit of different hearing aids, enable hearing aid adjustments to be made, and even evaluate progress achieved over time through auditory rehabilitation or auditory training programmes. In addition, since each test has several lists of verbal material, they can be deployed without reusing the lists, thus avoiding the learning effect, although the impact of the training effect is unknown. Despite these advantages, the lack of homogeneous variables in free-field facilities in clinical practice (room soundproofing, number and distribution of loudspeakers) may lead to data heterogeneity at different facilities. Free-field presentation is therefore limited to the individual values at a specific clinic.

Headphone presentation mode is also worth considering, since monaural and bilateral presentation modes are possible. These modes are covered in several tests, such as the Matrix Test and the PAHRE test, and go beyond SIN discrimination assessments for auditory intervention decisions, because they can also contribute to the diagnosis of conditions involving interaural asymmetry, as reported in the study by Qian *et al.* (2023).

The only Spanish-language test designed to be used for self-assessment is the spatial release from masking task. This Spanish-language paucity contrasts with other languages that have several tests for self-assessment and that have been amply demonstrated to be useful for screening when administered via an app or website. However, all the other tests described above can be directly administered for diagnostic purposes, for indications for various therapeutic interventions, and for assessing the effectiveness of interventions.

In addition to SIN tests themselves, SIN performance can also be predicted by means of spectrotemporal modulation detection tests, such as the Audible Contrast Threshold (ACT; Jürgens *et al.*, 2022; Zaar *et al.*, 2024). This type of test lacks the linguistic component that is characteristic of SIN tests, along with the cognitive processes involved in speech recognition. However, because no linguistic component is present, spectrotemporal modulation detection tests are language agnostic and they therefore can be applied regardless of the language. Another advantage of this test is that it takes only three to four minutes to administer, although the mode of presentation is binaural. A recent study by Zaar *et al.* (2023) showed that the ACT test is clinically feasible and that it provides a highly useful measure of the spectrotemporal modulation sensitivity that predicts the performance of speech reception in hearing-impaired individuals with hearing aids. However, to date, no comparisons have been made between the ACT test results and those obtained using one of the Spanish-language SIN tests.

Based on the wide range of tests reviewed, no test should be ruled out, while no single test can unequivocally provide all the necessary data. Nevertheless, we hope that the information provided on each test will help clinicians make an informed choice based on certain factors, such as the type of information the test provides, the patient's characteristics and their hearing loss, the existence of reference values, and test duration.

Although we have presented information to further the reader's understanding of auditory SIN tests in Spanish, the ultimate goal of this review is to provide guidance for clinical practice, which in turn, might increase the use of this type of tests. Several international audiology societies and associations endorse the use of these tests in their recommendations, guidelines and standards, including the International Hearing Society (2020), American Academy of Audiology (2023), American Speech-Language-Hearing Association (2023), Société Française d'Audiologie and the Société Française d'ORL et de Chirurgie Cervico-Faciale (2022) and the British Society of Audiology (2019). Furthermore, the results obtained in a recent study by Fitzgerald *et al.* (2023) with more than 5000 patients suggest that SIN tests provide more information than WRQ tests, since participants displayed significant challenges in the QuickSIN test despite having excellent scores in the WRQ test. In fact, the study actually hypothesizes replacing WRQ with SIN tests, which would lead to a change in clinical practice, benefitting both patients and professionals alike.

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In short, audiology professionals should reflect on the data provided by all these tests and their place in clinical practice. By no means should we rule out the use of WRQ tests; instead, we should insist on adding SIN tests to hearing protocols, given that their benefits have been amply demonstrated.

Finally, although it is acknowledged that these tests are useful and that it is necessary to incorporate them into clinical practice in the Spanish-speaking population, obtaining the test material is impossible in many cases. Considering the number of Spanish-speaking individuals with hearing loss, and with the progressive increase of cases by 2050 that is predicted by the World Health Organization (WHO, 2021), we must not ignore the needs of this population, whose life expectancy is increasing and whose quality of life correlates to some extent with their quality of hearing.

In summary, this article highlights the importance of incorporating Spanish-language SIN testing into routine clinical practice, because of its diagnostic utility and its potential to improve audiological interventions. Despite the limited availability of materials and the regional linguistic differences among Spanish speakers, these tests provide a fuller picture of a patient's hearing ability than speech-in-quiet tests. Looking ahead, we must promote the development and standardization of SIN tests that are accessible and adaptable for Spanish variants, and ensure their global availability. Furthermore, we should foster research exploring the relationship between SIN tests and new tools such as ACT, to ensure they achieve a maximum impact in clinical practice, improving the quality of life of Spanish-speaking patients with hearing loss.

Conclusions

This article has reviewed the main characteristics of SIN tests as well as the different tests available for the Spanish-speaking population. These tests have many different applications in diagnoses and interventions and therefore audiology professionals in Spanish-speaking countries must be familiar with them. Equipped with this knowledge, professionals will be able to guide clinical practice and improve diagnostic processes and therapeutic interventions, not only selecting the most appropriate hearing aid for a patient, but also ensuring correct fitting together with subsequent auditory training or rehabilitation. Recent studies in this field, together with the latest recommendations of various international audiology societies and associations, endorse the use of SIN tests in clinical practice, and we must therefore analyse what changes are needed in hearing protocols. Finally, these tests must be made available for use and incorporated into audiometers manufactured by electromedical device companies, to ensure patients are correctly assessed.

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