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Article

Development of a Speech-in-Noise Test in European Portuguese Based on QuickSIN: A Pilot Study

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Abstract

Background and Objectives: The Quick Speech-in-Noise test is a widely used clinical tool for assessing an individual's ability to understand speech in the presence of background noise. Building on this framework, the present study aimed to develop a Speech-in-Noise Test for European Portuguese (SiN-EP), specifically adapted for native speakers of European Portuguese. The goal was to create a reliable and linguistically appropriate tool to evaluate speech perception under realistic listening conditions. **Materials and Methods:** The development of the SiN-EP involved several stages. Sentences were drafted to reflect natural speech patterns and reviewed by native speakers for clarity and grammatical correctness. Selected sentences were recorded by a female native speaker in a controlled environment. The recordings were then combined with multi-talker babble noise at varying levels to simulate different listening situations, ranging from easy to challenging. A pre-test was conducted in a free field setting at 65 dB SPL with fifteen young adults with normal hearing. Participants listened to and repeated each sentence, and their responses were used to refine the test materials. **Results:** Participants understood the sentences clearly and consistently across all listening conditions, showing that the SiN-EP effectively reflects speech perception in noise. The final version included thirteen lists of six sentences, carefully designed to maintain natural phonetic balance and realistic speech structure. **Conclusion:** The SiN-EP represents a significant advancement in evaluating speech understanding in noise for Portuguese-speaking populations. This standardized and linguistically adapted test provides valuable information about auditory performance and supports both clinical assessments and research on hearing and auditory processing challenges.

Keywords: signal-to-noise ratio; hearing difficulties; auditory processing; speech perception; Portuguese

1. Introduction

When we attempt to understand speech, the brain integrates two primary sources of information: bottom-up sensory input from the acoustic signal and top-down cognitive processes from the language system, such as word frequencies and possible grammatical structures. These mechanisms operate together to enable comprehension, even in challenging listening conditions [1].

Perceiving speech in noise or otherwise degraded environments is a common difficulty, particularly for older adults and individuals with hearing loss. Understanding the underlying causes and their impact across populations is essential for developing effective interventions [2].

Noises sharing spectral components with speech, such as other voices, are particularly disruptive because they mask critical speech frequencies, making it harder to distinguish the target signal from background noise [1,3].

When such noise overlaps with the frequency range of key speech sounds, especially consonants, it can induce phonetic confusion, increasing listening effort and the likelihood of misunderstanding [1,3].

Difficulties in noisy environments often emerge between the ages of 45 and 55. At this stage, standard tonal audiograms may reveal only mild hearing loss, insufficient to explain the severity of reported difficulties. Middle-aged adults with slight hearing loss frequently expend significantly more effort to process speech in noise than younger adults with similar audiometric thresholds. This increased cognitive load can lead to listening fatigue, reducing both communicative effectiveness and enjoyment [4].

When audiograms indicate normal or near-normal hearing, patients reporting real-world difficulties may feel dismissed if their concerns are not acknowledged. Overlooking their subjective experience can cause frustration, as everyday listening challenges remain unresolved [4,5].

To address these limitations, incorporating speech-in-noise tests into audiological assessments is strongly recommended. These tests better reflect real-world listening demands than pure-tone audiometry [6].

In audiology, several speech-in-noise tests assess the ability to understand speech among background noise. Two widely used measures are the Hearing in Noise Test (HINT) and the Quick Speech-in-Noise Test (QuickSIN). Evidence indicates that QuickSIN is particularly sensitive and correlates well with patients' subjective perceptions of their listening difficulties [6–9].

QuickSIN is a standardized measure designed to detect speech-in-noise deficits that may not appear on traditional audiograms [6]. Its sensitivity supports audiologists in making informed decisions regarding hearing aid selection, fitting, and fine-tuning, as well as tailoring auditory training and providing accurate counseling about hearing abilities and potential interventions [6,10].

The QuickSIN test includes twelve lists, each with six sentences containing five keywords, presented in four-talker babble. The signal-to-noise ratio (SNR) decreases in 5 dB steps from 25 (very easy) to 0 (very difficult), covering normal to severely impaired performance. Administering a single list takes approximately one minute [11].

This study aimed to describe the design and development process of the sentence lists for the European Portuguese Speech-in-Noise Test (SiN-EP), based on the QuickSIN format.

The development of the SiN-EP followed a structured multi-step process. Initially, 165 sentences were drafted, each containing five target keywords and designed for semantic coherence, syntactic correctness, and phonetic representativeness. Fifteen native speakers evaluated the sentences, and 120 high-rated sentences were recorded in a controlled environment with clear articulation and natural intonation. Recorded sentences underwent intelligibility testing with twenty normal-hearing adults, retaining only those repeated correctly. The final sentences were organized into fifteen phonemically balanced lists, mixed with multi-talker babble noise, calibrated across SNRs from 25 to 0, and pre-tested with fifteen young adults to confirm intelligibility and finalize the test.

2. Materials and Methods

This work forms part of a larger study assessing auditory perception in older adults using the SiN-EP. The protocol was approved by the Ethics Committee of the Polytechnic Institute of Coimbra (Approval No. 142_CEIPC/2022) and followed the Declaration of Helsinki. All participants provided informed consent.

The development process involved several stages:

- Sentence Drafting: An initial set of 165 sentences was drafted based on the structure and principles of the QuickSIN test, with each sentence containing exactly five target keywords. Sentences were designed to be semantically coherent, syntactically correct, and phonetically representative of

European Portuguese. Care was taken to ensure natural sentence length, everyday vocabulary, and diversity in sentence construction to reflect realistic speech patterns.

- Semantic and Syntactic Evaluation: The drafted sentences were evaluated by fifteen native European Portuguese speakers for semantic and syntactic appropriateness. Each sentence was rated on a 1–3 scale (1 = poor, 2 = acceptable, 3 = excellent). Sentences achieving an average score above 2.5 were retained for the next phase. This rigorous evaluation ensured that only linguistically accurate and natural-sounding sentences were included, minimizing the risk of comprehension difficulties unrelated to noise perception during later testing.

- Final Selection, Recording, and Intelligibility Testing: From the evaluated sentences, 120 were selected for the final test. These sentences were recorded using a female voice in the Audiology Laboratory of the School of Health Technology of Coimbra, with Audacity® software. Recordings were conducted in a quiet environment, ensuring consistent speech rate, natural intonation, and clear articulation of all keywords, producing high-quality audio suitable for subsequent testing and signal-to-noise ratio calibration.

For intelligibility testing, the sentences were presented at 65 dB SPL in a free-field setting to twenty normal-hearing adults (thresholds ≤ 20 dB HL for 500–8000 Hz). Only sentences repeated correctly by all participants (100% intelligibility) were retained for the next stage of the test development.

- Sentence Grouping and Phoneme Balancing: The selected sentences were organized into fifteen sets of six, carefully designed to ensure that the distribution of phonemes within each set reflected their natural occurrence in European Portuguese. This balancing process maintained linguistic representativeness and phonetic diversity, preventing bias toward specific sounds or syllables. Each set thus provided a consistent and reliable measure of speech perception across all phonemes, supporting accurate assessment of participants' ability to recognize speech in noise. [12].

- Noise Addition and SNR Calibration: Each sentence set was mixed with multi-talker babble noise, specifically developed from recordings of European Portuguese speakers, using Audacity® software. The signal-to-noise ratios (SNRs) were systematically adjusted from 25 dB, representing very easy listening conditions, down to 0 dB, representing highly challenging conditions. This approach ensured that the test materials spanned the full range of listening difficulty, enabling precise assessment of speech perception in noise. Special care was taken to maintain consistent mixing levels, preserve sentence intelligibility at higher SNRs, and ensure a gradual and controlled increase in listening difficulty across the SNR spectrum.

- Pre-Test: The pre-test was conducted in a free-field environment at 65 dB SPL in the Audiology Laboratory of the Coimbra Health School. Fifteen normal-hearing adults (hearing thresholds ≤ 20 dB HL at 500–8000 Hz), with type A tympanograms and present ipsilateral and contralateral reflexes at 1000 Hz, participated in this phase. Participants were aged 18–22 years (3 males and 12 females) and had no cognitive impairments. Each participant was instructed to listen carefully and repeat every sentence they heard. The responses were recorded, and the number of correctly repeated keywords was tallied for each sentence. From these data, the percentage of correctly repeated keywords was calculated for each signal-to-noise ratio (SNR), providing a quantitative measure of sentence intelligibility and guiding the final selection of sentences for the test.

3. Results

The analysis of intelligibility across the fifteen sentence sets at different signal-to-noise ratios (SNR) revealed clear patterns of performance and variability, which were assessed using mean, median, standard deviation (SD), and range for each set. The results indicate progressively decreasing performance with decreasing SNR and highlight outlier sets that were subsequently excluded from the final version of the test.

At an SNR of 25 dB, participants demonstrated near-ceiling performance across all sets. Median scores reached 100% for every set, indicating that the speech signal was well above the background noise and easily intelligible. Mean scores were uniformly high, ranging from 97.33% to 100%, with

low standard deviations (0.0–7.04%), reflecting minimal variability among participants. Score ranges were narrow, predominantly between 80% and 100%, showing consistent performance across individuals. These results confirm a clear ceiling effect: at 25 dB, sentences were readily understood by all participants, and no sets presented unusual difficulty.

At an SNR of 20, participants exhibited near-ceiling performance across all sets. Median scores were 100% for every set, reflecting that the speech signal was well above the background noise and easily intelligible. The mean scores were consistently high, ranging from 92.0% to 100%, with low SDs between 0.0% and 9.8%, indicating minimal variability among participants. Ranges were narrow, mostly between 80% and 100%, showing consistent performance across individual responses. This ceiling effect confirms that at SNR 20 dB, the sentences were easily understood by all participants, and no sets displayed unusual difficulty.

At an SNR of 15, median scores remained uniformly high at 100% across most sets. Mean scores were slightly lower than at 20 dB, ranging from 90.7% to 100%, reflecting small reductions in average performance. Standard deviations increased slightly, ranging from 0.0% to 12.3%, and ranges expanded to 70–100% for some sets, indicating slightly greater variability in participant responses. All sets met the five-target-word criterion except for set 14, which contained an incomplete sentence. Despite its high median of 100%, this set was flagged for exclusion in the final test version.

At SNR 10, median scores remained high at 100% across all sets, with mean scores ranging from 88.0% to 97.3%. Standard deviations ranged from 4.9% to 16.2%, and ranges varied between 70–100% and 60–100%, showing slightly greater variability than at higher SNRs. These results indicate that participants were still able to reliably perceive the sentences, though minor difficulties began to emerge in certain sets.

At SNR 5 dB, intelligibility declined substantially, and variability between sets increased markedly. Median scores ranged from 0% to 80% (Table 1), with mean scores spanning 18.7% to 85.3%. Standard deviations varied widely, from 12.8% (set 6) to 38.9% (set 8), and ranges spanned the full scale (0–100%) in multiple sets, reflecting heterogeneous performance across participants.

Set 5 was identified as an outlier: it had a median of 0%, a mean of 18.7%, an SD of 34.2%, and a full range from 0% to 100%. The low median and extreme variability indicated that this set was disproportionately difficult at moderate noise levels. Other sets, such as 14, had a median of 80% and a minimum of 60%, demonstrating atypical performance compared to the rest of the sets.

Table 1. Results of the different sets in the signal-to-noise ratio of 5 (N=15).

Set	Mean	Median	SD	Range
1	46.7	40	27.9	0–100
2	18.7	20	20.7	0–60
3	21.3	20	16.0	0–40
4	45.3	60	37.4	0–100
5	18.7	0	34.2	0–100
6	50.7	60	12.8	20–60
7	42.7	40	23.7	0–80
8	41.3	40	38.9	0–100
9	34.7	20	38.1	0–100
10	73.3	60	19.5	40–100
11	34.7	20	35.8	0–100
12	18.7	20	27.7	0–100
13	74.7	80	31.6	0–100
14	85.3	80	14.1	60–100
15	72.0	80	19.7	20–100

Table 2. Results from Set 5 across different signal-to-noise ratios (N=15).

SNR	Mean	Median	SD	Range
10	93.3	100	9.8	80–100
5	18.7	0	34.2	0–100
0	33.3	40	34.4	0–80

At the most challenging SNR of 0, intelligibility decreased sharply across all sets. Median scores ranged from 0% to 20%, mean scores varied from 12.0% to 40.3%, and standard deviations were high (up to 34.4%), reflecting large variability among participants. Ranges spanned nearly the full 0–80% scale for several sets, confirming that comprehension was generally low under extreme noise conditions.

Based on these results, set 5 was removed from the final version of the SiN-EP due to its inconsistent performance at SNR 5 dB. Set 14 was also excluded because the sentence at SNR 15 dB did not contain the required five target words, and its minimum performance at SNR 5 dB deviated substantially from the other sets. The removal of these sets resulted in a more uniform and statistically reliable set of sentences for the final test.

4. Discussion

The present study reports the development of the SiN-EP, a speech-in-noise (SiN) test specifically adapted for European Portuguese speakers. The results demonstrate consistent performance across thirteen lists of six sentences in varying noise levels, indicating that the SiN-EP functions reliably as a linguistically tailored measure of speech perception in noise. These findings align with the broader SiN literature and extend existing tools to Portuguese-speaking populations.

Adaptations of the QuickSIN framework into other languages have similarly aimed to ensure linguistic appropriateness, phonetic balance, and psychometric stability. For example, the Turkish QuickSIN was developed using native speakers and multi-talker babble noise to achieve list equivalence [13]. Likewise, investigations of the original QuickSIN's 18 lists revealed that only a subset met criteria for homogeneity across listener groups [14]. Such work highlights the importance of sentence balance, controlled signal-to-noise ratios (SNRs), and realistic noise conditions—principles followed in the present study. The SiN-EP development process included drafting 165 sentences, evaluating them with native speakers, recording with a female voice, balancing phonemic content, and mixing with multitalker noise across SNRs from 25 to 0.

Broader reviews of SiN assessments emphasize that standard audiometric tests (pure-tone thresholds, speech in quiet) often fail to capture everyday listening challenges. Reynard et al. [15], for example, stressed the need for clinically feasible tests simulating realistic listening. The SiN-EP contributes to this goal for Portuguese speakers, offering performance patterns comparable to other validated adaptations such as the Spanish and French QuickSIN tests [16,17]. Previous research further shows that SiN tests reveal listening difficulties in older adults and hearing-impaired listeners that are not detected by pure-tone audiometry [18,19]. Collectively, these findings support the SiN-EP as a reliable and context-appropriate tool for evaluating speech perception in noise.

A key strength of this study lies in the linguistic and phonetic adaptation process. Sentences were rated by native speakers for semantic and syntactic naturalness, ensuring that comprehension difficulty derived from noise rather than language factors. Phoneme balancing across lists promoted comparable difficulty, and systematic noise mixing produced graded listening conditions from 25 dB to 0 dB SNR. Pre-testing with young adults enabled the elimination of lists that failed performance criteria, resulting in thirteen consistent and intelligible lists. Together, these procedures support the SiN-EP's methodological robustness and readiness for further validation.

Nonetheless, several limitations must be acknowledged. First, the pre-test sample consisted solely of young adults (18–22 years) with normal hearing. Broader normative data, including older adults and hearing-impaired listeners, are required to establish reference values. Second, while the

SNR range (25 to 0) captures a range of difficulty, real-world conditions can involve more adverse noise levels, spatial separation, or reverberation. Third, reliability measures such as test–retest consistency, list equivalence in clinical populations, and sensitivity to hearing status remain to be evaluated. Fourth, although list performance was consistent in this sample, equivalence should be confirmed across diverse populations. Finally, the influence of higher-level linguistic processes (e.g., semantic expectancy) was not manipulated, though prior research shows that listeners increasingly rely on context under challenging SNRs [20].

Despite these limitations, the SiN-EP has substantial potential for both clinical and research applications. Clinically, it provides a more ecologically valid assessment for Portuguese speakers who have trouble understanding speech in noise despite near-normal audiograms. It can aid in quantifying speech-in-noise deficits, guiding hearing-aid fitting or auditory training, and monitoring outcomes over time. For researchers, the SiN-EP offers a standardized, repeatable instrument for examining factors influencing SiN perception—such as aging, cognitive decline, or auditory processing disorders—and for tracking intervention effects. The use of thirteen equivalent lists minimizes learning effects, facilitating longitudinal studies and repeated testing.

Future work should address several directions. First, normative data must be collected across age ranges and hearing profiles to establish reference norms and clinically meaningful cut-offs. Second, comprehensive reliability testing (test–retest, list equivalence, group sensitivity) is essential, following procedures used in the QuickSIN validation [14]. Third, expanding test conditions to include more realistic listening scenarios—negative SNRs, spatial noise, reverberation, or competing talkers—would enhance ecological validity [21]. Fourth, examining the effects of cognitive and linguistic factors (e.g., working memory, bilingualism, semantic context) could deepen understanding of performance variability. Finally, applying the SiN-EP in intervention studies and linking test outcomes to self-reported listening difficulty or quality-of-life measures will help translate its findings into meaningful clinical practice.

5. Conclusions

In summary, the SiN-EP emerges as a methodologically sound and linguistically appropriate speech in noise test for European Portuguese speakers. The development process followed accepted best practices for adapting QuickSIN-style materials, and the initial data show clear and consistent participant performance across listening conditions. While further validation in broader populations and real-world listening settings is needed, the SiN-EP provides a promising tool for both clinical assessment and research of speech perception in noise among Portuguese speaking listeners.

Future studies will establish normative data and explore the test's diagnostic sensitivity across diverse hearing populations.

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