

Original Research Article

Development and standardization of new hearing in noise test in Arabic language

Wessam Mostafa Essawy^{1*}, Enaas Ahmad Kolkaila¹,
Ibrahim Ali Kabbash², Afaf Ahmad Emara¹

¹Department of Otorhinolaryngology, ²Department of Public Health and Community Medicine, Faculty of Medicine, Tanta University, Egypt

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*Correspondence:

Dr. Wessam Mostafa Essawy,
E-mail: wessamessawy@yahoo.com

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ABSTRACT

Background: Hearing in noise test (HINT) sentence test is one of adaptive speech in noise tests. It has been used in many clinical applications such as recording of speech perception threshold using sentences material in quiet and in noise and verifying the benefit from hearing-aid amplification and cochlear implants, especially in noise. The aim of the present study was to design and to develop and standardize an Arabic version of HINT sentences lists and also to apply HINT to subjects with SNHL.

Methods: Everyday sentences were used in an adaptive procedure to estimate the sentences speech recognition thresholds (sSRT) in quiet and noise; the material consisted of 28 phonemically balanced lists. This study included 150 normal hearing subjects and also 30 subjects with bilateral mild to moderate sensorineural hearing loss.

Results: The mean sSRT threshold in normal hearing subjects in quiet was 19 dB(A)±0.08 dB. The mean of S/N ratio at threshold in the noise 0° condition was -10.36 S/N ratio ± 0.58. The mean S/N ratio at threshold in the noise 90° condition was -10.45 S/N ratio ±0.41. While, the mean S/N ratio at threshold in the noise 270° condition was -11.69 S/N ratio ±1.70. As regards SNHL group, the mean of sSRT in quiet was 49.46 dB(A)±0.68 dB. The mean of S/N ratio at threshold was -7.69 S/N ratio ±0.68, -8.18±0.33 and -8.18±0.35 in the noise conditions 0°, 90° and 270° respectively.

Conclusions: The statistical reliability and efficiency of the test suit it to practical applications.

Keywords: Hearing in noise test, Sentences speech recognition thresholds, Signal to noise ratio, Sensorineural hearing loss

INTRODUCTION

Speech recognition is essential for social integration, as it enables efficient interpersonal communication. The ability to understand speech in the presence of background noise is a major challenge for any listener, especially for those with hearing impairment.¹

There are several speech-in-noise tests that can be used clinically. Two main types of these tests are available. These are the fixed and adaptive SNR tests. Two readily

available types of fixed SNR tests are connected speech test (CST) and speech perception in noise test (SPIN). While, hearing in noise test (HINT) and quick speech in noise (SIN) test are the main types of adaptive SNR tests.²

The HINT was developed by Nilsson et al, 1994 for the measurement of Reception threshold for sentences (sSRT) in quiet and in the presence of noise. The HINT includes 25 phonemically balanced lists of 10 sentences which were adapted from the Bamford-Kowal-Bench

(BKB) sentences. The goal of the HINT is to provide a reliable and efficient tool to estimate hearing handicap, directional hearing, hearing aid benefits and to perform comparison between hearing aids.^{3,4}

The technique for measuring sSRT is derived from adaptive testing. The adaptive procedure avoids the ceiling and floor effects associated with most word recognition tests, which are presented at a fixed level.⁴

HINT has been adapted for a large number of populations and languages: Latin; American; Spanish; Brazilian; Portuguese; Turkish; Castilian Spanish; Bulgarian; Korean; Norwegian; Malay; Japanese; Cantonese; Taiwanese Mandarin; and Mainland Mandarin.^{1,5-16}

METHODS

This work was done in Audiology Unit, Tanta University in the period from May 2013 to November 2016. Ethical approval Code No. is 1821/04/13.

The idea of the research was explained in details to the participants. An informed consent was obtained from all participants in this research. The participation was voluntary and that the subjects may discontinue participation at any time without penalty or loss of benefits.

Subjects

This study included 150 normal hearing subjects (74 males and 76 females). Their age ranged from more than 18 years up to 60 years. Normal hearing sensitivity is defined as having pure-tone air-conduction thresholds less than or equal to 25 dB HL at audiometric test frequencies 250 Hz to 8000 Hz (American National Standards Institute, 1996). All participating subjects had normal middle ear function as determined by normal type (A) tympanograms, with ipsilateral and contralateral acoustic reflex thresholds at expected levels when using pure tone of the following frequencies 500, 1000, 2000 and 4000 Hz in both ears.

Inclusion and exclusion criteria

The inclusion criteria for normal hearing group were to have bilateral normal peripheral hearing with hearing threshold level not exceeding 25 dB at any frequency from the range of 250 to 8000 Hz. Age ranged from (18-60) years. The participants should have Arabic as a native language with variation in the educational background. No systemic diseases (e.g., any endocrinal, vascular, renal, cardiovascular or neurological complaints). Participants should have no history of ototoxic drugs intake or history of noise exposure.

Exclusion criteria for normal hearing group were Subjects with any hearing complaints, history of unilateral or bilateral audiological diseases or family history of hearing loss. Also, subjects with any general

health problems (e.g., any endocrinal, vascular, renal, cardiovascular or neurological complaints) were excluded from this study.

The inclusion criteria for sensorineural hearing loss group were to have bilateral symmetrical flat configuration SNHL with hearing threshold average more than 25 up to 55 dB HL at audiometric test frequencies 250 to 8000 Hz. Age ranged from (18-60) years. The participants should have Arabic as a native language with variation in the educational background.

The exclusion criteria for sensorineural hearing loss group were unilateral SNHL, asymmetrical SNHL and any configuration other than flat one.

Procedure

All subjects were subjected to full audiological history, otological examination and basic audiological evaluation.

Development of hearing in noise test material

This was based on the principles of the original HINT developed by Nilsson et al.⁴

The following steps were done:

Development of sentence materials

We began with creation of a large set of new speech material consisting of everyday sentences that sound natural despite differences in dialect, education and background. The sentences were short and simple. They were chosen from children books at first grade reading level or from equivalent sources of uniform sentence lengths of three to six words.

Testing of naturalness of sentences materials

The goal of this step was to make all sentences be perceived natural by native Arabic speakers. The 'naturalness' is defined as the appropriateness of the vocabulary, style and usage expressed by the sentence. We began with 338 sentences evaluated by twenty five subjects (Arabic native speakers and varied in the educational background) for naturalness on a seven point scale (7="completely natural," 1 ="artificial or highly complicated"). The requirements for a sentence to be 'natural' were firstly it did not contain unusual Arabic words and secondly it could have been used in an ordinary conversation.

Any sentence that did not receive a mean rating of at least six was excluded. Fifty two sentences were excluded after the first revision. All revised 286 sentences were rated again by another twenty subjects. The second set of revisions on a four point scale (4="completely natural," 1="artificial or complicated"). Any sentence that did not receive a mean rating of at least three was excluded. Six

sentences were excluded again after the second revision. The remaining sentences were 280 sentences used to develop the 28 lists of the Arabic HINT (A-HINT).

Creation of sentences lists

The resulting set of sentences was sorted into equivalent lists to be used in the measurement of sSRTs. The phoneme distribution within the sentence set was determined according to the phonological transcriptions and classification into 28 consonants and 6 vowels (3 long and 3 short vowels).¹⁷

Twenty-eight lists of 10 sentences, which matched the phonemic distribution of the entire sentence set, were formed using a trial-and-error process to exchange sentences between lists in an effort to match the distribution for each list to the overall distribution as closely as possible.

Recording of lists

Recording was made of the revised materials using a male native professional voice speaker. The speaker was a radio broadcaster, news reader, etc., with professionally trained voice. The speaker was instructed to maintain clarity, pace and effort while reading the sentences.

Recordings were made in a double-walled sound treated room with acoustic foam on the walls and ceiling. A Neumann microphone was placed perpendicular to the speaker at a distance of 1 m. Average signal levels at the microphone were maintained at about 65-70 dB SPL. Signal levels were monitored with an oscilloscope throughout the recording session to confirm that peak signals were not clipped.

Masking noise

Multitalker babble was recorded, transferred to computer programs and mixed with the recorded A-HINT sentences lists in the CD material in a fashion that enabled to direct separate inputs to the audiometer (one channel can transfer sentences material and the other channel can transfer masker noise).

Measuring Arabic hearing in noise test

The test environment

The test required a sound-treated room with two loudspeakers, a chair, a compact disk player and an audiometer. The two loudspeakers were positioned so that the center of the subject's head is one meter from each loudspeaker. The loudspeakers are separated by a 90° azimuth at the ear level of the tested subject. Sentences SRT was measured in quiet and in noise. Sentences speech material location remained fixed at 0° in all tested conditions. The location of noise source

differed in three tested conditions: noise front (0°), noise (90°) and noise (270°) (Figures 1 to 4).

Calibration of fixed signal-to-noise ratio A-HINT audio CDs

The loudspeaker calibration protocol involved the presentation of calibration noise and measurement of the output level. Once this calibration was performed, the speech stimuli were also calibrated.

Position of the reference microphone (here we used sound level meter) (SLM) at the location corresponding to the center of the subject's head and one meter from each of the speakers. The HINT system was recalibrated each time the audiometer was recalibrated and whenever the loudspeaker positions were changed or the loudspeakers were replaced.

The test procedure

The sentence lists were administered using adaptive testing procedure according to HINT guidelines. In quiet condition, the starting level was 30 dB SL (referred to SRT by loudspeaker). In noise conditions, the noise level was fixed at 65 dB (A), whereas the intensity levels of sentences were adjusted according to the participant's response. The sentence was initially presented at -5 dB signal-to-noise (SNR) and the sentence presentation level was increased in 4-dB steps until the participants repeated 100% of the words in the sentence. The presentation level then was lowered by 4 dB after a correct repetition of the entire sentence or raised after an incorrect response. The 4 SNRs in the first four sentences were averaged and used as the starting presentation level for the 5th sentence.

Thereafter, the adaptive procedure was preceded to the 10th sentence that would have been presented using 2-dB steps. The averaged SNR from the 5 to 10th sentences in a sentence list was regarded as the Reception threshold for sentences (RTS) for that list. This procedure was similar to Nilsson et al (1994) and Hallgren et al (2006) who found that the mean and SD of threshold becomes stable after 4th or 5th sentences.^{4,18}

All participants were given one practice list each in quiet and noise at 0° azimuth conditions to familiarize them with the task (this was proven by Nilsson et al (1994) and Hallgren et al (2006) who found that one list is sufficient for subject to be acquainted with the test procedure). Each participant then was given all the 12 sentence lists in four listening conditions, including speech in quiet, noise at 0°, 90° and 270° azimuth, respectively, with each listening condition containing three threshold measurements (i.e., three sentence lists) with a total of 14 lists used for each subject.^{4,18}

Participants were instructed to listen carefully and repeat aloud whatever they heard as much of the sentence as

possible. The sentences were presented one at a time. The listener is encouraged to guess if they were not sure what was spoken.

Statistical analysis

The collected data were organized, tabulated and statistically analyzed using SPSS version 19 (Statistical Package for Social Studies created by IBM, Illinois, Chicago, USA).

For numerical values the range mean and standard deviations were calculated. For each list and at different noise level, the X variable was presented as range, mean and standard deviations.

To identify the accuracy and sensitivity of measurement the standard error and the 95% confidence interval (95% CI) for both the mean and standard deviations were calculated.

Comparison of value of measurements by one list or more than one list was performed using analysis of variance (F). When analysis of variance was significant, the least significant difference (LSD) was used as post hoc test to compare between each two mean values. The level of significant was adopted at $p \leq 0.05$.

Cronbach’s alpha test was used to test the reliability of the test with repeated threshold measurements.

RESULTS

This study included 150 normal hearing subjects. They all had pure tone air-conduction thresholds less than or equal to 25 dB HL at audiometric test frequencies from 250-8000Hz. These subjects were 74 males and 76 females. Their age ranged from 18-50 years with a mean 33.10 ± 9.90 years.

Normative values of sSRT in normal hearing subjects

The sSRT in quiet ranged from 19.0 to 19.7 dB (A) with mean and standard deviation of sSRT 19 dB (A) ± 0.08 dB. The S/N ratio at threshold in the noise 0° condition in all subjects ranged from -8.0 to -11.0 S/N ratio with the mean and standard deviation -10.36 ± 0.58 . The S/N ratio at threshold in the noise 90° condition in all subjects

ranged from -9.7 to -11.0 S/N ratio with the mean and standard deviation -10.45 ± 0.41 . While, the S/N ratio at threshold in the noise 270° condition in all subjects ranged from -9.0 to -15.3 S/N ratio with a mean and standard deviation -11.69 ± 1.70 (Table 1).

List equivalence for each condition in normal hearing subjects

The second step was to get the list equivalence. The mean sSRT for each list across all subjects tested with that list was computed and expressed as a deviation score from the mean across all lists and all subjects.

List equivalence was computed and expressed as a deviation score from the mean across all lists and all subjects. In other words, we tried to get the deviation of each list from the mean value of this condition which was calculated for the all normal hearing group. For each list we calculated range, mean, standard deviation, standard error, 95% confidence interval of mean and standard deviation. All list means fluctuated within less than 1 dB of the overall mean.

The reliability of the sSRT measures

This was estimated from the standard deviation of differences between repeated sSRT measurements. These measures were done for 15 subjects within 2 weeks interval. These estimates were computed separately for the quiet and noise test conditions. The standard deviation of difference scores in quiet condition was 0, and in noise 0° condition was ± 0.65 and for noise 90° condition was ± 0.38 and finally for noise 270° condition was ± 0.60 . Cronbach’s alpha test was used to test the reliability and revealed a value of 0.687 which is a good indicator of reliability of the test for repeated measurements.

The statistical power of the Arabic HINT test

The last question we had asked as regards Arabic HINT test was the statistical power of that test. In other words, how many lists should be used to detect the true threshold differences of sSRT? One way ANOVA test was done comparing the threshold or S/N ratio, in quiet and noise conditions respectively, when using only one list and when using the average of two repeated lists and when using average of three lists measurements.

Table 1: Range, mean, SD and SE of sSRT for each condition (quiet, noise 0, 90 and 270) in normal hearing subjects.

Condition	Range	Mean±SD	SE	95% CI of mean	95% CI of ±SD
Quiet	19.0 to 19.7 dB(A)	19±0.08	0.01	19.01-19.01	0.08-0.08
Noise 0	-8.0 to -11.0 S/N ratio	-10.36±0.58	0.05	-10.36 to -10.36	0.58-0.58
Noise 90	9.7 to -11.0- S/N ratio	10.45±0.41-	0.05	-10.54 to -10.54	0.58-0.58
Noise 270	-9.0 to -15.3 S/N ratio	11.69±1.70-	0.14	-11.69 to -11.69	1.70-1.70

SD: Standard deviation; SE: Standard error; CI: Confidence interval.

Table 2: Comparison between average of one, two and three list in sSRT measurements using A-HINT using ANOVA test.

	Condition	Range	Mean±SD	F	P
Quiet	One list	19.0-19.7	19.04±0.16	2.056	0.135
	Two lists	19.0-20.7	19.06±0.30		
	Three lists	19.0-20.1	19.04±0.20		
Noise 0°	One list	-7.0 to -11.0	10.56±1.00	0.562	0.572
	Two lists	-7.6 to -11.0	10.54±0.78		
	Three lists	-7.9 to -11.0	10.51±0.73		
Noise 90°	One list	-9.8 to -11.0	10.62±0.38	3.895	0.025*
	Two lists	-10.0 to -11.0	10.56±0.35		
	Three lists	-9.9 to -11.0	10.56±0.35		
Noise 270°	One list	-12.0 to -15.3	13.71±0.86	8.304	0.001*
	Two lists	-12.7 to -15.4	13.89±0.62		
	Three lists	-11.9 to -15.3	13.95±0.61		

*LSD: One list significantly different from two and three lists.

Results of ANOVA showed no significant difference in quiet and in noise 0 conditions. In other words, this result means that only one list is sufficient for accurate sSRT threshold detection. Moreover, results of one way ANOVA in the other two conditions (noise 90 and noise 270) were completely different. A significant difference was found between repeated measurements (one, two and three lists average). In other words, in noise 90 and 270 one list is not sufficient for accurate threshold detection (Table 2).

DISCUSSION

Our results agreed to a large extent with the normative data of a Cantonese version of the Hearing in noise test (CHINT) with mean sSRT thresholds in quiet were measured at 19.4 dB (A) and sSRT thresholds for sentences of -10.6 S/N ratio for noise 90° and -10.5 S/N ratio for noise 270°. For Noise 0° condition, our results were far away from the Cantonese results which were -3.9 S/N ratio.¹⁴

Many versions of HINT had normative values near to our results. Using the Mandarin hearing in noise test (MHINT), the mean sSRT for quiet was 19.4 dB (A), -11.7 dB S/N ratio for noise 90° and -11.7 dB s/n ratio for noise 270°. For noise 0° condition, our results also were far away from the Mandarin results which were -4.3 S/N ratio.^{15&16}

Therefore, our results in noise 0° condition, which was -10.36±0.58 S/N ratio, were out of proportional of the results of many studies. Our results in all noise conditions were nearly equal (-10.36±0.58, -10.45±0.41 and -11.69±1.70 S/N ratio in noise 0, 90 and 270° conditions respectively). This can be explained by the equal difficulty of speech recognition ability in different azimuths as we used recorded multitasker babble which had a speech spectrum near to the sentences material.

Results of ANOVA showed no significant difference in quiet and in noise 0 conditions. In other words, this result means that only one list is sufficient for accurate sSRT threshold detection. Moreover, results of one way ANOVA in the other two conditions (noise 90 and noise 270) were completely different. A significant difference was found between repeated measurements (one, two and three lists average). In other words, in noise 90 and 270 one list is not sufficient for accurate threshold detection (Table 2).. Moreover, results of one way ANOVA in the other two conditions (noise 90 and noise 270) were completely different. A significant difference was found between repeated measurements (one, two and three lists average). In other words, in noise 90 and 270 one list is not sufficient for accurate threshold detection (Table 2).sSRTs, in spectrally matched noise for sentences developed with a similar procedure, with average S/N ratios of -7.3 dB which is also far from our results.^{15,19,20}

Our results in noise conditions fall slightly outside the range of -5.3 to -2.6 dB S/N ratio observed for the 13 versions of HINT listed in Soli and Wong in 2008. Nilsson et al (1994) found that average sSRTs in quiet were 23.91 dB (A). Average sSRTs in 72 dB (A) noise -2.92 dB signal/noise ratio which was close to the -2.00 dB (A) value reported by Gelfand et al for the high-predictability SPIN sentences presented in multitalker babble.^{4,15,21}

Other languages as Dutch, mean -5.9±0.9 S/N ratio; Canadian-French, mean -3.3±0.5 S/N ratio and Swedish HINT, mean S/N ratio -3.0±1.1.¹⁸⁻²⁰

The relatively high sSRT for noise in our Arabic version might be due to the simplicity of the sentences, the use of a professional talker and the high redundancy of the Arabic language. This represents an advantage of our test material. Also, differences in presentation techniques (headphones vs loudspeakers) and instrumentation and calibration differences could influence sSRT thresholds

in quiet and in noise making these differences in test results in many studies.

In summary, our new Arabic HINT can be used as a reliable and standardized test for measuring sSRT for sensorineural hearing loss subjects. HINT can be used as a unique testing technique as a predictive of real-world and functional hearing ability. The goal of the HINT is to provide a reliable and efficient tool to estimate hearing handicap, directional hearing, and hearing aid benefits and to perform comparison between hearing aids.

CONCLUSION

HINT can provide a reliable and efficient tool to estimate hearing handicap, directional hearing, and hearing aid benefits and to perform comparison between hearing aids. The new Arabic HINT can be used as a reliable and standardized test for measuring sSRT for sensorineural hearing loss subjects. In Quiet condition: Lists 3, 4 and 16 are the best lists used. In noise 0° condition: lists 20, 21 and 22 are the best lists used. In noise 90° condition: lists 9, 10 and 25 are the best lists used. In noise 270° condition: lists 26, 27 and 28 are the best lists used. In quiet and noise 0° conditions, using only one list is sufficient for accurate measurements. In noise 90° and 270° conditions, two lists should be used for accurate measurements.

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