Kamal *et al.*
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Using the hearing in noise test (HINT) in the assessment of the performance of directional microphone

Wafaa Ahmed Kamal, Wessam Mostafa Essawy*, Afaf Ahmad Emara and Amani Mohamed El-Gharib

Abstract

Objectives Hearing in noise test (HINT) is used to evaluate and compare the performance of different hearing aid. This research was designed to compare the performance of a fixed directional microphone (FDM) and an automatic adaptive directional microphone (AADM) with different noise directions using aided Arabic HINT.

Methods Control group (CG): 20 normal peripheral hearing adults. Study group (SG): 40 adults with bilateral symmetrical sensorineural hearing loss. Arabic HINT was performed in three noise situations at 0°, 90°, and 270° azimuths for both groups. For SG, test was done in 4 conditions: condition (I), without hearing aid; condition (II), aided response with omnidirectional microphone; condition (III), aided response with FDM; and condition (IV), aided response with AADM.

Results For all azimuths, there was a statistically considerable difference between CG and SG in all conditions. Also, there was a statistically significant difference between SG conditions I and II and II and III. But no statistically significant difference was observed between conditions III and IV when the noise was at 90° and 270° azimuths.

Conclusion AADM is the best choice of selection in hearing aid fitting, and it performs better in noise, especially when the noise and speech are in front of the patient.

Keywords Hearing in noise test (HINT), Fixed directional microphone, Adaptive directional microphone, Sensory neural hearing loss (SNHL)

Background

Speech recognition is crucial for effective person-to-person communication and social integration. Every listener has a significant barrier when trying to understand speech over background noise, but those with hearing loss have an additional difficulty. The person's hearing loss features will determine whether speech perception can be recovered. Users of hearing aids (HA) reported several problems in noisy settings. Understanding speech, discomfort with noise loudness, and background noise are some of these difficulties [1]. In addition, technological advances can improve signal processing in digital HAs. Currently, the functionality of HA users in noisy environments is enhanced by the employment of a directional microphone and noise suppression [2].

When attempting to enhance speech recognition in noise for HA users, choosing the appropriate type of microphone is one of the crucial tasks. Depending on directionality, the HAs may have either omnidirectional or directional microphones (DM) [3]. DM may be further classified into fixed, automatic adaptive, and automated fixed microphones [4].

Standard static responses are provided by fixed directional microphones (FDM), which concentrate on

*Correspondence:
Wessam Mostafa Essawy
wessamessawy@yahoo.com
Faculty of Medicine, Tanta University, El Nahas Street, Tanta, El Gharbia, Egypt

sound directionality toward the subject's front. This technique is predicated on the idea that sound coming from the side or the rear is deemed noise since the speaker is facing the listener. However, according to certain investigations, the voice signal is not coming from the listener's front in more than 20% of scenarios [5, 6].

The directionality of the automatic adaptive directional microphone (AADM) is altered in response to input from the surroundings. According to the direction of speech signals and the input sound's overall intensity, the microphone's polar pattern response fluctuates when speech sounds and noise are detected [7]. Since enhancing speech reception is one of the primary goals of HA fitting, therefore, it is essential to use standardized testing to confirm HA's effectiveness [8].

The hearing in noise test (HINT) was created as an accurate and effective method for assessing and identifying a person's speech reception threshold in noisy conditions [9]. HINT has been used to assess and compare the performance of various HAs [10]. The present research was designed to compare the performance of FDM and AADM with different noise directions using aided HINT in Arabic.

Methods

This work was performed between November 2019 and December 2020 after being approved by The Research Ethics Committee (No.33498/11/19) and included 60 adults aged 18–60.

Subjects

Patients included in this study were divided into study and control groups (SD and CG, respectively).

CG consisted of 20 adults having bilateral normal peripheral hearing, according to the American National Standards Institute [11].

SG consisted of 40 adults with bilateral symmetrical sensorineural hearing loss.

Inclusion criteria for SG:

- Bilateral symmetric sensorineural hearing loss with the average threshold for pure tone from more than 40 dB to less than 70 dB
- HA user not less than 6 months

Exclusion criteria:

- Asymmetric sensorineural hearing loss
- Irregular HA users

Method

The equipment

- Sound-treated room: locally manufactured
- Pure tone audiometry: Madsen Astera, type-1, two channels, and PC-based audiometer with multiple sound field speakers (front-left, front-right, and rear), which are Martin-Audio London type
- HA: digital multichannel HA with omnidirectional, directional front, and automatic adaptive microphones

Methodology

All subjects were submitted to the following.

Basic audiological evaluation

Hearing in noise test (HINT): we used adaptive testing techniques in accordance with HINT standards of the US House Ear Institute in 1994 [12].

The noise level for CG was constant at 65 dB (A) throughout the test. For SG, the noise level was constant at 75 dB throughout the test (to be heard by all patients as some patients have HL up to 70 dB).

The HINT test material was incorporated into the Astera software, and lists can be selected from the software playlist.

Sentences' degrees of intensity were modified in an adaptive technique in response to the participant's response. The initial presentation of the first phrase was at a signal-to-noise (SNR) ratio of − 5 dB. In the first four phrases, the step size was 4 dB. The beginning presentation level for the fifth sentence was determined by averaging the four SNRs from the previous four sentences. The average SNR from the past 5 sentences, with step sizes of 2 dB each, was used to determine the list's reception threshold for sentences (RTS). According to Nilsson et al. [9] and Hallgren et al. [13], the mean and SD of the threshold stabilize after the fourth or fifth phrase.

To familiarize themselves with the assignment, each participant was given one practice list with noise at azimuth 0° and encouraged to pay close attention and repeat loudly anything they heard as much as possible. The sentences were offered one at a time. If a listener is unsure about what was said, they are advised to make a guess.

Scoring was determined by accurately reporting whole sentences. Minor variations, in verb tense, articles, and singular versus plural nouns, were accepted [14].

The HINT test was done in three situations: signal and noise at 0° azimuth; signal at 0° azimuth and noise at 90° azimuth; signal at 0° azimuth and noise at 270°.

For the SG, these three situations were done in four different conditions using monaural HA. First, the side of monaural HA was considered when collecting data. Then, the noise results at 90° azimuth were calculated by adding the results of noise at 90° azimuth of right HA users to the results of noise at 270° azimuth of left HA users. Finally, and vice versa in noise at 270° azimuth, when collecting data, the results of noise at 270° azimuth were calculated by adding the results of noise at 90° azimuth of left HA users to the results of noise at 270° azimuth of right HA users.

SG condition 1: unaided. Condition 2: aided response with the omnidirectional microphone. Condition 3: aided response with FDM. Condition 4: aided response with AADM.

The three loudspeakers were separated by a 90° azimuth and placed such that the subject's head center is 1 m from each loudspeaker, just at the subject's ear level (Figs. 1, 2, and 3).

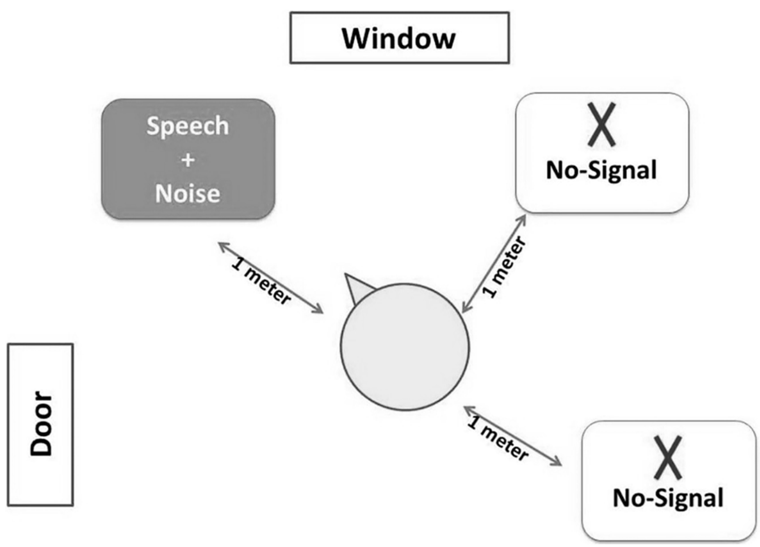

Fig. 1 Signal and noise arrangement in noise 0° azimuth condition

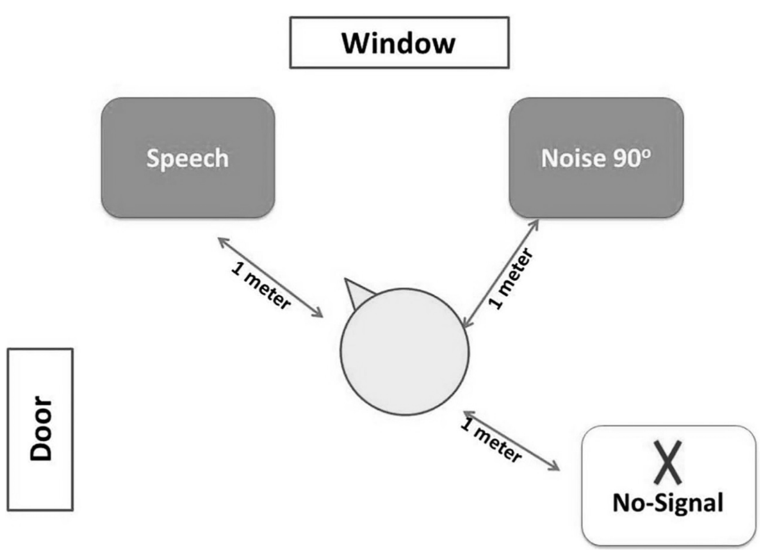

Fig. 2 Signal and noise arrangement in noise 90° azimuth condition

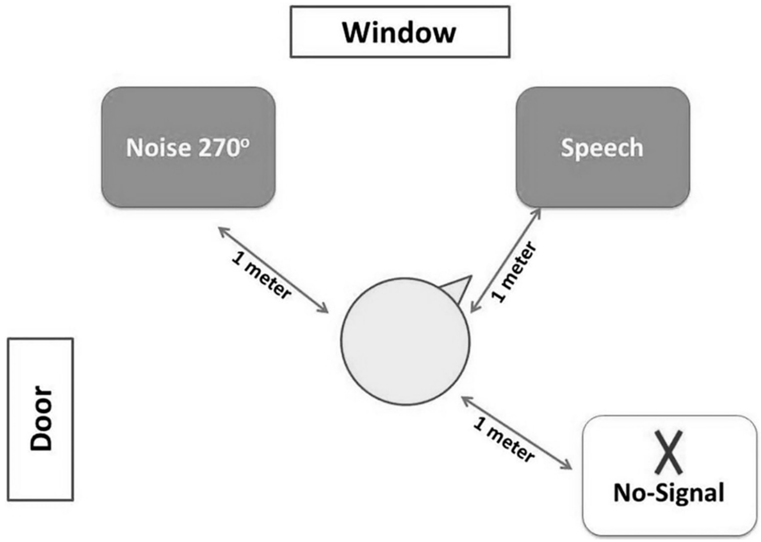

Fig. 3 Signal and noise arrangement in noise 270° azimuth condition

Statistical analysis

Statistical presentation and analysis of the present study were conducted using SPSS V.22 for the mean value, standard deviation, standard Student "*t*-test," and degree of freedom (DF). We have also used the analysis of variance (ANOVA) tests (*f*), post hoc test, and chi-square test of significance.

Results

The mean age was 31.80 ± 8.82 years and 36.95 ± 14.95 years in the CG and SG, respectively. The subjects were 9 males (45%) and 11 females (55%) for CG, while for SG, they were 18 males (45%) and 22 females (55%) (21 right HA users and 19 left HA users).

Regarding age and gender, no statistically significant difference was discovered between the two groups.

Average PTA thresholds are presented in Table 1.

Table 1 Pure tone audiometry (PTA) threshold for both groups

PTA		Range	Mean ± SD	*t*-test	*p*-value
250 Hz	**CG**	5–20	13.13 ± 3.43	9.143	0.001*
	SG	15–70	42.00 ± 13.86		
500 Hz	**CG**	10–20	14.38 ± 3.13	13.118	0.001*
	SG	30–75	50.25 ± 11.98		
1 kHz	**CG**	7.5–20	14.88 ± 3.29	18.621	0.001*
	SG	40–75	58.75 ± 10.24		
2 kHz	**CG**	7.5–22.5	15.75 ± 3.54	21.762	0.001*
	SG	45–75	62.63 ± 9.27		
4 kHz	**CG**	7.5–25	15.00 ± 4.73	21.396	0.001*
	SG	45–90	68.50 ± 10.63		
8 kHz	**CG**	10–25	18.00 ± 4.63	21.372	0.001*
	SG	45–95	75.50 ± 11.54		
PTA average	**CG**	9.58–20.42	15.19 ± 3.08	22.560	0.001*
	SG	44.17–74.17	59.60 ± 8.50		

Effect of sensory neural hearing loss in HINT results

RTS average and standard deviation for both groups are illustrated in Table 2. The comparison between CG and SG condition I (unaided) revealed statistically significant differences at 0°, 90°, and 270° azimuths (Table 2).

The results showed that patient with SNHL needs ~ 11 dB SNR more than normal to repeat 50% correctly in HINT.

Table 2 Comparison of RTS between CG and SG in condition I at 0°, 90°, and 270° azimuths

Azimuth		Range	Mean ± SD	*t*-test	*p*-value
0°	**CG**	− 11 to − 9.7	− 10.77 ± 0.39	14.615	0.001*
	SG Con I	− 7.8 to 7	1.05 ± 3.59		
90°	**CG**	− 11 to − 10.33	− 10.87 ± 0.27	14.745	0.001*
	SG Con I	− 9.8 to 7	0.71 ± 3.49		
270°	**CG**	− 12 to − 10.33	− 10.95 ± 0.35	15.216	0.001*
	SG Con I	− 7.4 to 10.2	1.22 ± 3.55		

Comparison between CG and SG conditions I, II, III, and IV using noise at 0° azimuth

There was a highly statistically significant difference among all conditions. The post hoc test has also shown a

Table 3 Comparison among CG and SG conditions I, II, III, and IV using noise at 0° azimuth

HINT at 0° azimuth	CG	SG			
		Condition I	Condition II	Condition III	Condition IV
Range	− 11 to − 9.7	− 7.8 to 7	− 8.6 to 6.2	− 11.8 to 3	− 13 to 2.2
Mean ± SD	− 10.77 ± 0.39	1.05 ± 3.59	− 3.14 ± 3.25	− 6.52 ± 3.36	− 8.37 ± 3.69
F test	65.240				
p value	0.001*				
P1		0.001*	0.001*	0.001*	0.008*
P2			0.001*	0.001*	0.001*
P3				0.001*	0.001*
P4					0.013*

P1: Comparison between CG and SG condition I

P2: Comparison between SG condition II and SG condition I

P3: Comparison between SG condition III and SG condition II

P4: Comparison between SG condition IV and SG condition III

Condition I: Without hearing aid (unaided)

Condition II: Aided response with omnidirectional microphone

Condition III: Aided response with directional front microphone

Condition IV: Aided response with adaptive directional microphone

highly statistically significant difference between CG and SG conditions I, II, III, and IV, also among SG conditions II and III, II and IV, and III and IV (Table 3).

Comparison between CG and SG conditions I, II, III, and IV using noise at 90° azimuth

When collecting data, the results of noise at 90° azimuth were calculated through adding the results of noise at 90° azimuth of right HA users to the results of noise at 270° azimuth of left HA users. Similarly, the results of noise at 90° azimuth showed a highly statistically significant difference between CG and SG in all conditions. Also, there was a statistically significant difference between SG conditions I and II and II and III. But there was no statistically significant difference between conditions III and IV (Table 4).

Comparison between CG and SG conditions I, II, III, and IV using noise at 270° azimuth

When collecting data, the results of noise at 270° azimuth were calculated by adding the results of noise at 90° azimuth of left HA users to the results of noise at 270° azimuth of right HA users. Similarly, the results of noise at 270° azimuth showed a highly statistically significant difference between CG and SG in all conditions. Also, there was a statistically significant difference between SG

Table 4 Comparison among CG and SG conditions I, II, III, and IV using noise at 90° azimuth

HINT at 90° azimuth	CG	SG			
		Condition I	Condition II	Condition III	Condition IV
Range	− 11 to − 10.33	− 9.8 to 7	− 10.2 to 5.4	− 13.4 to 3.8	− 14.6 to 2.2
Mean ± SD	− 10.87 ± 0.27	0.71 ± 3.49	− 3.71 ± 3.22	− 7.98 ± 3.70	− 8.76 ± 3.72
F test	63.218				
p value	0.001*				
P1		0.001*	0.001*	0.002*	0.015*
P2			0.001*	0.001*	0.001*
P3				0.001*	0.001*
P4					0.416

P1: Comparison between CG and SG condition I

P2: Comparison between SG condition II and SG condition I

P3: Comparison between SG condition III and SG condition II

P4: Comparison between SG condition IV and SG condition III

Table 5 Comparison among CG and SG conditions I, II, III, and IV using noise at 270° azimuth

HINT at 270° azimuth	CG	SG			
		Condition I	Condition II	Condition III	Condition IV
Range	− 12 to − 10.33	− 7.4 to 10.2	− 11.4 to 4.6	− 13 to 3.8	− 14.6 to 3.0
Mean ± SD	− 10.95 ± 0.35	1.22 ± 3.55	− 4.14 ± 3.25	− 8.31 ± 3.74	− 8.60 ± 3.84
***F* test**	67.332				
***p* value**	0.001*				
P1		0.001*	0.001*	0.005*	0.019*
P2			0.001*	0.001*	0.001*
P3				0.001*	0.001*
P4					0.547

P1: Comparison between CG and SG condition I

P2: Comparison between SG condition II and SG condition I

P3: Comparison between SG condition III and SG condition II

P4: Comparison between SG condition IV and SG condition III

conditions I and II and II and III. But there was no statistically significant difference between conditions III and IV (Table 5).

Discussion

Any listener, but prominently those with hearing impairment, finds it extremely difficult to understand speech when there is background noise present. The person's hearing loss features will determine whether speech perception may be recovered. However, users of HA report a number of problems in loud settings. Speech comprehension, discomfort with the noise level, and background noise are a few of these problems [15].

To help HA users better understand speech in loud environments, digital HAs now employ directional microphone techniques and digital noise reduction. HA may be furnished with omnidirectional, directional, and adaptive directional microphones for directionality [16].

The main aim of this investigation was to study aided hearing in noise test (HINT-Arabic Version) utilizing HA with a directional microphone and to compare between results of aided HINT in different noise directions and different microphone directionality algorithms.

Regarding the effect of sensorineural hearing loss on HINT, our findings were in accordance with Sultan et al., who reported a highly statistically significant difference between the healthy group and patients with sensorineural hearing loss. They reported that the mean of RTS for normal hearing subjects was − 7.65 ± 2.54 S/N ratio and for sensory neural hearing loss subjects was − 1.3 ± 2.84 S/N ratio at 0° azimuth [17]. These findings concluded that patients with SNHL loss needed a better SNR environment when compared to healthy individuals. In contrast to Essawy (2019), the present study showed that the patient with SNHL needs ~ 11 dB SNR loss more than the controls. This variation is due to the difference in selection criteria. Essawy (2019) studied mild to moderate SNHL, and also configurations were flat [14]. It was probable that the severity of hearing loss and the SNHL group audiogram configuration significantly affected the test outcomes [18].

This research results showed that patients using HA needed lower SNR in all tested noise directions using AADM technology. However, there was no statistically significant difference between FDM and AADM when noise was at 90° and 270° azimuth but still RTS lower using AADM.

These findings were in line with several laboratory studies that demonstrated greater speech comprehension in background noise for HAs equipped with DM and adaptive microphones over omnidirectional microphones [19–21].

In a study by Browning et al. (2019), 14 children (5–14 years old) with mild to severe bilateral SNHL were tested for speech-in-noise and speech-in-speech detection while a completely adaptable directional HA algorithm was activated. For two HA settings—omnidirectional (OMNI) and completely adaptable directionality—open-set word recognition thresholds were adaptively evaluated. They concluded that children with hearing impairments needed a better signal-to-noise ratio than children with normal hearing to perform comparably in noisy environments. Additionally, they noted that using HAs with completely adaptable directionality seems to have several benefits over fixed directionality as it does not require kids to face the target talker and gives them access to a variety of talkers in the surrounding area [22].

The results of the present investigation disagreed with Walden et al., who declared that directional processing was often favored only when both the noise source and signal source were in front of the listener. However, these research results suggested that ADM and FDM improve the S/N ratio needed even with noise at 90° and 270° azimuth [23].

Our results were supported by Bentler et al. (2004)'s investigation of 46 participants with mild-to-moderate hearing loss revealed that irrespective of the amount of microphones used, directional microphone modes enhanced speech perception in stationary noise environments compared to omnidirectional microphone modes and that in moving noise environments, the three-microphone choice (whether in adaptive or fixed mode) and the two-microphone choice (in its adaptive mode) produced the best results [24].

According to Surr et al. (2002), users may recognize listening scenarios when a directional microphone is preferable than an omnidirectional microphone [19].

Conclusions

In conclusion, the AADM is the best selection choice in HA fitting, and it has the better performance in noise, especially when the noise and speech are in front of the patient. DM and AADM also have better performance when the noise is at 90° and 270° azimuth of the patient. Also, this research showed an improved S/N ratio in patient with sensorineural hearing loss, even with omnidirectional microphones, compared to the unaided response.

Recommendations

Additional study using HINT is needed in environments that mimic the natural environment characteristic, i.e., reverberation environment and changeable noise directions.

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Authors' contributions
WAK: for clinical cases and writing manuscript. WE: for clinical cases interpretation and data analysis. AAE: for study concept and design. AME: for interpretation and writing manuscript. The authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The research approved by The Research Ethics Committee Tanta University, Egypt (approval code No.33498/11/19). An informed written consent to participate in the study was provided by all participants.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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