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Comparison of the Effects of Asymmetrical Directionality and Narrow Directionality on Speech Perception in Noise in Hearing Aids

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ABSTRACT

Objective: The speech perception performance of hearing aid users decreases in the presence of noise. The most effective way to improve speech intelligibility in noise is to use directional microphones close to the sound source. This study aims to investigate the effect of asymmetric directionality, a microphone directionality mode, on speech intelligibility in difficult listening conditions, while maintaining environmental awareness through a mechanism acting like the human ear.

Methods: The study included 32 participants aged 20-50 years with bilateral flat moderate-to-moderately severe sensorineural hearing loss. At the time of assessment, participants used hearing aids bilaterally, with the fitting performed using the Real Ear Measurement method. Speech performance in noise across various microphone directional modes was evaluated using the Turkish Matrix test.

Results: According to the obtained data, a significant signal-to-noise ratio (SNR) increase was found for all microphone directionality modes when comparing the adaptive procedure in quiet and noisy conditions ($p<0.01$). A significant correlation was also found between the adaptive noise and non-adaptive procedures in terms of performance gain ($p<0.01$). In the asymmetric directionality mode, a statistically significant higher performance was observed compared to the omnidirectional mode ($p<0.05$).

Conclusion: Our study has revealed that the narrow and asymmetric directionality modes of the microphone improve speech performance by enhancing the SNR in noisy environments. We also concluded that asymmetric directional microphones proved more advantageous than the omnidirectional mode.

Keywords: Hearing aid, adaptive directionality, narrow directionality, asymmetric directionality, speech intelligibility

INTRODUCTION

One of the greatest challenges for hearing aid users is speech perception in the presence of background noise. This is partly because listeners with sensorineural hearing loss require a better signal-to-noise ratio (SNR) than people with normal hearing in order to understand the same information (1). Near-source directional microphones, which detect sounds from multiplefocus on sounds from specific directions within the auditory field, are the most effective way to improve speech intelligibility in noisy environments. These microphones enhance signals from the front and attenuate those from the side or rear, thereby improving SNR.

Binaural directional hearing aids operate in directional or omnidirectional modes, configured symmetrically and asymmetrically as needed. Hearing aids are designed to automatically switch between these modes in order to optimise speech intelligibility. This automatic switching provides the localisation and sound quality benefits of omnidirectional microphones without compromising speech intelligibility (2).

The narrow directionality of hearing aids enables users to focus on speech coming from directly in front of them by reducing distracting noise from behind and to the sides. Unlike hearing aids with narrow directionality, asymmetric directionality technologies improve speech intelligibility by making use of the benefits of directional microphones while maintaining users' environmental awareness. In this technology, the microphone of one hearing aid is omnidirectional, while the microphone of the other hearing aid is directional (3).

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While studies have shown the positive effects of directional microphones on speech intelligibility, debate continues as to whether hearing aid users benefit from directional microphones in noisy environments. When determining directional algorithms, other factors such as environmental awareness and localization ability should also be considered in addition to speech intelligibility (4).

The most recent test battery used to evaluate speech intelligibility in noise is the Turkish Matrix test (TURMatriks). This test has both adaptive and non-adaptive procedures and uses five-word sentences consisting of a subject, number, adjective, object, and verb as the target stimulus. Background noise is obtained by superimposing the target stimuli 30 times. The noise level is fixed at an intensity level of 65 dB and the test starts with an SNR of 0 dB. In the adaptive procedure, the noise level is automatically adjusted by the software depending on the participant's response (5). This method determines the lowest SNR at which the 50% speech perception threshold is obtained in noise. In the non-adaptive procedure, the intensity level is fixed and speech discrimination performance is evaluated in the presence of background noise.

Speech-in-noise tests should be used to assess the effectiveness of hearing aids for people with hearing loss. These tests more accurately reflect the acoustic environments encountered in everyday life and the factors affecting communication abilities. Additionally, these tests can evaluate microphone directionality technologies, which enhance speech perception by amplifying the signal while reducing background noise.

The aim of our study is to identify the microphone directionality mode that provides the highest level of speech intelligibility in challenging listening environments involving negative factors, such as background noise. This will allow us to program hearing aids most appropriately depending on the auditory scene, thereby increasing patient satisfaction.

METHODS

Participants

The study included 32 participants with bilateral moderate or moderately severe sensorineural hearing loss and no history of hearing aid use. There are no mental disorders present in the participants. To prevent the possible effects of the duration of hearing loss, the study included patients diagnosed within the last year. Eighteen of the participants were female, and 14 were male; the mean age of the participants was 40.41 (±9.92) years (Table 1). Subgroups were formed by applying the three-directionality mode to all participants in sequence.

The power analysis based on microphone directionality yielded an effect size of 4.57 and 85% power at a 95% confidence interval and a significance level of 0.005, with n=32 participants.

Procedure

All participants in the study underwent an otoscopic examination first. If a plug that would prevent the REM procedure was present, the external ear canal was cleaned using curette removal or aspiration techniques.

Participants with pathology that could cause conductive hearing loss were excluded from the study. Following this, the participants underwent an audiological assessment consisting of impedance measurement, pure tone audiometry (125-8000 Hz), and speech audiometry. Hearing aid trials were then carried out on participants with bilateral moderate to moderately severe sensorineural hearing loss.

In our study, we evaluated the performance of different microphone directionality modes on a single brand of hearing aid, so that different hearing aid parameterswould not affect performance. We used the Beltone Trust 17 Receiver in Ear model hearing aid, which has an asymmetric directional microphone mode. For bilateral programming, the hearing aids were fitted with three different microphone directionality modes. All other hearing aid features, except for the microphone directionality modes, were disabled. Fitting was performed using the REM procedure. Gain adjustments for each microphone mode were recorded in the device memory during fitting.

Speech-in-noise tests are widely accepted as more representative of real-life listening conditions, and tools such as the TURMatriks, are more effective for assessing listeners' hearing when they are exposed to sentences containing an average of seven to eight syllables in everyday life, rather than to isolated words in a quiet environment. Given these advantages, the TURMatriks was administered to participants using the AuricalAud clinical audiometer (GN Otometrics; Taastrup, Denmark) and Oldenburg Measurement Applications software, after fitting in order to assess their ability to understand speech in noisy environments.

The test stimulus and background noise were presented through two loudspeakers. The loudspeaker through which the test stimuli were presented was positioned at an azimuth of 90°. The loudspeaker through which the background noise was presented was positioned at an azimuth of 270°. Both loudspeakers were placed 1 m from the subject (Figure 1).

Both adaptive and non-adaptive procedures were used in the TURMatriks. The adaptive procedure applied to the participants was performed in both quiet, and in listening conditions in the presence of noise. The non-adaptive procedure was performed under listening conditions of 0 dB SNR and +10 dB SNR. The protocol used to administer the test is shown in Table 2.

Statistical Analysis

The results of the TURMatriks were compared for all three microphone directionality modes. The Shapiro-Wilk test was used to assess the distribution of the data. The independent Samples t-test was used to compare normally distributed data between two groups. The Mann-Whitney U test was used to compare non-normally distributed data between two groups. Spearman's correlation analysis was used to analyze the relationship between numerical variables. Descriptive statistics for normally distributed

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Table 1. Demographical and audiological findings of participants

		Median	IQR	Mean ± sd.	
Age		20	44.5	40.41±9.92	
Gender	Female n (%)	18 (56.25%)			
	Male n (%)	14 (43.75%)			
Test ear		Air-conduction PTA (dB)	Bone-conduction PTA (dB)	SRT (dB)	SDS (%)
		Mean ± sd.	**Mean ± sd.**	**Mean ± sd.**	**Mean ± sd.**
Right		52.78±6	48.16±5.90	48.28±6.91	80.34±7.91
Left		53.81±5.32	48.53±5.21	49.63±6.76	80.69±7.49

IQR: Interquartile range, PTA: Pure-tone average, sd.: Standard deviation, SRT: Speech reception threshold, SDS: Speech Discrimination scores

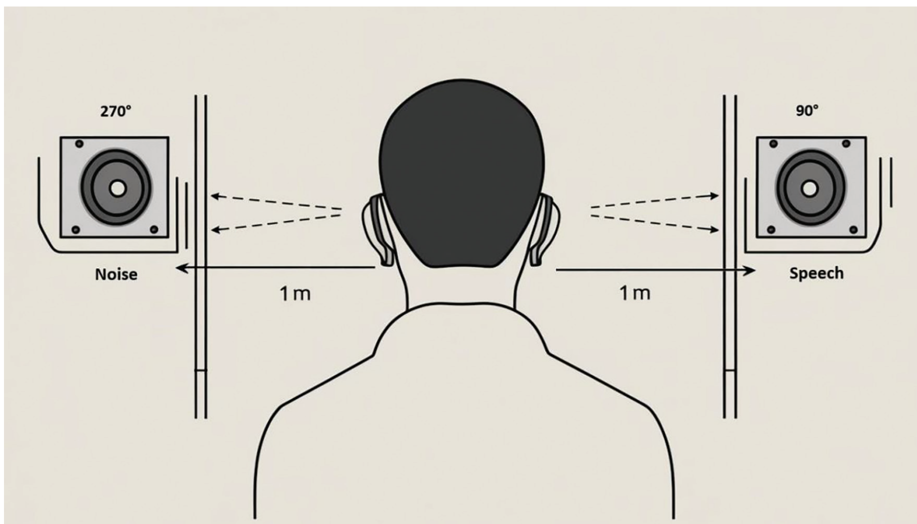

Figure 1. Patient and speaker positions in the Turkish Matrix test

Table 2. Presentation of Turkish Matrix test procedures applied to subjects, microphone directionality modes, and test sequence

Test sequence	Microphone directionality mode	Adaptive procedure	Non-adaptive procedure
1	Omnidirectional	Quiet	
2	Directional	Quiet	
3	Asymmetric directional	Quiet	
4	Omnidirectional	Noise	
5	Directional	Noise	
6	Asymmetric directional	Noise	
7	Omnidirectional		+10 dB SNR
8	Directional		+10 dB SNR
9	Asymmetric directional		+10 dB SNR
10	Omnidirectional		0 dB SNR
11	Directional		0 dB SNR
12	Asymmetric directional		0 dB SNR

SNR: Signal-to-noise ratio

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numerical data were expressed as the mean ± standard deviation, while descriptive statistics for non-normally distributed data, they were expressed as the median (interquartile range). All statistical analyses were performed and reported using IBM SPSS Statistics 22.0 at a significance level of p=0.05.

Ethical Statement

Our study was conducted at İstanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine, Department of Audiometry. (Ethical Committee No: 59491012-300-154161). This study protocol was reviewed and approved by the Clinical Research Ethics Committee of Cerrahpaşa Faculty of Medicine (approval number: 186586, date: 05.12.2019). All participants in this clinical evaluation received verbal and written information. Written informed consent was obtained from all individuals before the start of the evaluation.

RESULTS

Table 1 shows the participants' pure-tone audiometry results, including air and bone conduction thresholds, as well as the pure-tone average (PTA). The PTA is calculated by taking the four-frequency average (500, 1000, 2000, and 4000 Hz). It also shows the results of the speech reception threshold (SRT) test. All results are shown in dB. The results of the Speech Discrimination scores (SDS) test are shown as a percentage of performance in Table 1. Additionally, the age and gender distributions of the participants are also provided in Table 1.

Figure 2 shows the results of applying the Adaptive Quiet and Adaptive Noise procedures, in three different modes of the same hearing aid. A statistically significant difference was observed between the procedures applied for all three microphone directionality modes (p<0.001). It was concluded that the values obtained using the Adaptive Quiet procedure were significantly lower than those obtained using the Adaptive Noise procedure in all three microphone directionality modes. Consequently, it can be seen that the 50% SRT increases and performance deteriorates in a noisy environment.

The Non-Adaptive Matrix +10 dB SNR and Non-Adaptive Matrix 0 dB SNR procedures were applied to three modes of the same hearing aid. When the results were compared, a statistically significant difference was found between the two procedures in the omnidirectional and asymmetric directional microphone modes (p=0.008 and p=0.037, respectively; Figure 3).

However, when the results obtained in directional mode were compared, no statistically significant difference was found between the tests (p=0.079) (Figure 3). Speech intelligibility decreased and performance deteriorated significantly at 0 dB SNR for the Non-Adaptive Matrix procedure in both the omnidirectional and asymmetric directional microphone modes (Figure 3).

The results of the Spearman correlation analysis examining the relationship between the results obtained using the Adaptive Matrix Noise procedure and the Non-Adaptive Matrix 0 dB SNR and +10 dB SNR procedures, in three different microphone directivity modes, are summarised in Table 3.

The relationship between SNR (dB) values obtained in the adaptive noise procedure test and SDS (%) values obtained in the non-adaptive procedure at 0 and +10 dB SNR was examined in the omnidirectional, directional, and asymmetric directional modes of the hearing aid. A significant negative correlation was found for all three modes of microphone directionality (p<0.001) (Table 3). Applying the adaptive noise procedure to participants in each of the three directional modes separately resulted in significant improvements in speech performance compared to the non-adaptive procedure at a lower SNR compared to +10 dB SNR. Significant improvements in speech performance were observed in the non-adaptive procedure, 0 dB SNR tests (Table 3).

The results evaluating the difference between the paired values obtained in the different microphone directionality modes are summarised in Table 4 for each subtest. It was concluded that there was no statistically significant difference between the groups for all four subtests in omnidirectional and directional microphone modes (p>0.05).

When the results of the four subtests of the TURMatrix test were compared for omnidirectional microphone configuration directional microphone modes, a statistically significant difference was observed in the results of the 0 dB SNR tests for the adaptive quiet, adaptive noise, and non-adaptive procedures (p=0.040, p=0.021 and p=0.042, respectively). The statistical analysis of these comparisons is shown in Table 4. According to these results, the Adaptive Quiet Procedure test showed that the intensity level required for a 50% SRT was significantly higher with the omnidirectional mode than with the asymmetric directional mode (p=0.04). The Adaptive Noise Procedure test results showed that the SNR for a 50% SRT in noise was significantly higher with the omnidirectional mode than with the asymmetric directional mode (p=0.021). The non-adaptive procedure 0 dB SNR test showed that speech intelligibility was significantly lower with the omnidirectional mode than with the asymmetric directional mode (p=0.042). However, the non-adaptive procedure +10 dB SNR test did not reveal a statistically significant difference between the two modes (p=0.134) (Table 4).

When the results of the four subtests of the directional and asymmetrical directional microphone modes were compared with those of the TURMatriks test, and the Adaptive-Quiet, Adaptive-Noise, Non-Adaptive +10 dB SNR, and Non-Adaptive 0 dB SNR procedures, no statistically significant differences were found (p>0.05). The statistical analysis of the comparisons made is shown in Table 4.

DISCUSSION

Directional microphones in hearing aids are designed to transmit sounds from the front while attenuating those from other directions (5). These characteristics mean that directional microphones play an important role in speech perception in noisy environments by preserving interaural cues due to their directional sensitivity. They can increase the SNR by up to 6 dB (6). They can improve localization and, consequently, speech

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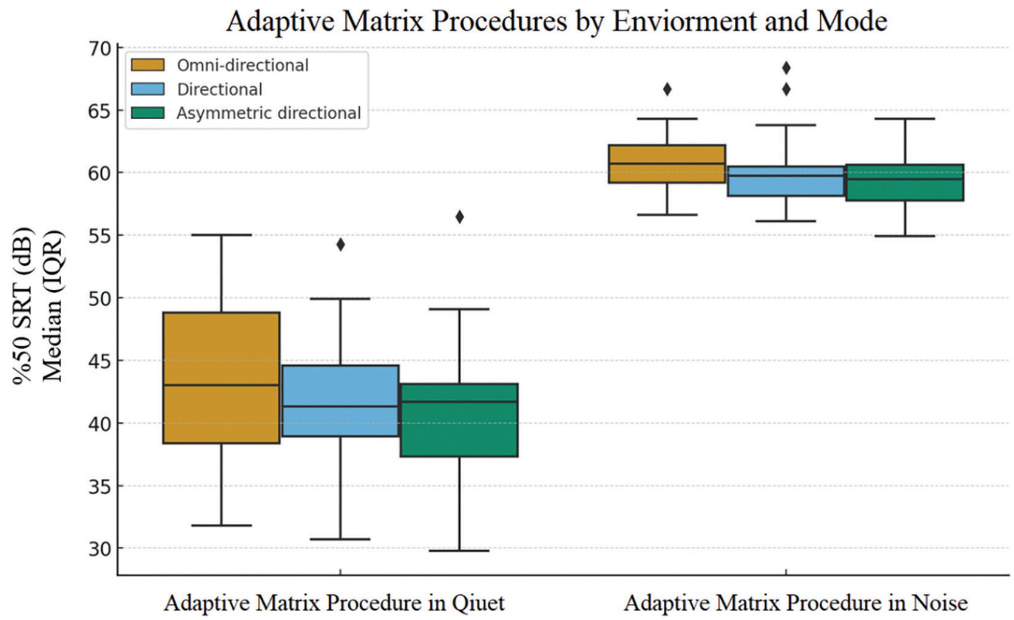

Figure 2. Comparison of sound pressure levels in dB at which 50% SRT is achieved in different microphone directionality modes, Adaptive-Silent and Adaptive-Noise procedures. Data are reported as median (IQR)

SRT: Speech reception threshold, IQR: Interquartile range

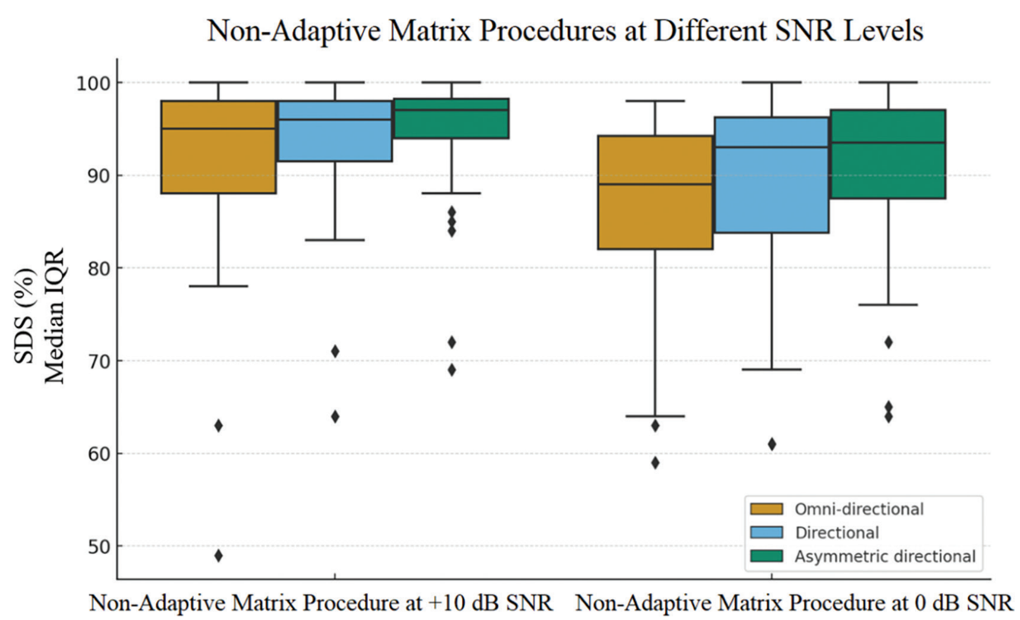

Figure 3. Comparison of Speech Discrimination scores (SDS) values obtained in Non-Adaptive Matrix Procedure +10 dB SNR and Non-Adaptive Matrix Procedure 0 dB SNR tests for different microphone directionality modes, expressed as a percentage. Data are reported as median (IQR)

IQR: Interquartile range, SNR: Signal-to-noise ratio

Table 3. Evaluation of the correlation of SNR (dB) value negativity obtained in the adaptive-noise procedure test with the high SDS (%) performance obtained in the non-adaptive procedure +10 dB SNR and 0 dB SNR procedures in different microphone directivity modes

			Non-adaptive procedure +10 dB SNR	Non-adaptive procedure 0 dB SNR
Omnidirectional	Adaptive-noise procedure	r	-0.646	-0.700
		p	p<0.001	p<0.001
			Non-adaptive procedure +10 dB SNR	**Non-adaptive procedure 0 dB SNR**
Directional	Adaptive-noise procedure	r	-0.646	-0.710
		p	p<0.001	p<0.001
			Non-adaptive procedure +10 dB SNR	**Non-adaptive procedure 0 dB SNR**
Asymmetric directional	Adaptive-noise procedure	r	-0.595	-0.764
		p	p<0.001	p<0.001

SNR: Signal-to-noise ratio, SDS: Speech Discrimination scores

Table 4. Comparison of the findings from the Turkish Matrix test subtests between omnidirectional, directional, and asymmetric directional microphone modes

	Omni-directional	Directional	$p^{a,b}$-value
Adaptive-quiet procedure-SRT (dB)	43.74±6.3	41.78±5.1	0.181[a]
Adaptive-noise procedure -SNR (dB)	-4.30 (3.53)	-5.30 (2.33)	0.058[b]
Non-adaptive procedure +10 dB SNR-SDS (%)	95 (10)	96 (7.50)	0.571[b]
Non-adaptive procedure 0 dB SNR-SDS (%)	89 (16.50)	93 (12)	0.129[b]
	Omni-directional	**Asymmetric directional**	**$p^{a,b}$-value**
Adaptive-quiet procedure-SRT (dB)	43.74±6.3	40.63±5.45	**0.040[a]**
Adaptive-noise procedure -SNR (dB)	-4.30 (3.53)	-5.40 (3.03)	**0.021[a]**
Non-adaptive procedure +10 dB SNR-SDS (%)	95 (10)	97 (4.75)	0.134[b]
Non-adaptive procedure 0 dB SNR-SDS (%)	89 (14.75)	93.50 (10.50)	**0.042[b]**
	Directional	**Asymmetric directional**	**$p^{a,b}$-value**
Adaptive-quiet procedure-SRT (dB)	41.78±5.17	40.63±5.45	0.392[a]
Adaptive-noise procedure -SNR (dB)	-5.30 (2.33)	-5.40 (3.03)	0.610[b]
Non-adaptive procedure +10 dB SNR-SDS (%)	96 (7.50)	97 (4.75)	0.318[b]
Non-adaptive procedure 0 dB SNR-SDS (%)	93 (12)	93.50 (10.50)	0.623[b]

p^a: The p-value for the independent samples t-test. p^b: The p-value for the Mann-Whitney U test. *Data are reported as mean ± standard deviation and median (IQR).
SRT: Speech reception threshold, SDS: Speech discrimination score, SNR: Signal-to-noise ratio, IQR: Interquartile range

recognition, particularly when speech and noise originate from different directions (7).

Geetha et al. (8) concluded that people with mild to moderate hearing loss benefit from hearing aids with wireless technology in terms of speech perception and localisation in noise. When directional microphones in hearing aids with wireless synchronisation were compared with those without, it was found that wireless synchronisation improves hearing in noise. In our study, speech performance was better with the asymmetric directional mode in hearing aids that use wireless synchronisation technology and constantly analyzes the acoustic environment, than with omnidirectional microphones (p<0.05) (Table 4). Our results support the study by Geetha et al. (8).

Härkönen et al. (9) reported that despite achieving good scores on the Finnish Speaking test in quiet environments, cochlear implant users experienced significant difficulties in everyday listening conditions. Dietz et al. (10) argued that, although good SRT scores were obtained using the use of monosyllabic isolated words, listening problems persisted in everyday life, and that the Adaptive Quiet Procedure test would provide a more realistic assessment than speech tests using isolated words. This study compared the values obtained in the Adaptive Quiet Procedure and Adaptive Noise Procedure tests to investigate the effects of quiet and noisy environments on the speech understanding of hearing aid users. However, for all three microphone directionality modes of the hearing aids, the SRT level providing a 50% SRT was

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significantly higher, statistically ($p<0.05$) when the Matrix test was used in noise compared to the Adaptive Quiet Procedure (Figure 2). Considering that everyday life consists of noisy listening conditions and that a decrease in speech perception performance is detected in the presence of noise, it is necessary to include tests for listening in noise when assessing hearing aid users. When conducting these tests, it is also important to establish evaluation procedures that include different microphone modes to determine which mode gives each individual the best results.

Slugocki et al. (11) investigated the electrophysiological representation of speech stimuli using directional microphones and noise reduction technologies. The study used cortical (P1-N1-P2 complex) and subcortical evoked potentials. It observed statistically significant improvements in cortical potential components when directional microphones and noise reduction technologies were used. However, no such changes were found in subcortical potential components (11). In our study, no statistically significant differences were observed between adaptive and non-adaptive procedures of the TURMatriks, or between directional and omnidirectional microphones ($p>0.05$) (Table 4). These studies recommend evaluating speech performance and microphone directionality modes in noise more thoroughly, by investigating different parameters using electrophysiological and behavioral methods.

Browning et al. (12) investigated the effect of microphone directionality on critical SNR in noisy environments. Although both omnidirectional and directional microphones were used, a statistically significant improvement in SNR values was observed with directional microphones in the presence of noise compared to omnidirectional microphones (12). In our study, no statistically significant improvement in critical SNR values was observed when omnidirectional and directional microphones were compared ($p>0.05$), (Table 4). In their studies, Browning et al. (12) worked with a pediatric group and always delivered the target stimulus from a front loudspeaker at a 0° or 300° azimuth. In our study, however, the adult group was included. In addition, the acoustic stimulus was delivered from a loudspeaker located at a 90° azimuth (Figure 1). It is therefore assumed that the reasons for the different results in the two studies are factors such as the Factors such as age distribution of the study group, stimulus presentation angle, and hearing aid use experience are presumed to contribute to the different results observed in the two studies.

Ricketts and Picou (13) investigated the impact of microphone directionality modes on the ability to understand speech in the presence of background noise, which included children aged 11-17 in their study. As the participants were of school age, the researchers simulated a classroom environment to evaluate their speech comprehension skills in the presence of background noise. The evaluations were conducted using omnidirectional and directional microphone modes within the framework of symmetric directionality, as well, and another mode of asymmetric directionality as well. The target stimulus for the different directionality modes was delivered by front (0°) and rear (180°) loudspeakers. In the test condition where speech stimuli were presented from the front loudspeaker, the directional microphone mode performed better than the asymmetric and omnidirectional modes, with participants performing similarly to their normal-hearing peers (13). While lower performance was observed with directional microphones in our study ($p=0.181$, $p=0.058$, $p=0.571$, $p=0.129$; Table 4), whereas, higher performance was observed with asymmetric directionality thancompared to omnidirectional microphones ($p=0.040$, $p=0.021$, $p=0.134$, $p=0.042$; Table 4). A review of related studies shows that directional microphones are advantageous for speech stimuli coming from the front speaker; our study obtained similar results to those in the literature (14-16).

In the same study, Ricketts and Picou (13) included a test condition in which the target stimulus was presented from the rear speaker (180°) and the noise from the front speaker (0°). They found that the benefits of directional microphones were lost in the front loudspeaker test condition when the target stimulus was presented from the rear loudspeaker. In another study, Keidser et al. (17), conducted experiments with azimuths of 90 and 270 and found no significant difference between omnidirectional and directional modes. However, Van den Bogaert et al. (18) showed that the directional mode performed worse than the omnidirectional mode under the same conditions. Based on these findings, azimuths of 0° and 180° are ideal for directional microphones. However, these azimuths do not accurately reflect real-world listening conditions. Therefore, to better reflect the challenging listening conditions encountered in daily life, our study was designed with stimuli using listening conditions at 90 and 270 azimuths.

These findings emphasised the importance of switching appropriately between microphone directionality modes, particularly in environments such as classrooms where the source of the target stimulus is constantly changing. It was thought that using the asymmetric directionality mode could reduce the decrease inmitigate the decline in performance. However, it has been argued that maximum speech perception performance cannot be achieved with the asymmetric directionality mode compared with bilateral directional microphones (13). In our study, however, a target speech stimulus was presented by a 90° azimuthally positioned loudspeaker, which reduced the advantages of directional microphones and created challenging listening conditions. In light of our results, no significant difference was observed in performance between directional microphones, omnidirectional microphones, and asymmetric directional microphones in light of our results. Our study, while supporting the work of Rickett and Picou (13), found statistically significant improvements ($p<0.05$, Table 4) in the asymmetric directional mode compared to the omnidirectional mode. This suggests that asymmetric directionality offers an advantage under challenging listening conditions.

In their study of 30 cochlear implant users aged between 20 and 66 years, Polat et al. (19) found a correlation between the Non-Adaptive Quiet procedure and the Adaptive Quiet procedure.

However, they did not investigate the correlation in the presence of noise in both procedures (18). In our study, we investigated the correlations between the adaptive noise procedure and the Non-Adaptive +10 dB SNR, and Non-Adaptive 0 dB SNR subtests for all three microphone directionality modes. A statistically significant correlation was found between the Adaptive-Noise and non-adaptive procedure tests (p<0.001) (Table 3). Notably, the Adaptive-Noise procedure of the TURMatriks more accurately simulates everyday life with background noise. This procedure determines the critical SNR value, i.e., the most challenging listening condition at which the 50% SRT is achieved in the presence of noise. In the adaptive noise procedure, a more negative obtained SNR value was characterized by an increase in speech performance. Our study found a significant correlation between values obtained in the adaptive noise procedure and those in the non-adaptive +10 dB SNR (p<0.001), as well as the non-adaptive 0 dB SNR (p<0.001) tests. These are subtests that examine speech intelligibility at constant SNR values (Table 3). From this perspective, as the critical SNR improved in the presence of noise, an increase in speech intelligibility performance was observed at a fixed SNR in the presence of noise.

Study Limitations

Although subjective verification methods such as International Outcome Inventory for Hearing Aids (19), Abbreviated Profile of Hearing Aid Benefit (20), Speech, Spatial and Qualities of Hearing Scale (21) and Satisfaction with Amplification in Daily Life (22) were not used in our study, they are useful tools for assessing patient satisfaction and amplification success. It is believed that non-adaptive procedure tests that function as SDS in noise are also useful for evaluating hearing aids. Within the limitations of the study, increasing the number of subjects and comparing subjects with different types and degrees of hearing loss would allow more consistent differences between parameters to be identifiedus to identify more consistent differences between parameters. More detailed results on the effect of asymmetric directionality on hearing ability are expected to be obtained by presenting the speech stimulus from different speaker angles and by evaluating experienced hearing aid users.

CONCLUSION

The literature contains a limited number of studies on asymmetric directionality. This mode needs to be investigated in detail to better understand its effect on speech discrimination in noise and the role of the binaural squelch effect, especially in difficult listening conditions where directional microphones largely lose their advantage. Based on clinical findings, our study suggests that the asymmetric directionality mode is successful and better simulates the human hearing system compared to traditional methods. Achieving high speech intelligibility performance in this mode, while maintaining environmental awareness, indicates that further development and clinical validation of this mode are encouraged compared to directional and omnidirectional microphone modes. In crowded environments such as classrooms and meeting rooms, where the presence and location of sound and noise sources change daily, the effectiveness of directional microphones decreases, as they are more successful with frontal sounds. Conversely, asymmetric directionality, with its ability to rapidly adapt to changing listening conditions, is advantageous in such environments. This study mayserve as a valuable reference for future research in areas such as microphone directionality and listening skills in noisy environments.

Ethics

Ethics Committee Approval: Our study was conducted at İstanbul University-Cerrahpaşa, Cerrahpaşa of Medicine, Department of audiometry. (Ethical Committee No: 59491012-300-154161). This study protocol was reviewed and approved by the Clinical Research Ethics Committee of Cerrahpaşa Faculty of Medicine (approval number: 186586, date: 05.12.2019).

Informed Consent: All participants in this clinical evaluation received verbal and written information. Written informed consent was obtained from all individuals before the start of the evaluation.

Footnotes

Author Contributions: Surgical and Medical Practices - G.Y., E.K.; Concept - G.Y., E.K.; Design - G.Y., E.K.; Data Collection and/or Processing - G.Y.; Analysis and/or Interpretation - G.Y., E.K.; Literature Search - G.Y.; Writing - G.Y., E.K.

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