DIRECTIONALITY AND SPEECH IN NOISE RECOGNITION: STUDY OF FOUR CASES

Direcionalidade e reconhecimento de fala no ruído: estudo de quatro casos

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ABSTRACT

The difficulty of understanding speech with background noise is perceived as one of the main disabilities of the hearing aids users. The purpose of this study was to compare the hearing performance of subjects with sensorioneural, bilateral, light to moderate degree hearing loss with the microphones omnidirectional, fixed directional mode and automatically activated adaptive directional mode, activated through the signal/noise ratio (S/R) in which the Sentence Recognition Threshold in Noise are obtained. It was used the hearing aid Reach, RCH62, Beltone in omnidirectional, fixed directional and automatically activated adaptive microphone modes. The following presentations of acoustic stimulus had been tested: speech 0° azimuth and noise 180° azimuth (0°/180°), speech 90° azimuth and noise 270° azimuth (90°/270°) and speech 270° azimuth and noise 90° azimuth (270°/90°). The average signal to noise ratio ranged from 6,6 dB to –6,9 dB. The microphone that had the best average for signal to noise ratio, considering the three conditions of stimulus presentation, was the automatically activated adaptive. However, because it is a small sample, there was great individual variability. Further studies should be performed to obtain scientific support for the most appropriate selection of microphones.

KEYWORDS: Hearing Aid; Hearing Loss; Speech Intelligibility; Noise

INTRODUCTION

The speech recognition depends on the integrity of the peripheral and central hearing system and on the combination of the traits like the intensity, the acoustic signal length, the phoneme frequency track, the prosody, the familiarity with the vocabulary and the linguistics context. In propitious hearing conditions the listener is able to discard some of these traits without losing the message content.

However, in a daily basis, it's not a rare thing to be in unpropitious hearing conditions, such as the presence of voice and background noise at the same time. This condition requires that the listener makes use of all the traits available in order to be able to comprehend the message.

For the subject with hearing loss, even though the very slightly one, all the traits coming from the environment became fundamental for the message recognition due to the deficit that exist in the hearing system. Thus, in unpropitious hearing conditions, the access to these traits is harmed. Therefore, for those subjects, the difficulty of understanding speech with background noise is perceived as one of the main hearing disabilities, as it affects his/her life quality, leading to, in many cases, the social isolation, familiar and professional.

One of the ways to minimize those effects have been the adaptation of the Individual Sound Amplifier Device (ISAD). The ISAD consists of a system that amplifies the background sounds in a way that these sounds can be perceived by the users. The digital ISAD capture the sound signal from the background transforming it in equivalent electric signal and then in a digital pattern, they are transformed according

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to the needs and they are delivered to the subject in an acoustic signal format[2].

An ISAD is basically made of a microphone, an amplifier and a receptor. The microphone is the component responsible for converting the background acoustic signal into equivalent electric signal, being the ISAD entrance the transducer. This component may vary in terms of sensitivity to the source of the sound direction, being divided into two big groups: omni-directional and directional [2]

The omni-directional microphones are the most used ones and they can capture the same way sounds coming from all directions. Yet, the directional microphones can better capture the sounds coming from the front, reducing the sensitivity to the sounds coming from behind and from the sides [2.]

Nowadays, with the technological big advance, the directional microphones can be divided into directional fixed, directional mode and automatically activated adaptive directional[3].

The directional fixed microphone system provides a static answer pattern which focus on the subject's front direction. This strategy is based on the supposition that the speaker will be in front of the listener and the noise background will came from the sides or from behind, however, some studies reveal that the voice signal does not come from the listener's front in more than 20% of the cases[4].

The automatically activated adaptive directional microphone has as its main trait the directionality activation in accordance with the information given by the environment[3]. This way, the polar pattern vary according to the voice and background noise sound detection, general level of the entrance sound and voice signal direction.

Thus, to distinguish the voice and the background noise, this system supposes that the noise is a rather even sound while the voice varies in terms of intensity, frequency and length. As soon as the voice signal is identify, the polar pattern is modified in a way that this can be more amplified in relation to the others[5].

Considering that the difficulty to comprehend the speech with background noise can be a limiting factor for the ISAD users and that the microphones directionality can contribute for the comprehension of the speech with background noise, the purpose of this study was to compare the hearing performance of subjects with sensor neural hearing loss, bilateral, degree light to moderate with the microphones omni-directional, directional fixed mode and automatically activated adaptive, through the signal-to-noise ratio (SNR) which are obtained the Sentence Recognition Threshold in Noise (SRTN).

CASES PRESENTATION

The sample was constituted by four subjects, being two men and two women, age between 56 and 63 years old, being the average age 59,8 years old ±3,3 standard deviation they have been seen at the Hearing Aids Department at Clélia Spinato Manfro Hearing Health Center, Nossa Senhora de Fátima College, at the ISAD selection moment.

The patients have been selected based on an evaluation of the waiting list for the ISAD test executed at the mentioned Center, its aim is to qualify for the following inclusion criteria: being an adult up to 65 years old, with sensor neural hearing loss degree light to moderate (26 to 70 dB), according to Davis and Silverman's classification, 1970[6], symmetrical, being on the waiting list for the hearing aid selection test, at the Clélia Spinato Manfro Hearing Health Center with the designation for the binaural ISAD adaptation. None of them had made use of the ISAD until the present moment.

Subject 1: male, 62, retired. Sensor neural hearing loss moderate degree, in both ears. He has referred voice comprehension difficulty with the presence of background noise.

Subject 2: female, 56, housewife. Sensor neural hearing loss moderate degree, in both ears. She has referred voice comprehension difficulty with the presence of background noise.

Subject 3: male, 63, plumber and electrician. Sensor neural hearing loss light degree, in both ears. He has referred voice comprehension difficulty only with the presence of background noise.

Subject 4: female, 58, housewife. Sensor neural hearing loss light degree, in both ears. She has referred voice comprehension difficulty in some conditions, with or without background noise.

Firstly, the subjects have been submitted to the visual inspection of the external acoustic meatus. In a second moment, the standard procedures for the ISAD selection were executed, precompiled by the service.

After that, the four subjects were submitted to the Portuguese Sentences Lists, proposed by Costa, in 1998, using the device Reach, model RCH62, Beltone, open adaptation in both ears. Finally, they filled out a quality evaluation survey elaborated for this research.

The test was executed with the device microphones switched to the omni-directional, directional fixed cardioids and adaptive directional automatically activated. It was selected the big radius in the directional fixed microphone set up and the dynamic radius in adaptive directional automatically activated set up. About the ISAD algorithm, it was opted to keep the sound cleaner,

the background noise muffler and the wind noise suppresser turned off.

The adjustments related to the study were done in the ISAD through the NoahAud3 (NOAH System) and Beltone Solus version 2.7 program.

To obtain the Sentence Recognition Threshold in Noise, initially, it was presented 10 sentences with azimuth 0° without noise and 10 other sentences were presented with the same angle but with noise azimuth 180°, in order to get the subject familiarized with the test. At those moments the subjects were using the devices with omni-directional microphones. Those measures were not considered on the result analysis.

After that, the three types of microphone were tested in three different hearing situations. speech 0° azimuth and noise 180° azimuth (speech in the front and noise behind), speech 90° azimuth and noise 270° azimuth (speech to the right and noise to the left) and speech 270° azimuth and noise 90° azimuth (speech to the left and noise to the right). It was used the lists 1B, 2B, 3B, 4B, 5B, 6B e 7B from the Compact Disc (CD).

The measures were obtained in an acoustic booth, it was made use of the two channels digital audiometer, brand Interacoustics, model AC-33. The sentences and the noise were presented through a digital CD Player, brand Philips, model Jogproof, clutched to the audiometer above described.

Considering the necessity to always keep the same environment acoustic conditions during the whole study the measures on free field were monitored by the examiner with a help from a Digital Measurer of Sound Pressure Level, brand Realistic, for each evaluated patient.

To establish the sentences channel calibration parameter was used the pure tone present on the CD track number 1. For the noise the calibration was made using the noise itself as reference, present on the CD track number 18. Each channel exit was calibrated using the audiometer VU-meter, both settled up at zero level.

To determine the Sentence Recognition Threshold in Noise it was used the sequential strategy or adaptative. Thus, it was presented the speech stimulus in a specific signal-to-noise ratio (SNR). If the subject was capable of recognizing correctly the sentence, the stimulus intensity was reduced in pre-established intervals, otherwise the intensity was increased[7].

It was used intervals of 4 dB until the first change in the type of answer and afterwards intervals of 2 dB until the end of the list. Only one answer was considered correct when the subject repeated, without mistakes or omissions, the presented sentence.

To obtain the SNR value the sound level presented was subtracted from the sound level in which was obtained the Sentence Recognition Threshold in Noise. The noise sound level was kept in 65dB during all the measures.

The present case study was approved by the Ethic in Research Committee from the Virvi Ramos Cultural and Scientific Association, under the protocol number 047/10. All of the subjects have signed the Free and Clarified Consent Term.

Considering the sample size, it was chosen to elaborate the present case study presenting a descriptive analysis, from central standards tendency obtained for the SNR, with each evaluated microphone in each of the investigated hearing conditions.

RESULTS

The SNR consists on the difference between the sound level of the speech signal and the sound level of a competitive sound. The closer this relation is the more difficult it is the hearing condition. Thus, the smaller the SNR result is in a test situation, the better is the subject ability.

On the test with the omni-directional microphone, this can capture the same way sounds coming from any direction, referring to the hearing situation in which the speech signal was presented at 0° azimuth and the noise at 180° azimuth (speech on the front and noise on the back), the average found for the SNR was 6,6dB (Table 1).

In the hearing condition in which the speech signal was presented at 90° azimuth and the noise at 270° azimuth (speech to the right and noise to the left), the average for the SNR found was 1,8dB (Table 1)

Still referring to the omni-directional microphone, in the hearing condition in which the speech signal was presented at 270° azimuth and the noise at 90°

Table 1 – Descriptive measurements obtained for the SNR for the tested microphones and the stimulus presentation situation

Variable	n	Minimum	Maximum	Average	Standard Deviation
SNR omni-directional front speech and back noise	4	1.0	13.7	6.6	6.3
SNR omni-directional speech at the right and noise at the left	4	-8.7	14.8	1.8	10.3
SNR omni-directional speech at the left and noise at the right	4	-4.5	11.9	3.6	6.7
SNR directional fixed front speech and back noise	4	-2.0	5.5	0.6	3.4
SNR directional fixed speech at the right and noise at the left	4	-8.7	2.0	-3.5	4.5
SNR directional fixed speech at the left and noise at the right	4	-3.3	4.2	-0.3	3.6
SNR automatically activated adaptive front speech and back noise	4	-6.1	1.7	-1.5	3.3
SNR directional automatically activated adaptive speech at the right and noise at the left	4	-7.3	4.6	-0.6	5.0
SNR directional automatically activated adaptive speech at the left and noise at the right	4	-11.3	-2.5	-6.9	3.7

Subtitle: SNR: signal-to-noise ratio

azimuth (speech to the left and noise to the right), the average for the SNR found was 3,6dB (Table 1).

Therefore, while testing the omni-directional microphone on the four subjects, it was taken notice that the best SNR obtained was for the situation in which the speech was presented to the right and the noise to the left.

In the measurement using the directional fixed microphone, which best captures the sounds coming from the front and it does not change the polar answer pattern, referring to the hearing situation in which the speech signal was presented at 0° azimuth and noise at 180° azimuth (speech on the front and noise on the back), the average for SNR found was 0,6dB (Table 1).

With the same microphone, in the hearing situation in which the speech was presented at 90° azimuth and noise at 270° azimuth (speech to the right and noise to the left), the average for the SNR found was –3,5dB (Table 1).

Still referring to the directional fixed microphone, in the hearing condition in which the speech signal was presented at 270° azimuth and the noise at 90° azimuth (speech to the left and noise to the right), the average for the SNR found was 0,3dB (Table 1).

Thus, in the measurement of the four subjects with the directional microphone the best average for the SNR was also found in the situation in which the speech was presented to the right and the noise to the left.

In the measurement using the automatically activated adaptive directional microphones, which identify the speech signal and change the polar pattern, so this gets more amplified in relation to the noise, in the situation in which the speech signal was presented at 0° azimuth and noise at 180° (speech on the front and noise on the back), the average for the SNR found was –1,5dB (Table 1).

Using the same microphones, in the situation in which the speech signal was presented at 90° and noise at 270° (speech to the right and noise to the left), the average for the SNR found was –0,6dB (Table 1).

Yet, on those microphones evaluation in the hearing situation in which the speech signal was presented at 270° azimuth and noise at 90° azimuth(speech to the left and noise to the right), the average found was –6,9 dB (Table 1).

In relation to the automatically activated adaptive directional microphone the best average for the SNR was found in the situation in which the speech incited to the left and the noise to the right.

Considering the three microphones and the three tested hearing conditions, the best SNR found

was 6,9dB for the situation in which the speech was presented to the left and the noise to the right with the automatically activated adaptive directional microphone.

The average, found for the SNR, considering the three stimulus presentation situation, for the omni-directional microphone, was 4dB. For the fixed directional microphone was –1,06dB. And for the automatically activated adaptive directional microphone, the average found was –3dB.

Besides the above presented aspects, it was also found, through a qualitative analysis, the subjects` perception in relation to their communicative performance in silent and noisy places and their subjective evaluation for the different tested microphones in this research.

While the main communicative restrictions presented by the subjects were being tested, it was noticeable that only one subject mention the difficult in comprehending the speech in a silent situation, while three of subjects mentioned the difficulty in comprehending the speech in noisy situations.

In the case which the subjects gave a grade out of 10 for the tested microphones, considering the facility to comprehend the speech with each of them, where 1 corresponded to very little facility and 10 to a big facility, the average found for the omni-directional microphones was 7,0 points ±1,4. For the fixed directional microphone the average was 7,3 points ±2,1. And for the automatically activated adaptive directional microphone, the average grade given was 6,8 points ±2,5.

The subjects were also asked about in which hearing situation there was better speech comprehension, for each of the microphones. For the omni-directional microphone three subjects pointed out that the situation in which the speech is presented on the front and the noise on the back is the easiest to comprehend the speech and one subject could not point it out.

Regarding to the fixed directional microphone, the four subjects referred to the situation in which the speech is presented on the front and the noise on the back as the one they believed having obtained the best results.

For the automatically activated adaptive directional microphone, three subjects pointed the situation in which the speech is presented on the front and the noise on the back for this question one of them pointed out the situation in which the speech was presented to their right and the noise to the left.

DISCUSSION

Because of the sample size, the present article is referent to a study of four cases. Thus, it is understood that the answers variability, the age factor and the cognitive aspects, short term memory, attention and the motivation to take the test are factors that must be considered on the obtained results interpretation.

In a study which has evaluated 14 subjects, ISAD users retro auricular mono aural or binaural, with omni-directional microphone (n=9) and ISAD users of retro auricular with directional microphone (n=5), who were submitted to the same test and had the S/N relation results analyzed, the researches concluded that the directionality worked in favor of the speech recognition with background noise, however they have not found a significant statistics difference [8].

The average for the SNR found in the present study show similar results. The subjects' performance using the directional microphones was better than when they used omni-directional microphones.

In the comparative study which has investigated the 17 subjects performance in speech tests in silence and speech tests with background noise with three different types of microphone: omni-directional microphones, directional fixed microphone hyper-cardioids and totally adaptive microphones or automatic, the obtained results have shown that, in the silence, the performance of the subjects who were using the directional totally adaptive was similar to the omni-directional microphones. The authors have referred that o directional fixed microphone and the totally adaptive microphone have similar results in the speech and noise measurements[9].

It was possible to see similarities between this present study and the supra-mentioned study in terms of obtained results with directional fixed microphones and automatically activated adaptive microphone in the measurements involving speech and noise. In both studies the found values for the microphones with directional technology, either fixed or adaptive, are similar and get far from the found values in the omni-directional microphones.

In a study involving 20 subjects, who suffer from neural sensorial hearing loss, who already make use of the ISAD, was applied the Haring in Noise Test with the subjects without the device, with their own devices, with the device which was tested in the omni-directional mode and with the same device in the automatically activated adaptive microphone. It was perceived that the o automatically activated adaptive microphone provided a improvement in the SNR presented by the subjects[10]. This study's results corroborate with the founding results above described, because it was also possible to notice an improvement in the SNR with automatically activated adaptive microphone in relation to the others.

In a study which the main objective was to investigate if the SNR measured in speech above noise

intelligibility tests, could be used as a measurement that represents the necessary distance between the speaker and listener for a calculation in the automatic directionality algorithms based in the analysis of different environments or scenes, the authors have also investigated the advantages of the directional microphone in the several SNR, making use of the sentences list IIEE/Harvard, presented in front of the subject and the noise being presented on the back. It was noticed that the directional microphone had an advantage in relation to the omni-directional microphone, providing a significant improvement in the speech comprehension. However there was a great individual variability, while analyzing each subject's answers, individually, it was noticed that in some situations the better performance was with the omni-directional microphone[11].

In the present study, the quantitative results have pointed an advantage in terms of dB in the average found for automatically activated adaptive microphone. Nevertheless, when the qualitative survey was analyzed, it was noticed that the subjects, in general, gave better grades to the omni-directional microphones.

In another research which has investigated the effects of the directional microphones asymmetry in the speech above noise comprehension through the Hearing in Noise Test and the Acceptable Noise Level, the authors have evaluated subjects using omni-directional microphones, directional and directional e omni-directional alternated between their ears. For this investigation, it was used an speech signal presentation angle of 0° azimuth and the noise at 180° azimuth. The results obtained by the authors show that the speech in noise comprehension was better when the subjects were using asymmetric microphones rather than the other types of microphones, being statistically significant only in relation to the binaural omni-directional microphones[12].

The study has compared the SNR obtained in the SRTN test between subjects who are norm-listeners and the ones who have light to moderate severe neural sensorial hearing loss. The average found for norm-listeners was –7,57dB, while for the ones with hearing loss was –2,10dB [7].In this study it was obtained bigger values than –2,10dB, even with the use of ISAD.

The best average found for the SNR in this study was in the measurement with the automatic microphones in the situation in which the speech was presented at the left and the noise at the right (SNR –6,9dB).This result is similar to the result found for the subjects norm-listeners in the study above mentioned. However, it is possible that this more favorable relation is related to the learning effect, since this was the last situation measured in the four cases and that this value gets far from the others found, even for the same microphones.

In another study that has evaluated, objectively and subjectively, the 18 ISAD user intelligibility of speech in noise who had a directional microphone totally adapted and noise reduction algorithms, the authors have verified that both resources had brought benefits in terms of recognizing the speech with noise background. However, the directional microphones were the ones which have presented bigger benefits, according to what has been related by the subjects[13].

In a study which has compared the relation S/N obtained for the norm-listeners subjects with noise in different angles (0°/0°, 0°/90°, 0°/180° e 0°/270° azimuth), the authors have verified that, from the two evaluated situations, the situation in which the speech and the noise came from the same angle was the more difficult one. The situation in which the noise came from the back and the speech from the front was the second one in terms of difficulty[14].

The found average for the relation S/N for the test situation in which the speech came from the front and the noise from the back (0°/180°) in the study above mentioned, was 9,751dB. In the present study, the found average for the SNR for the same situation was 6,6dB for the omni-directional microphones, 0,6 dB for the directional microphones and –1,5dB for the automatic directional microphones. This difference can be related to the fact that the subjects that took part in this research had neural sensorial hearing loss and had never used ISAD before.

Yet, the situation which was pointed as the easiest one in the present study was (0°/180°). Only one subject, in a specific hearing situation, has said that it was easier to comprehend when the speech was presented at the right and the noise at the left (90°/270°).

It is noticed that the microphone choice is only one of the aspects when it comes to improve the speech in noise recognition for ISAD users. It is believed that the hearing training, in the pos adaptation period, can add to this ability improvement. This is not, at all, substituted by changes in the device algorithms.

CONCLUSION

The average for the SNR has varied from 6,6dB to –6,9dB. The microphone which has presented the best average for the signal/noise relation, considering the three stimulus presentation situation, was the directional automatically activated adaptive microphone. However, since it was a small sample, there was a great individual variability. Because it was a study which have involved only

04 subjects, with who have been tested only one type of equipment, and that the technological differences between the tested device microphones are, probably, very small, new studies must be done in order to obtain scientific subsides to indicate the most appropriated microphones to minimize the speech in noise comprehension difficulty. The speech therapist, who works in the hearing aid field, must comprehend and be an expert in terms of what is available in the technological resources market and be always up-to-date in order to extract everything from this technology to help the patients.

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RESUMO

A dificuldade de compreensão de fala no ruído é apontada como uma das principais incapacidades pelo usuário de Aparelho de Amplificação Sonora Individual. O objetivo desse estudo foi comparar o desempenho auditivo de sujeitos portadores de perda auditiva neurossensorial, bilateral, de grau leve a moderado, com os microfones ominidirecional, direcional fixo e direcional adaptativo automaticamente ativado, por meio da relação sinal/ruído (S/R) nas quais são obtidos os Limiares de Reconhecimento de Sentenças no Ruído (LRSR). Utilizaram-se os aparelhos Reach, modelo RCH62, da marca Beltone, nos modos microfone omnidirecional, direcional fixo e direcional adaptativo automaticamente ativado. Foram testadas as seguintes situações de apresentação dos estímulos acústicos: fala 0° azimute e ruído 180° azimute (0°/180°), fala 90° azimute e ruído 270° (90°/270°) azimute e fala 270° azimute e ruído 90° azimute (270°/90°). A média das relações sinal/ruído variou de 6,6 dB a –6,9 dB. O microfone que apresentou melhor média para a relação sinal/ruído, considerando as três situações de apresentação dos estímulos, foi o direcional adaptativo automaticamente ativado. Entretanto, por se tratar de uma amostra pequena, houve grande variabilidade individual. Mais estudos devem ser realizados a fim de que se tenham subsídios científicos para a seleção dos microfones mais apropriados.

DESCRITORES: Auxiliares de Audição; Perda Auditiva; Inteligibilidade da Fala; Ruído

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