Frequency modulation systems in hearing impaired children: outcome evaluation

Sistema de frequência modulada em crianças com deficiência auditiva: avaliação de resultados

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ABSTRACT

Purpose: To evaluate the speech perception of hearing impaired children fitted with hearing aids and frequency modulation (FM) system in noisy environments, as well as in the classroom. **Methods:** Participants were 13 hearing impaired children with ages between 7 and 17 years. The Hearing in Noise Test (HINT) was applied with hearing aids and with FM systems. The FM System Evaluation Questionnaire was answered by the children's teachers, in order to assess individually the children's performances in different hearing situations wearing only hearing aids, and with both the hearing aid and an FM system. **Results:** Difference was found for every situation with and without FM in the HINT. The same holds true for the results obtained with the questionnaire, and the score without the FM system was always lower than with FM, regardless of the condition. **Conclusion:** The use of subjective measures, such as the questionnaire, is essential to determine the efficacy of recommending auxiliary devices for hearing impaired people. The FM system's effectiveness can be observed by the "FM advantage", which is the mean minimum difference of 10 dB found in speech perception assessments with and without FM in noisy situations. The benefits found in this study with the use of FM systems for better speech perception might be extrapolated not only to the classroom and inclusive education legislation, but also to social and recreational activities.

Keywords: Hearing aids; Hearing loss; Speech perception; Noise; Questionnaire

INTRODUCTION

The programs for detection and early intervention in cases of hearing loss have enabled and urged access to the hearing environment through the use of hearing aids. The main focus of an early intervention program for hearing loss is to provide support and encourage family members to structure the communication process with the child[1,2], including counseling regarding the need to use auxiliary hearing equipment, such as frequency modulation systems (FM)[3].

According to the International Classification of Functioning, Disability and Health[4], it is considered a health problem what is harmful to the development of a functioning or structure which causes limitations to the individual's activities, restricting their participation in society. The main difference between the new and the old classification is that now, environmental factors are also taken into account when determining the problem. Within this context, rehabilitation assumes the individual must be fully adapted to the environment and the environment to the person with special needs [5].

Hearing impaired children demand more effort than their normal hearing peers in listening activities (especially in the school setting), regardless of the amplification used[6], and the current demand exposes the children to noisy environments very early. Thus, the aim of this study was to evaluate speech perception in hearing impaired children with a hearing aid device and FM system, in different free field noisy situations, as well as in the classroom environment.

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Conflict of interests: None

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METHODS

The children's parents were required to sign an Informed Consent Form, in compliance with the model approved by the Research Ethics Committee of the Bauru School of Dentistry, Universidade de São Paulo, Bauru (SP), Brazil granting their permission for the children's participation in the study and publication of the data obtained. Anonymity and the right to withdraw their consent at any given moment were guaranteed to the participants.

Participants

Thirteen hearing impaired children were evaluated. The children evaluated in this study were chosen based on the following criteria: moderate to severe bilateral neurosensoral hearing loss with uncompromised middle ear; established oral language (ability to make sentences with over five words, using connecting elements, conjugating verbs, using plurals) due to the use of speech material for the evaluation; 5/6 hearing category[7]; age group between 7 and 17 years; be an effective hearing aid wearer for at least one year.

Instruments and procedure

Frequency Modulation Systems

The participating children were fitted with the personal FM system from Phonak®, binaural receivers MLxS, MyLink, Campus Sx and EasyLink transmitters. To verify the FM system's electric acoustic characteristics, the "Transparency" concept, thus defined by the American Academy of Audiology[8], was evaluated and adopted. According to that definition, "transparency is achieved when a 65 dB SPL input for the FM's microphone produces an output equal to the input of 65 dB SPL for the hearing aid's microphone".

The following protocol was used:

1. Equipment calibration with 2cc coupler (FP35/Frye Electronics INC).
2. Connection between the FM receiver and the hearing aid – switch on the FM transmitter and put its microphone in mute mode or seal it with acoustic sealant.
3. Couple the HA to the 2 cc coupler inside the test box.
4. Draw curve 1 for a 65 dBSPL input (stimulus: digital speech).
5. With the HA still connected to the 2 cc coupler and test microphone, the device must be removed from the test box and sealed. The FM transmitter's microphone must be placed into the test box and curve 2 must be drawn the same way curve 1 was.
6. Subtract the response of curves 1 and 2 for the following frequencies: 750 Hz,
7. 1 kHz and 2 kHz. Calculate an average frequency for the differences. If the average difference is <2 dB, do not change FM configurations. If the difference is >2, change FM configurations accordingly and retest to confirm transparency. For instance, if curve 2's average difference is 4 dB below curve 1's, FM configurations should be increased 4 dB and the average differences recalculated. Perform a hearing test with simultaneous inputs in the FM's microphone and hearing aid to verify signal quality.

Brazilian Hearing in Noise Test – HINT[9]

HINT is an adaptive test which requires that the individual recognizes and repeats simple sentences in quiet and noise[10]. It is formed by 12 lists with 20 sentences each, for a total of 240 available sentences. The intensity of the presentation varies until the Sentence Recognition Threshold is established, which happens when 50% of the sentences are repeated correctly, with noise at 65 dBNA, under the following situations:

- Speech in quiet (S): 20 sentences produced by a speaker placed in front of the subject (0º) and presented with no competing noise;
- Speech with noise from the front (NF): 0 sentences produced by a speaker placed in front of the subject (0º) with noise presented at a fixed intensity of 65 dBNA, from the same speaker (0º);
- Speech with noise from the right (NR): 20 sentences produced by a loudspeaker placed in front of the subject (0º) with noise presented at a fixed intensity of 65 dBNA from a speaker on the right (90º);
- Speech with noise from the left (NL): 20 sentences produced by a loudspeaker placed in front of the subject (0º) with noise presented at a fixed intensity of 65 dBNA from a speaker on the left (90º);
- Composed noise (CN): calculated by the software HINTPro (HINTPro 7.2 Audiometric System/Bio-Logic Systems Corp), which provides the HINT test by means of an weighted average of the four previous conditions: NC = (2*NF+NR+ NL)/4.

Besides the Standard HINT situations described above, according to the recommendation that tests with FM be performed with diffuse noise, that is, originated from different angles in order to simulate classroom noise[11,12], an adaptation of HINTPro with four open field boxes was effected, at 45º, 135º, 225º and 315º. As recommended in the AAA guide[8], a sentence list with noise at 180º (noise from the back: NB) was also utilized. The test was performed with the child positioned exactly one meter from all five open field boxes.

HINT was applied to the study group wearing hearing aids only, and then with FM coupled with the hearing aid. The child was positioned exactly one meter from all five open field boxes.

It is important to point out that the presentation of speech stimuli and the lists used in different situations were randomly chosen. We tried to eliminate variations related to tiredness, participants' attention and learning phenomenon.

FM System Evaluation Questionnaire

The FM System Evaluation Questionnaire[13] is a subjective evaluation that allows a situational analysis of the benefits and usage of hearing aids and FM systems, which can be filled out by parents, teachers or audiologists. It was used to assess, individually, the children's performance in different listening situations with hearing aids only, and hearing aids with FM systems. The questionnaire contains five listening situations, with seven listening conditions each, for which the children's

answers with and without FM are scored from 1 (rarely) to 5 (always), or NA for 'non-applicable'. The situations included in the questionnaire are: the child answers when someone calls his/her name; the child follows someone's conversation; the child distinguishes words that sound similar; the child answers correctly verbal instructions and/or questions; the child understands oral instructions and concepts.

For every situation, it is asked whether the child answers or not: in a quiet classroom, one and three meters away; in a noisy classroom, one and three meters away; without visual clues; from another room or from the street. The scores are obtained through situational analysis in quiet, from a distance, noise, hearing only and total score (sum of all situations).

Statistical analysis

In order to compare the results of HINT with and without FM, and the comparisons between NR x NL, NF x 180 and 4 speakers x CN the paired Student T test was used. In order to verify the correlation between age and all conditions, Pearson Correlation Coefficient was used. In all statistical procedures, a 5% significance level was adopted ($p<0.05$). For the statistical analysis of the FM System Evaluation Questionnaire results, the repeated measurements analysis of variance with two criteria and Tukey test were used.

RESULTS

The FM systems fitted were verified and all achieved the FM transparency recommended by the AAA guide[8]. The results of HINT Brazil were obtained (Figure 1).

There was a difference ($p\leq0.001$, T test) for all situations with and without FM. In the comparison between the conditions (paired Student T test), there was a difference ($p\leq0.001$) only between composed noise (HINT formula: (2*NF+NR+NL)/4) and diffuse noise coming from the four sound fields at 45º; 135º; 225º and 315º, with better responses for composed noise. The correlation analysis with age (Pearson correlation coefficient; $p\leq0.05000$) there was a relation only for NF/FM and four speakers/FM as a function of HINT values.

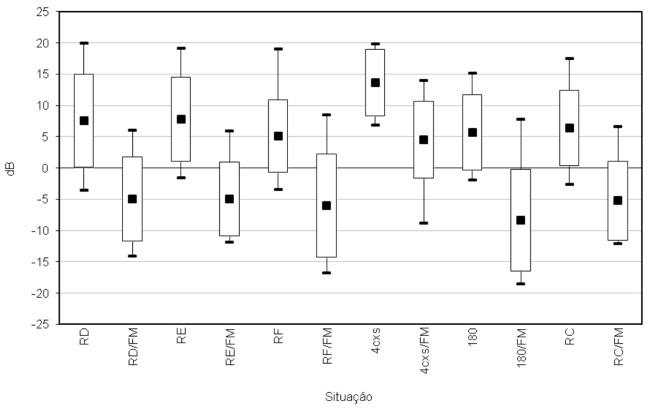
The FM System Evaluation Questionnaire was answered by the teachers (Figure 2).

In order to compare the five listening situations with and without FM, the repeated measurements analysis of variance with two criteria and Tukey test were used, and a difference ($p<0.001$) between the following situation was found: noise/ listening and quiet; distance/ listening and quiet; listening/ noise; distance/quiet; quiet/noise, distance/listening. There was a difference with and without FM systems, since without FM the score was always lower than with FM, regardless of the condition studied.

DISCUSSION

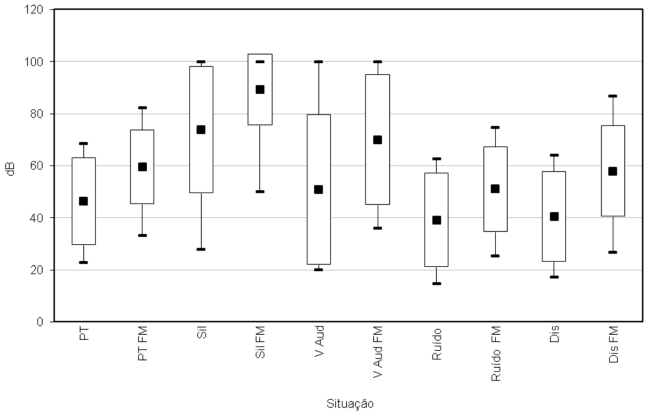
Benefits of FM systems

The FM systems fitted were verified and all achieved the FM transparency recommended by the AAA guide[8]. The



Note: NF = noise front; NR = noise right; NL = noise left; NC = noise composed; NB = noise back (from 180º); 4SF = four free field boxes

Figure 1. HINT average values for the study group in free field



Note: T = total score; Q = quiet; HA = hearing aid; FM = frequency modulated; AP = auditory pathway; D = distance; N = noise

Figure 2. Average score values for the study group in the FM System Evaluation Questionnaire answered by the teachers

FM systems' effectiveness could be observed by the 'FM advantage', which is the mean difference of 10 dB found in speech perception assessments with HINT in situations with and without FM, according to the recommendation that "in normal usage conditions, the FM system should improve speech perception for the wearer in at least 10 dB compared to the hearing aid alone"[8]. There was a difference for all assessed situations with and without FM in the FM System Evaluation Questionnaire.

Material used to assess speech perception and test environment

The challenge of investigating FM systems is to determine a controlled methodology that simulates the classroom environment. It is recommended that, when comparing different listening situations, that is, in noise with FM and without FM, it is important to determine which difference in the score represents a significant difference in speech perception performance[8]. Although it is not recommended to use adaptive tests in noise, nor to vary the speech/noise level, for they

underestimate speech intensity (changing speech and fixed noise) and overestimate noise levels (fixed speech and changing noise), in relation to typical classroom situations, several studies with FM systems have used those kinds of tests[14-17]. Still, those studies have been carried out with adults or implanted children, thus it was not possible to compare a sample of this study. Studies with children which used HINTPro with the application of sentences in quiet and noise adaptively, as indicated by the equipment manual[10], have not been found, only studies that adopted HINT sentences as material to assess speech, generally by means of CD recording, and with fixed SNR with results in percentage[10,18].

Several clinical tests have been elaborated to assess speech perception in young children, due to the need to study which hearing skills the child develops with the use of auxiliary hearing devices. However, few of those tests are available in Portuguese, especially for assessment in noise[19-21]. HINT Brazil[9] was used in this study because none of the children had previously been assessed by this instrument and for being hard enough to avoid the 'ceiling effect'.

Thus, the outcome analysis could be performed by both the 10 dB FM advantage and the possibility to compare to the rule that, for every 1 dB worse in HINT leads to a 10% reduction of speech intelligibility in noise[10].

HINT was developed in 14 different languages. In all of them, there is a list of phonetically balanced sentences which are also balanced in terms of difficulty, estimate of the performance-intensity rate, norm development and reliability. Taking into account that, currently, most available tests to assess speech perception in hearing impaired people has been standardized in a language that is not the Brazilian Portuguese, the development of HINT Brazil is an improvement in assessment of speech perception, providing parameters for both clinical and scientific analysis[9].

Although there is no pediatric version of HINT Brazil, as in other languages (Hearing in Noise Test for Children – HINT-C), several studies use HINT with this demographic[16,18]. Such application is justified by the fact that the material developed for the test tries to methodologically control the variation that might influence speech intelligibility in both adults and children.

It is important to point out that literature on HINT is restricted, and its results are analyzed according to the HINTPRo's manual. Several studies adopt a higher number of loudspeakers and describe the results as percentages in procedures related to fixed SNR and others Record sentences or say them out loud. Thus, some researches with HINT use for children a lower number of sentences per list, as HINT-C does, that is, ten instead of twenty sentences per list.

The differences obtained in HINT values with the different positions of the noise source confirm the need of further investigations that contemplate the standardizing of speech, noise and angulations of audio sources. The different HINT values obtained with the different positions of the noise source confirm the need of further investigations contemplating the standardizing of material including speech, noise and angulations of audio sources in order to contribute to the improvement of protocols for speech perception assessment in noise in hearing impaired children. Such definition must take into account the challenge of controlling the diverse factors that interfere with speech comprehension at the moment the assessments are performed, such as the listener's characteristics, including language and listening experience, and the kind and level of material presentation as well as the response[22-24].

The use of subjective measurements, such as the FM System Evaluation Questionnaire, together with objective measurements, is essential to determine the efficacy of recommending auxiliary devices for hearing impaired people. Studies linking both forms of measuring are necessary to adequately define recommendation and fitting protocols for FM systems[25].

In the questionnaire, in the comparison between the listening situations with and without FM, it was clear the difference between both situations, with better value with FM than without it. FM has proven to be an important tool regarding accessibility, which a highly discussed topic in Academic and Social Inclusion Laws. It is worth mentioning the importance of investigating resources that develop the necessary conditions for the inclusion of students with special needs as a premise to make them subjects of creation and production of goods produced by society[26].

CONCLUSION

After analyzing the study's results, it is possible to conclude that the FM system offers benefits in speech perception for hearing impaired children fitted with hearing aids and FM systems in open field noise situations and classroom situations. There are studies that assess speech perception with FM in non-academic environments, since the audiologist's role in the rehabilitation of hearing impaired people is to facilitate their access, and consequently, independence and safety in as many communication environments as possible, in all stages of life. That includes counseling regarding auxiliary devices, such as FM systems, which often provide the necessary means for the individual to actively participate in his/her community.

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RESUMO

Objetivo: Avaliar a percepção da fala de crianças deficientes auditivas com o aparelho de amplificação sonora individual (AASI) e sistema de frequência modulada (FM) em situações de ruído em campo livre e em sala de aula. **Métodos:** Participaram 13 crianças deficientes auditivas entre 7 e 17 anos. Foi aplicado o *Hearing in Noise Test* (HINT) com AASI e com o FM. Também foi aplicado o questionário Avaliação do Sistema FM, respondido pelos professores das crianças, com o intuito de avaliar, individualmente, o desempenho da criança em diferentes situações auditivas somente com AASI e com o AASI e o sistema FM. **Resultados:** Houve diferença para todas as situações com e sem FM no teste HINT. O mesmo aconteceu com os resultados do questionário, sendo que sem FM a pontuação foi sempre menor do que com FM, independentemente da condição. **Conclusão:** O uso de medidas subjetivas, como o questionário, **é** fundamental para determinar a eficácia da indicação dos dispositivos auxiliares para o deficiente auditivo. A efetividade do sistema FM pode ser observada pela "vantagem FM", que é a diferença média mínima de 10 dB encontrada nas avaliações de percepção da fala com e sem FM nas diferentes situações de ruído. Os benefícios encontrados na presente pesquisa com o uso do sistema FM na melhora da percepção da fala podem ser extrapolados não só para a sala de aula e para a legislação da educação inclusiva, mas também para atividades sociais e de lazer.

Descritores: Auxiliares de audição; Perda auditiva; Percepção da fala; Ruído; Questionários

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