Evaluating effectiveness of dynamic soundfield system in the classroom

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Abstract

Research has reported on the use of soundfield amplification devices in the classroom. However, no study has used standardized tests to determine the potential advantages of the dynamic soundfield system for normally hearing students and for the teacher's voice. Our aim was to evaluate the impact of using dynamic soundfield system on the noise of the classroom, teacher's voice and students' academic performance. This was a prospective cohort study in which 20 student participants enrolled in the third year of basic education were divided into two groups (i.e., control and experimental); their teacher participated. The experimental group was exposed to the dynamic soundfield system for 3 consecutive months. The groups were assessed using standardized tests to evaluate their academic performance. Further, questionnaires and statements were collected on the participants' experience of using the soundfield system. We statistically analyzed the results to compare the academic performance of the control group with that of the experimental group. In all cases, a significance level of $P < .05$ was adopted. Use of the dynamic soundfield system was effective for improving the students' academic performance on standardized tests for reading, improving the teacher's speech intelligibility, and reducing the teacher's vocal strain. The dynamic soundfield system minimizes the impact of noise in the classroom as demonstrated by the mensuration of the signal-to-noise ratio (SNR) and pupil performance on standardized tests for reading and student and teacher ratings of amplification system effectiveness.

Keywords: *Acoustics*, *child*, *schools*, *signal-to-noise ratio (SNR)*

Introduction

In school, children spend most of their time engaged in activities where the teacher's speech predominates. Children require more audibility and intelligible speech signal, and a quieter environment than adults to be able to discriminate words. This is because the child's brain is maturing, and it does not perform automatic cognitive tasks such as auditory closure in the same manner that an adult brain does. Therefore, in order to develop an environment conducive to learning, classrooms need acoustic management and a favorable signal-to-noise ratio (SNR).[1,2,3,4]

Proper classroom acoustics and a favorable SNR are essential for all students and for the teacher's voice. However, classroom noise levels vary according to the school and classroom.[5,6,7,8]

Further, noise is considered a risk factor for alterations in the teacher's voice[9,10] and studies suggest that the addition of noise inhibits auditory working memory processes in real time for school-age children.[4]

Various strategies are used to improve the SNR in order to encourage the recognition of speech through noise, including the fitting of frequency modulation (FM) systems for a more in-depth reading of indications for FM systems and classroom audio distribution systems (CADSs) in the classroom.[11,12,13]

Although originally developed for hearing-impaired children, FM systems have also been used for children with normal peripheral hearing. For this population, a favorable SNR seems to facilitate their attention to tasks as well as improve their response time; this is because when a teacher's speech becomes clearer, children exhibit a longer focus time and greater concentration on relevant sound stimuli, and ignore competitive stimuli.[14]

The literature describes improvements in academic performance, speech recognition, learning, and increased self-esteem as the benefits of using soundfield FM equipment by children with normal hearing.[15,16,17,18,19] Benefits for teachers include a reduction in effort and vocal fatigue, and greater ease in teaching.[20,21,22] For schools, maintaining a teacher's vocal health also means sustaining the quality of their teaching as well as reducing costs related to substitutions and treatments.[23]

The Acoustical Society of America (ASA)[24] affirms that classrooms shall meet the noise and reverberation levels specified in American National Standards Institute (ANSI) Standard S12.60. Further, provided that soundfield amplification systems are used in conjunction with ANSI S12.60, the ASA recognizes their usefulness for core classrooms to augment teachers' voices as multimedia sound distribution systems. In case of moderate activity noise, the soundfield amplification system can be employed to augment the teacher's voice, especially for a quiet topic. Amplification systems should not be used in an attempt to substitute for good acoustics. To ensure their success, the ASA advocates that classroom noise levels and reverberation times be documented prior to installing soundfield amplification systems. Acoustical consultants or credentialed school audiologists properly trained and equipped may screen and document classrooms for soundfield systems.

Studies reporting on the use of FM systems in educational settings have typically used questionnaires or checklists to evaluate academic performance and the teacher's voice although a few have used standardized tests.[25]

The literature pointed that additional research is needed in several areas pertaining to classroom acoustics and amplification including comparisons among various soundfield technologies currently available to educators.[13]

This study evaluates the impact of using the digital dynamic soundfield system (that automatically increases the gain if the noise increases in the classroom) on the teacher's voice and academic performance of students' normally hearing through standardized tests.

Methods

This study was approved by the Research Ethics Committee under protocol no. 90.685/2012. Upon having understood and agreed to the study objectives, all participants signed a free and informed consent form, granting permission for their participation in the work and the publication of any data obtained.

This study was conducted in a classroom at a private school. To determine the control and experimental groups, we considered the following inclusion and exclusion criteria for the students and the teacher: Students must be enrolled in the third year of basic education, present normal peripheral hearing, and not have any cognitive impairment. The teacher must be responsible for both shifts (i.e., morning and afternoon) for students in their third year of basic education and teach different groups of students in the same room.

Were invited to participate this study 18 students of the morning period and 19 students of the afternoon period who were regularly enrolled in the in the third year of basic education. However, 24 students' parents gave permission for their children and 1 child did not meet the inclusion criteria; 23 children were initially included in the study but three did not perform the second assessment for personal reasons. The final sample was of 20 students.

The study included one teacher as well as 20 children of both genders with normal peripheral hearing and without cognitive impairment who were in the third year of basic education in the morning and afternoon shifts. This study included one teacher who was responsible for two different student groups, both in their third year of basic education in the morning and afternoon shifts. The teacher was 44 years of age, with a degree in Education. She has been teaching for 23 years.

All 20 children underwent a hearing evaluation involving transient-evoked otoacoustic emissions from the Otoport Lite machine (Otodynamics Ltd), and ipsilateral acoustic reflex testing by using Interacoustics Titan (Interacoustics A/S). All students presented transient-evoked otoacoustic emissions and ipsilateral acoustic reflexes that were bilaterally present. We evaluated the cognitive aspects by using the Raven Scale,[26] and we considered the score obtained on the test to be in accordance with the age and score for private schools. All of the children achieved a score equal to the mean scores of 27.0 and 4.5 standard derivation, or above "intellectually average."

They were divided into the following two groups: The experimental group (morning shift) comprised 10 children with a mean age of 8 years, and their room was equipped with the dynamic soundfield system. The control group (afternoon shift) comprised 10 children with a mean age of 8 years. They were in the same school year and in the same room as the experimental group although conversely they did not use the dynamic soundfield system in the classroom.

Having the same teacher teach different classes of third year students during the morning and afternoon shifts in a single room was an optional criterion in order to minimize the variables involving acoustic and structural characteristics. The classroom was measured (3.20 m × 8.00 m × 6.50 m), and we calculated the reverberation time (Sabine RT) by using the "Cálculo do Tempo de Reverberação (T60) de um ambiente [calculating the reverberation time (T60) of an environment]" program.[27] The measurements were based on those of an office because it was the option most similar to a classroom; without acoustic treatment, the RT was 0.8 s.

The measurement of the SNR in the classroom in the experimental group was performed by a recording of three points (front, middle, and bottom), the remaining 5 min in each position, totaling 15 min. The analysis of the acoustic characteristics of the recorded material was based on the methodology called "sound assurance technique."[28]

The Phonak DigiMaster 5000 soundfield system (Phonak do Brasil – Sistema Audiológicos LTDA) was installed in the classroom; it consists of a portable DigiMaster speaker (available with a floor stand or wall mount), an Inspiro transmitter (dynamic technology), and a microphone. Dynamic SoundField is a new generation soundfield technology with automated settings, i.e., it increases the gain if the noise increases in the classroom, and a specially designed loudspeaker array for an even distribution of the teacher's voice in the classroom.[21]

Students’ academic performance

To evaluate reading, writing, and arithmetic skills with the academic performance test [teste de desempenho escolar (TDE)],[29] and reading comprehension skills using reading comprehension here after referred to as the reading comprehension test.[30] The professionals who administered the standardized tests to the children did not know if the children were in the test group or the control group.

Academic performance test (teste de desempenho escolar)

The academic performance test (i.e., TDE) was designed to evaluate the basic academic skills of students from the first year through the sixth year of basic education, and comprises three subtests:

1. Writing (writing one's own name and individual words upon dictation);
2. Arithmetic (oral problem-solving and written calculations of arithmetical operations); and
3. Reading (recognizing words that are out of context as well as classifying the test's performance as inferior, average, or superior).[29]

Reading comprehension

“Test to Evaluate the Reading Comprehension of Expository Text: For speech therapists and educational psychologists” was used. The texts of the test have a form of global organization, and are defined as what is called a superstructure. The importance of the text's organization for reading comprehension is that upon perceiving it, the reader “[...] can anticipate content categories and create a schema in their mind that can assimilate the contents of the text.” All of the texts are accompanied with relevant illustrations, helping activate students’ prior knowledge. The purpose of this tool is to evaluate the reading comprehension of expository texts (i.e., observation and analysis of the reader's cognitive, metacognitive, and motivational aspects, thus evaluating the decoding, speed, and comprehension).[30]

The first evaluation was performed before installing the dynamic soundfield system in the classroom. The second evaluation was conducted 3 months later after the experimental group used the dynamic soundfield system. All of the evaluations were performed individually at the school in a separate room at a time that was not detrimental to learning the curricular content; the participants were filmed if later consultation was required.

Questionnaires and statements

To obtain the participants' opinion on the use of the dynamic soundfield system and the classroom's acoustic environment, we elaborated a specific questionnaire to the teacher and another version to the students containing eight and nine questions, respectively. The questions were related to the teacher's voice, mobility in the classroom, the acoustic environment, attentive behaviors, and distraction and discipline in the classroom; these questions were based on findings in the literature used in this article.

It also collected individual statements for the question, "What is your opinion on using a microphone in the classroom?" which was posed to the experimental group and the teacher.

Data analysis

All statistical procedures were performed using Statistica, version 10.0 (StatSoft Inc., Tulsa, USA). In all cases, a significance level of $P < .05$ was adopted. We statistically analyzed the results of our study to compare the academic performance of the control group with that of the experimental group.

For statistical analysis, the values of TDE and reading time, both sets of data passed through the Kolmogorov-Smirnov normality test. For comparison between the first evaluation and second evaluation, we used the paired *t*-test. For comparison between the control group (CG) and experimental group (EG) in the first evaluation *t* test was used and for comparison between CG and EG in the second evaluation analysis of covariance (ANCOVA) was used, using as covariate the value obtained in the 1st evaluation.

We used the Wilcoxon test for a comparison of the student questionnaires before and after use of the dynamic soundfield system.

Results

Students' academic performance

The first evaluation was performed before installing the dynamic soundfield system in the classroom. The second evaluation was conducted 3 months later after the experimental group used the dynamic soundfield system.

Table 1 presents the values obtained on TDE (writing, arithmetic, reading, and total).

Table 1

Distribution of the groups according to the score obtained on TDE (writing, arithmetic, reading, and total; *n* = 10 in each group)

TDE	First eval		Second eval		Between eval	
	M	SD	M	SD	t(df)	*P*
Writing						
CG	24.8	5.2	28.1	3.1	2.83 (9)	.019*
EG	26.1	4.6	27.6	4.5	2.04 (9)	.071
Between groups	*t*(28)=.59,	*P*=.561	F(1,17)=1.33,	*P*=.265		
Arithmetic						

CG	11.8	1.9	13.2	2.1	2.94 (9)	.016*
EG	12.6	2.1	14.5	1.9	2.82 (9)	.020*
Between groups	*t*(28)=.89,	*P*=.383	F(1,17)=1.19,	*P*=.291		
Reading						
CG	64.6	6.0	68.9	1.2	2.25 (9)	.051
EG	65.5	4.2	68.8	1.4	2.44 (9)	.037*
Between groups	*t*(28)=.39,	*P*=.702	F(1,17)=.04,	*P*=.841		
Total						
CG	101.2	11.7	110.2	4.5	3.46 (9)	.007*
EG	104.2	8.6	110.9	5.3	3.22 (9)	.011*
Between groups	*t*(28)=.65,	*P*=.522	F(1,17)=.05,	*P*=.823		

CG = Control group, EG = Experimental group, eval = Evaluation, *P* = *P* value, *Statistically significant difference, *P value* between evaluations was obtained by paired *t*-test, *P value* between groups on first eval was obtained by *t*-test, *P value* between groups on second eval was obtained by ANCOVA *F*-test using as covariate the value of the first evaluation

The text used to evaluate the comprehensive reading texts was "The giraffe" for both groups. The text contained 172 words, and the students performed a complete reading, both silently and orally. Table 2 presents the mean values, standard deviation, and *P* values obtained on the times (in seconds) for silent reading and oral reading.

Table 2

Distribution of the groups according to the times (in seconds) for silent and oral reading on the comprehensive reading test (*n* = 10 in each group)

Comprehensive reading	First eval		Second eval		Between ev	
	M	SD	M	SD	t(df)	P
Silent reading						
CG	99.3	38.7	80.1	37.1	1.06 (9)	.3
EG	131.8	59.9	112.9	52.8	1.31 (9)	.2
Between goups	*t*(28)=1.44,	*P*=.167	F(1,17)=1.02,	*P*=.327		
Oral reading						
CG	123.8	40.2	101.7	28.2	3.88(9)	.00
EG	136.1	47.8	109.5	23.7	2.94(9)	.01
between goups	*t*(28)=.62,	*P*=.541	F(1,17)=.06,	*P*=.812		

CG = Control group, EG = Experimental group, eval = Evaluation, *P* = *P* value, *Statistically significant difference, *P value* between evaluations was obtained by paired *t*-test, *P value* between groups on first eval was obtained by *t*-test, *P value* between groups on second eval was obtained by ANCOVA *F* test using as covariate the value of the first evaluation

Questionnaires and statements

Figure 1 presents the mean values related to the results of the questionnaire on the students' experience with the dynamic soundfield system in the classroom.

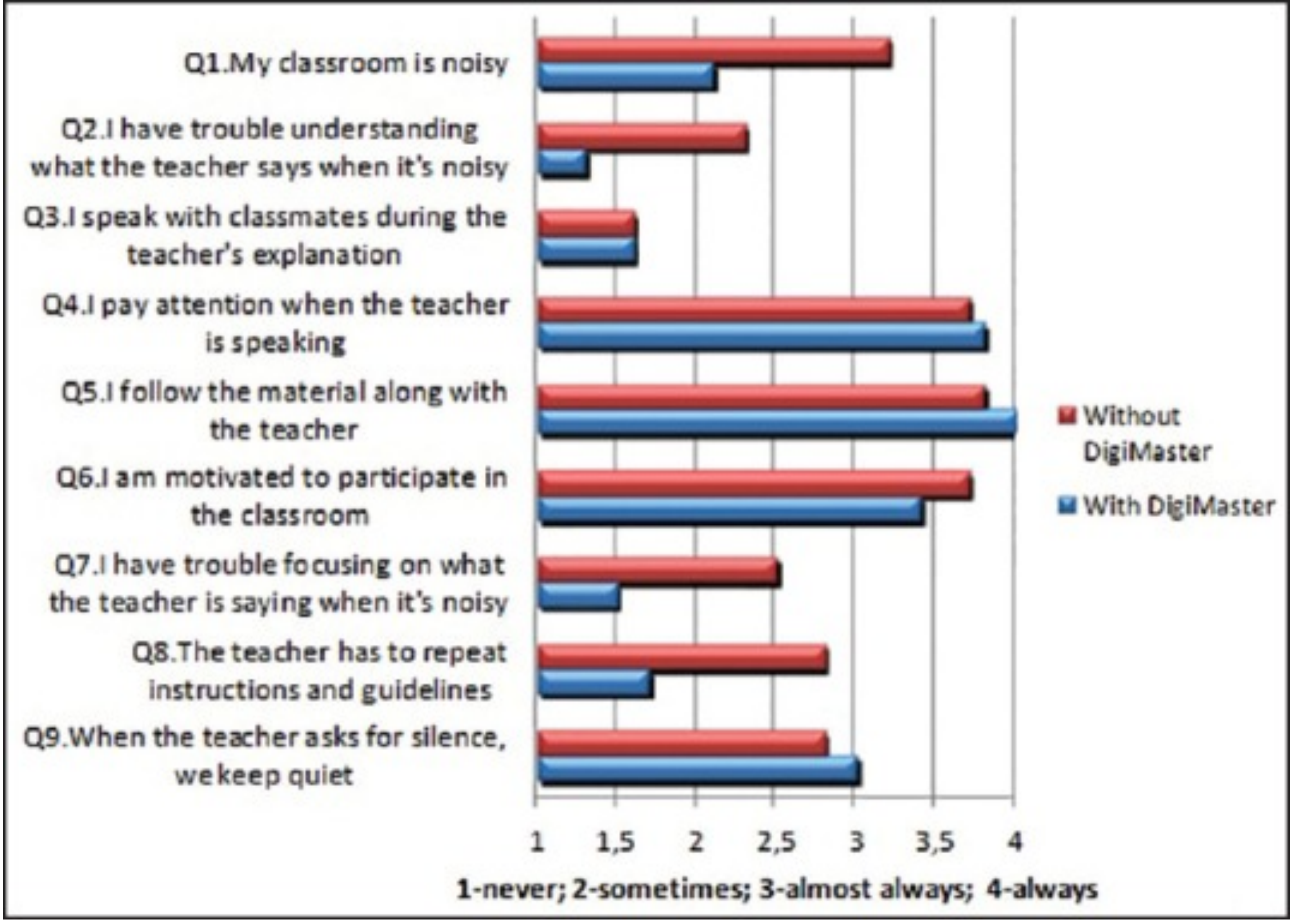

Figure 1

Mean results of the questionnaire on the students' experience with the dynamic soundfield system (*n* = 10)

The *P* values of the questionnaire results concerning the students' experience with the dynamic soundfield system are listed in Table 3.

Table 3

The P values obtained from the statistical analysis (Wilcoxon tests) of the results of the questionnaire applied to the students before and after using the dynamic soundfield system (*n* = 10)

Condition	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Without FM (Mdn)	3	2	2	4	4	4	2.5	3	3
With FM (Mdn)	2	1	2	4	4	4	1	1	3
P	.019*	.018*	1.000	1.000	1.000	.109	.018*	.018*	1.000

**P* = Statistically significant difference

Figure 2 presents the results of the questionnaire on the teacher's experience with the dynamic soundfield system in the classroom.

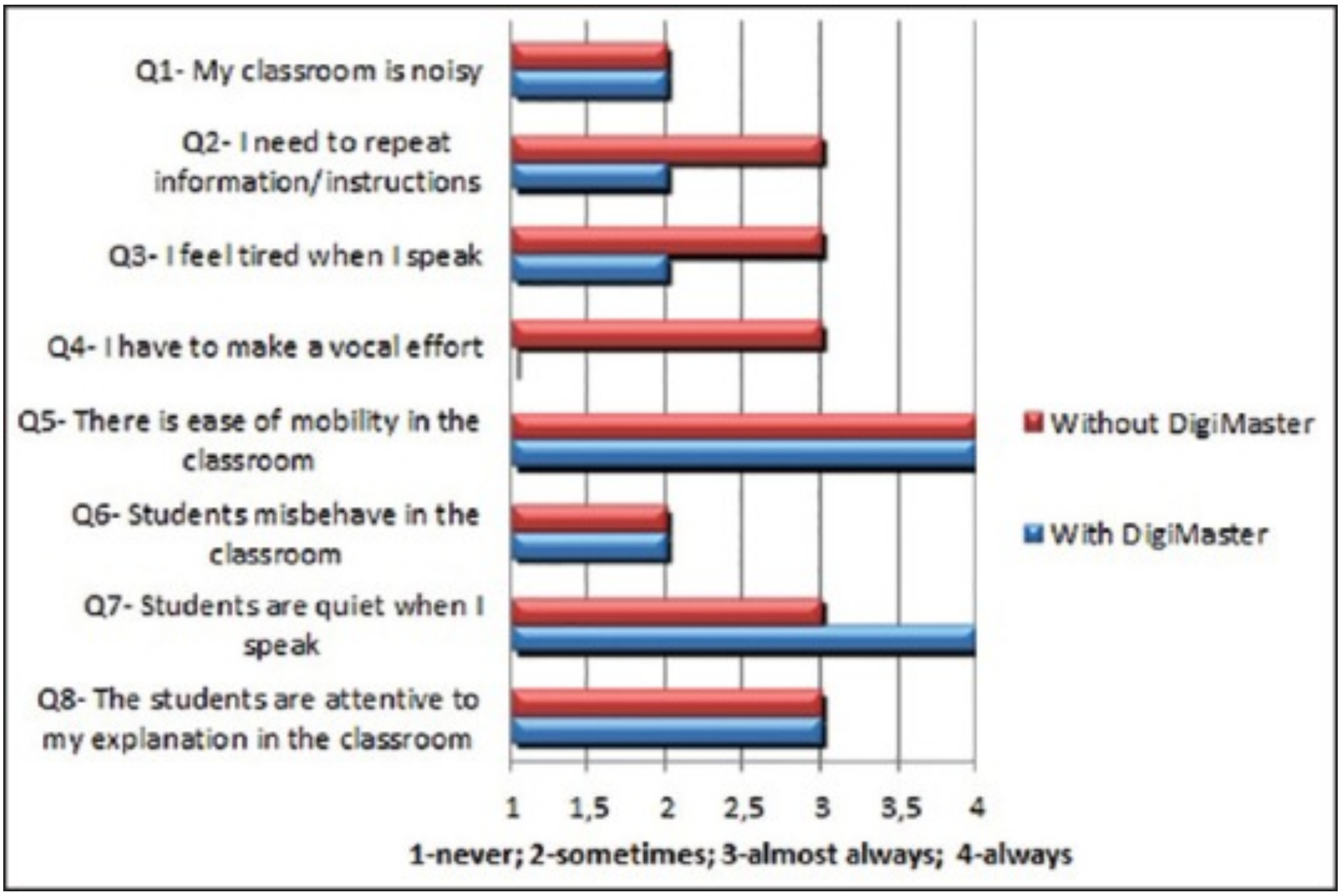

Figure 2

Results of the questionnaire on the teacher's experience with the dynamic soundfield system

The children's statements on their experience with the dynamic soundfield system in the classroom are as follows:

It is possible to hear better. She does not need to speak so many times with the microphone. (B., 8 years old);

It has changed. Her voice is higher now, and I can hear better. (D., 8 years old);

The teacher's voice is higher, and it is easier to pay attention. (G., 8 years old);

When she uses it, I pay more attention and her voice is louder. (B., 8 years old);

The teacher's voice is faster now, and when the teacher speaks, it is louder and easier to hear and to pay attention to. (M., 8 years old);

Her voice is louder now but the students are still speaking very loudly. (M., 8 years old);

The voice has changed. I am paying more attention. It is louder now. (C., 8 years old);

The voice is louder, and it is easier to understand the teacher. (J., 8 years old); and

The voice has changed. It is louder now. It is easier to pay attention. (R., 8 years old).

The teacher's statement on her experience with the dynamic soundfield system in the classroom is as follows: I saw that using the FM caused the children to be more attentive, and I did not get as tired when I speak. In situations where I had a sore throat in the morning, I believe it was because of the need to increase the tone of my voice in the afternoon and evening.

The values of the SNR obtained in the classroom in the experimental group, without and with the dynamic soundfield system are listed in Table 4.

Table 4

Values obtained of the signal-to-noise ratio (SNR) in the classroom in the experimental group (in dBA) in different positions (front, middle, and bottom), situations with and without the dynamic soundfield system

Classroom (EG)	SNR front	SNR middle	SNR bottom
Without FM	3,8 dBA	0,5 dBA	−0,6 dBA
With FM	9,8 dBA	5,5 dBA	2,3 dBA

EG = Experimental group, SNR = Signal-to-noise ratio

Discussion

The dynamic soundfield system is one instrument that is available within the sphere of assistive technology resources; its objectives are to improve the SNR in the classroom, and to help prevent damage to the teacher's voice. This study evaluated the impact of soundfield systems in classrooms on abilities related to the academic performance of individuals with normal peripheral hearing.

Students’ academic performance

In this study, the mean age of the 20 participating children was 8 years; classrooms from the third year of basic education were selected because at this age children should already be literate[31] and able to perform the tests proposed for assessing skills related to academic performance.

This study evaluated the repertory of basic skills, which allow the students learning of school performances expected for their series; learning of school subjects taught during the study period was not evaluated. The reasoning, which based the evaluation proposal was that for academic performance to occur, basic skills are required (writing, reading, arithmetic, reading comprehension), which can be classified more effectively through standardized tests, which allow the comparison of performances in these skills before and after the intervention.

The evaluations of abilities related to reading, writing, arithmetic, and reading comprehension were applied to basic education students in a private school. Both groups had already reached the score “ceiling” or were close to it on the first evaluation, which was performed before use of the dynamic soundfield system.

For the academic performance test (i.e., TDE), the experimental group showed a significant improvement in reading between the first and second evaluations, and in comparison the evaluations was statistically significant in both groups for TDE (arithmetic and total), and no significant difference emerged in the comparison between the groups for the values obtained on TDE (writing, arithmetic, reading and total; Table 1). This may have been a factor influencing the nonoccurrence of significant differences between the groups evaluations, with the exception of the TDE results on the reading subtest.

In the reading comprehension test, before the reading, the students showed interest but only partial concentration, asking few questions. They showed interest during silent reading, and they occasionally requested clarifications regarding the pronunciation. Most of the students neither made any comments on what they were reading and nor did they ask any question. During oral reading, they generally complied with the rules of punctuation. All of the children showed an adequate understanding of the text before and after use of the dynamic soundfield system.

Table 2 shows a significant difference only for the time of oral reading between the first and second evaluations on the reading comprehension test for both the groups, corroborating the findings of another study.[25] There was no statistically significant difference between the groups but numerically analyzing the time spent by both groups on the two evaluations shows that the experimental group reduced, on an average, the time of their silent reading by 18.9 s and the time of their oral reading by 26.6 s. The control group reduced the two tasks by 19.2 s and 22.1 s, respectively [Table 2].

In this study, it was possible to observe an improvement in reading by student groups in an amplified classroom, which does not occur with the control group. In previous studies, the academic progress of students was compared in grade four through grade six in the classroom amplified and unamplified. The results indicated that the greatest academic improvements were demonstrated by the students with amplification in classrooms, and these students were also achieving a faster rate on the reading assessment.[32] In other study that compared the results of standardized tests of students in first grade through fifth grade, and in classrooms with amplification, the students had better scores on the reading assessment test and in reading fluency than students who did not use the amplified system in classrooms.[15]

It is noteworthy that the learning process is a multifactorial phenomenon (that depends on factors such as nutrition, sleep, motivation, family support, pedagogical method, extracurricular tasks, and activities, teacher-student relationship) and longitudinal. So it is expected that during the school years, the student acquires an increasingly wider academic repertoire. Although some studies suggest the importance of these factors in learning, it would be valuable to investigate some other variables, which are rare or do not appear in the literature; one example could be the influence of the period in which the child attends school in the learning performance. For a better understanding of this subject, future research should verify the correlation between these factors with and without the use of the amplification system in the classroom.

Questionnaires and statements

The latest ANSI S12.60[33] international standard on the optimal values of noise and reverberation for schools recommends an RT of up to 0.6 s for a classroom of up to 283 m^3, and 35 dB for the noise level. In the classroom chosen for this study, these values were higher with an RT of 0.8 s. The noise level ranged 55-85 dB (A).

These data corroborate the findings reported in previous studies, which have stated that the noise levels exceed those recommended by standards.[5,7,8,34]

Environmental factors such as noise and RT may reduce the ability of speech recognition, compromising learning as well as interfering with student-teacher communication.[35]

The dynamic soundfield system helped the students and the teacher with the impact of these acoustic characteristics (noise, reverberation, and distance) in the classroom because there was a significant improvement on the questions that address noise issues in the classroom, an improvement in understanding and focusing on what the teacher is saying over noise, and a decrease in the teacher's need to repeat instructions and guidelines [Figure 1 and Table 3], confirming the findings obtained by another study.[21]

The use of the dynamic soundfield system provided improvements in SNR [Table 4] and according to the questionnaires, improved students' attention

[Figure 1 and Table 3] and decreased the vocal fatigue of the teacher [Figure 2], which could have influenced the performance of the evaluated skills of the students.

To evaluate the teacher's voice, the questionnaire before and after 3 months of using the dynamic soundfield system in the classroom was applied. The second application of the questionnaire causes decreases in the Hawthorne effect (when subjects are observed by researchers, they could temporarily change behavior) because the teacher did not have have access to the answers of the first questionnaire, as well as students of their questionnaires. In addition, teachers and students did not know what the expected “correct” answer was to improve their results.

In the present study, the portable DigiMaster speaker (i.e., the transmitter) was attached to the wall at the front of the room in accordance with the manufacturer's instructions for the proper distribution of sound. However, the American Academy of Audiology (AAA) Clinical Practice Guidelines: Remote Microphone Hearing Assistance Technologies for Children and Youth from Birth to 21 Years states that whereas the benefits of listening within the critical distance of the sound source have already been well-established, research showing the impact of hearing at shorter distances is still required.[36]

In a pilot study, the author evaluated the number of words recorded through language environment analysis (LENA) during 1 schoolday, with and without the use of a soundfield system, and he found that the number of intelligible words spoken by an adult (teacher) increased by 5,000 units with an amplified classroom compared with 1 day when the machine was switched off, and he noted that whereas the teacher did not speak 5,000 additional words, the students were exposed to 5,000 additional intelligible words.[37]

Figure 2 presents the results of the questionnaire on the teacher's experience with the dynamic soundfield system. According to the teacher, fatigue and the effort to speak decreased, as did the need to repeat verbal instructions.

The students' and teacher's statements are in line with the findings reported in the literature on the dynamic soundfield system concerning the benefits related to the teacher's speech intelligibility and increased attention and improvement in voice quality.[16,21] All of the children in the experimental group reported an improvement in the abilities of listening and attention with the use of the dynamic soundfield system.

Our findings on soundfield amplification are in line with the information obtained in other studies, which have related statements or results obtained from questionnaires. The most recurrent statements are as follows: The students reported better hearing and better attention in the classroom, [20,22] whereas the teachers reported less vocal fatigue and less of a need to repeat verbal instructions.[20,23,32]

This study the dynamic soundfield system helped in improving the SNR in the classroom, [Table 4], confirming the findings by the other study that indicating the FM system as a strategy to improve the SNR in classrooms. In the other study, 100% of the participants chose adaptive FM as the preferred setting for half of the activities instead of traditional FM.[38] For the remaining activities, adaptive FM also was preferred by 80-90% of the participants.[39]

The results of this study should be considered preliminary because the sample must be expanded to classrooms with different acoustic characteristics, with larger samples of students and teachers, different school stages, a comparison between private and public schools, and the length of time taken to use the dynamic soundfield system in order to evaluate the abilities related to academic performance and the impact on the teacher's voice.

Conclusion

The dynamic soundfield system minimizes the impact of noise in the classroom as demonstrated by the mensuration of the SNR, and pupil performance on standardized tests for reading and student and teacher ratings of amplification system effectiveness.

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Conflicts of interest

There are no conflicts of interest.

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