Phonak Field Study News.

Reduced listening effort and improved speech intelligibility with Roger™ SoundField.

The benefits of Roger technology for speech intelligibility in noise and over distance for wearers of hearing devices are well established. This study examined the benefits of Roger SoundField for primary school children with normal functional hearing in noisy, reverberant classrooms.

Tania Rodrigues & Matthias Latzel, July, 2023

Key findings

- Roger SoundField leads to improved speech intelligibility in noise for children with hearing levels in the normal range compared to situations without Roger SoundField.
- It results in reduced perceived listening effort in a noisy listening condition.
- Improvements are observed in both good and poor classroom acoustics conditions.

Considerations for practice

- The use of Roger SoundField in classrooms with poor acoustics has the potential to support learners with hearing within normal range as well as with hearing loss.

Introduction

In primary school, basic forms of learning mathematical, linguistic and factual knowledge are taught to lay the foundation for secondary school education. This requires that children hear and understand their teachers well. However, noise in the classroom, distance between teacher and children, as well as reverberation often create a less than ideal learning environment.

As quoted in Part I of this study[19], background noise levels in unoccupied classrooms tend to be 5-15 dB higher than the recommended 35 dB(A), and reverberation times may exceed the 0.55 seconds recommended by DIN 18041 (2016)[1, 2, 3, 4]. Children often complain about the excessive noise levels in occupied classrooms.

According to Sust & Lazarus (1997)[5], our speaking apparatus is designed for speaking at a level of 60 dB(A) and this level is considered pleasant. The higher the background noise, the more vocal adjustments by teachers in terms of voice intensity, pitch, and phonation time, are provoked[6, 7]. Thus, teachers often develop vocal problems[8, 9, 10] and this is known to hamper speech reception and understanding for listeners[3, 11, 12, 13].

Soundfield amplification systems have been shown to support students with hearing loss wearing compatible hearing devices and teachers in classroom settings[3,14-16]. When it comes to cognitive development, maintaining a consistently positive signal-to-noise ratio (SNR) in a noisy and reverberant classroom makes it easier for young students to pay attention, hear and understand the teacher better[17, 18]. Studies with soundfield systems found increased ability of students to attend and focus on a specific task by as much as 16%[17, 18].

However, the extension of research with Roger SoundField for students whose hearing falls within normal range is more limited.

In Part I of the study, the influence of the Roger SoundField system on the objective value STI (Speech Transmission Index) in a noisy and reverberant classroom environment was evaluated (Rodrigues, 2022). The STI is a measure of the quality with which speech is transmitted from speaker to listener. The results indicated that Roger SoundField has the potential to improve speech intelligibility for all conditions tested, and especially in rooms with higher reverberation times. It was not clear however, if the improvements found were of clinical relevance.

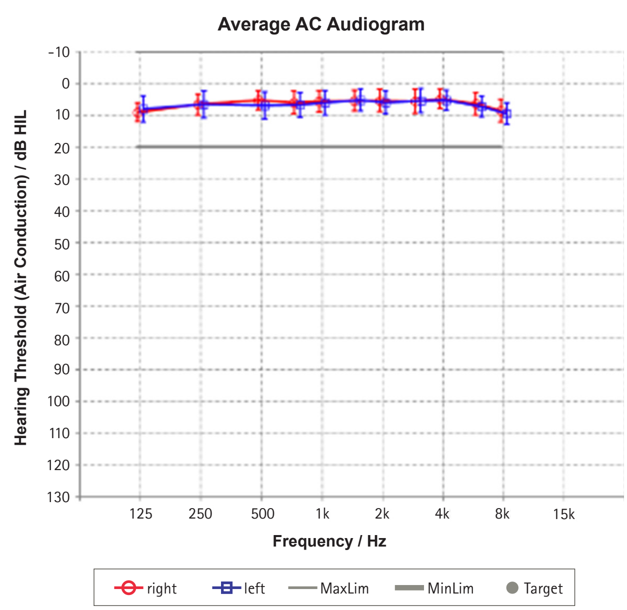
Thus, the purpose of Part II of the study was to analyze the effects of Roger SoundField for school children, within classrooms with good and poor acoustical conditions. Specifically, the effects of Roger SoundField on speech intelligibility and listening effort were assessed. This paper reports of the findings of Part II of the study.

Methodology

Participants

Fifty-six school children between the ages of 7 yrs 9 mths and 10 yrs 0 mths participated in the study (24 female and 32 male). All participants attended primary school in Germany.

Pure tone hearing thresholds were within normal range (< 20 dB HL) for all children. The mean hearing thresholds of all children are depicted in Figure 1. The mean Pure tone averages are as follows:



- 5.3 dB ± 2.3 dB (standard deviation) for the right ear
- 6.0 dB ± 2.9 dB (standard deviation) for the left ear

Figure 1: Mean air conduction thresholds of the participating children for the right (red) and left (blue) ears.

Procedure

The study was organized into 2 appointments:

1. Individual testing
2. Group testing

1st Appointment – Individual Testing

This took place in sound attenuated standard audiometry and Free Field rooms in the House of Hearing, Oldenburg, Germany.

During this appointment, the children's ears were assessed for **ear health** via otoscopy and tympanometry with a 226 Hz probe tone to detect any obstruction of the tympanic membrane and to rule out an acute middle ear problem. **Pure tone audiometric** air conduction thresholds between 125 – 8000 Hz were obtained.

Monaural speech intelligibility in noise (better ear) was measured with the Oldenburg Children Sentence Test with a female speaker (OLKISAf[9, 20]). It uses partial sentences (number, adjective and object) presented in quiet or in noise to obtain the speech reception threshold (SRT). Speech and noise signals were presented via headphones (HDA200) to the better ear.

Two training lists were used:

1. Fixed (signal-to-noise) SNR of 5 dB (non-adaptive), with noise (Olnoisef[20, 25]) presented at 65 dB SPL.
2. Adaptive estimation of SRT 50% with noise fixed at the same level. The test list was used to adaptively estimate SRT (noise at 65 dB SPL).

The TROG-D[21] (digital version, Schulz-Kirchner Verlag GmbH, Idstein) was used to test the **speech comprehension** of children of primary school age. It is a language and grammar comprehension test using sentence-to-picture-matching with four options. The word or phrase was spoken by a male voice and the T-value (or TROG-D result value) was given by the software, based on the child's responses.

A complex oral instructions test[13] was performed as a practice for the complex oral instructions task the children would undergo in the group appointment. This task involves a heavy load on verbal working memory with respect to both storage and processing resources[13]. Complex oral instructions (e.g. "Draw a cross between the saw and the box.") were presented by a female speaker, with and without noise, and the children had 18 seconds to complete the task on the provided response sheets. Signals were pre-recorded in the Communication Acoustic Simulator (KAS) with 'good' classroom acoustics switched on.

2nd Appointment – Group Testing

The group measurements took place in a laboratory room with a Variable Room Acoustics System (VRAS[22]) – the KAS – in which various room acoustic situations with short and long reverberation times can be simulated.

Two preset room acoustics from Part I of the study were used:

1. Good classroom with reverberation time = 0.48 s
2. Poor classroom with reverberation time = 0.83 s

As in Part I of the study, 8 tables were arranged in 3 rows with 1 seat at each table (this was in line with COVID-19 hygiene standards) – Figure 2.

Figure 2 also shows:

- The position of Roger SoundField consisting of the Roger DigiMaster 5000 loudspeaker, front left, aligned at ear level.
- The sound source – a Head and Torso Simulator (HATS) with mouth simulator (Bruel & Kjaer 4128, Nærum, Denmark), front right.
- The Roger Touchscreen Microphone around the neck of the HATS, 15 cm from the voice output source.

The EasyGain function was set to "0" in the Touchscreen Mic, which corresponds to the default adaptive behaviour of the system.

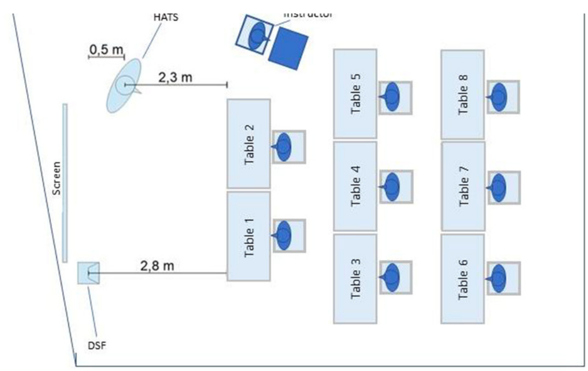


Figure 2: Classroom set-up in the communication acoustics simulator KAS. Performance of the children was measured in the presence of background speech-simulating noise (Olnoisef at a level of 55 db(A)), in both room acoustical conditions.

The Roger SoundField system was either switched ON or muted/OFF.
This resulted in four different test conditions:

a. Good classroom with Roger SoundField on
b. Good classroom without Roger SoundField off
c. Poor classroom with Roger SoundField on
d. Poor classroom without Roger SoundField off

For all assessments in this 2nd appointment, the effect of reverberation (good vs poor classroom), in addition to the effect of Roger SoundField (on vs off) in noisy listening conditions, was assessed. Fifty of the 56 recruited school children were tested in groups of up to 8 children per appointment.

Speech Perception

The Oldenburg Rhyme Test for children (OLKI[23]) was used to determine intelligibility as a percentage at a fixed presentation level or SNR.[24] The children were asked to select the illustration of the word presented out of a selection of three familiar objects. The German names for the objects differ in only one sound (e.g. 'Rose' – 'Dose' – 'Hose').

The speech signals were presented via the mouth simulator of the HATS, at a presentation level calibrated to 60 dB (A) at 1 meter distance from the mouth simulator.

The background noise was generated by playing 6 time-shifted outputs of the Olnoisef fragment (speech-simulating female Olnoise). This was played through 6 loudspeakers distributed along the length of the room, at a 55 dB (A) presentation level (roughly the average classroom level[15]), resulting in a quasi-diffuse sound field. The noise started about 30 seconds before the speech signals were presented so that the system had time to adjust into a steady state.

Listening Effort
After speech perception testing, the children were asked to rate the listening effort on a 3-point pictorial rating scale: "low", "medium" and "high".

Listening Comprehension
Complex oral instructions were integrated into a PowerPoint presentation and audio instructions were presented to the children. The children had to carry out the instructions on the prepared response sheets within 18 seconds of the presented instruction. The background noise started about 30 seconds before the speech signals were presented.

Results

Results were analysed using repeated-measures ANOVA (IBM SPSS, versions 23 and 28) with "Room" (good vs poor) and "DSF" (on vs off) as within-subject factors.
Potential effects on children's ratings of listening effort were evaluated using Wilcoxon signed-rank tests.

Individual Testing
None of the 56 children showed obstruction of the tympanic membrane or acute middle ear problems. The children had Pure tone audiometric air conduction hearing thresholds of ≤ 20 dB HL in the frequencies tested (between 0.125 and 8 kHz), with 2 exceptions, who withdrew from the study. Monaural SRTs in noise for 53 of the 56 children were within the reference area for primary school children 26 for the OLKISAf . The SRTs for the remaining 3 children were only 2 dB SPL above the reference. Thus, no child was excluded due to performance on the OLKISAf.

Eight children had values below 40 (below average) on the TROG-D test assessing the children's language comprehension and receptive grammatical skills. Three of them were excluded after consultation with a parent since they showed problems in the training for the complex oral instructions test.

Group Testing
A further three children did not participate in the group testing due to withdrawal from study or illness, resulting in 50 children participating in the group testing. In total, the data from 49 of the 50 children participating in group testing were included in the analysis of **speech perception**. One participant was excluded from the analyses because of extremely low performance in one condition of the speech perception task and mixing up of response sheets in the listening comprehension task. This was indicative of overload and/or lack of concentration.

For **listening comprehension**, 48 children were included in the analysis. A further participant was excluded from the analyses due to a sneezing attack which led to incomplete entries on the answer sheets.

On average, **speech perception** performance improved by 7% (0.02 standard error) with Roger SoundField on, irrespective of classroom reverberation. Inspection of individual data revealed that, with Roger SoundField "on", 53% (26) of the children performed better in the good classroom and 57% (28) performed better in the poor classroom.

Roger SoundField also improved **listening comprehension** performance scores by 2.0 points ($p < 0.01$), irrespective of classroom reverberation. Thus, a significant main effect of Roger SoundField was revealed, resulting from better performance in the conditions with DSF "on". Inspection of individual data revealed that, with Roger SoundField "on", 50% (24) of the children performed better in the good classroom and 60% (29) performed better in the poor classroom.

Subjective **listening effort** was rated lower in both good and poor classroom conditions with Roger SoundField "on" by most children. In contrast, in conditions without Roger SoundField, the majority of children experienced medium to high listening effort. The results are depicted in Figure 3 below.

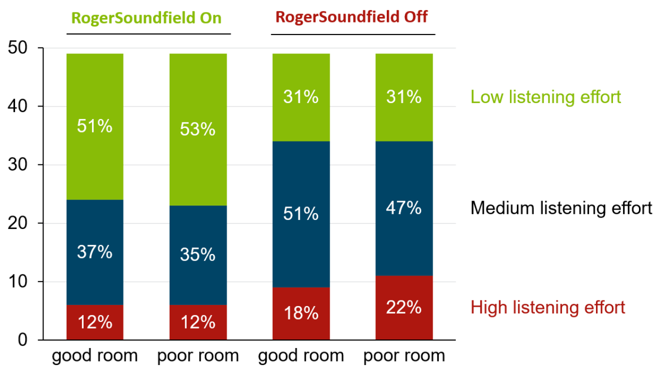


Figure 3: Response frequencies for children´s ratings of listening effort with respect to experimental condition. Conditions are 'good classroom' T20 = 0.48 s and 'poor classroom' T20 = 0.83 s, with and without DSF.

The results indicate that Roger SoundField improves speech perception and listening comprehension and reduces perceived listening effort in all reverberant classrooms tested.

Conclusion

Noise and reverberation conditions used in the present study do not represent unrealistic listening situations for school children. Mean reverberation times of up to 1 second and more are not uncommon in primary school classrooms, and noise levels during school lessons often exceed 55 dB(A)[3, 4] depending on the classroom activity (e.g. silent individual work or group work).

It may be concluded that Roger SoundField represents an opportunity to enhance speech perception and speech comprehension for school children by raising the level of the teacher's voice and making or keeping it audible.

From a practical viewpoint, this means that Roger SoundField can improve the situation for the majority of the children by improving the SNR. Improving speech intelligibility seems to be key to establishing good teaching conditions for young school learners in classrooms with favorable but also unfavorable reverberating times.

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