Phonak Field Study News.

Improved objective speech transmission in noisy, reverberant rooms with Roger™ SoundField.

The benefits of Roger technology for speech intelligibility in noise and over distance are well established. Technical measurements in this study aimed to pre-select optimal acoustic room parameters of Roger SoundField for children with normal functional hearing in noisy, reverberant classrooms. Speech Transmission Index (STI) assessment in simulated classroom acoustics demonstrated that Roger SoundField may improve speech intelligibility for various acoustic conditions.

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Key highlights

- The Speech Transmission Index (a measure of the quality with which speech is transmitted from speaker to listener) improves and is categorized as "excellent" with Roger SoundField (compared to without), according to the STI categorization, DIN EN ISO 9921.
- Roger SoundField showed improved STI values, indicating improved objective speech transmission in reverberant classroom-simulated rooms.

Considerations for practice

- The use of Roger SoundField in classrooms with poor acoustics has potential to improve speech intelligibility for students.

Introduction

Children listen differently than adults. The auditory network in a child's brain is not fully developed and, their listening skills are immature until around 15 years of age.2 In situations where acoustics are poor, background noise is excessive, or when a speaker is talking from a distance, adults can use their life and language experience to fill in the blanks in a message. In contrast, young students are still learning language and have limited life experience to draw from.[3] This can compromise their ability to learn, increase their listening effort and reduce their academic achievements.[4]

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 0.6 seconds standard by twofold or more.[5] This can significantly reduce speech recognition and understanding for the listener.[6] For these reasons, it is important to ensure that within the classroom, all children have access to intelligible speech produced by teachers, fellow students and others.

The benefits of soundfield amplification systems in the classroom have been well documented.[7] 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.[4, 8] Studies have documented an increase in the student's ability to better attend and focus on a specific task by as much as 16%.[4] Furthermore, improvements in phonemic awareness and phonic skills for reading have been noted.[9]

For teachers, being heard and commanding attention in the classroom, without having to raise their voices means less vocal strain and fatigue at the end of each day.[10, 11] Since these systems enhance the quality of the teacher's voice over background noise and distance, children with hearing loss, 2nd language learners, those with attention deficit disorders or developmental delays are also no longer physically limited to where they sit in the classroom.[11] These solutions have also been shown to have a positive impact on the behavior and attitudes of students, their participation and engagement[8, 12, 13] in the classroom, as well as their self-esteem development while learning.[14] Since children willingly accept these systems, stigmatization of children with any learning challenges is reduced.[15]

Recent global events have further confounded the challenge of listening in the classroom as a result of Covid-19 safety protocols of social distancing and wearing face masks.

A solution like Roger SoundField, with its adaptive microphone technology, can help to overcome these challenges and optimize audibility for classroom learning.

Previous studies have shown the ability of Roger technology in conjunction with personal assistive listening devices, to improve speech intelligibility.[4, 16, 17] However, the extension of research with Roger SoundField for students whose hearing falls within normal range is more limited. This is why we sought to better understand the benefit of Roger SoundField in the classroom for all students.

The primary objective of this study was to evaluate the influence of the Roger Dynamic SoundField system on the objective value STI in a noisy and reverberant classroom environment.

Methodology

Equipment

Room acoustic measurements for several room conditions were performed in the Communication Acoustic Simulator (KAS) laboratory room, at the Hörzentrum Oldenburg. The KAS is equipped with a digital reverberation system which can be used to simulate various classroom acoustic situations that differ in terms of reverberation time as well as early reflections.[18]

Four reverberation conditions in the 125 to 4000Hz frequency range were measured. The resulting mean reverberation times were:

- KAS OFF – 0.35 seconds
- KAS ON in good acoustics – 0.48 seconds
- KAS ON in poor acoustics – 0.83 seconds
- KAS ON in very poor acoustics – 0.97 seconds

Eight tables with 2 chairs at each, were arranged in 3 rows within the room (figure 1). A microphone was positioned in the center of each chair at 1.20 m above the floor, simulating the ear height of a seated student. With pink noise as the excitation signal, impulse responses were measured in the furnished KAS room at the 16 microphone positions.

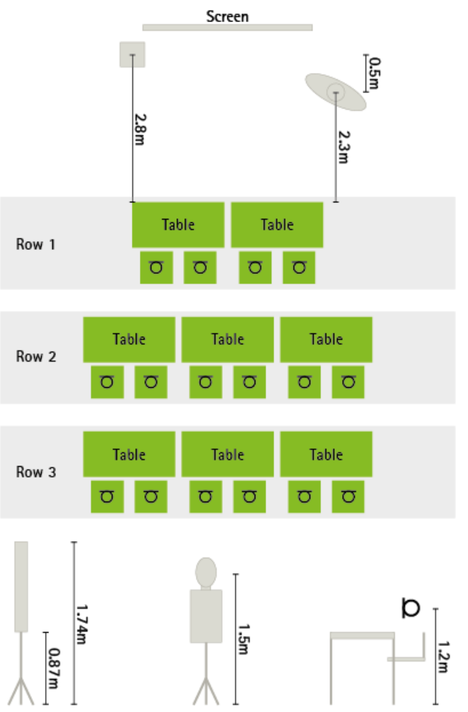

Figure 1. Experimental setup for impulse response measurements in the KAS in Hörzentrum Oldenburg.

Two sound conditions were compared as indicated in Table 1 below:

1. Roger SoundField OFF: Provided by a mouth simulator only, built into an artificial head – HATS 4128-C-001 by Brüel & Kjaer. This provided a signal with an equivalent continuous sound level of 65 dB(A). The sound level reaching the microphones in Row 1 was 57 dB(A) and 54 dB(A) in Row 3, respectively.
2. Roger SoundField ON: Roger DigiMaster 5000 with its 12-speaker in-line array and audio input of the Roger Touchscreen Mic. This generated a signal with an equivalent continuous noise level of 63 dB(A). Roger SoundField ON resulted in a 3 dB increase in the level of speech signals reaching the microphones, i.e. 60 dB(A) in Row 1 and 57 dB(A) in Row 3, respectively.

	SoundField OFF	SoundField ON
Row 1	57 dB(A)	60 dB(A)
Row 3	54 dB(A)	57 dB(A)

Table 1. Sound levels reaching microphones in Row 1 and Row 3 for SoundField OFF versus ON

Procedure

The Speech Transmission Index (STI) was calculated from measured impulse responses at the different chair positions and the equivalent continuous sound level was determined. The influence on the STI of different noise signals, noise levels and reverberation times in the rooms was measured, according to DIN EM ISSO 3382-1.

The STI is a measure of the quality with which speech is transmitted from the speaker to the listener. It indicates the transmission quality as a numerical value in the range from 0 (bad/unintelligible) to 1 (excellent) (or < 0.3 and > 0.95 respectively, according to DIN EN ISO 9921). STI is a room acoustic measurement method only suitable for analyzing linear, time-invariant systems or rooms, and it describes the speech intelligibility to be expected by the listener.[21]

In order to circumvent the influence of the dynamic behavior of the Roger system, its adaptive gain function was bypassed and impulse responses for Roger SoundField linear signal processing were measured. This was done by feeding the input signal electrically through the 3.5 mm direct signal input on the Roger Touchscreen Mic. Three manual easy gain levels were measured, 0, +2 and +4. This allowed for a direct comparison of STI for Roger SoundField OFF vs ON, at specific background noise levels.

The influence of noise on the STI was determined for 2 stationary noise signals (male and female Olnoise). Olnoise is a synthesized mixture of time-shifted utterances derived from OLSA test sentences. It was decided to use Olnoisef (female) for further investigations, since this had the best masking effect for the speech materials used, and for the fact that the majority of primary school teachers are female.

Results

Results were analyzed using repeated-measures ANOVA (IBM SPSS) with the following within-subject factors:

- Roger SoundField OFF vs ON
- Room acoustics reverberation times for KAS OFF (0.35 sec), KAS ON Good (0.48 sec), KAS ON Poor (0.83 sec) and KAS ON Very poor (0.97 sec)
- Levels of background noise (Olnoisef) as follows: 23 dB(A) ground floor, 45, 50, 55, 60 and 65 dB SPL.

Significant main effects for all 3 factors were found, as well as significant interactions between Roger SoundField and room acoustics, Roger SoundField and noise level, and between room acoustics and noise level (all $p<0.001$).

The results indicate that Roger SoundField is beneficial in reverberant rooms. Mean STI generally decreased with increasing noise level (figure 2) and became worse with increasing reverberation time (but posthoc comparison of good and poor classroom acoustics did not show a significant difference). Roger SoundField led to significant mean STI improvement of 0.048 for the stationary Olnoisef stimuli.

- Roger SoundField interaction with room acoustics:

An increase in STI was seen for Roger SoundField ON, in comparison to OFF. This effect was about the same for the acoustic conditions KAS OFF, KAS ON in Good and Poor acoustics, and was larger for the KAS ON Very poor classroom acoustics condition.

- Roger SoundField and noise level interaction:

For conditions without noise, mean STI values of between 0.72 (good) and 0.78 (excellent) were obtained. With Roger SoundField ON, STI showed even further improvement. Mean values between 0.75 and 0.8 were noted – i.e. "excellent" according to the DIN EN ISSO 9921 STI categorization.

The difference in STI for Roger SoundField ON vs OFF grew with increasing noise level. However, for background noise levels above 55 dB SPL, STI scores with Roger SoundField ON lay below 0.45 ("poor" to "bad/unintelligible"). This indicates that Roger SoundField improves STI for all conditions, although only marginally in adequate room acoustics and low background noise levels.

- Room acoustics and noise level interaction:
  The difference in STI for rooms with increasing reverberation times decreases significantly with increasing noise level until it vanishes for background noise levels of 60 dB(A) and higher. This interaction confirms validity of the setup[22, 23].

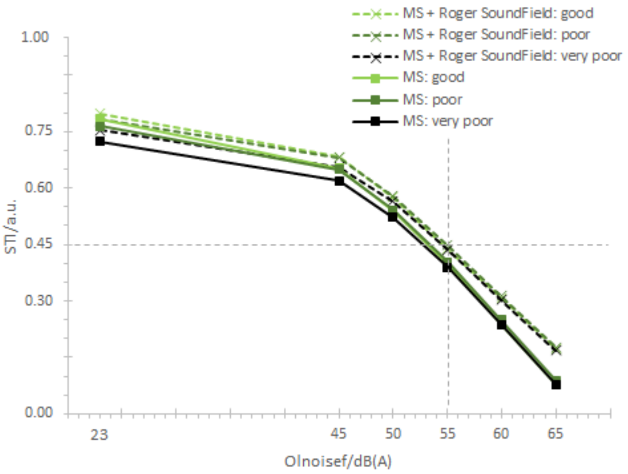

Figure 2 Average STI across all chair positions using Olnoisef in Good (0.48 sec), Poor (0.83 sec) and Very poor (0.97 sec) reverberation room conditions, and for Roger SoundField OFF vs ON. MS = Mouth Simulator

Conclusion

With classroom acoustics often failing to meet the American Speech-Language-Hearing Association,[15] and the German recommendations of the DIN 18041, Roger SoundField represents an opportunity to enhance speech intelligibility for all students, ensuring that the teacher's voice remains audible, regardless of the student's seating position. The substantial impact of noise and reverberation on children's speech perception was documented in several papers.[23, 24, 25, 26]

With Roger SoundField, improvements in STI of between 0.04 and 0.052 (on average) were shown. Overall, the results of this study indicate that Roger SoundField has the potential to improve speech intelligibility for all conditions, and especially in rooms with higher reverberation times.

Since assessment of speech intelligibility for research purposes can be arduous, especially for young learners, the results of this study enabled the researchers to pre-select the optimal room acoustic parameters to use. In order to investigate clinical relevance, in a follow up study, the performance of Roger SoundField will be tested with children with normal functional hearing, in different room conditions, using the classroom acoustics and noise level parameters defined in this study. In the follow-up study four conditions will be investigated: KAS ON for good and poor classroom acoustics, as well as Roger SoundField ON and OFF in background noise of 55 dB(A).

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Authors and investigators

Internal investigator

Dr. Latzel studied electrical engineering in Bochum and Vienna in 1995. After completing his Ph.D. in 2001, he carried out is PostDoc from 2002 to 2004 in the Department of Audiology at Giessen University. He was the head of the Audiology department at Phonak Germany from 2001. Since 2012, he has been working for Sonova HQ in Switzerland. His current role is Senior Expert Clinical Studies.

External investigators

Dr. Meis received his Ph.D. in Medical Psychology in 1997 from Ludwig Maximilians University Munich. He was a postdoctoral fellow at the Oldenburg Graduate School of Psychoacoustics. In his scientific role he coordinates publicly funded projects, as well as contract research, such as Health Services Research, in the domains of Audiology, Quality of Life, Man-Machine Interaction, and Requirements Analyses. He was engaged in standards committees, such as the DIN 18041 ("Acoustic quality in rooms – Specifications and instructions for the room acoustic design").

Dr. Zokoll focuses on hearing and audio systems evaluation studies, and audiological research. She joined the Hörzentrum team in 2017, after research activity at the University of Oldenburg in the field of audiology and speech audiometry. Melanie studied biology at the Technical University Munich, and has a doctor of natural sciences degree from Oldenburg University, as well as a background in psychoacoustics and neurosciences.

Author

Tania qualified as an Audiologist the University of Cape Town, South Africa. She gained diverse experience in clinical practice, working within both the public and private sectors in the United Kingdom, before joining Phonak in 2013.