WHITEPAPER
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Enhanced learning with EduMic

SUMMARY

Hearing devices for children and teens with hearing loss have evolved significantly over the past few years. Despite these advancements, children and teens with hearing loss still face barriers to good listening when learning in their classroom at school. Remote microphone systems (RMS) have been used to improve auditory access to the teacher's voice and while this technology has become very sophisticated in its feature set, little attention has been given to the importance of RMS design and usability by school-based professionals.

This whitepaper introduces the new educational RMS, EduMic. It describes the needs of children with hearing loss in the classroom, the technology of EduMic and the testing and research completed.

Results of the usability testing on teachers indicate that EduMic facilitates easy transition and consistent use for classroom teachers working with children with hearing loss. For children, EduMic shows improvements of speech understanding in both noisy and reverberant acoustic environments. Additionally, EduMic shows similar benefit compared to the use of traditional RMS, and in more challenging environments EduMic even shows better benefit for adults. With the use of EduMic, children can experience enhanced learning because of the benefits concerning improved speech understanding in classroom environments.

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Introduction

Noise in Classrooms: Barriers to Learning

Today's classrooms are primarily auditory-verbal environments where the assumption is that the teacher will lead the lesson using oral, spoken language, and that all students in the classroom can hear them. However, this may not be the case, particularly for those children with hearing loss. The classroom acoustics may interfere with the access to good speech understanding and impact learning (Sato & Bradley, 2008). The difficulties created by classroom noise have been understood for some time. The American Acoustical Society of America and the American National Standards Institutes (ANSI) have since 2002 made recommendations for classroom noise in unoccupied classrooms, suggesting it should not exceed 35 dBA. Unfortunately, while many schools have included this standard in the construction of new schools, there is no formalized strategy to ensure implementation. This becomes problematic as research has shown that children need quieter conditions and better signal-to-noise ratios than adults to have good speech understanding (Bradley & Sato, 2008). This is because children with developing language and auditory systems have smaller vocabulary size and are unable to rely on the redundancy of language to fill in missing words (Neuman, Wroblewski, Hajicek, & Rubenstein, 2010). Studies have shown that an inability to understand the teacher due to poor listening conditions directly impacts the learning of new concepts (Yang & Bradley, 2009; Leibold, Hillock-Dunn, Duncan, Roush, & Bess, 2013). Mental energy and listening effort are also much higher when poor acoustic conditions exist (Bess, Gustafson, & Hornsby, 2014; McGarrigle, Gustafsson, Hornsby, & Bess, 2019). In addition, Klatte, Lachmann, & Meis (2010) found that many students did not understand the impact of noise on their classroom listening and therefore did not know when they were at risk for poor speech understanding.

Remote Microphones: Auditory Accessibility for Children and Teens with Hearing Loss

Remote microphone systems (RMS) are a technology that has successfully been used for individuals with hearing loss for decades. The operation behind all RMS is essentially the same; by placing a body-worn microphone close to a speaker's mouth, their voice can be transmitted to a receiver worn by a person with hearing loss. When the speaker's voice is picked up by the microphone placed close to their mouth, a favorable signal-to-noise ratio (SNR) is created. The result is that the RMS can overcome the negative effects associated with background noise, reverberation, and distance. This improvement is important as research has shown that background noise, reverberation, and distance in elementary school classrooms interfere with verbal communication between the teacher and student (Bradley & Sato, 2008). The American Academy of Audiology (2008) has developed an evidence-based clinical practice guideline for the management of children and adults with hearing loss. As part of this guideline, they have endorsed the use of RMS as a solution to manage challenging listening environments.

While there have been advancements in hearing technology such as sophisticated directional microphones and advanced signal processing, the use of RMS with hearing devices continues to provide superior speech understanding compared to the use of a hearing device alone (Wolfe et al., 2013). Hagen and colleagues (2004) completed a study and their aim was to measure the experiences of school-aged children with hearing loss and RMS, and their perspective on being in a classroom with and without acoustic treatments. They found that the use of RMS was critical to support the students and their good classroom listening. In addition, RMS also contributed to the student's learning and helped to reduce stress among both students and teachers (Hagen Kahlert, Hemmer-Schanze, Huber & Meis, 2004). Benefits of RMS have also been documented for preschool children with hearing loss. In studies in the United States and the United Kingdom, educators reported that the use of RMS enhanced preschool-aged children's academic performance, speech and language development, behavior, and attention (Nelson, Poole, & Munoz, 2013; Mulla & McCracken, 2014).

While the use of RMS and its applications has primarily focused on those environments where distance and background noise are most prevalent (e.g., school classrooms), there is a small body of research that has looked at use of RMS in home environments. Although the number of studies is small, results have been encouraging. Parents and caregivers noted several positive outcomes that included improvements in overhearing, incidental learning, and clarity of speech, as well as an increased number of imitations (Mulla & McCracken, 2014). Benitez-Barrera and colleagues also investigated the impact of remote microphone use at home but focused on how it affected access to caregiver talk (Benitez-Barrera, Angley, & Tharpe, 2017). The results of their study showed that when an RMS was worn by the parent or caregiver in the home, children with hearing loss had access to about 42% more talk of their parents or caregivers.

Teachers' Adoption of Remote Microphone Technology: The Importance of Usability

The use of technology in the classroom to support student learning has increased significantly over the past ten years. Computer-based interactive whiteboards, learning stations, and augmentative communication technology are all aimed at enhancing the learning of students with typical and special needs. While these systems are technologically advanced, the usability and feasibility for teachers may not be thoroughly understood. Researchers have investigated new classroom technology use and how teachers perceived and adopted it (Aldunate and Nussbaum, 2013; Mundy, Kupczynski, Kee, 2012; Ertmer, Ottenbreit-Leftwich, and York, 2007). The technology adoption model is a model which describes two elements that effect technology adoption; perceived usefulness and ease of use (Davis, 1989). These were critical factors that influenced successful use of technology by the classroom teacher. When teachers are provided with the resources to help them understand the purpose and use of the technology, they were more likely to use it with their students. For example, a study in Taiwan found a strong relationship between teacher training and successful implementation of the technology (Hsu, 2010). According to Mundy et al. (2012), one of the greatest barriers to technology use by classroom teachers is when they lack knowledge on how to use it.

Aldunate and Nussbaum (2013) completed a study where they looked at a classroom teachers' process of adopting classroom technology which examined the effect of ease of use and teacher attitude. Results showed that the more complex technology had an impact on teacher adoption. When teachers perceived technology to be difficult to use, it was more likely to lead to abandonment than use of a simpler technology.

Teacher adoption of hearing technology was investigated by Nelson, Poole and Munoz (2013). Their study aimed to understand the usability of RMS by educators working with preschool children with hearing loss. They found that 45% described the remote microphone system as being difficult to use and 60% found the remote microphone uncomfortable to wear. While the researchers did not measure the impact of these factors on adoption, data on other technology use in the classroom suggests that these conditions are not optimal to promote device uptake.

The technology of EduMic

What is it?

EduMic is an educational RMS built on the Velox S™ platform that allows transmission of a signal from the teacher to one or more students. It transmits seamlessly to compatible hearing devices with integrated receivers on the Velox™ and Velox S platform; this includes Oticon Opn Play™, Xceed Play as well as Opn,

Figure 1. EduMic design and functionality

Opn S™, and Siya. This creates a partnership between the Oticon hearing aids on the children's ears and the EduMic on the teacher.

Figure 1 shows the design and functionality of EduMic. While the primary function of EduMic is the microphone and transmitter mode, EduMic has more modes useful in and outside the classroom. EduMic can be connected to stream stereo audio via a jack cable, it can be connected to Frequency Modulation (FM) and Digital Modulation (DM) via a universal receiver, and it can function in telecoil mode. LED indicators are placed on top of the EduMic to help indicate the status of the device including notifications, alerts, and which mode they are in.

The EduMic hardware is built to withstand the potentially rough environment in a busy classroom. EduMic has undergone rigorous testing to ensure robustness and durability, which is of great importance when providing a device for use with children. Because the modern classroom can host a Wi-Fi heavy environment, testing ensured that the EduMic's transmission of the teacher's voice is strong and stable. It is important that teachers as well as students can enjoy full-day use of the EduMic during a school day and this is provided with a 10-hour battery life.

How does it work?

The EduMic transmitter uses a proprietary digital audio system to share information with compatible Oticon hearing devices. EduMic utilizes 2.4 GHz to complete the digital broadcasting. EduMic converts the teacher's voice from an analog signal to a digital signal, and these small data packages are transmitted to the student's receiver where they are decoded. EduMic preserves speech, operating within a wide bandwidth of 150 Hz to 10000 Hz.

Being built on the fast Velox S platform means that EduMic can use advanced signal processing including OpenSound Navigator™ technology. In EduMic, OpenSound Navigator has been optimized for use as an educational RMS; Transition is set to the highest possible level and the noise reduction is always at -10 dB, which provides the greatest amount of help in both simple and complex sound environments. The optimization of OpenSound Navigator is done to ensure prioritization of the teacher's voice, while the technology cleans the signal in a similar way as when functioning in hearing aids. This is completed by analyzing, balancing, and applying noise removal to the streamed signal (see Le Goff et al., 2016, for technical details). To improve the signal in outdoor environments, EduMic features Wind Noise Management. This works by cleaning the signal from the wind noise created by the "swirl" which can occur at the microphones.

EduMic is a coordinated partnership with the Oticon hearing aids on the Velox and Velox S platform. This means high quality speech signals for the child which provide access to incidental learning (Ng, 2019, Oticon Whitepaper) and allowing for improved SNR that the children need from the teacher. Technical measurements performed with EduMic confirm this across varying SNRs in a simulated classroom set-up.

Transparency of EduMic

In 2008, the American Academy of Audiology released a clinical practice guideline for the use of RMS for children and adults with hearing loss. This document outlined considerations for candidacy, selection, fitting, and verification or transparency measures of these devices. As Eiten and Lewis (2010) noted, transparency measures for RMS and hearing aids are a crucial part of obtaining optimal amplification for children with hearing loss. This is because like hearing aids, RMS are technologically advanced pieces of equipment. The intent behind carrying out transparency measures with these combined systems is to confirm that the hearing aid is managing speech from the RMS as expected, and audibility and comfort are preserved for the child. Volume or gain of the RMS can be adjusted to achieve an equal output for speech at the hearing aid microphone and the RMS. This allows for the balance of hearing the speaker with the RMS while still hearing yourself and others around you with your hearing aid (Eiten and Lewis, 2010).

The EduMic has been calibrated which will allow transparency measures to be completed using coupler and on ear measures. When using Oticon Velox or Velox S BTEs, it is recommended that you use test box coupler measurements, connecting the hearing aid to the 2cc coupler and run simulated measurements with recorded speech. For Oticon Velox or Velox S RITE devices with open and closed molds, "On Ear" or "Real Ear" measures using recorded speech are recommended to ensure we are getting a stable signal, where loudness and signal integrity is consistent. Verification guides are available that outline the procedure for completing these measurements (Oticon, 2019a; Oticon, 2019b).

Studies on EduMic

At Oticon, we value scientific evidence, particularly those that support clinician understanding and decision making when managing children with hearing loss. That is why research has always been given top priority when we introduce new hearing technology. In this section, we describe studies with the EduMic remote microphone system that investigated the experiences of classroom teachers, teachers of the deaf and hard of hearing, and individuals with hearing loss.

EduMic usability study – teachers' perceptions

Introduction

Teachers who have children with hearing loss in their classrooms need a flexible, intuitive, and easy-to-use classroom solution that will promote consistent usage. During development, usability testing is important to investigate how effective and easy to use a product is. Teachers were included in a test of usability of EduMic and asked to do the same tasks using a competitor solution.

> "I prefer the EduMic because it is easier to use, smaller and lighter.....I like the wearing options of the EduMic on the lanyard or on the clip"*
>
> *Teacher from usability study*

Method

Twenty teachers (ten teachers of deaf and hard of hearing, nine elementary school teachers, one high school teacher) were recruited from the greater Toronto area in Ontario, Canada.

The test included open questions, task completion, and questionnaire ratings. To explore usability, the test included five commonly performed tasks that the teachers had to complete and then rate ease of use on a 5-point Likert scale where 1 = very easy and 5 = very difficult. The tasks included the following: turn on, mute, pair with hearing aids, connect with jack plug, place lanyard around neck at correct distance. The teachers were also asked to rate the wearing comfort of the two solutions on a 5-point Likert scale where 1 = very comfortable and 5 = really not comfortable. Last, the teachers were asked to share their opinions on both RMS regarding look, design and preference.

Results

Regarding experience, 85% reported having experience using RMS, while 60% were currently using RMS.

An overall score was calculated based on the average of the five tasks of each participant and was calculated for both RMS solutions. The existing competitor solution reached an average score of 1.80 while the new solution a score of 1.47. The EduMic was rated as easier to use than the competitor system with this difference

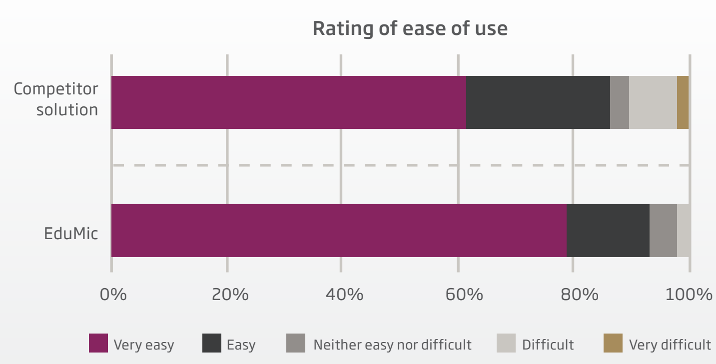

Figure 2. Average rating of ease of use

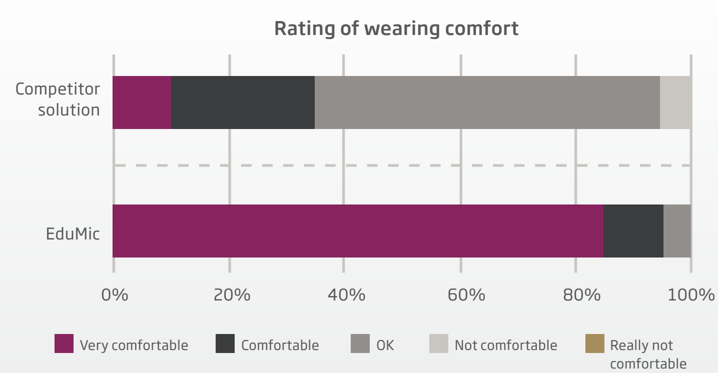

Figure 3. Rating of wearing comfort

* These testimonials represent the opinion of the concerned individuals only and may not be representative of the experience of others. The participants have not been paid for their participation, but received a gift card to offset their travel expenses. The testimonials may not be indicative of the future performance or success of any other individuals.

being significant, t(19) = 4.21, $p < .001$. The distribution of ease of use ratings can be seen in figure 2.

The teachers also rated the wearing comfort of the two RMS, figure 3, where EduMic was rated as very comfortable by 85%, with only 10% of teachers rating the competitor solution as very comfortable.

After rating the comfort of the two RMS solutions, teachers were asked to choose if they had a preference in term of wearing comfort; 100% preferred EduMic. When asked about which solution was most discreet, 85% chose EduMic. When participants considered preference of look and design, 84% reported preferring EduMic, 5% preferred the existing solution and 11% had no preference.

Open-ended questions were asked and included those that inquired about overall perception of the two RMS solutions and if they had a preference of either system. EduMic was reported as preferred solution for 80% of the participants. Emerging themes for EduMic included the ease of use, wearing comfort, and look and design.

Conclusion

To ensure the adoption of RMS technology in the classroom usability testing can be done throughout the development of a new device. Based on results from the teachers participating in the present usability test, the EduMic provided the opportunity for easy transition into the classroom. The teachers reported that EduMic was easy to use and comfortable to wear. These are essential elements to ensure consistency in usage and provide the SNR benefits that children with hearing loss need to support auditory access.

Benefits of EduMic use on speech understanding in noise and reverberation

Introduction

This independent study was led by principal investigator Dawna Lewis, Ph.D., at Boys Town National Research Hospital in Omaha, Nebraska. Described are preliminary findings from part of a larger study. Full study results are expected to be presented by Dr. Lewis in a conference presentation and/or publication in Spring 2020.

> "I am excited to see the EduMic – it's new design – because it is more discreet. This is very important for the self-esteem of the students"
>
> *Teacher from usability study*

The purpose of this study was to investigate the benefits of remote microphone technology in complex listening environments for children who are hard of hearing. This will be completed by evaluating speech understanding in school-aged children when using their hearing aid(s) alone and hearing aid(s) with the EduMic.

Methods

Twenty-one children were recruited from the Boys Town research volunteer database and Audiology clinics, and invited to participate in the study. The children had a) permanent hearing loss (PTA = 44.5 dB HL (range: 13.75-85)), b) unaided better ear speech intelligibility index of less than or equal to 80%, c) were aged seven to eighteen years of age, d) used English as their primary spoken language, and e) no identified cognitive disabilities.

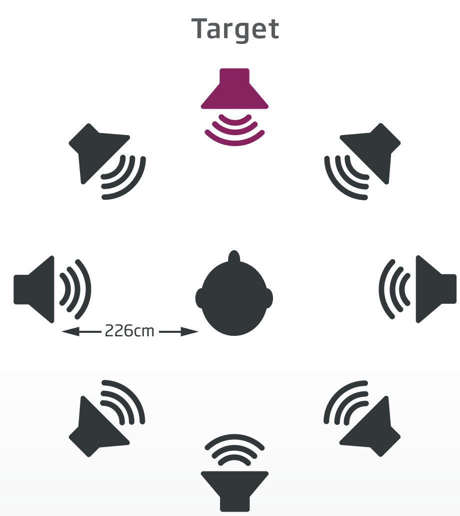

Figure 4. Spatial set-up of speech understanding task in noise and reverberation. Target presented at 0° and speech-shaped noise from surrounding loudspeakers.

Participants were fitted using the DSL prescriptive method with hearing aids that included Oticon Opn Play 1 BTE PP and Opn Play 1 miniRITE style hearing instruments. An EduMic was also fitted using the AAA Remote Microphone Guidelines (2008). A simulated classroom environment was created, with an eight-loudspeaker set up, placed equidistant (2.26 meters) around the listener (45 degrees apart), with the target speech coming from the loudspeaker at 0 degrees azimuth (see figure 4). Speech was presented at 60 dB SPL using the pediatric AzBio sentences in quiet, in speech-shaped noise, and noise and reverberation (RT = 400 milliseconds) with hearing aid only, and then repeated with hearing aid and EduMic. An adaptive task was used to evaluate the signal-to-noise ratio at which the children scored 50% on the sentence recognition task.

Results

Figure 5 shows speech recognition threshold across device configuration and acoustic environments. Results showed a significant effect of device on speech recognition ($F(1,20) = 183.2$, $p < .001$). On average, children were able to tolerate a 5.73 dB poorer SNR when using the EduMic. Analyses also revealed a significant effect of acoustic environment on speech recognition ($F(1,20) = 167.0$, $p < .001$). On average, children were able to tolerate a 5.12 dB poorer SNR in the noise-only environment than in the noise plus reverberation environment. There was no interaction between device and acoustic environment ($p > 0.05$).

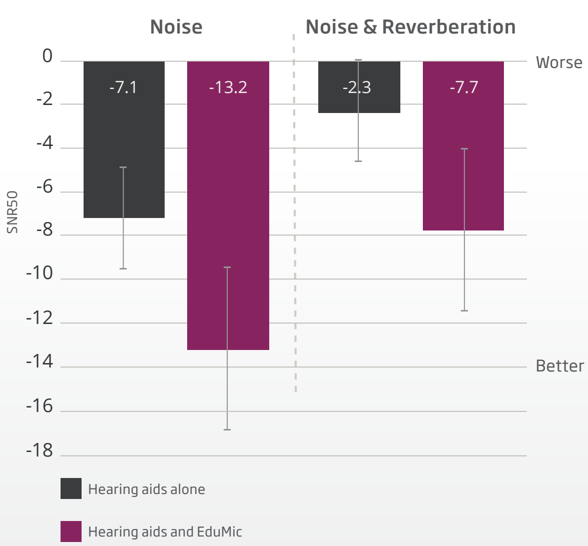

Figure 5. Speech recognition threshold across device configurations and acoustic environments

"The EduMic is beautiful and it is light, I love that"

Teacher from usability study

Conclusion

The Oticon EduMic RMS improved speech understanding in children with hearing loss in both noise and noise plus reverberation environments. We can conclude that children using Oticon hearing aid built on the Velox and Velox S platform along with the EduMic will have improved auditory access to the speech of their classroom teacher in complex environments, even including reverberation compared to hearing aids alone.

Speech understanding benefit using different RMS technology

Introduction

For RMS, traditional technology has consisted of using FM or DM. With EduMic, the communication between the hearing aids and the remote microphone is completed using 2.4 GHz BLE. The purpose of this study was to investigate speech understanding using traditional RMS technology compared to 2.4 GHz BLE in complex listening environments. This was completed by comparing the new EduMic with the Oticon Amigo RMS.

Method

Ten adults (mean age = 75.3) who were experienced hearing aid users and had bilateral moderate-to-severe hearing loss (mean PTA = 64.2 dB HL) were recruited for the test. They completed speech understanding tasks using the Danish Hearing In Noise Test (HINT). Each HINT list has 20 sentences that the participant repeated, with correctly repeated words being scored. Each test participant had a randomized order of HINT lists presented across all conditions. The test participants completed 13 HINT lists; 1 practice list and 1 HINT list per test condition. The test included the following twelve conditions; there were three device configurations each tested in four different acoustic environments.

The three device configurations were:

- Hearing aid + Amigo
- Hearing aid + EduMic.
- Hearing aid only

The four acoustic environments had the following noise levels:

- 0 dBA (quiet)
- 55 dBA
- 65 dBA
- 75 dBA

Figure 6 shows the spatial set-up of the test. The participants listened to HINT sentences from a front speaker with a speech level of 65 dBA. The noise source was diffuse noise presented from four speakers; two speakers beside the test participant, and two placed beside the mannequin presenting the target speech. Participants were fitted with Opn S1 BTE PPs to match their current hearing aid fitting.

Results

Figure 7 shows speech understanding score across noise level and device. Statistical analyses showed significant effect of noise level, $F(3, 27) = 229.7$, $p < .001$, and device, $F(2, 18) = 110.7$, $p < .001$, and significant interaction effect, $F(6, 54) = 915.2$, $p < .001$.

Further analysis showed that in quiet, speech understanding scores between devices did not significantly differ. However, speech understanding, as indicated by the percentage of words correctly repeated, were significantly lower for the conditions where noise was in the acoustical environment (input level 55, 65 and 75 dBA) for the conditions where participants wore hearing aids only compared to both of the RMS. Participants scored similar percentages when using both Amigo and EduMic at input levels 55 and 65 dBA. However, at input level 75 dBA (at -10 dB SNR), participants scored significantly more words correctly when using the EduMic compared to the use of the traditional remote microphone.

Conclusion

The present study confirms the negative impact of noise in the environment; results show that with increasing noise levels, speech understanding decreases. When noise was present in the acoustical environment, speech understanding was significantly lower for the conditions where participants relied on their hearing aids alone, and the use of RMS provided a substantial difference.

In specifically challenging environments (e.g. like those found in classrooms), we found that the use of EduMic improved speech understanding and was better when compared to traditional RMS technology.

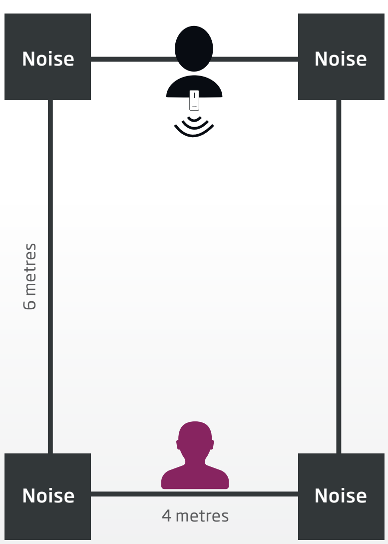

Figure 6. Spatial set-up of speech understanding task comparing RMS technology. Listener (magenta) is facing the mannequin (black) presenting target speech with surrounding loudspeakers presenting noise

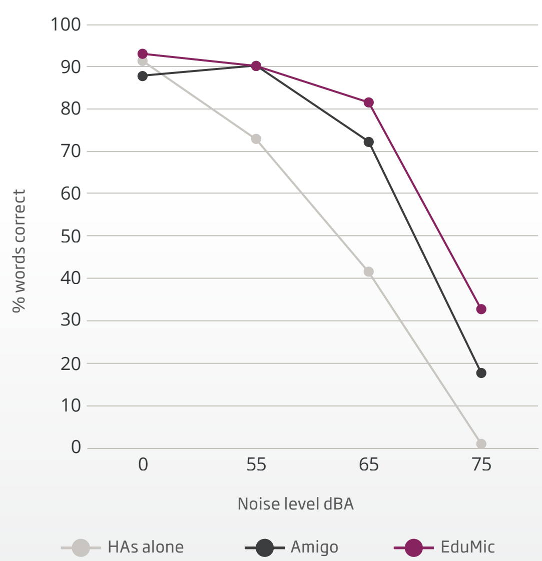

Figure 7. Speech understanding across noise level and device

Summary and call to action

The use of RMS is a crucial component for auditory accessibility for children with hearing loss. It is recommended for children using amplification to help improve speech understanding in complex listening environments that are typical of today's classrooms. The results of the study investigating speech understanding across SNRs supported this, where hearing aids alone resulted in the poorest speech understanding across different noise levels. The study also found that the EduMic provides equal or greater benefit than traditional RMS technology, with significantly greater benefit in the noisiest condition. EduMic can be considered as an excellent alternative to the conventional RMS, especially in classroom environments where noise levels are typically high.

Complex acoustic environments in a typical classroom setting includes both noise and reverberation. An independent study at Boys Town National Research Hospital showed benefits for children with hearing loss listening through EduMic in a typical classroom set-up, thus enhancing learning opportunities by providing better access to the teacher's speech.

"The EduMic is lighter, smaller, less bulky, and more discreet"

Teacher from usability study

Based on the teachers' perspectives from the teacher usability test, EduMic shows excellent potential for easy transition into classroom because of its ease of use and its wearing comfort. These features of EduMic are very important to ensure consistency in RMS usage, which allow the child with hearing loss to obtain improved SNRs that they need. The EduMic is a great balance of design and usability combined with advanced hearing technology to optimize the classroom experiences of children with hearing loss. Teacher adoption of RMS technology is critical for students' auditory accessibility and their school success.

With the use of EduMic, children can experience enhanced learning in a classroom because of the benefits concerning improved speech understanding in classroom environments.

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