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A Sound Foundation Through Early Amplification

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Legit innovations for teens

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Abstract

Classrooms are becoming ever more diverse and complex listening environments, where peer-to-peer learning comprises over 30% of the average school day. This evolution in teaching styles presents additional listening challenges for children with hearing loss who require very favorable signal-to-noise ratios in order to achieve adequate comprehension. This paper reviews recent work describing modern classroom environments and the challenges posed to children with hearing loss. A survey of high school students will be shared. This survey attempts to uncover attitudes and perceived benefits of users and non-users of technology that is available to improve auditory access in the classroom. Research findings suggest that users of remote microphone technology in the classroom perceive strong benefit, not just for hearing the teacher, but for hearing peers and media as well. Non-users do not like the look and feel of remote microphone systems and report poor benefit for understanding the teacher and peers. Finally, new innovations targeting teen users will be described, including the use of hearing aid directional microphones in tandem with remote microphone systems and remote microphones that offer table top solutions for improving access to small group conversations. Research findings with both of these innovations indicate that they are helpful for improving understanding of peers in classroom environments.

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Introduction

The iconic classroom chalkboard, along with many other traditional fixtures of the classroom environment, have become obsolete. This includes the entire notion that the teacher provides most of the spoken information while standing dependably at the front of neat rows of desks. Modern classrooms differ from this traditional model in numerous ways. Children often sit at small clusters of desks, rather than neat rows. They gather in discussion circles on the floor and move off in small groups to complete assignments in teams. Numerous forms of media including application software, interactive boards, computer exercises, and streamed internet content all provide audio content in the classroom. These dynamic scenarios challenge students with hearing loss who need access to these varied and changing inputs to be successful classroom learners.

In traditional classrooms, simple remote microphone systems were recommended to ensure consistent access to the curriculum for children with hearing loss. These systems were designed to deliver the teacher's voice to children's ears at a consistent level with priority over competing signals. A wireless microphone worn by the teacher (Figure 1) transmitted his or her voice via radio waves to students wearing miniature receivers (Figure 2) coupled to their hearing aids or cochlear implants. These systems were very effective at providing consistent and high quality access to the teacher's voice regardless of the background noise level or distance between talker and listener (Lewis, Crandell, Valente, & Enrietto Horn, 2004; Thibodeau, 2010; Wolfe et al., 2013; Thibodeau, 2014).

Figure 1. Examples of remote microphone systems that were worn by teachers to transmit their voice to children with hearing loss.

Figure 2. Depicts various wireless receivers worn by students on their hearing aids to improve access to signals, often the teacher's voice, broadcast from the wireless microphone.

One of the reasons for this evolution in the classroom layout and teaching styles is the adoption of Common Core State Standards by 42 states (Common Core State Standards, 2017). These standards identify the skills and knowledge that students should possess by the end of each grade to be prepared for college, a career, and life in general. Skills that should be explicitly taught as part of the Common Core are communication skills and teamwork/collaboration. As a result, teachers are required to bring collaboration into the classroom by assigning group work and other forms of peer-to-peer learning. These changes are not limited to the United States and, in fact, more dynamic, interactive teaching styles can be observed around the world. A recent study conducted by Phonak in schools in Europe, North America, South America, and Asia measured the time students engaged in various activities throughout the school day (Feilner, Rich & Jones, 2016). The results can be seen in Figure 3. Traditional frontal

instruction by the teacher accounted for only 22% of students' school day, while group work accounted for equally as much time and interactive lessons accounted for another 12% of the average day. These changes limit the effectiveness of remote microphones exclusively worn by the teacher throughout the school day and highlight the need for evolving technology that can meet the real-life needs of kids with hearing loss in school.

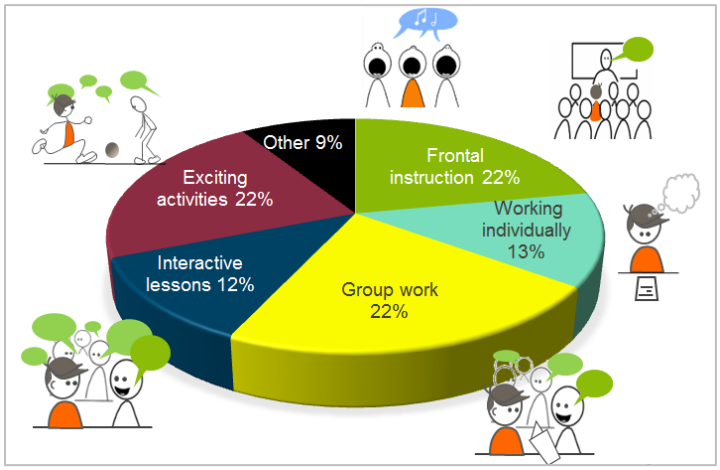

Figure 3. Pie chart showing the average amount of time that school children in 3 countries spend engaged in various activities. Consistent with the Common Core emphasis on group work and collaboration, 33% of time is spent in group work and engaged in interactive lessons, compared to 22% in frontal instruction by the teacher.

In addition to the variety of sources to which children must be attuned in the classroom, excessive noise adds additional challenges for children with hearing loss. The importance of favorable classroom acoustics for children with hearing loss is often acknowledged but not implemented or maintained to recommended standards. The American Speech- Language-Hearing Association (ASHA, 2017) reports that children with normal hearing require a +15 dB signal–to-noise ratio for children with normal hearing to understand spoken words clearly. However, children with hearing loss will have less than perfect word discrimination even in quiet and have been shown to understand less than 50% of words spoken at a +6dB SNR (Finitzo-Hieber & Tillman, 1978). Recent work by Cruckley, Scollie and Parsa (2011) showed that the long-term average sound levels for children in elementary and high school were over 60 dB, indicating that with the prevalence of elevated noise levels, the +15dB recommendation would often not be met for many children in the classroom. Additionally, the authors classified the time spent in quiet, speech in quiet, speech in noise, and noise alone. They reported that more than 90% of grade-schoolers' time and 80% of high-schoolers' time was spent in speech and noise. This indicates that directional microphones and remote microphones are needed to support speech understanding.

To further understanding of hearing aid performance in these challenging, mainstream classroom environments, researchers at Phonak undertook a study to identify when students heard and understood well and in what situations they struggled to hear (Feilner et al., 2016). Audio and video recordings were made and compared with interviews about the students' experiences. The student reports were also compared to hearing aid behavior throughout the day to evaluate when the hearing aids and their scene-dependent behaviors were facilitating successful communication and when opportunities existed for improvement. Several key findings were reported. First, there was far less frontal instruction than expected, and the amount of time spent engaged in interactive lessons increased as students got older. Second, there was a significant multi-media component with the involvement of several technologies in the lesson. Third, hearing difficulties reported by the students were more strongly correlated with teaching style than acoustics, and group work in particular was highlighted as an unsatisfactory listening condition for the students. These findings illuminated the need for more flexible remote microphones, especially for older students, in order to assist listening and understanding for multiple talkers and in changing classroom environments.

Because traditional remote microphones were designed to address the listening situation that now comprises only 22% of the typical school day, we wanted to explore how teens felt about these realities and the use of remote microphones. Eighty-six high school students between 13-18 years old who were candidates for remote microphone systems completed surveys in August and September 2016 as the school year commenced (Figure 4). Sixty per cent (n = 52) were male and 40% (n = 34) were female. Sixty-four per cent (n = 55) of students wore hearing aids, 5% (n = 4) wore cochlear implants, and 31% (n = 27) wore no primary amplification. The degrees of hearing loss of the participating students can be seen in Figure 5. The average degree of hearing loss of all surveyed was mild to moderate, and ranged from normal to severe loss (Figure 6). Seventy per cent (n = 60) of students responded that they had used remote microphones in the past and planned to use systems again this year. Twenty-four per cent (n = 34) of students had used systems in the past, but were not planning to remote microphone systems in the coming school year. Six per cent (n = 5) of students had never used a wireless system and were not planning to use one that year.

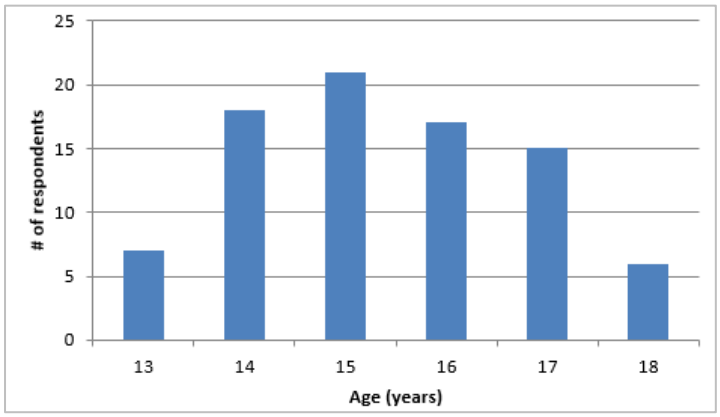

Figure 4. Distribution of survey respondents by age.

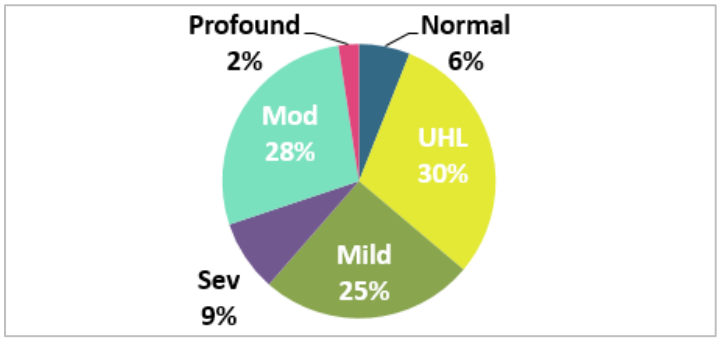

Figure 5. The degrees of hearing losses of the teen-age survey respondents

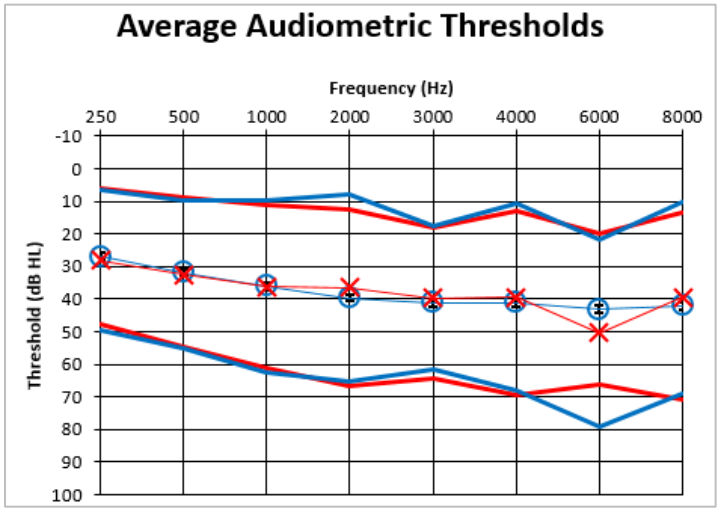

Figure 6. The average audiometric thresholds of surveyed teens. (x=left ears and o=right ears)

The reasons for use were explored with wireless system users. The students were asked to rate nine reasons on a scale of *extremely important* to *not important*. Their ratings can be seen in Figure 7. The strongest reasons given were (1) ability to hear the teacher; (2) ability to hear in noise; and (3) improves my confidence. The three reasons given the lowest ratings were (1) makes me less tired; (2) my parents make me use it; and (3) my teachers or audiologist make me use it. In addition, students wrote in reasons including "*connecting to video*," and "*keeps me from getting headaches*". A few students also wrote in "*I choose to use it*", seemingly to dispute the suggestion by two of the provided reasons that parents or teachers made them use it. The perceived benefit by situation was also explored for these wireless system users. A rating of benefit was provided for eight different situations. Ratings are shown in Figure 8. The situation that received the highest benefit rating was, predictably, listening to the classroom teacher. They also rated listening to peers and listening to media highly. It was also clear that students did not have access to the wireless system at home and during extra-curricular activities. In general, the teenage students seem to have successfully adapted these systems to a variety of classroom use cases including listening to media and peers.

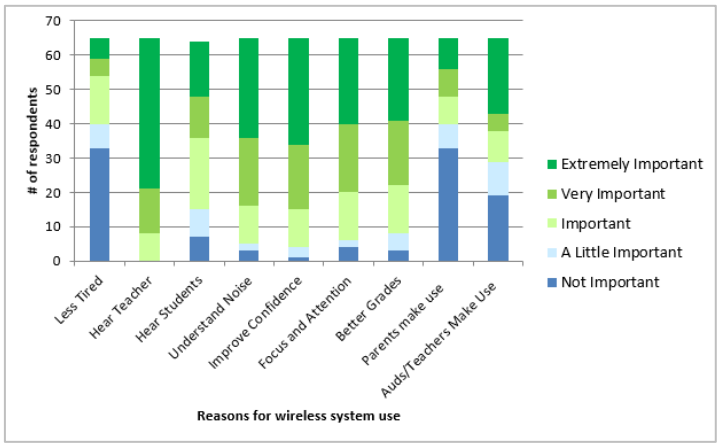

Figure 7. Reasons for use rated by teens who plan to continue utilizing wireless systems in the coming school year.

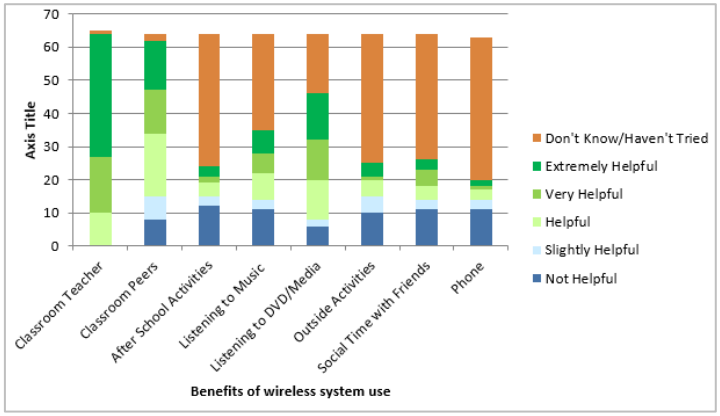

Figure 8. Ratings of benefit by listening situation provided by teens planning to continue the use of wireless systems during the coming school year.

Reasons for non-use among the 24% of the students who were former users were also explored. The reasons cited most strongly were that they did not like the way the system looked/felt and that they did not like handing the system to the teacher (Figure 9). This indicates that there is opportunity to improve the cosmetics of wireless systems to make them more appealing to teens. Additionally, students wrote in comments including "*I don't like carrying it around*", and "*I have an interpreter*". These results highlight that there are design opportunities to make remote microphone systems more cosmetically appealing and less obtrusive for children with hearing loss. Such changes might result in higher user rates by teens. In response to evidence that teens want inconspicuous classroom listening solutions that go beyond

access to the teacher, Phonak has developed some targeted solutions. Technologies that have already been brought to market include the Roger+directional hearing aid feature and the Roger Touchscreen Mic (TSM). Both of these solutions strive to maintain the proven advantage of a teacher or primary talker using a remote microphone, but balance that priority with the additional need to engage effectively with peers. The Roger TSM has the additional feature that in small group mode, it functions on a table or desk, rather than being handed to a teacher.

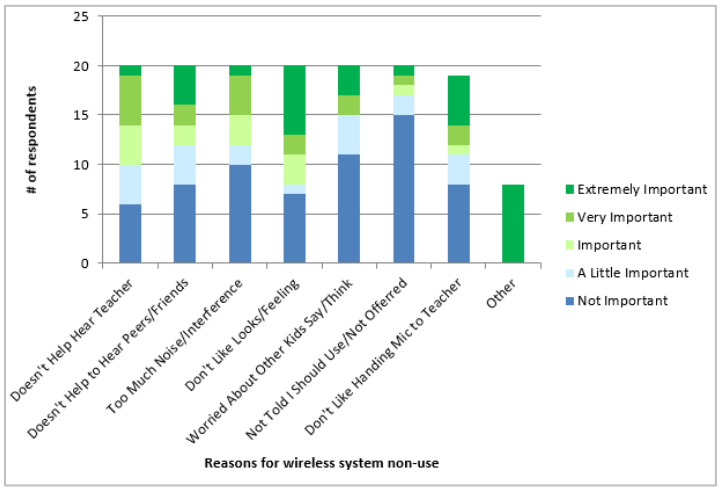

Figure 9. Reasons for non-use among former remote microphone users.

Until now, remote microphone users had to make a choice between using a directional microphone to assist with near-field listening in noise and using a remote microphone to understand a talker from a distance. When the remote microphone program was activated in hearing instruments, the input from the back microphone of the beamformer was repurposed for the remote microphone input, necessarily rendering the hearing aid in an omni-directional microphone mode. A new development for the Phonak Sky V platform of hearing instruments, Phonak's dedicated pediatric product family, was the incorporation of a second A/D converter to allow the dual microphone inputs from the beamformer to function simultaneously with a remote microphone input. The expectation for this new design was that classroom listeners would simultaneously benefit from the beamformer to understand near-field peers while profiting from the remote microphone for the teacher.

The behavior of the beamformer in Roger+directional was carefully considered, based on research specific to the listening situations of teenage hearing aid users. Various polar patterns can be assigned to a beam former, yielding different patterns of sensitivity around the head. Modern hearing aids typically apply an adaptive beamformer, in which the polar pattern can adapt to place the null at azimuths where the strongest noise source is detected. As beneficial as an adaptive beamformer can be at cancelling noise sources originating from either side, findings from the Phonak internal research group (Feilner, 2015) revealed that students were often seated with their peers at their sides, such as at long benches in a cafeteria or in rows in the classroom. To prevent an adaptive beamformer from cancelling input from these lateralized speakers, a fixed beamformer with maximum reduction to the rear is applied. Additionally, the activation of the directional microphone mode is an intelligent decision, made by the hearing aid automatically, depending on whether the scene is classified as quiet or speech in background noise.

In order to test the effectiveness of this new combination of remote microphone and beamforming functionalities, an evaluation was completed with 15 children with sensorineural hearing loss aged 7-17 years (Wolfe, Jones, & Rakita, 2016). Subjects were seated in a classroom environment surrounded by an 8-speaker array, simulating a noisy classroom scene. Classroom noise was presented from speakers at 90, 135, 180, 225, and 270 degrees. Speech representing a peer talker was presented from a speaker at 315 degrees and speech representing a teacher from 45 degrees. The Inspiro transmitter was hung from the speaker so that the microphone was placed 20 centimeters below the center cone of the speaker. There was also a condition in which speech was presented from 225 degrees in quiet. This final condition was included to illustrate that in quiet, the microphone automatically reverts to the omni-directional mode. This adaptation prevents the system from reducing input from behind, such as a student asking a question from the back of a quiet classroom.

Average speech recognition scores for all subjects in this experiment can be seen in Figure 10. A repeated measures ANOVA revealed a significant main effect for microphone mode. Post hoc analysis confirmed a significant difference ($p=.003$) in the second listening condition between the Roger+omni-directional and Roger+directional programs for the "peer talker" in noise. Average speech recognition when the fixed directional beamformer was activated in the Roger program was 26% better compared to performance with the Roger+Mic program using only omni-directional mode. No difference was seen between Roger+Omni-directional mode and Roger+directional for speech coming from the "teacher". These results confirm that the benefit of Roger microphones will not be impacted negatively by the activation of a directional microphone in the Roger+Mic hearing aid program. Moreover, no difference was seen between the two hearing aid programs when a peer was speaking from behind in a quiet classroom. This confirms that the hearing aid microphone adapts, as intended, in quiet to an omni-

directional pattern, preventing undesirable loss of hearing when the speaker of interest is coming from behind the listener.

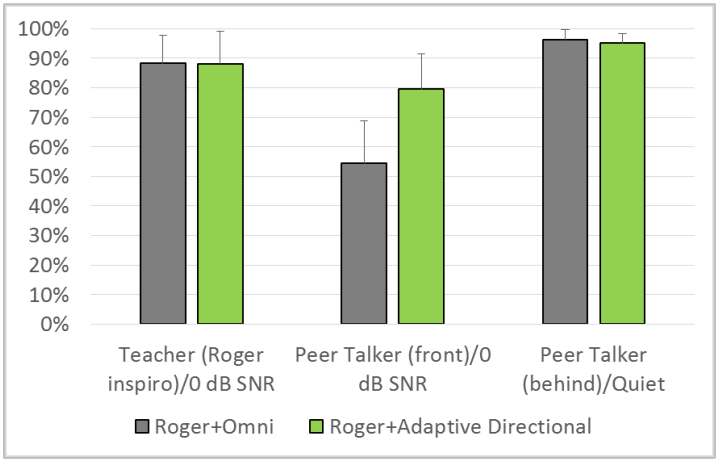

Figure 10. Results show significant (p=.003) benefit of Roger+directional compared to Roger+omni-directional for peer, near-field, talkers. Benefit for the teacher using a remote microphone is maintained. Understanding of peer talkers from behind is preserved in quiet because of the adaptive microphone.

Another difficulty highlighted in regards to current remote microphone implementation was the growing need for more flexible remote microphone solutions to accommodate a higher percentage of the day in group-work situations. A new remote microphone has been marketed to address this need. The so-called Roger Touchscreen Mic automatically switches into small group mode (SGM) when it is laid flat, rather than worn vertically as would be worn by a teacher. SGM activates an array of three microphones that automatically adjust the beam of focus 360 degrees around the listener. Specific signal characteristics, such as signal-to-noise ratio and energy level, are analyzed and used to localize speech information and to identify the talker's direction. This allows the device to follow the conversation automatically by always focusing towards the active talker.

A study was completed in the Phonak Audiology Research Center (Standaert & Jones, 2016) to assess the benefit of small group mode. Thirteen adults were evaluated in a classroom-type set up (Figure 11) in which three speakers were arranged to simulate a small group conversation in a room with multi-talker babble coming from 4 meters away in each of the corners. Subjects were tested with the hearing aid in an omni-directional microphone and with Roger Touch Screen Mic (TSM) in small group mode. IEEE sentences (1969) were randomly presented from the near field speakers placed at 0, 90 and 270 degrees around the subject to simulate an activity like a student working on a lab exercise or team project. Subjects also completed a 5- point comparative rating between the hearing aid alone and the hearing aid with TSM. On the subjective rating scale, a strong preference for the TSM was scored as a +2, no preference was 0, and -2 was strong preference from hearing aid alone. Subjects made comparative ratings between the conditions for comfort, speech intelligibility, sound quality, background noise, and overall preference. The results can be seen in Figure 12. The distribution of preferences for each question revealed a strong preference for the Roger TSM in this scene for comfort, clarity of speech, overall sound quality, and as an overall preference. There was a moderate preference for the TSM for suppressing noise.

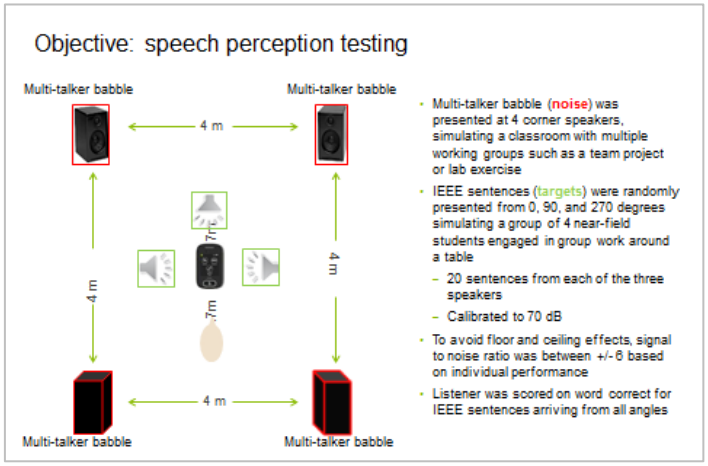

Figure 11. Room set up for the evaluation of small group mode.

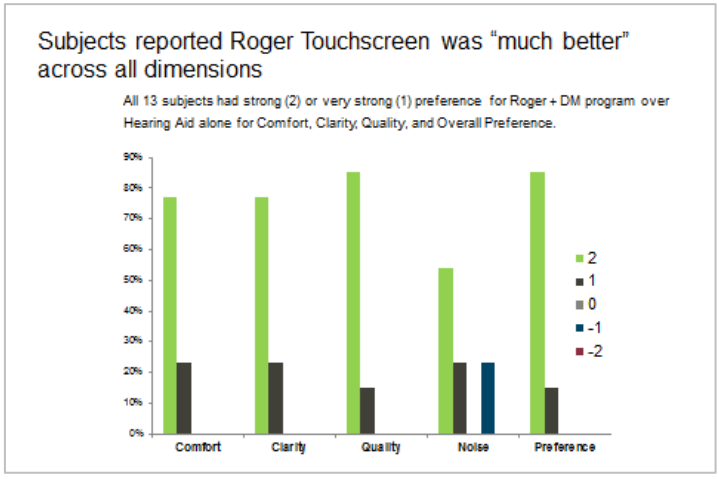

Figure 12. All 13 subjects had a very strong (2) or strong (1) preference for using the Roger TSM over the hearing aid alone for comfort, clarity, quality and overall preference.

Speech perception was also compared with the hearing aid alone, the Roger Pen, the TSM in group work mode with hearing aid in omni-directional mode, and the TSM in small group mode with the hearing aid directional microphone. The signal-to-noise ratio was individually set between +/- 6 to avoid floor and ceiling effects. The average speech recognition scores for sentences in all four conditions can be seen in Figure 13. There was a significant difference ($p<.05$) between the HA only and the SGM+omni-directional conditions. There was a significant improvement for Roger SGM+directional compared to both the HA only and the Roger pen. This study suggested that the Roger SGM expands

the range of listening environments in which teens can benefit from remote microphone technology, including group work situations that have become more prevalent in the school day.

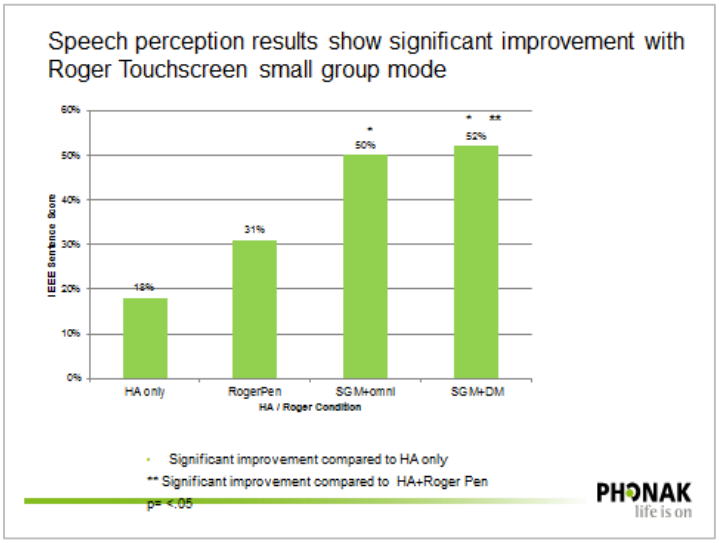

Figure 13. Speech recognition for IEEE sentences show significant improvement with Roger TSM in small group mode. * significant improvement compared to HA only. **Significant improvement compared to HA and Roger Pen. p=<.05.

Conclusion

The classroom is filled with increasingly diverse listening challenges. Opportunities for improved hearing performance have been identified by subjective and objective research. The use of directional microphones in combination with remote microphones have been shown to improve the understanding of near-field talkers in the presence of background noise. Additionally, the use of the multi-microphone small group mode in the Roger TSM improved understanding of near-field talkers in a simulated classroom environment.

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