



Addressing listening needs of underserved school children

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Presenter disclosures

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- Financial: I am employed by Phonak.
- Non-financial: I have no relevant non-financial relationships to disclose.

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Addressing listening needs of underserved school children



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What is Autism Spectrum Disorder?



According to the 5th edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V), Autism Spectrum Disorder (ASD) is a developmental disorder with symptoms that:

- Include persistent challenges with communication and social interaction
- Include restricted or repetitive interests or behaviors
- Symptoms must manifest in the early developmental period
- Can't be better explained by intellectual or developmental disability
- Cause clinically significant impairment in social, occupational or other functioning

1. American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). <https://doi.org/10.1176/appi.books.9780890425596>

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Prevalence of ASD

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¹ Elsabbagh, M., Divan, G., Koh, Y. J., Kim, Y. S., Kauchali, S., Marcin, C., ... & Fombonne, E. (2012). Global prevalence of autism and other pervasive developmental disorders. *Autism research*, 5(3), 160-179.
² Maenner, M. J., Shaw, K. A., & Bal, J. (2020). Prevalence of autism spectrum disorder among children aged 8 years—autism and developmental disabilities monitoring network, 11 sites, United States, 2016. *MMWR Surveillance Summaries*, 69(4), 1.

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Impact of ASD on hearing and auditory skills

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Auditory differences in children with ASD

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Over 50% of parents of children with ASD surveyed reported auditory issues¹



1. Tomchek, S. D., & Dunn, W. (2007). Sensory processing in children with and without Autism: A comparative study using the short sensory profile. *American Journal of Occupational Therapy*, 61(2), 190-200

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Common auditory issues in children with ASD

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Hyperacusis¹

Elevated behavioral thresholds²

Deficient cortical speech encoding³

Reduced auditory attention⁴

1. Williams, Z. J., Suzman, E., & Wojnarowski, T. G. (2021). Prevalence of decreased sound tolerance (hyperacusis) in individuals with autism spectrum disorder: A meta-analysis. *Ear and Hearing*. Advance online publication. doi: 10.1097/AUD.0000000000001005
2. Thorpe, A. M., Bless, F. H., Sladen, D. P., Schissel, H., Couch, S., & Schery, T. (2006). Auditory characteristics of children with autism. *Ear and hearing*, 27(4), 430-441.
3. Russo, N., Zecker, S., Trommer, B., Chen, J., & Kraus, N. (2009). Effects of background noise on cortical encoding of speech in autism spectrum disorders. *Journal of autism and developmental disorders*, 39(8), 1185-1196.
4. Corbett, B. A., & Constantine, L. J. (2006). Autism and attention deficit hyperactivity disorder: Assessing attention and response control with the integrated visual and auditory continuous performance test. *Child Neuropsychology*, 12(4-5), 335-348.

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Atypical auditory responses in children with ASD



- Hyperacusis - abnormal sound sensitivity¹
- Elevated behavioral thresholds – reduced sensitivity to soft tones despite normal OAEs²
- Poorer cortical speech encoding – delayed latency and reduced amplitude speech-evoked brainstem responses³



1. Williams, Z. J., Suzman, E., & Wojnarowski, T. G. (2021). Prevalence of decreased sound tolerance (hyperacusis) in individuals with autism spectrum disorder: A meta-analysis. *Ear and Hearing*. Advance online publication. doi: 10.1097/AUD.0000000000001005

2. Tharpe, A. M., Bess, F. H., Sladen, D. P., Schissel, H., Couch, S., & Schery, T. (2006). Auditory characteristics of children with autism. *Ear and hearing*, 27(4), 430-441.

3. Russo, N., Zecker, S., Trommer, B., Chen, J., & Kraus, N. (2009). Effects of background noise on cortical encoding of speech in autism spectrum disorders. *Journal of autism and developmental disorders*, 39(8), 1185-1196.

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Auditory filtering deficits in children with ASD



“Auditory filtering is defined as the ability to hear, function, and complete tasks in the presence of background noise (...), and this skill is critical for hearing in real-world, noise-enriched environments.”¹

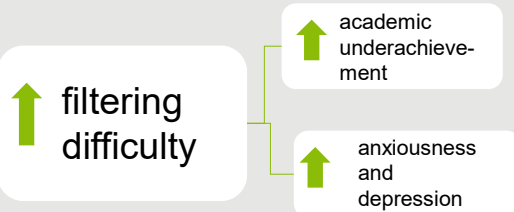
1. Schafer, E. C., Wright, S., Anderson, C., Jones, J., Pitts, K., Bryant, D., ... & Reed, M. P. (2016). Assistive technology evaluations: Remote-microphone technology for children with Autism Spectrum Disorder. *Journal of communication disorders*, 64, 1-17.

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Consequences of auditory issues

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Auditory filtering is significant predictor of educational performance.¹



Ashburner, J., Ziviani, J., & Rodger, S. (2008). Sensory processing and classroom emotional, behavioral, and educational outcomes in children with autism spectrum disorder. *American journal of occupational therapy*, 62(5), 564-573.

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Consequences of auditory issues

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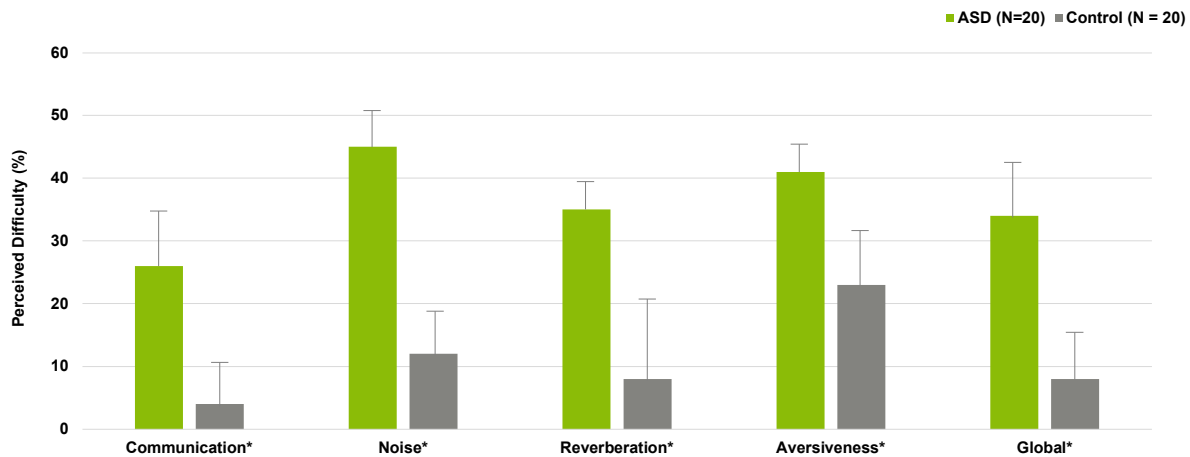


Figure 1. Mean APHAB hearing disability survey results for 20 children with ASD and 20 controls: Error bars represent 1SD from the mean. Asterisks show the metrics in which there was significant difference between groups ($P < .001$). Mean Global APHAB score for the ASD group was $36.3\% \pm 17.2\%$, and that for the control group was $7.6\% \pm 6.6\%$ CI 19.3%-38.1%; ($P < .001$).

1. Rance, G., Saunders, K., Carew, P., Johansson, M., & Tan, J. (2014). The use of listening devices to ameliorate auditory deficit in children with autism. *The Journal of pediatrics*, 164(2), 352-357.

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Addressing listening challenges

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Addressing listening challenges

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Interventions for listening challenges in ASD include:

- Auditory training
- Psychological therapy, sound therapy, tinnitus retraining therapy, medication for hypersensitivity
- Remote microphone technology

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Auditory training

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Auditory training can address:

- Dichotic deficits¹
- Listening in noise deficits

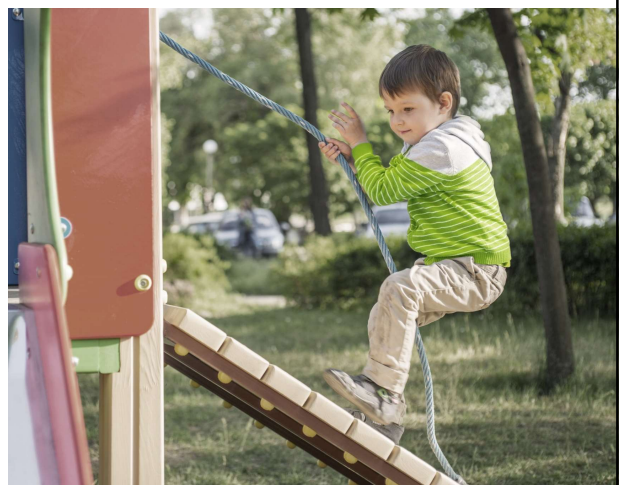
1. Schafer, E. C., Gopal, K. V., Mathews, L., Thompson, S., Kaiser, K., McCullough, S., ... & Hutcheson, A. (2019). Effects of auditory training and remote microphone technology on the behavioral performance of children and young adults who have autism spectrum disorder. *Journal of the American Academy of Audiology*, 30(5), 431-443.

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Psychological therapy and sound-attenuators

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- Hyperacusis can be treated with psychological therapy.¹
- Sound-attenuating devices are discouraged because they limit access to speech and environmental sounds.²








1. Potgieter, I., Fackrell, K., Kennedy, V., Crunkhorn, R., & Hoare, D. J. (2020). Hyperacusis in children: a scoping review. *BMC pediatrics*, 20(1), 1-13.
2. Pfeiffer, B., Stein Duker, L., Murphy, A., & Shul, C. (2019). Effectiveness of noise-attenuating headphones on physiological responses for children with autism spectrum disorders. *Frontiers in integrative neuroscience*, 13, 65.

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Remote microphone technology

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Remote microphone technology can produce immediate benefits including:

-  • Improved listening-in-noise¹⁻⁵
-  • Increased noise tolerance¹
-  • Improved listening behavior¹⁻⁴
-  • Reduced listening stress³
-  • Reduced hearing disability²⁻³

1. Schaffer, E. C., Wright, S., Anderson, C., Jones, J., Pitts, K., Bryant, D., ... & Reed, M. P. (2016). Assistive technology evaluations: Remote-microphone technology for children with Autism Spectrum Disorder. *Journal of communication disorders*, 64, 1-17.
2. Rance, G., Saunders, K., Carew, P., Johansson, M., & Tan, J. (2014). The use of listening devices to ameliorate auditory deficit in children with autism. *The Journal of pediatrics*, 164(2), 352-357.
3. Rance, G., Chisari, D., Saunders, K., & Rault, J. L. (2017). Reducing listening-related stress in school-aged children with autism spectrum disorder. *Journal of autism and developmental disorders*, 47(7), 2010-2022.
4. Schaffer, E. C., Gopal, K. V., Mathews, L., Thompson, S., Kaiser, K., McCullough, S., ... & Hutcheson, A. (2019). Effects of auditory training and remote microphone technology on the behavioral performance of children and young adults who have autism spectrum disorder. *Journal of the American Academy of Audiology*, 30(5), 431-443.
5. Feldman, J.L., Thompson, E., Davis, H., Koceli-Kaysili, B., Dunham, K., Woynarowski, T., Tharpe, A.M., Picou, E. (Accepted). Remote microphone systems can improve listening-in-noise accuracy and listening effort for youth with Autism. *Ear Hear*.

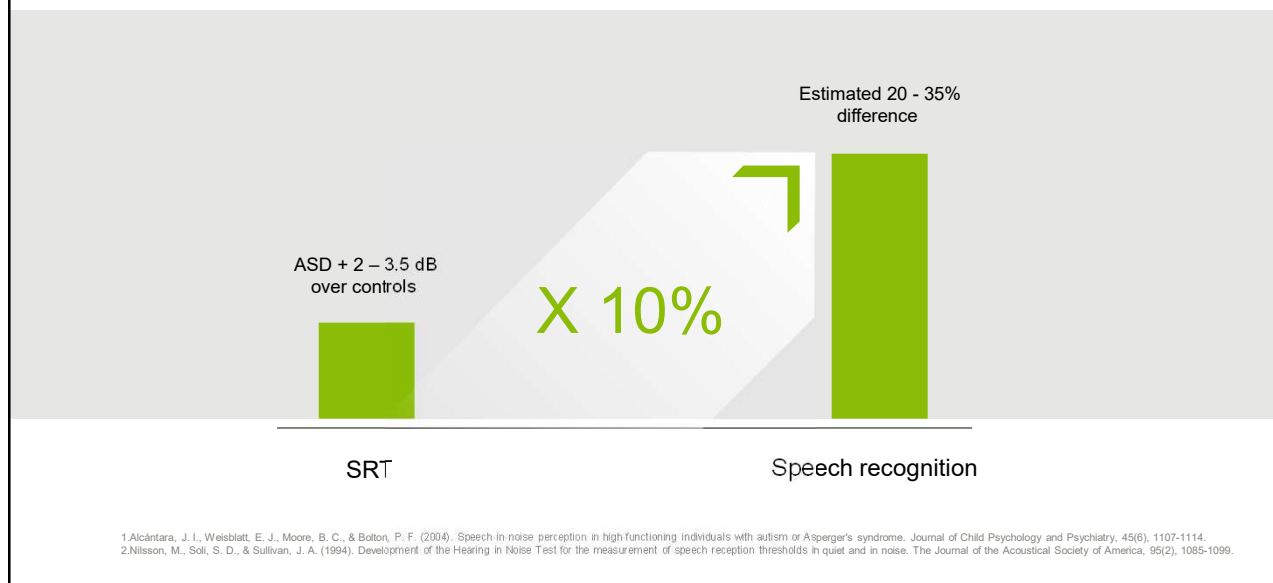
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**Remote microphones (RM)
applications for auditory
filtering issues**

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Why remote microphone technology?

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Proven benefits of remote microphone technology in children with ASD

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- Improves speech understanding in noise¹⁻⁵
- Reduces self-perceived hearing and listening difficulties (APHAB, CHAPS)¹⁻⁴
- Reduces listening stress³
- Improves parent- and teacher-reported listening behavior and attentiveness²⁻⁴
- Increases acceptance of noise⁴
- Improves auditory responsiveness and object identification in some preschoolers⁶

1. Schafer, E. C., Wright, S., Anderson, C., Jones, J., Pitts, K., Bryant, D., ... & Reed, M. P. (2016). Assistive technology evaluations: Remote-microphone technology for children with Autism Spectrum Disorder. *Journal of communication disorders*, 64, 1-17.
2. Rance, G., Saunders, K., Carew, P., Johansson, M., & Tan, J. (2014). The use of listening devices to ameliorate auditory deficit in children with autism. *The Journal of pediatrics*, 164(2), 352-357.
3. Rance, G., Chisari, D., Saunders, K., & Rault, J. L. (2017). Reducing listening-related stress in school-aged children with autism spectrum disorder. *Journal of autism and developmental disorders*, 47(7), 2010-2022.
4. Schafer, E. C., Gopal, K. V., Mathews, L., Thompson, S., Kaiser, K., McCullough, S., ... & Hutcheson, A. (2019). Effects of auditory training and remote microphone technology on the behavioral performance of children and young adults who have autism spectrum disorder. *Journal of the American Academy of Audiology*, 30(5), 431-443.
5. Feldman, J.I., Thompson, E., Davis, H., Keceli-Kaysili, B., Dunham, K., Woyanowski, T., Tharpe, A.M., Picou, E. (Accepted). Remote microphone systems can improve listening-in-noise accuracy and listening effort for youth with Autism. *Ear Hear*.
6. Keller, M. A., Tharpe, A. M., & Bodfish, J. (2021). Remote Microphone System Use in Preschool Children With Autism Spectrum Disorder and Language Disorder in the Classroom: A Pilot Efficacy Study. *American Speech-Language-Hearing Association*, 30(1), 266-278.

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Benefits of soundfield classroom systems

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- Improved functional listening ability in some¹
- Reduced listening stress²



1. Keller, M. A., Tharpe, A. M., & Bodfish, J. (2021). Remote Microphone System Use in Preschool Children With Autism Spectrum Disorder and Language Disorder in the Classroom: A Pilot Efficacy Study. *American Speech-Language-Hearing Association*, 30(1), 266-278.

2. Rance, G., Chisari, D., Saunders, K., & Rault, J. L. (2017). Reducing listening-related stress in school-aged children with autism spectrum disorder. *Journal of autism and developmental disorders*, 47(7), 2010-2022.

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Benefits of soundfield classroom systems

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Soundfield classroom systems can improve functional hearing in preschoolers with ASD by:

- reducing prompt level, or
- reducing response latency¹



1. Keller, M. A., Tharpe, A. M., & Bodfish, J. (Submitted). A Remote Microphone System Improves Listening Behavior in Children with Minimally Verbal Autism (MVA).

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Benefits of soundfield classroom systems

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- Soundfield classroom system use is associated with reduced cortisol concentration in children with ASD when listening in noise.¹
- Effects are larger for children with greater behavioral listening deficits.



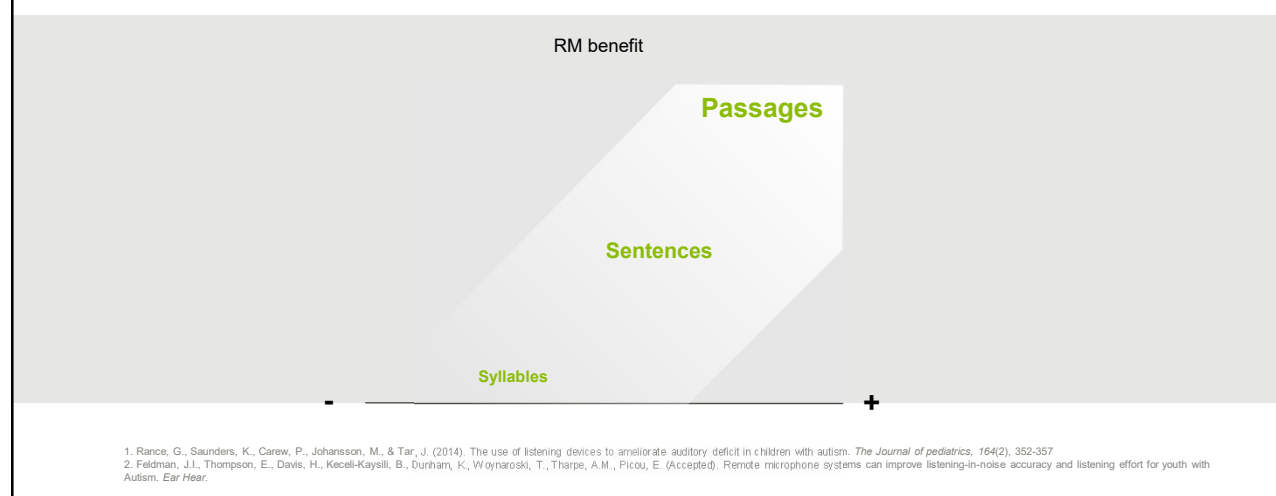
1. Rance, G., Chisari, D., Saunders, K., & Rault, J. L. (2017). Reducing listening-related stress in school-aged children with autism spectrum disorder. *Journal of autism and developmental disorders*, 47(7), 2010-2022.

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Benefits of personal remote microphone technology

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- Using personal remote microphone technology reduces listening stress¹ and effort² in children with ASD.
- Remote microphone benefits were greater for more complex speech stimuli²



1. Rance, G., Saunders, K., Carew, P., Johansson, M., & Tar, J. (2014). The use of listening devices to ameliorate auditory deficit in children with autism. *The Journal of pediatrics*, 164(2), 352-357

2. Feldman, J.I., Thompson, E., Davis, H., Keceli-Kaysill, B., Dunham, K., Woytnarowski, T., Tharpe, A.M., Picou, E. (Accepted). Remote microphone systems can improve listening-in-noise accuracy and listening effort for youth with Autism. *Ear Hear.*

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Benefits of personal remote microphone technology (Rance et al., 2017)

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Lower cortisol concentrations and improved measured behavioral and self-reported listening ability have been reported with versus without personal remote microphone technology.

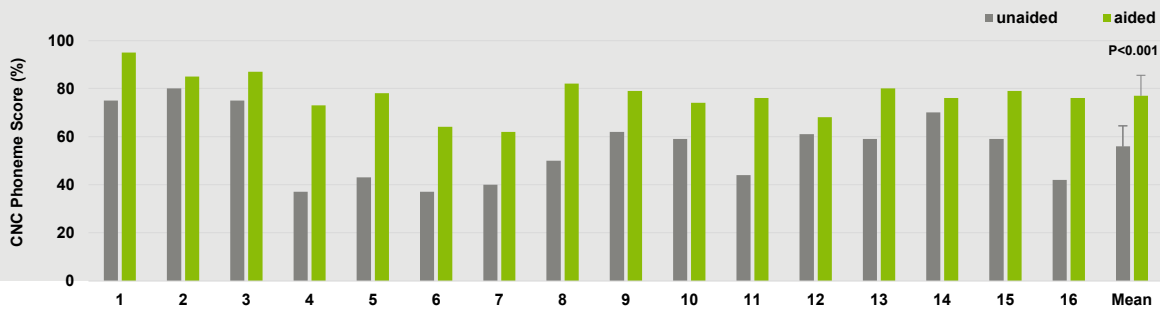


Figure 1. Unaided and device-aided open-set speech perception in noise (0 dB SNR) scores for each participant. Group scores represent the mean + 1 standard deviation.

1. Rance, G., Chisari, D., Saunders, K., & Rault, J. L. (2017). Reducing listening-related stress in school-aged children with autism spectrum disorder. *Journal of autism and developmental disorders*, 47(7), 2010-2022.

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Benefits of personal remote microphone technology (Feldman et al., accepted)

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- Improved speech-in-noise performance with remote microphone has been accompanied by reduced listening effort.
- Performance on a dual task paradigm was improved with versus without the device.

1. Feldman JI, Thompson E, Davis H, Keceli-Kaysili B, Dunham K, Woynaroski T, Tharpe AM, Picou EM. Remote Microphone Systems Can Improve Listening-in-Noise Accuracy and Listening Effort for Youth With Autism. *Ear Hear.* 2022 Mar/Apr;43(2):436-447. doi: 10.1097/AUD.0000000000001058. PMID: 35030553; PMCID: PMC8861266.

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What benefits are observed in children with ASD when using RM technology?

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Observed benefits

Improved speech understanding puts children in a better position to engage and learn.



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¹ Feldman JI, Thompson E, Davis H, Keceli-Kaysali B, Dunham K, Woynaroski T, Tharpe AM, Picou EM. Remote Microphone Systems Can Improve Listening-in-Noise Accuracy and Listening Effort for Youth With Autism. *Ear Hear*. 2022 Mar/Apr;43(2):436-447. doi: 10.1097/AUD.0000000000001058. PMID: 35030553; PMCID: PMC8881266.

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Observed benefits

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“Nick has been using the device and the teacher still says it makes such a difference. He is able to give encouragement, redirection and remain a calm voice as he knows Nick can hear what he is saying.”

-Nick's Mother

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Observed benefits: parents and teachers

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Questionnaires show improved listening and behavior in children with ASD when using remote microphone systems.

- Teachers considered the FM device fitting to be 'highly beneficial' for all children¹
- Parent questionnaires indicated reduced hearing disability with RM¹

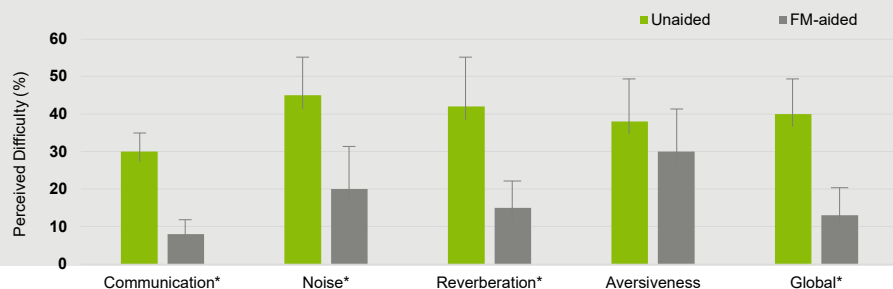


Figure 3. APHAB hearing disability questionnaire results for unaided and aided conditions. Error bars represent 1 SEM. Asterisks represent the metrics in which there was significant difference between conditions ($P < .001$). CNC, Consonant-Nucleus-Consonant.

1. Rance, G., Saunders, K., Carew, P., Johansson, M., & Tan, J. (2014). The use of listening devices to ameliorate auditory deficit in children with autism. *The Journal of pediatrics*, 164(2), 352-357.

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Benefits

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Benefits associated with RM use in children with ASD include:

- Improved functional hearing ability
- Improved speech understanding in noise
- Reduced listening stress
- Improved behavior in school and at home

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Unilateral hearing loss in children

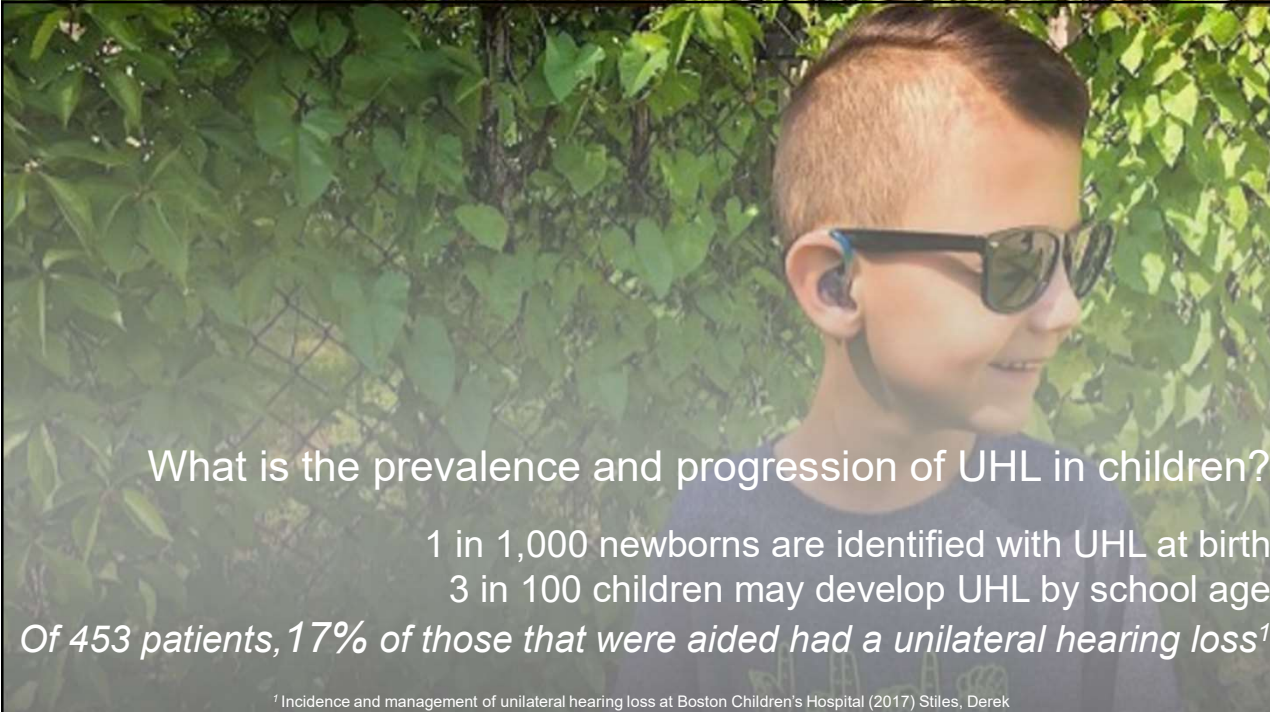
Impact and hearing solutions



A Sonova brand

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What is the prevalence and progression of UHL in children?

1 in 1,000 newborns are identified with UHL at birth
3 in 100 children may develop UHL by school age

Of 453 patients, 17% of those that were aided had a unilateral hearing loss¹

¹ Incidence and management of unilateral hearing loss at Boston Children's Hospital (2017) Stiles, Derek

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Hearing with both ears **PHONAK**
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Binaural hearing capabilities

- Binaural summation
- Head shadow effect
- Sound localization
- Spatial release from masking
- Precedence effect in reverberant enclosures

Any impairment can result in difficulties such as:

Hearing in noise or at a distance

Localization

Segregating sounds

Selective attention

Speech understanding

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Children with UHL have the same quality of life issues as children with BHL

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Hearing Environments And Reflection on Quality of Life Measurement for Children

Instructions:

The purpose of this scale is to find how your hearing is affecting you. Put an "X" in the box that best answers each question for you: Never, Rarely, Sometimes, Often, or Almost Always. If you use a hearing aid or cochlear implant, please answer the way you hear with the hearing aid or cochlear implant.

Environments	Never	Almost Never	Some- times	Often	Almost Always
1. Is it hard to hear your friends when you are playing?					
2. Do you have a hard time hearing your friends at recess?					
3. Is it hard to hear in gym class (Physical Education, PE)?					

HEAR-QL questionnaire developed and tested

- 35 children with NH
- 35 children with UHL
- 45 with BHL

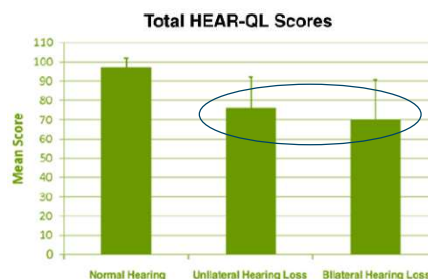


Figure 2 Mean (± 1 standard deviation) health-related quality of life score as measured by Hearing Environments and Reflection on Quality of Life (HEAR-QL) in 35 children with normal hearing, 35 children with unilateral hearing loss, and 45 children with bilateral hearing loss.

No significant difference between children with UHL and BHL

Lieu, JEC. **Children with Unilateral Hearing Loss**. *Seminars in Hearing* 31(4):275-289, 2010. doi:10.1055/s-0030-1268030

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What's the risk of effort and fatigue in children?

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Fatigue is a problem because as effort increases, fatigue increases

Children with hearing loss have a greater cognitive and overall fatigue compared to peers with normal hearing¹

- ✓ Associated with poor language abilities in children²
- ✓ Associated with perceived difficulties in adults (Hearing Handicap)³

Listening related fatigue is a significant problem for at least some adults and children with unilateral and bilateral hearing loss^{1,2}



¹ Hornsby, B. (2017) Effort and Fatigue in Children with Unilateral Hearing Loss-What's the risk? Presented at *Unilateral Hearing Loss in Children Conference* 2017.

² Lieu, J. et al. (2010) Unilateral Hearing Loss Is Associated With Worse Speech-Language Scores in Children. *Pediatrics*, 125, 2009-2448.

³ Al-Hanbali, S. et al., (2016). Self-Reported Listening-Related Effort and Fatigue in Hearing-Impaired Adults. *Ear and Hearing*.

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Frequency of academic difficulties in children with UHL



Investigation	Failed (1 or more grades)	Resource help (1 or more grades)	Combined (failed and resource help)
Bess (1986)	35.0%	13.3%	48.3%
Oyler (1988)	24.3%	40.7%	65.0%
Jensen (1988)	18.0%	36.0%	54.0%
Martini (1988)	25.0%	-	-
Watier-Launey et al. (1998)	40.4%	-	-
Lieu (2004)	22.0 - 35.0%	12.0 – 41.0%	-

Gravel, J. (2004) *Minimal Hearing Loss in Children*. Presented at Phonak Satellite Conference 2004.

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Educational impact of UHL



↑ **10 x**

More likely to
repeat a year of school

↑ **5 x**

More likely to need
additional educational resources



Gravel, J. (2004) *Minimal Hearing Loss in Children*. Presented at Phonak Satellite Conference 2004.

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Children with UHL have other academic/social-emotional skill difficulties also

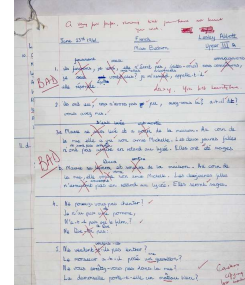
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Higher incidence of failure rate/negative comments on report cards¹



Behavioral concerns²



Teachers rate these children more negatively than normal hearing peers³

- Attention to academic task
- Peer relations and social confidence
- Dependence-independence
- Emotional lability

1. Keller, W.D., & Bundy, R.S. (1980). Effects of unilateral hearing loss upon educational achievement. *Child: Care and Health Development*, 6(2), 93-100.
2. English, K., & Church, G. (1999). Unilateral hearing loss in children: An update for the 1990's. *Language Speech & Hearing Services in Schools*, 30, 26-31.
3. Culbertson, J.L., & Gilbert, L.E. (1986). Children with unilateral sensorineural hearing loss: cognitive, academic, and social development. *Ear & Hearing*, 7, 38-42.

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Children with UHL

“With infants being identified with UHL at a very early age, it is time for clinicians to consider all intervention avenues available and take the opportunity to positively impact the development of children with UHL to help them reach their maximum potential.”

Krishnan LA, Van Hyfte S. Management of unilateral hearing loss. *Int J Pediatr Otorhinolaryngol*. 2016 Sep;88:63-73. doi: 10.1016/j.ijporl.2016.06.048. Epub 2016 Jun 30. PMID: 27497389.

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To Aid or Not to Aid: Children with Unilateral Hearing Loss

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Surveys rating aspects of the child's daily life. 20 surveys from parents of children with mild to moderately severe UHL, aged 2-17

Parent comments:

"It would be a blessing if we put hearing aids on these kids sooner"
"He was missing one half of everything before he got his hearing aid"

Results:

Auditory areas - improvement

All areas - same, improved, or significantly improved

Children liked their hearing aids, parents were happy and had wished their children had been fit earlier



Author's conclusion

✓ "[W]e believe that children with UHL (who fit candidacy requirements) should minimally receive a trial with **amplification**. Fitting these children has appeared to improve their quality of life. We believe that without this opportunity, the children are being denied access to their full potential."

McKay, S (2017) To Aid or Not to Aid: Children with Unilateral Hearing Loss. Presented at Unilateral Hearing Loss in Children Conference 2017.

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American Academy of Audiology Clinical Practice Guidelines Pediatric Amplification (2013)

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AMERICAN ACADEMY OF AUDIOLOGY 
How's your hearing? Ask an Audiologist!

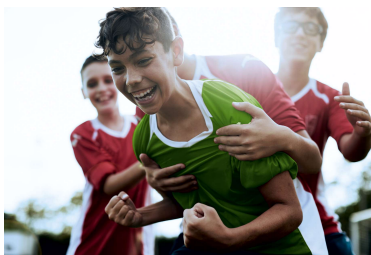
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3 Scenarios of Unilateral Hearing Loss

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Mild to moderately-severe UHL



Severe to profound UHL or SSD not aidable



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For children with an aidable ear

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- Impaired ear can be mild to more severely impaired
- Consider for timing of treatment
 - Delaying amplification may lead to auditory deprivation
 - “The hearing aids use contributed to the improvement of hearing abilities and language development of the children, preventing the effects of late deprivation.” ¹

¹ Boechat, E. & Lot, A. (2017) Auditory and language abilities in children with aided unilateral sensorineural hearing loss. Presented at *Unilateral Hearing Loss in Children Conference 2017* poster session.

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Hearing aid fitting on impaired ear

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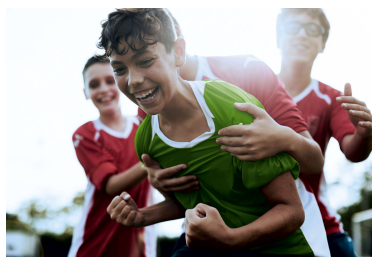
- Benefit determined through trial period
- Remote microphone usage for noisy situations or listening at a distance

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For children with an unaidable ear

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- Significantly poor speech understanding
- No benefit from hearing aid



Severe to profound UHL



Single Sided Deafness

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Contralateral Routing of Signal - CROS

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Candidates and considerations for using CROS technology:

- Goal is to access sound from the 'bad side'
- Child is able to recognize dynamics of the acoustic environment
- Trial period is helpful
- Remote microphone usage for noisy situations or listening at a distance will provide best hearing

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Roger Focus-Ear level receiver with remote microphone

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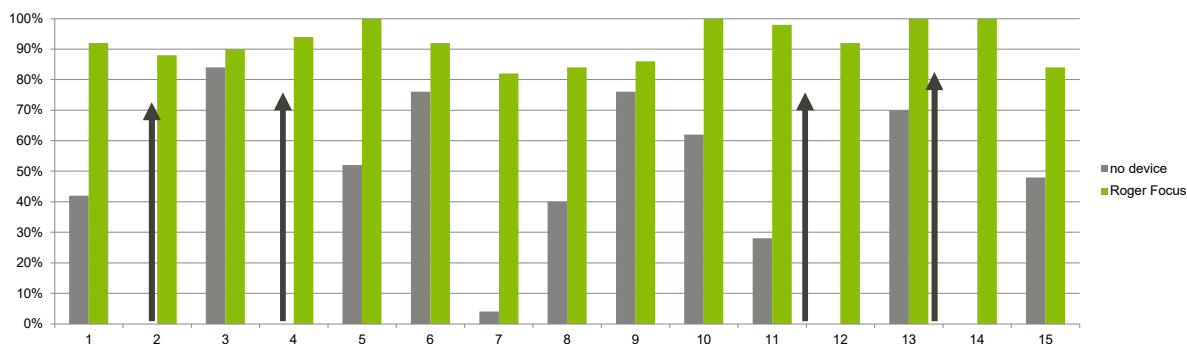
- Increase in signal-to-noise ratio of the important information to the normal hearing ear
- Benefit for hearing in noise and over distance.
 - Classroom
 - Car
 - Social outings

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Maximum performance: Roger Focus evidence

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Speech-in-noise testing revealed an average improvement of 53% with Roger Focus compared to no device



N=15 BKB-SIN, -5dB SNR noise at 65dB SPL

Note: with the exception of subjects 3 and 9 all individual scores showed significant improvement

Subjects 2, 4, 12, and 14 scored 0% without any device and almost 100% with Roger Focus.

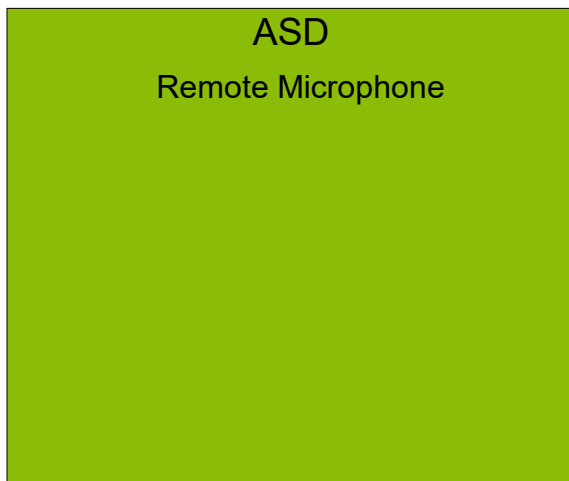
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Jones, et al. (June, 2014) Phonak Field Study News

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Addressing listening needs of underserved school children

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Together,
we change lives