PEDIATRIC WHITEPAPER 2019

Children's learning environments and listening needs: Implications for amplification

SUMMARY

Children with hearing loss face diverse challenges and difficulties in everyday listening. They have additional difficulty in perceiving speech and learning words in noise compared to their normally hearing peers. Research has showed that compared to children with normal hearing, children with hearing loss have generally poorer language and educational outcome. Previous studies have also reported that with adequate hearing aid amplification, the negative impacts of hearing loss on learning and language development can be reduced. This indicates early intervention is important.

This whitepaper discusses 1) the learning environments and 2) listening needs of children with hearing loss, and 3) how OpenSound Navigator™ differs from the conventional hearing aid technologies in providing optimal conditions for listening and learning.

Elaine Hoi Ning Ng, PhD

Senior Research Audiologist,
Centre for Applied Audiology Research,
Oticon A/S

oticon
PEOPLE FIRST

Introduction

Speech and language development is one of the most important developmental processes during childhood, and learning new words and their meanings, or vocabulary development, is an essential aspect of this. Noise has negative effects on speech understanding and word learning. Children, however, very often listen and learn in educational settings where the noise level is high.

Typical listening environments

A study performed by Crukley et al. (2011) looked at the acoustic properties over the course of an entire day in three different listening environments: daycare, elementary school, and high school. The results showed that on average, children spent 80% of their total time in a mixture of speech in noise, with sound levels ranging from 40 to 90 dBA (see Figure 1). Children with normal hearing require a greater signal-to-noise ratio (SNR) to that of adults to perceive speech in noise (Werner, 2011). It is not until adolescence that the ability to understand speech in noise has matured (Soli and Sullivan, 1997). Learning typically takes place in environments, for example occupied classrooms, where noise level could be high and SNRs vary from +3 to +7 dB (Picard & Bradley, 2001). When children do not receive the full auditory signal, which could be due to reduced hearing sensitivity and/or poor acoustics in classroom, language attainment, reading ability and academic achievement can be negatively affected (Ross, 1990).

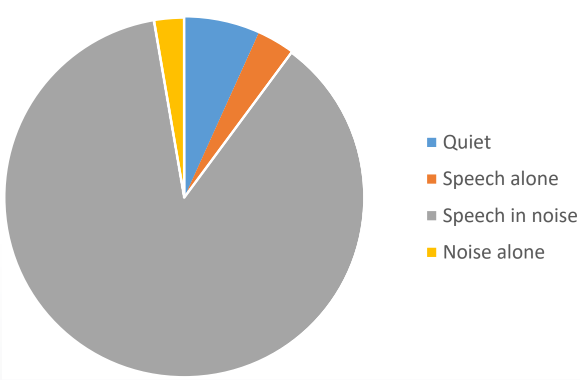

Figure 1. Proportion of time spent in each sound environment. Data from Crukley et al. (2011)

Noise hampers word learning

People expand vocabulary and learn new words through reading and everyday oral communication. Children learn words in classroom with formal instructions, for instance when a teacher introduces a new word by showing the referent object at the same time to students. New words can also be acquired without formal instructions or in unstructured contexts. This is often referred to as incidental learning. In oral communication, children typically and frequently learn new words and their meanings in adult-child interaction (Bates et al., 1988). Previous research has shown that young children of age 2.6 are capable to monitor third-party conversations and can take advantage of overheard speech to learn new words (Akhtar et al., 2001).

As discussed above, typical listening environments are usually noisy. Learning new words in noise is challenging for children whether or not they have a hearing loss. For instance, Riley and McGregor (2012) investigated word learning in typically developing children aged 9 to 10. The results suggested that words learned in noise were less accurate than words learned in quiet. That is, noise affected the *quality* of representation in lexicon of the newly learnt words. Background noise has a similar impact on word learning in toddlers aged 2 to 3 (McMillan & Saffran, 2016) and preschool children aged 4 to 5 (Han et al., 2019).

Negative consequences of hearing loss on learning

Children's vocabulary grows at a tremendous rate. Compared to children with normal hearing, children with hearing loss have poorer vocabulary knowledge (e.g. Tomblin et al., 2015). Along the same lines, it has been shown that word learning is less efficient in children with hearing loss than their peers with normal hearing (e.g. Pittman, 2008, 2011; Stelmachowicz et al., 2004). They often have a slower learning rate and would need more repetitions to achieve successful learning of new words. Having reduced hearing sensitivity causes degradation of auditory input signal, and this may demand extra linguistic processing to form stable representations of the newly learnt words in the lexicon. Consequently, learning of new words would become less efficient for these children.

Figure 2. Illustration of the impact of listening environments and hearing loss (left), and the implication for amplification (right).

Learning new words is related to the quality of auditory signal. By providing amplification and clearer signal to children with hearing loss, it is reasonable to expect that successful word learning can be achieved with fewer repetitions.

Studies were conducted to investigate the effect of hearing aid technology on word learning in children. Pittman (2011) reported that a digital noise reduction algorithm improved incidental learning in noise (steady-state noise) for children aged 11 to 12, such that word learning in noise with noise reduction was as good as that in quiet. Pittman et al. (2017) also showed that auditory signal of better quality (extended bandwidth) improves word learning speed. Ching (2015) pointed out that untreated hearing loss can negatively influence speech and language acquisition and development, which consequently contribute to negative long-term results in terms of educational and social outcomes. Another research study by Tomblin et al. (2015) suggested that children with hearing loss are at risks for language delay. However, these risks are moderated by the intervention of well-fitted hearing aids and optimal amplification, which can have positive impact on language development (see Figure 2).

Paediatric amplification: Goals and challenges
The goal of amplification is *to provide to an infant or child with impaired hearing the opportunity to have access to as much of the auditory environment, and in particular speech, as feasible* (American Academy of Audiology, 2013). Giving these children appropriate amplified auditory input maximizes the opportunities to develop age-appropriate receptive and expressive oral communication, language development, literacy skills, and psychosocial skills.

The recommendations for using noise management systems in paediatric amplification are mixed. For instance, the protocol for paediatric amplification in Australia (King, 2010) recommends the use of directional microphones for children of all ages, while the American Academy of Audiology Clinical Practice Guidelines on Paediatric Amplification (2013) states that full-time usage of directionality is not recommended. Directional microphone technology provides better speech understanding in noise by focusing on speech coming from a relatively narrow angle in front of the hearing aid user. The drawback of this technology is that it reduces audibility of talkers outside the directionality beam, which may consequently reduce audibility of off-axis talkers (see Figure 3). Children do not always look or turn in the direction of the target speech when they listen, such as during note-taking, which consequently limits the benefit from directional microphones (Ricketts & Galster, 2008). This technology also limits the opportunities to overhear people talking from different directions. To be able to overhear is particularly important for children, because they learn new words and gain knowledge incidentally. Directional microphone technology also reduces the awareness to the environmental sounds, which also raises a safety concern.

Figure 3. Conceptual photos visualizing the possible limitations of two conventional technologies: omni-directional processing strategy in noise (left) and directional frontal focus in noise (right).

Omni-directional technology is commonly prescribed in paediatric amplification. This technology allows access to all sounds in the environment. However, it does not attenuate noise and therefore does not provide good speech understanding in noise (see Figure 3). A previous study by Gustafson et al (2014) has shown that using the omni-directional technology resulted in higher listening effort (quantified by reaction time) than a digital noise reduction algorithm in a speech recognition task for children with normal hearing.

In summary, noise impedes speech understanding and slows down word learning, and the negative effects of noise are exacerbated by reduced hearing sensitivity. Neither of the conventional technologies, i.e. omni-directional and directional technologies, can fully support the unique listening needs of children with hearing loss. These children need auditory signal of good quality for better speech understanding and learning in noise without the need of pointing their heads towards the talker. They need a technology which also allows them to overhear so that they can learn and acquire new words and knowledge incidentally.

Using OpenSound Navigator in paediatric amplification

In our previous work, we demonstrated that OpenSound Navigator in Oticon Opn™ hearing aids improves speech understanding in noise and reduces listening effort for adults with hearing loss (Oticon whitepapers Juul Jensen, 2018; Le Goff et al., 2016a; Le Goff & Beck, 2017). This technology is designed to meet the unique listening needs of children by attenuating unwanted noise while preserving speech in the environments (see Le Goff et al., 2016b for technical details). Two independent studies were performed to document the benefits of OpenSound Navigator for children, and these benefits are compliant with the existing guidelines and goals for paediatric amplification.

Evidence

The two research studies focused on speech understanding in noise as well as listening effort. The first study with children aged 6 to 15 (see Browning et al., 2019 and Oticon whitepaper Ng, 2017 for details) demonstrated that, relative to omni-directional setting, OpenSound Navigator improved speech recognition performance by an average of 4 dB SNR both when the children faced the target speech and when they faced away from the target speech. This result showed that OpenSound Navigator gives equal benefit to children even when target speech source is off-axis. The same study also demonstrated that OpenSound Navigator preserves interfering speech coming from different directions. This suggests that OpenSound Navigator allows access to other talkers in the environment, which provides opportunities for incidental learning for children.

The second study (see Oticon whitepaper Ng et al., 2019 for details) investigated the effect of OpenSound Navigator on speech understanding and listening effort for children aged 12 to 16. Results showed that, compared to omni-directional setting, OpenSound Navigator improved speech recognition in both simple and complex listening conditions by up to 5 dB SNR, which is highly similar to the finding of the first study. Subjectively, these children perceived significantly less effort while listening to speech in noise when OpenSound Navigator was activated. The importance of using less effort in a listening task is that this would allow the children to allocate more mental resources on other simultaneous tasks such as learning.

In summary, our evidence has shown that OpenSound Navigator consistently improves speech understanding in noise and supports different challenges and needs in everyday listening, namely to be able to overhear and to benefit from the technology even when not looking at the target speech source. Furthermore, OpenSound Navigator reduces perceived effort during a listening task. This benefit is of great importance for children because hearing loss often imposes increased fatigue and effort (e.g. Hornsby et al., 2017).

Enabling OpenSound Navigator for younger children and infants

The above two studies concerning OpenSound Navigator tested school-age children. OpenSound Navigator is also available for infants and young children between 0 and 3 years with a default setting (Low balancing profile in Open Sound Transition with minimal Noise Reduction in Complex environment, see Figure 4) to ensure audibility of speech and comfort in these very difficult listening environments, and access to all sounds in other environments. The full effect of this setting is available for levels above about 85 dB SPL in the lowest frequency channels and about 55 dB SPL in the highest frequency channels. For children of age 4 and above, the Medium balancing profile is set as default. The full effect of this setting is available for levels above about 80 dB SPL in the lowest frequency channels and about 50 dB SPL in the highest frequency channels. The prescription of any noise management features should always be based on an individual assessment of the child's listening needs. The settings can be customized to accommodate local clinical practice guidelines.

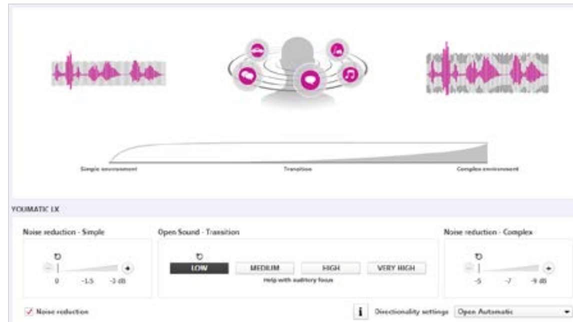

Figure 4. Default setting for young children and infants between 0 and 3 years. Screenshot from Oticon Genie 2 / 2019.1.

Conclusion

Children with hearing loss face diverse challenges and difficulties in everyday listening. Early intervention is crucial because it can minimize the negative impacts of hearing loss on learning and language development. The American Academy of Audiology Clinical Practice Guidelines on Paediatric Amplification (2013) states that the ultimate goal of paediatric amplification is to give children as much of the auditory environment as possible, in particular speech, in order to provide the best opportunities for learning and language development. Evidence shows that OpenSound Navigator provides benefits including improved speech understanding and reduced listening effort for children by optimizing SNR across varying listening environments. Besides hearing aid amplification, wireless assistive listening systems such as FM and remote microphones should also be used in educational or other settings where detrimental effects of distance and reverberation are involved.

The essence of Oticon's BrainHearing Philosophy is to deliver optimal input to the auditory system so that speech processing is facilitated and hence it is easier to make sense of sound. Along with well-fit hearing aids verified based on best practice guidelines, Oticon Opn Play™ featuring OpenSound Navigator provides children with hearing loss the optimal conditions to listen and learn.

References

1. Akhtar, N., Jipson, J., & Callanan, M. A. (2001). Learning words through overhearing. Child development, 72(2), 416-430.
2. AAA American Academy of Audiology. (2003). American Academy of Audiology Clinical Practice Guidelines on Pediatric Amplification.
3. Bates, E., Bretherton, I., & Sukdner, L. (1998). From first words to grammar. Cambridge: Cambridge University Press.
4. Browning, J. M., Buss, E., Flaherty, M., Vallier, T., & Leibold, L. J. (2019). Effects of Adaptive Hearing Aid Directionality and Noise Reduction on Masked Speech Recognition for Children Who Are Hard of Hearing. American Journal of Audiology, Early online.
5. Ching, T. Y. (2015). Is early intervention effective in improving spoken language outcomes of children with congenital hearing loss? American Journal of Audiology, 24(3), 345-348.
6. Crukley, J., Scollie, S., & Parsa, V. (2011). An exploration of non-quiet listening at school. Journal of Educational Audiology, 17, 23-35.
7. Gustafson, S., McCreery, R., Hoover, B., Kopun, J. G., & Stelmachowicz, P. (2014). Listening effort and perceived clarity for normal hearing children with the use of digital noise reduction. Ear and Hearing, 35(2), 183.
8. Han, M. K., Storkel, H., & Bontempo, D. E. (2019). The effect of neighborhood density on children's word learning in noise. Journal of Child Language, 46(1), 153-169.
9. Hornsby, B. W., Gustafson, S. J., Lancaster, H., Cho, S. J., Camarata, S., & Bess, F. H. (2017). Subjective fatigue in children with hearing loss assessed using self-and parent-proxy report. American Journal of Audiology, 26(3S), 393-407.
10. Juul Jensen, J. (2018). Closing a gap to normal hearing. Oticon Whitepaper.
11. King, A. M. (2010). The national protocol for paediatric amplification in Australia. International Journal of Audiology, 49(sup1), S64-S69.
12. Le Goff, N., & Beck D. (2017). Pushing the noise limit. Oticon Whitepaper.
13. Le Goff, N., Jensen, J., Pedersen, M.S., & Callaway, S.L. (2016b), An introduction to OpenSound Navigator™, Oticon Whitepaper.
14. Le Goff, N., Wendt, D., Lunner, T., & Ng, E. (2016a). Opn Clinical Evidence. Oticon Whitepaper.
15. McMillan, B. T., & Saffran, J. R. (2016). Learning in complex environments: The effects of background speech on early word learning. Child Development, 87(6), 1841-1855.
16. Ng, E. (2017). Benefits of OpenSound Navigator in children. Oticon Whitepaper
17. Ng, E., Goverts, T., Kramer, S., & Zekveld, A. (2019). Improved speech understanding with less effort in children: An OpenSound Navigator™ study. Oticon Whitepaper.
18. Picard, M., & Bradley, J. S. (2001). Revisiting speech interference in classrooms. Audiology, 40(5), 221-244.
19. Pittman, A. (2011). Age-related benefits of digital noise reduction for short-term word learning in children with hearing loss. Journal of Speech, Language, and Hearing Research, 54, 1448-1463.
20. Pittman, A. L. (2008). Short-term word-learning rate in children with normal hearing and children with hearing loss in limited and extended high-frequency bandwidths. Journal of Speech, Language, and Hearing Research, 51, 785-797.
21. Pittman, A. L., Stewart, E. C., Willman, A. P., & Odgear, I. S. (2017). Word recognition and learning: Effects of hearing loss and amplification feature. Trends in Hearing, 21, 2331216517709597.
22. Ricketts, T. A., & Galster, J. (2008). Head angle and elevation in classroom environments: Implications for amplification. Journal of Speech, Language, and Hearing Research, 51, 516-525.

23. Riley, K. G., & McGregor, K. K. (2012). Noise hampers children's expressive word learning. Language, Speech, and Hearing Services in Schools, 43(3), 325-337.

24. Ross, M. (1990). Definitions and descriptions. In Davis, J. (Ed.) Our forgotten children: Hard-of-hearing pupils in the schools, US. Department of Education, Washington DC, pp 3-1 7.

25. Soli, S. D., & Sullivan, J. A. (1997). Factors affecting children's speech communication in classrooms (Doctoral dissertation, ASA).

26. Stelmachowicz, P. G., Pittman, A. L., Hoover, B. M., Lewis, D. E., & Moeller, M. P. (2004). The importance of high-frequency audibility in the speech and language development of children with hearing loss. Archives of Otolaryngology–Head & Neck Surgery, 130(5), 556-562.

27. Tomblin, J. B., Harrison, M., Ambrose, S. E., Walker, E. A., Oleson, J. J., & Moeller, M. P. (2015). Language outcomes in young children with mild to severe hearing loss. Ear and Hearing, 36(0 1), 76S.

28. Werner, L. A. (2011). Auditory Development 1: Retrieved from http://faculty.washington.edu/lawerner/sphsc462/Development.pdf

3174BUK / 2019.06.24

oticon.global/evidence

oticon
PEOPLE FIRST