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Improved speech understanding with less effort in children: An OpenSound Navigator™ study

SUMMARY

A study at VU University medical center in Amsterdam, the Netherlands looked into the effect of OpenSound Navigator™ on speech understanding and listening effort in noise for children with hearing loss. The level of effort the children used in differing listening conditions was assessed using subjective and objective measurements in a speech recognition task. The test simulated two listening environments, complex and simple, comparing OpenSound Navigator and omni-directional technology.

Results showed that OpenSound Navigator improved speech recognition across listening conditions by up to 5 dB SNR. Subjectively, these children perceived significantly less effort while listening to speech in noise with OpenSound Navigator activated. In addition, the objective measure of listening effort, pupillometry, showed a tendency that OpenSound Navigator slightly reduces the average pupil response in simple listening environment, indicating less effort.

Less listening effort devoted to a listening task would allow children to spend more effort on other concurrent activities such as acquiring new skills and knowledge in classroom.

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Introduction

Over the past few decades, research in hearing loss and hearing aid use has been putting a strong focus on speech recognition performance as the outcome measure. Because people with hearing loss often experience and report effortful listening especially in noisy situations, there is a growing interest in looking at the interplay between hearing loss, listening effort, and cognition.

Similar to adults, children with hearing loss often need to spend more effort and experience more fatigue and signs of stress in listening-related tasks. Both Hicks and Tharpe (2002) and McGarrigle et al. (2018) reported that children with hearing loss showed a consistent reduction in reaction time in a dual task (performing a primary speech perception task and a secondary visual/motor monitoring task simultaneously) when compared to children with normal hearing. Their results indicate that children with hearing loss need to spend more effort in a listening task. Hornsby et al. (2017) found that school-age children with hearing loss reported experiencing more fatigue, in particular in the cognitive fatigue domain, than their normal hearing peers.

Hearing aid technology is designed to optimise speech perception in noise. In our previous work, we demonstrated that OpenSound Navigator™ (OSN) in the Oticon Opn™ hearing aid improves speech understanding in noise and reduces listening effort for adults with hearing loss (Oticon whitepapers Juul Jensen, 2018 ; Le Goff et al., 2016; Le Goff & Beck, 2017). In addition to the perceived effort rating and behavioural measures such as reaction time, changes in listening effort related to the use of advanced hearing aid technology have also been assessed using the objective measure pupillometry (for example Ohlenforst et al., 2017, 2018; Wendt et al., 2017). In short, an increased pupil dilation response is associated with an increased cognitive processing load required during a speech recognition task (for example Zekveld et al., 2010), and has been used to indicate the benefit of hearing aid technology during a speech recognition task. The benefits of OSN on speech intelligibility and listening effort in adults are reported in two Oticon whitepapers. Le Goff et al. (2016) reported that OSN effectively reduced the pupil dilation response during listening to speech in noise (see Wendt et al., 2017 for details of the study). Le Goff and Beck (2017) reported similar results, which confirms that OSN reduces listening effort across a wide range of signal-to-noise ratios (SNRs) that are representative of everyday listening environments (see Ohlenforst et al., 2017, 2018 for details).

Although the evidence for reduced listening effort with the use of advanced hearing aid technology has grown, it is still unclear whether these results translate to children with hearing loss. For example, one study showed that a digital noise reduction system was associated with reduced verbal response times when children (aged 7-12 years) with normal hearing listened to non-words presented in noise (Gustafson et al., 2014). This finding supports the notion that the use of advanced hearing aid technology results in reduced listening effort. However, this may not reflect the outcomes in children with hearing loss.

The aim of this study was to assess the benefits of OSN on the speech recognition and listening effort for children. This study compared OSN to Oticon's omni-directional technology, which is the PinnaOmni mode (OMNI) that emulates the pinna by providing slight directionality at high frequencies. A previous study showed that compared to OMNI, OSN improved speech recognition in steady noise for children, even when they faced away from the target source (Browning et al., 2017). We therefore expected to see similar improvement in speech recognition in noise in this study.

Methods

- Participants

Ten participants between age of 12 and 14 were included in the analyses. They had symmetrical mild to severe sensorineural hearing loss (Figure 1) and were regular hearing aid users. They were all native speakers of Dutch. They had normal or corrected-to-normal eyesight, and none had any eye disease such as diabetes mellitus that may influence pupil dilation response.

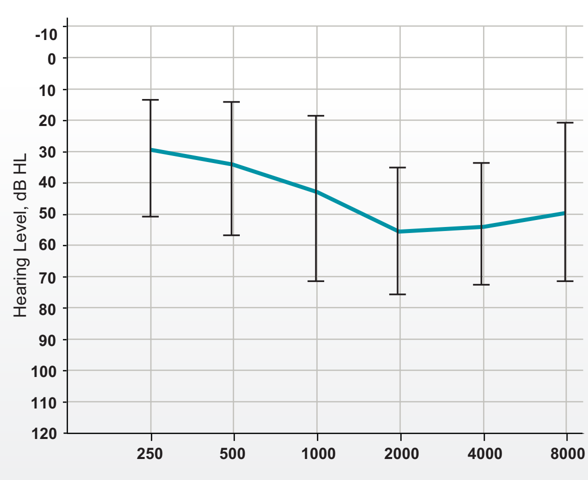

Figure 1. Average pure-tone hearing thresholds of the best ear for 10 participants who completed the study. Error bars indicate standard deviations.

- Hearing aid fitting

To provide these participants with appropriate amplification, two styles of hearing aid were used, Oticon Opn1 miniRITE style hearing aid coupled to an 85 speaker (seven participants), and Oticon Opn1 BTE13 PP (three participants) hearing aid. The output of the hearing aids was set according to the DSLv5 rationale.

- Tests administration

The study was conducted in the VU University Medical Center in Amsterdam, the Netherlands and was approved by an ethics committee. The participants and their parents/caregivers provided written informed consent.

Speech understanding

In each test condition, a speech recognition threshold (SRT) was obtained using Dutch sentences spoken by a female talker (Versfeld et al., 2000). The masker speech signals consisted of speech uttered by two male speakers. The test set-up consisted of one loudspeaker positioned in front of the listeners, two loudspeakers positioned at ±120 degrees presenting speech maskers, and one loudspeaker at 180 degrees presenting steady state noise. All four loudspeakers were positioned at a distance of 1 m from the listener (See Figure 2).

Four speech recognition test conditions were applied: *Intelligibility level* (50%, 84%) and *Hearing aid technology* (OSN versus OMNI). For every participant, an adaptive SRT test was presented that targeted the correct recognition of 50% or 84% of the sentences, which resembles a complex and simple listening environment respectively. The overall level of the maskers was fixed at 70 dB SPL and the level of the target speech was adaptively varied.

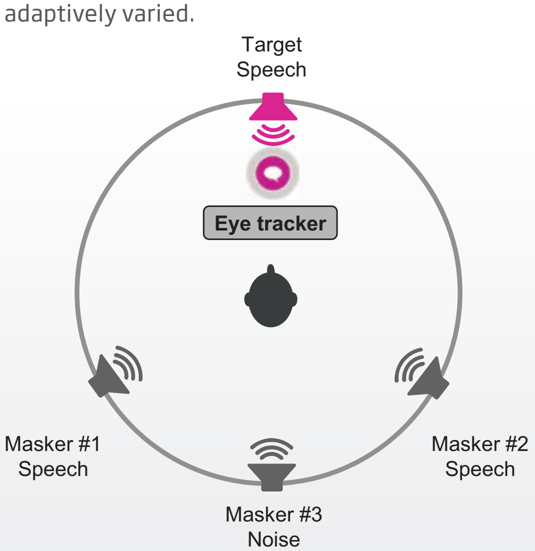

Figure 2: Schematic illustration of the experimental room. The booth is equipped with an eyetracker and four loudspeakers (front = target speech, back = steady state noise, ±120 degrees = speech maskers)

Listening effort

Listening effort was assessed subjectively and objectively. For the subjective measure, the participants were asked to rate their subjective effort level (on a scale of 1 to 10) in completing the SRT test after each of the four conditions. For the objective measure, pupil dilation response was recorded during every test condition. A larger pupil size during a listening task is indicative of more listening effort. This method has been successfully applied to assess listening effort during speech perception for adult listeners (for example Koelewijn et al., 2014). A recent study suggests that the application of pupillometry in children is also feasible (Steel et al., 2015). An eyetracker was used to assess the size of the pupils. The participants were positioned in a comfortable chair located between 51 and 70 cm from the pupillometer. The peak pupil dilation and mean pupil dilation was determined relative to the pupil size while listening to the masker stimuli (baseline pupil size as determined for each trial). See Zekveld et al. (2010) for more details about the procedure.

Results

- Speech understanding

Figure 3 shows the results of the speech recognition test. Statistical analysis (ANOVA) showed that OSN significantly improved SRT, such that the difference between OSN and OMNI was 3.98 and 4.78 dB SNR at 50% and 84% speech intelligibility levels respectively, $F(1, 9) = 12.5$, $p < 0.01$.

OSN improves speech understanding by up to 5 dB even at a high speech intelligibility level

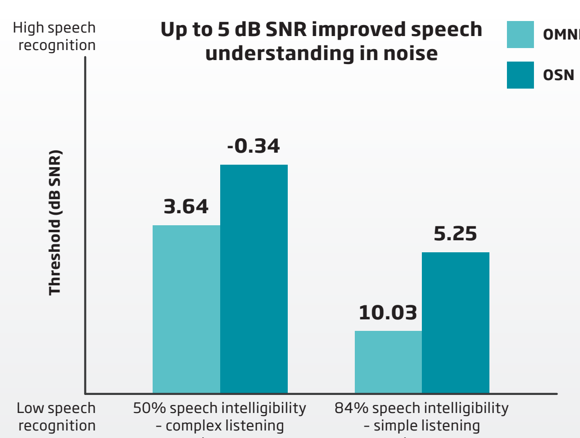

Figure 3. Results of the speech recognition test. The number on top of each bar represents speech recognition threshold in dB SNR. A smaller number (or a longer bar) indicates better speech recognition.

- Listening effort

Subjective measure. After each test condition, the participants rated their perceived effort (on a scale of 1 to 10). Results are shown in Figure 4. Statistical analysis indicated that the subjective effort rating, as averaged over intelligibility levels, was lower for OSN as compared to OMNI, $t(9) = 2.05$, $p < 0.05$.

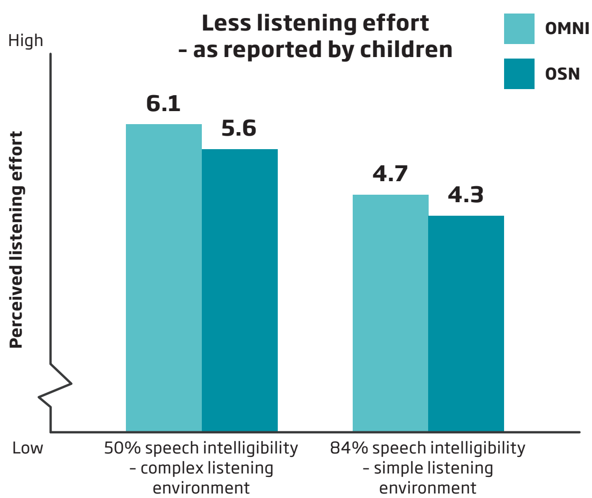

Figure 4. Results of the subjective measure of listening effort. The number on each bar represents the average self-rated listening effort in the corresponding test condition.

Objective measure. Pupil response was measured for each of the participants. The distribution of the peak pupil dilation response data was heavily skewed for two test conditions, so these are not analysed here. For the mean pupil dilation response data, statistical analysis showed a marginally significant interaction, $F(1, 9) = 5.06$, $p = 0.051$. This interaction suggests a tendency that at 84% intelligibility, OSN slightly reduced the mean pupil response compared to OMNI, indicating less listening effort. A similar trend was not observed at 50% intelligibility level.

Interpretation and implications

Results showed that OSN improved speech recognition across speech intelligibility levels by an average of 4 to 5 dB SNR, which is in good agreement with the results reported by Browning et al. (2017), who found that OSN improved speech recognition by approximately 4 dB SNR compared to OMNI. This is also in line with the subjective ratings, in that these children reported perceiving significantly less effort while listening to speech in noise with OSN. Results from the pupillometry measurement also showed a tendency of reduced listening effort when OSN was activated, which is in line with the SRT test performance and the subjective effort rating.

To our knowledge, this was the first pupillometry study assessing listening effort in children wearing hearing aids. There was a tendency but not a statistically significant effect of OSN on objective listening effort. This could relate to the fact that the sample size of the study is considered to be small (10 participants), which reduces statistical power to detect differences between test conditions. Age-related development of language and auditory processing in children may also limit the benefit from noise reduction algorithms as compared to that observed in adult hearing aid users. This could also be a reason why we did not observe a significant difference in the pupillometry measurement. Further research is warranted in order to find out whether age (adults versus children) affects pupil responses, and benefits from advanced hearing aid technology.

Listening effort is defined as *the deliberate allocation of mental resources to overcome obstacles in goal pursuit when carrying out a listening task* (Pichora-Fuller et al., 2016). In cognitive psychology, it is hypothesized that every individual has a limited capacity of mental resources that can be allocated to doing tasks. Figure 5 conceptualises in a simplified way how effort is typically spent in different acoustic environments. Listening effort gradually increases as the acoustics of the listening environment transitions from quiet to very noisy. OSN improves speech understanding with less effort as compared to the omni-directional technology. If less effort is devoted to listening in very noisy environments (indicated by the red dashed line in the figure), such as traditional classrooms, this will allow the children to have more remaining resources for other concurrent activities such as acquiring new skills and knowledge in classroom, and other everyday activities.

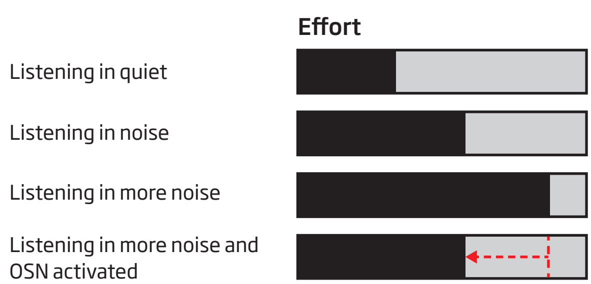

Figure 5. Schematic representations of how effort is typically spent in different acoustic environments. Bars in black represent effort devoted to a listening task and bars in grey represent remaining mental resources. (Figure inspired by Lunner et al., 2009).

Conclusion

Consistent with our evidence showing that OSN improves speech recognition in noise for children (Browning et al., 2017; Oticon whitepaper Ng, 2017), this study further demonstrates that OSN reduces perceived effort during a speech recognition task. This OSN benefit is particularly important because hearing loss imposes increased fatigue and effort as experienced by children. Oticon's BrainHearing technology is designed to support the unique day-to-day challenges and developmental needs of children. Together with amplification prescribed according to best practice, OSN delivers an optimised speech signal and hence provides these children with the optimal conditions to listen and learn.

References

1. Browning, J. M., Buss, E., Flaherty, M., & Leibold, L. J. (2017, March). Integrated directionality and noise reduction: Effects on children's masked thresholds. Poster session presented at the Annual Scientific and Technology Conference of the American Auditory Society, Scottsdale, AZ.
2. 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.
3. Hicks, C. B., & Tharpe, A. M. (2002). Listening effort and fatigue in school-age children with and without hearing loss. *Journal of Speech, Language, and Hearing Research*, 45(3), 573-584.
4. 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.
5. Juul Jensen, J. 2018. Closing a gap to normal hearing. Oticon Whitepaper.
6. Koelewijn, T., Zekveld, A. A., Festen, J. M., & Kramer, S. E. (2014). The influence of informational masking on speech perception and pupil response in adults with hearing impairment. *The Journal of the Acoustical Society of America*, 135(3), 1596-1606.
7. Le Goff, N., & Beck D. (2017). Pushing the noise limit. Oticon Whitepaper.
8. Le Goff, N., Wendt, D., Lunner, T., & Ng, E. (2016). Opn Clinical Evidence. Oticon Whitepaper.
9. Lunner, T., Rudner, M., & Rönnberg, J. (2009). Cognition and hearing aids. *Scandinavian journal of psychology*, 50(5), 395-403.
10. McGarrigle, R., Gustafson, S. J., Hornsby, B. W., & Bess, F. H. (2018). Behavioral Measures of Listening Effort in School-Age Children: Examining the Effects of Signal-to-Noise Ratio, Hearing Loss, and Amplification. *Ear and hearing*.
11. Ng, E. 2017. Benefits of OpenSound Navigator in children. Oticon Whitepaper.
12. Ohlenforst, B., Wendt, D., Kramer, S. E., Naylor, G., Zekveld, A. A., & Lunner, T. (2018). Impact of SNR, masker type and noise reduction processing on sentence recognition performance and listening effort as indicated by the pupil dilation response. *Hearing Research*.
13. Ohlenforst, B., Zekveld, A. A., Lunner, T., Wendt, D., Naylor, G., Wang, Y., ... & Kramer, S. E. (2017). Impact of stimulus-related factors and hearing impairment on listening effort as indicated by pupil dilation. *Hearing research*, 351, 68-79.
14. Pichora-Fuller, M. K., Kramer, S. E., Eckert, M. A., Edwards, B., Hornsby, B. W., Humes, L. E., ... & Naylor, G. (2016). Hearing impairment and cognitive energy: The framework for understanding effortful listening (FUEL). *Ear and Hearing*, 37, 5S-27S.
15. Steel, M. M., Papsin, B. C., & Gordon, K. A. (2015). Binaural fusion and listening effort in children who use bilateral cochlear implants: A psychoacoustic and pupillometric study. *PLoS One*, 10(2), e0117611.
16. Versfeld, N. J., Daalder, L., Festen, J. M., & Houtgast, T. (2000). Method for the selection of sentence materials for efficient measurement of the speech reception threshold. *The Journal of the Acoustical Society of America*, 107(3), 1671-1684.
17. Wendt, D., Hietkamp, R. K., & Lunner, T. (2017). Impact of noise and noise reduction on processing effort: A pupillometry study. *Ear and Hearing*, 38(6), 690-700.
18. Zekveld, A. A., Kramer, S. E., & Festen, J. M. (2010). Pupil response as an indication of effortful listening: The influence of sentence intelligibility. *Ear and Hearing*, 31(4), 480-490.

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