WHITEPAPER
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The audiology of Oticon More™

ABSTRACT

This whitepaper dives into the underlying principles of the audiology in Oticon More 1, inspired by our latest BrainHearing™ insights telling us that, for successful hearing, the brain benefits from access to full amplified sound scenes with elements in balance. To achieve this, Oticon More makes use of the intelligence of a deep neural network, trained on millions of real-life sound scenes and directly embedded on the hearing-aid's new Polaris™ platform, to provide users access to clear sound scenes in which the meaningful sounds are in balance and stand out from the background. This fundamentally new approach to sound processing is supported by a new rapid and high-resolution amplification strategy, ensuring that important sound details are delivered to the brain. These innovations in hearing technology differ from traditional noise reduction and compression approaches and address their limitations, giving the brain access to more of the full sound scene, so that users can better focus on what matters to them without losing track of the meaningful sounds happening around them, as documented in clinical research with Oticon More.

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For the brain, more is more

Having a passionate conversation with a group of friends? You want to be able to follow what all of them say and seamlessly redirect your attention between them over time. Is there a loud fan or traffic noise in the background? You do not want to be disturbed by these irrelevant sounds, but you still want to know they are out there. Is there a band playing? Are some people cheering? You want to enjoy the atmosphere of the place but still follow what your friends are saying. Are you more into quiet forest walks? You may want the singing of birds and the rustling of leaves to be part of the experience. These are only a few examples, but in most everyday listening situations, we would like to be able to easily focus on some specific sounds but also to keep aware of what is going on around us and refocus our attention if needed. What does it take to achieve this?

To make sense of sound, we constantly combine our sensory, cognitive, and social abilities (Pichora-Fuller et al., 2017; Meyer et al., 2016 – see Figure 1). Thanks to this fine balance of skills, we humans are equipped to navigate successfully through life's complex cacophony of sound. For this to work, the whole sound scene first needs to be correctly transmitted through the ear and converted into a precise neural code that travels through the auditory nerve before it reaches the brainstem and the hearing centre in the brain (Man & Ng, 2020; Lesica, 2018) – these are our sensory hearing skills. Starting in the auditory cortex, the brain then needs to be able to orient itself through the elements of the incoming sound scene (O'Sullivan et al., 2019; Puvvada & Simon, 2017) and, through interaction with other specialized brain areas, to focus on the important sounds at every given moment so that we can understand and remember what matters to us (Man & Ng, 2020; Shinn-Cunningham et al., 2017) – this defines our cognitive hearing skills. Having made sense of all sounds of interest in relation to the context of the whole sound scene, we can then decide and act, listen and speak, pay attention and react to what is going on around us, navigate through our environment and communicate with others (Pichora-Fuller, 2016; Borg et al., 2008) – forming our social hearing skills.

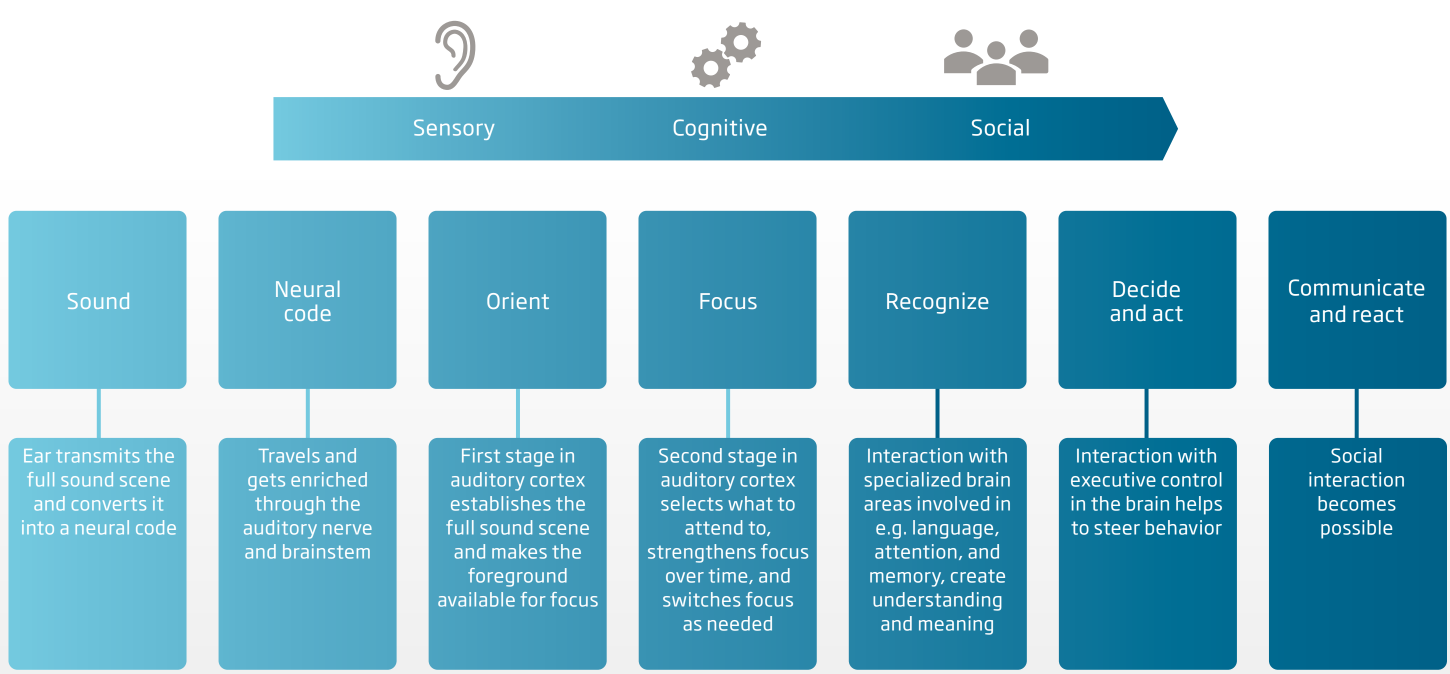

Figure 1: Hearing is a biopsychosocial process, involving sensory perception, cognition, and behavior.

There is now ample scientific evidence that hearing loss does not only affect the sensory part of the hearing system (Moore, 2007) but also has important consequences for our cognitive and social abilities, even beyond the hearing domain (e.g., Livingston et al., 2020; Edwards, 2016; Campbell & Sharma, 2014; Rönnberg et al., 2013; Strawbridge et al., 2000; for a review, see Man & Ng, 2020). Hearing loss can originate in many different parts of the complex auditory pathway linking the ears to the brain. Importantly, wherever these changes may occur at first, they typically result in a poorer neural code sent to the brain (Lesica, 2018): The brain receives less information and this information is less precise, making it challenging for people with hearing loss to use their cognitive and social skills successfully. Providing more information to the brain in a more precise way is thus essential to give people with hearing loss an optimal auditory stimulation and help them achieve the best possible cognitive and social outcomes. This key insight is the main driver behind the audiological design of Oticon More™, delivering a whole new level of hearing care technology based on the latest BrainHearing™ knowledge (Man & Ng, 2020).

Giving the brain access to more with hearing-aid technology

Hearing-aid technology has long been designed according to four main assumptions: 1) The most relevant sound source for people with hearing loss is always speech from the front; 2) Non-speech sounds exacerbate communication difficulties and are always unwanted; 3) People with hearing loss have access to a reduced range of sound levels, such that amplification must ensure audibility, whilst maintaining comfort; and 4) Amplification without feedback occurrence has to be ensured. Conventional hearing care solutions have typically addressed these points by applying four types of signal processing algorithms: 1) Directionality, prioritizing access to frontal speech; 2) Noise reduction, attenuating all non-speech-like sounds; 3) Dynamic-range compression, making soft sounds audible and loud sounds comfortable; and 4) Feedback management counteracting audible feedback even if that means sacrificing full prescribed gain levels in dynamic situations. While advanced versions of such algorithms have become very effective, the purpose they serve and the assumptions they are built on may not always be in line with what the latest scientific evidence tells us about how the brain makes sense of sounds. Therefore, they may limit people with hearing loss.

What the brain is naturally programmed to do is to represent the entire sound scene and orient through it at all times, so it can then work on the different elements of the scene (Man & Ng, 2020). The combination of conventional directionality, noise reduction, compression, and anti-feedback systems can limit the sound scene in several ways: limiting access to all sounds from the sides and the back of the user (directionality), limiting access to all sounds that are not seen as speech by the hearing aid (noise reduction), limiting access to important sound details that matter to the brain (compression), and limiting access to optimal gain in dynamic situations (feedback management). In order to give the brain access to all sounds that carry information, hearing-aid technology should ideally open up to all meaningful sounds, not only speech-like sounds, to create a clear and natural contrast between the important elements in the scene and the background, and to amplify all elements in the scene accurately and in sufficient detail. Only then can attention work naturally on all the clear elements available (Man & Ng, 2020).

The OpenSound paradigm in Oticon hearing aids running on the Velox and Velox S platforms has been an important step in opening up to speech sounds all around the user, not only from the front (Le Goff et al., 2016a), with numerous audiological benefits compared to traditional directionality (Juul Jensen, 2018; Le Goff et al., 2016b). Oticon's recently introduced unique new approach to preventing feedback has also ensured that users have access to optimal gain also in dynamic situations (Løve, 2019).

[1] Changes can arise at many levels, e.g., in the conductive ability of the middle ear, the sensory function of hair cells in the cochlea, the mechanical properties of structures surrounding the hair cells, the connections between the inner ear and the auditory nerve, the function of the auditory nerve itself or that of more central auditory neural entities in the brainstem and cortex.

With Oticon More, built on the new powerful Polaris™ platform, we are now able to challenge conventions even further by introducing new BrainHearing™ technology designed to give access to full sound scenes that are easier to decode for the brain, so that it can better orient, focus, and make sense of what's going on. Below, we illustrate how the key audiological innovations in Oticon More, MoreSound Intelligence™ and MoreSound Amplifier™, break with traditional noise reduction and compression approaches to achieve such benefits, and are supported by upgrades to the OpenSound Optimizer in Oticon Opn S, creating the MoreSound Optimizer in Oticon More.

MoreSound Intelligence™ – A brain-inspired sound scene clarifier

When you have a hearing loss, sounds are not only less audible but also tend to blend in together. This explains why people with hearing loss often perceive sound scenes as "blurry" or "muddy" and have a hard time focusing on specific sounds. This difficulty in separating sounds from one another also makes a person's auditory system less robust to noise and disturbing sound that the person would like to keep in the background. In order to give people with hearing loss access to clear and full sound scenes in real-world listening environments, the new MoreSound Intelligence (MSI) feature makes meaningful sounds stand out from the background while preserving access to all sound sources and all directions that have distinct information. This makes it easier for the brain to separate sounds and focus on what's relevant (Santurette et al., 2020).

First, MSI analyses the full sound scene to detect how complex the listening environment is and constantly benchmarks this complexity against the individual listening needs of the user specified in the Genie 2 fitting software. MSI then makes the meaningful sounds more distinct based on how easy or how difficult the current environment is for the user, seamlessly adapting to how the environment complexity changes over time. Two processing steps are applied to enhance clarity of the sound scene: Spatial Clarity Processing and Neural Clarity Processing.

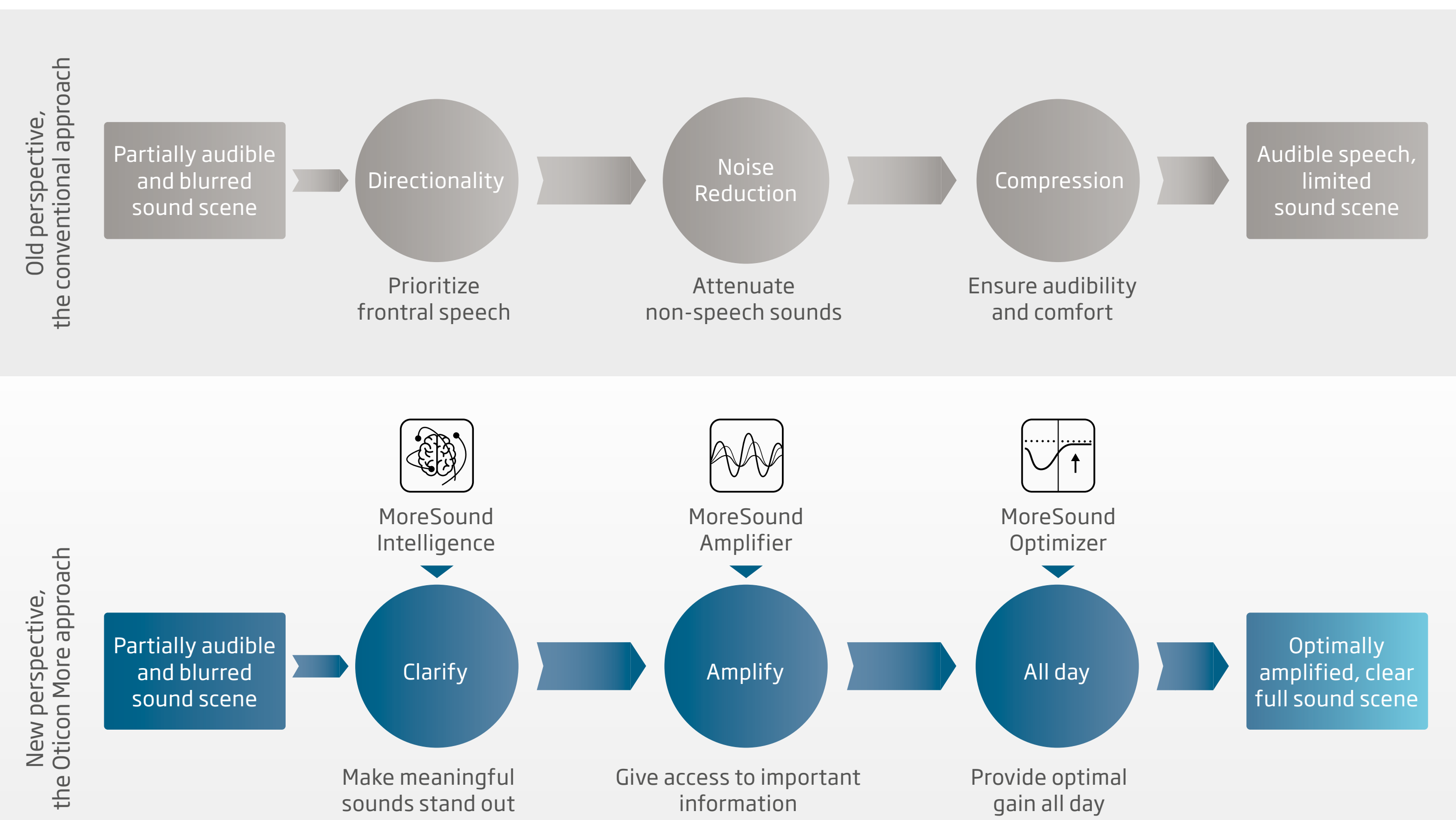

Figure 2: Comparison between conventional technology approach and the new BrainHearing based approach in Oticon More.

In relatively easy environments, MSI's Spatial Clarity Processing uses new virtual outer ears that better mimic the filtering of real human pinnae, to ensure that the sound scene picked up by the two hearing-aid microphones is reproduced with accurate and natural spatial information. In more difficult environments, spatial balancing makes sure that meaningful sounds remain accessible and stay balanced against dominating noises around the user, with a precision that surpasses that achieved by Oticon's OpenSound Navigator.

Once sounds are well balanced in space, MSI's Neural Clarity Processing kicks in. In contrast to traditional noise reduction algorithms, manually tweaked to preserve speech and attenuate noise based on mathematical assumptions, Neural Clarity Processing makes use of the knowledge that a deep neural network (DNN) has acquired by being trained on 12 million real-life sound scenes (Brændgaard, 2020a), in a way that mimics how a human brain works. The full sound scene is processed based on what the DNN has learned should be in the foreground (the sounds that carry meaning and may become the focus of attention for the user, such as speech, music, and important environmental sounds) and in the background (the sounds that carry less meaning and are not as relevant to focus on, such as babble or noise). Because the DNN has learned which elements of real sound scenes carry most information and which don't, and what the natural relationship between these elements should be, the result is a more fine-grained and nuanced contrast between the meaningful sounds and the background, compared to traditional noise reduction, as illustrated in Figure 3.

In Figure 3, note how the Neural Noise Suppression (D) is more accurate in detecting the speech and that the contrast enhancement has more organic shapes than the noise reduction system in Oticon Opn S 1 (C), which reflects learning from the real-life sounds it has undergone. This is further supported by the Sound Enhancer, which ensures that the areas detected as the foreground by MSI see their gain dynamically preserved (white areas) or enhanced (blue areas). For further technical details about MSI, see Brændgaard (2020a).

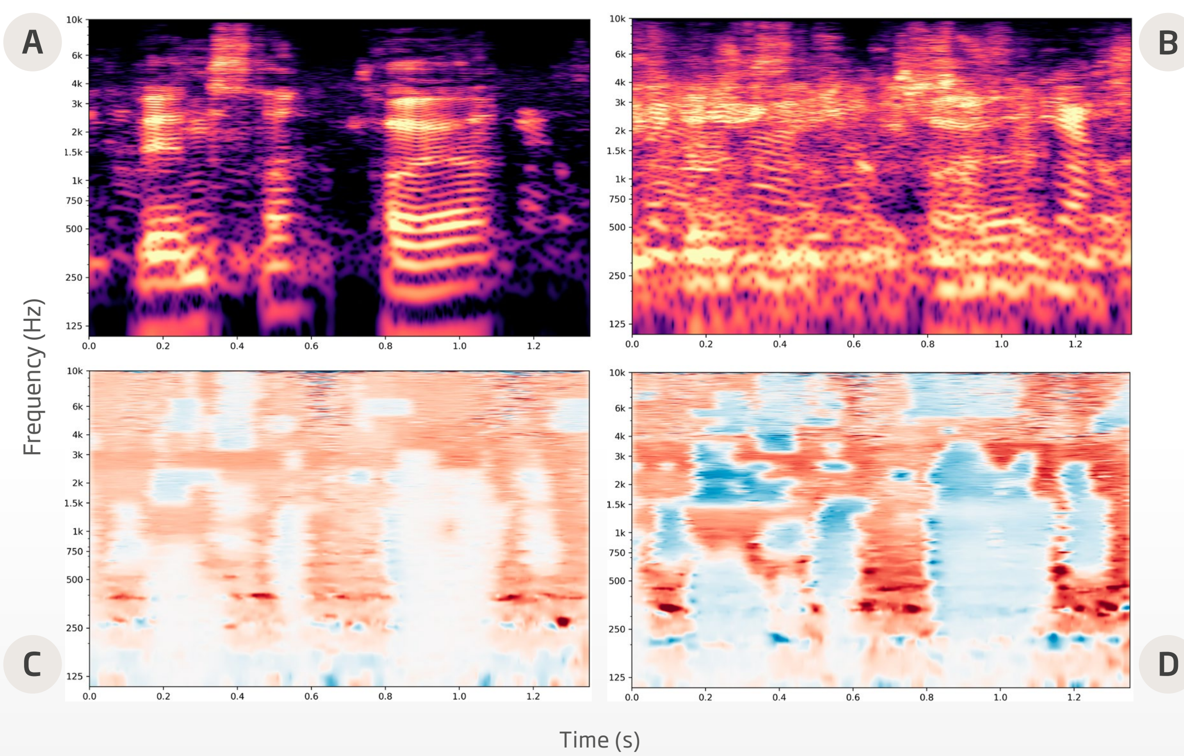

Figure 3: (A) shows the spectrogram of a clean speech signal – the Danish word for "left" ("venstre") followed by the Danish word for "right" ("højre"). (B) shows the spectrogram of the same speech signal in babble noise. (C) and (D) show which areas of such a sound scene are attenuated (red areas), preserved (white areas), and enhanced (blue areas) by traditional noise reduction (as implemented in Oticon Opn S 1 with a fast noise removal algorithm, (C)) and by the new DNN-based approach in Oticon More 1 (D). The Neural Noise Suppression in More leads to increased contrast between the areas of the sound scene containing meaningful information – in this case, the speech – relative to the background, compared to the noise reduction as implemented in the OpenSound Navigator in Oticon Opn S. With the action of the DNN, this contrast becomes more gradual and nuanced, with more of the speech information (white and blue areas) delivered to the user, especially at high frequencies due to the increased frequency resolution of the Polaris platform compared to Velox S.

MoreSound Amplifier – A high-resolution flexible amplification system

Once the sound scene has been properly balanced by MSI, with a foreground of meaningful sounds that is sufficiently distinct from the background to fit the needs of the user, this balanced sound scene has to be amplified in a way that preserves this careful balance between sounds but also conveys all their important details. This is especially crucial as we know that hearing loss makes it hard for the brain to access details in the sound even when it is made audible. Taking a visual analogy, we could see the sound scene delivered by MSI as a small picture that we have to magnify to become a big picture, but without compromising on its clarity. How do we achieve this?

In order to give the brain access to important details of the sound scene at any given time, the new MoreSound Amplifier (MSA) in Oticon More adapts not only in terms of speed but, importantly, also in terms of resolution, depending on the characteristics of the sound scene and how it changes over time. Traditional hearing-aid compression systems have evolved towards the use of adaptive time constants over the past decade, starting with Oticon's Speech Guard technology. While such systems have the advantage to steer the amplification based on how fast or how slowly the sound level changes over time, both allowing audibility of speech and avoiding discomfort from loud sounds, they typically operate at one fixed frequency resolution (i.e., with a fixed number of channels) that is often kept low to avoid audible distortion of the sound as it gets compressed. Going back to our visual analogy, it is easy to visualize that magnifying a small picture with low resolution will inevitably lead to a pixelated big picture that has lost in clarity and detail, and that you cannot get these details back once the picture has been enlarged.

This is why, thanks to the increased resolution of the Polaris platform, MSA is able to run with six times the resolution of Speech Guard, while still adapting in speed with high accuracy. When the sound scene changes quickly, we need to make sure to convey these changes precisely so that loud sounds are comfortable and soft sounds are audible. In such cases, MSA thus prioritizes being precise in time over using high frequency resolution. Conversely, when the sound scene changes slowly, we need to make sure that details of the scene are not lost while we amplify it. Therefore, as soon as the sound scene is more stable, the system switches to the use of a higher frequency resolution in order to make all relevant sound details audible. This higher resolution allows individual sounds with different frequency content to be better separated, and thus amplified more accurately by the system and in balance with each other.

Ensuring better access to optimal gain

Feedback risk and open fittings have long been two main causes of limited access to proper gain for the user. However, ensuring that optimal gain is delivered in all situations, also in open fittings, is essential to get the full audiological benefits of the clarified and amplified sound via MSI and MSA. In Oticon More, The MoreSound Optimizer, an upgrade of Oticon's OpenSound Optimizer for the Polaris platform, makes sure that feedback is prevented by detecting it before it occurs, enabling better access to optimal gain also in dynamic situations. In addition, open fittings with Oticon More can now benefit from the new Open Bass Dome that provides better access to gain at speech frequencies than an open dome and ensures that, when streaming your favorite music or podcast, you get access to more low-frequency gain without compromising on the comfort of an open fit. Finally, Oticon More can be fine-tuned in up to 24 fitting bands, giving even more flexibility to hearing care professionals to provide precise gain to users.

Oticon More – Adding perspective in hearing care

The MSI and MSA innovations in Oticon More are designed to give the brain better access to more relevant and precise information, breaking with traditional approaches to noise reduction and compression in hearing aids. Taking advantage of the learnings of a DNN embedded on Oticon's new Polaris platform, MSI first clarifies the full sound scene by making important sounds stand out from the background and giving access to all sound sources that have distinct information. MSA then makes all sounds audible from simple to complex environments by providing precise access to sound dynamics and details thanks to its flexible speed and resolution. By adapting over time, capturing the complexity of the sound scene as it unfolds, and ensuring elements of the scene are delivered with precision and balance to the user, these two features are designed to convey the information that is most important to the brain in creating full and precise sound scenes. As a result, Oticon More is proven to give the brain better access to the full sound scene at hand and to elements in the foreground, allowing users to better focus on, understand, and remember sounds of interest, as documented in clinical research (Santurette et al., 2020).

References

1. Borg, E., Bergkvist, C., Olsson, I. S., Wikström, C., & Borg, B. (2008). Communication as an ecological system. International Journal of Audiology, 47(sup2), S131-S138.
2. Brændgaard, M. (2020a). MoreSound Intelligence™. Oticon Tech Paper.
3. Brændgaard, M. (2020b). The Polaris platform. Oticon Tech Paper.
4. Campbell, J., & Sharma, A. (2014). Cross-modal re-organization in adults with early stage hearing loss. PloS one, 9(2), e90594.
5. Edwards, B. (2016). A model of auditory-cognitive processing and relevance to clinical applicability. Ear and hearing, 37, 85S-91S.
6. Juul Jensen, J. (2018). Closing a gap to normal hearing. Oticon Whitepaper.
7. Le Goff, N., Jensen, J., Pedersen, M. S., & Løve C., S. (2016a). An introduction to OpenSound Navigator™. Oticon Whitepaper.
8. Le Goff, N., Wendt, D., Lunner, T., & Ng, E. (2016b). Opn clinical evidence. Oticon Whitepaper.
9. Lesica, N. A. (2018). Why do hearing aids fail to restore normal auditory perception? Trends in neurosciences, 41(4), 174-185.
10. Livingston, G., Huntley, J., Sommerlad, A., Ames, D., Ballard, C., Banerjee, S., ... & Costafreda, S. G. (2020). Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. The Lancet.
11. Løve, S. (2019). Introduction to OpenSound Optimizer™. Oticon Whitepaper.
12. Man K. L., B., & H. N. Ng, E. (2020). BrainHearing™ – The new perspective. Oticon Whitepaper.
13. Meyer, C., Grenness, C., Scarinci, N., & Hickson, L. (2016). What is the international classification of functioning, disability and health and why is it relevant to audiology? In Seminars in Hearing (Vol. 37, No. 03, pp. 163-186). Thieme Medical Publishers.
14. Moore, B. C. J. (2007). Cochlear hearing loss: physiological, psychological and technical issues. John Wiley & Sons.
15. O'Sullivan, J., Herrero, J., Smith, E., Schevon, C., McKhann, G. M., Sheth, S. A., ... & Mesgarani, N. (2019). Hierarchical Encoding of Attended Auditory Objects in Multi-talker Speech Perception. Neuron, 104(6), 1195-1209.
16. Pichora-Fuller, M. K., Alain, C., & Schneider, B. A. (2017). Older adults at the cocktail party. In The auditory system at the cocktail party (pp. 227-259). Springer, Cham.
17. Puvvada, K. C., & Simon, J. Z. (2017). Cortical representations of speech in a multitalker auditory scene. Journal of Neuroscience, 37(38), 9189-9196.
18. Rönnberg, J., Lunner, T., Zekveld, A., Sörqvist, P., Danielsson, H., Lyxell, B., ... & Rudner, M. (2013). The Ease of Language Understanding (ELU) model: theoretical, empirical, and clinical advances. Frontiers in systems neuroscience, 7, 31.
19. Santurette, S., Ng, E. H. N., Juul Jensen, J., Micula, A. & Man K. L., B. (2020). Oticon More clinical evidence. Oticon Whitepaper.
20. Shinn-Cunningham, B., Best, V., & Lee, A. K. (2017). Auditory object formation and selection. In The auditory system at the cocktail party (pp. 7-40). Springer, Cham.
21. Strawbridge, W. J., Wallhagen, M. I., Shema, S. J., & Kaplan, G. A. (2000). Negative consequences of hearing impairment in old age: a longitudinal analysis. The Gerontologist, 40(3), 320-326.

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