

A Continuing Education Article

# Talking to Patients about Deep Neural Networks in Hearing Aids

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*Learn about the latest technology that addresses your brain's deep neural networks, currently offered by elite hearing aid manufacturers. Publication of this article is not an endorsement of Oticon's More™, but a means to educate all IHS members on the latest emerging technology that involves deep neural networks.*

Take the CE quiz on page 59.

## INTRODUCTION

Deep neural networks (DNNs) present new opportunities and outcomes as sound processors in commercially available hearing aids. DNNs offer significant improvements regarding the ability to understand speech in noise (SIN), improved selective attention (SA), and better cortical representation of the acoustic sound scene as represented via electroencephalography (EEG), arguably derived from an improved neural code.

In this article, we will review and discuss examples of artificial intelligence, machine learning and DNNs and we will explore DNNs in biology and technology. We will examine the literature regarding outcomes of DNNs in hearing aids

and we will offer guidance and alternatives regarding how to explain these technologies to patients, to deliver the ideas and concepts maximally and realistically, without overwhelming them.

## DEEP NEURAL NETWORKS IN HEARING AIDS

Technology-based deep neural networks (DNNs) are extremely sophisticated digital processing systems, which attempt to learn in ways analogous to how humans and other beings learn. In biology, examples of DNNs might include typically developing babies as they learn to talk after listening to, and being “trained” on millions of speech sounds over the course of some 12 to 18 months. Another example is how babies learn to walk slowly over

time, while learning to balance and control ankle, knee and hip sway, as well as leg and torso muscles, to safely ambulate quite literally in “baby steps” at first, and then walking, skipping and running. Likewise, fish learn to swim and birds to fly, all without a step-by-step algorithm.

Technology-based DNNs are also “trained” on vast data sets, from which they search for and identify hard-to-identify patterns within vast data sets such as speech in noise. DNNs organize those patterns into a best-fit solution for the problem they are tasked to solve. DNNs self-check their output to make sure the output maximally represents the input and faithfully solves the stated problem. Although the term “deep neural network” is not yet part of the main-stream vernacular, facial recognition, speech recognition, self-driving cars, weather prediction, GPS as well as searches, interactions and suggestions from Amazon, Facebook, and Google, are often based on DNNs.

Regarding hearing aids, an ideal DNN sound processor should facilitate a complete and balanced sound scene in which the most important sounds appear in the foreground, while attenuating (yet allowing access to) background sounds (Santurette & Behrens, 2020).

### HOW DNNs WORK IN OTICON HEARING AIDS

In 2021, Oticon Inc. released an onboard DNN technology, within their new premium product Oticon More™, built on the all new Polaris™ platform. The embedded DNN found inside Oticon More

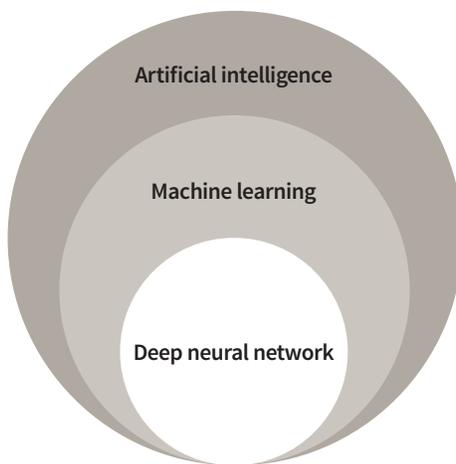


Figure 1: Deep neural networks (DNNs) are a subset of machine learning. Machine learning is a subset of artificial intelligence.

has been trained on 12 million real life sounds to identify and better manage speech and noise in difficult listening environments. These millions of training experiences avail to the listener a deep learning result and a deep neural network which intelligently prioritizes and maintains the primary and secondary speakers and other important

acoustic information. The prioritized and balanced acoustic sound scene provides acoustic context and a rich three-dimensional soundscape, from which the listener can determine which sounds to selectively attend to. Oticon More has been shown to provide improved speech in noise ability, improved recall/memory, a very high sound quality, and improve selective attention (Santurette, Ng, Jensen, Loong, 2020, and see Beck, 2021).

Recently, a 64 channel EEG study demonstrated that Oticon More improved selective attention (Santurette, Ng, Jensen, Loong, 2020). The study included more than two dozen listeners (mean age 65 years) with mild-to-moderate sensorineural hearing loss. Participants were instructed to pay attention to one of two talkers in a challenging 3 dB signal-to-noise ratio with multi-talker

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## Details on the Oticon More™ Device

The Oticon More DNN, embedded in the Polaris Chip offers the advantage of being trained on 12 million sounds, as well as the ability to process sounds in real-time. There are no intermediary devices/dongles to carry in your pocket or purse, or re-charge daily, and there is no need for a cloud-based connection (i.e., hearing aids communicate with phone, phone sends message to cloud-based facility, cloud sends instructions to phone, phone sends instructions to hearing aids). The Polaris chip has twice the processing power of Oticon’s previous best chip (Velox S), 6 times the compression/amplification resolution, 64 channel signal processing, streams directly to Apple devices and uses the ASHA protocol to stream from multiple Android™ smartphones. Android devices need to support ASHA to allow direct streaming to Oticon More. Please visit [www.oticon.com/solutions/compatibility](http://www.oticon.com/solutions/compatibility) for more information.

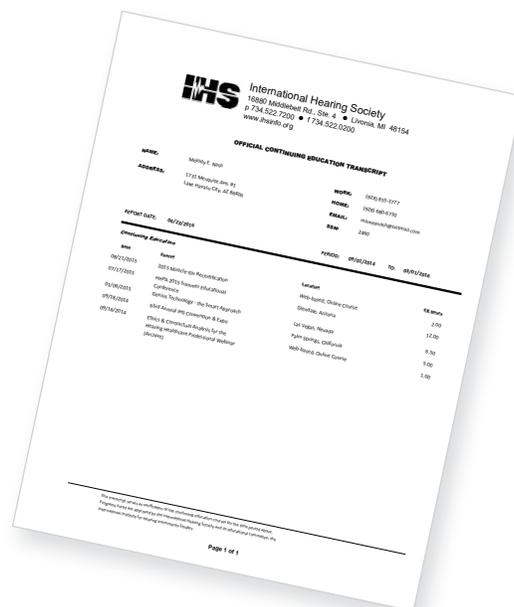
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babble as the noise source. Of note, the EEG recordings made with the DNN on (versus off) improved the brain's ability to "track all the objects in the full sound scene" by 60%. With the DNN on, subjects demonstrated improvements in speech in noise ability, required less listening effort and demonstrated a statistically significant improved ability to recall spoken words (Santurette, Ng, Jensen and Loong, 2020). These studies indicate DNN-based hearing aids provide more access to the complete sound scene, as well as an improved ability to focus on selected sounds in the foreground, while maintaining access to meaningful incidental and background sounds (Santurette & Behrens).

### HEARING VERSUS LISTENING

As we consider hearing (perceiving or detecting sound) and listening (assigning meaning, comprehending, de-coding sound) we might consider hearing as the foundation, and listening as the structure built upon that foundation.

Hearing is (in general) dependent on air molecules wiggling and bumping into each other, which initiates mechanical motion at the tympanic membrane and ossicular chain, which initiates fluid motion of endolymph and perilymph along the basilar membrane, which initiates sophisticated bio-electric activity which synapses with the 8th cranial nerve, which tonotopically transmits the signal to the lower and upper brainstem and to the superior



temporal lobes through ipsilateral and contralateral pathways. That's the easy part, that's hearing.

Listening poses a greater challenge and listening in noise (i.e., SIN) is the greatest challenge. The distinction between hearing (perceiving/detecting sound) and listening (de-coding, comprehending, applying meaning to sound) is significant, as listening involves vast, almost instantaneous neurologic synchrony, across the entire brain. For example, during conversational discourse, the occipital lobe receives the visual signal as someone smiles, gestures or speaks. If the conversation is sad or joyous, the emotional center of the brain (i.e., the amygdala) is engaged. Further, the hippocampus instantly assigns meaning to the perceived words while simultaneously accessing long-term memory to retrieve definitions and meaning in tandem with bolstering

working memory to facilitate an understanding of the conversation. Billions and billions of neurons and multiple neurological sub-systems are simultaneously engaged as the brain decodes speech from a primary speaker, while dismissing the speech sounds of a secondary speaker (i.e., background noise).

Multiple biologic attributes are highly beneficial to humans, such as standing upright which leaves our upper extremities available to do unrelated tasks while ambulating. Human bi-peds can scan a farther horizon than equivalent-sized quadrupeds. And of course, humans have opposable thumbs which allows us to build and use tools, grab, hold and more. However, our ability to hear is not our species' strong suit. It is comparatively rather weak. Dogs, cats, dolphins, whales, lions, and many

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other mammals perceive sounds we cannot. However, our ability to listen is unmatched and unchallenged and is to a large degree, dependent on a rich neural code and extreme processing (i.e., listening) by the human brain.

### THE NEURAL CODE

Many common amplification systems use directionality, beam-forming and other technologies to reduce the natural sound scape from 360 degrees, to a lesser sound field, or angle of interest. Further, typical compression ratios such as 2:1, theoretically reduce an average speaking voice with a 30 dB dynamic range to only 15 dB, and within the remaining 15 dB, all sounds have been compressed. As such, the sound which exits the hearing aid's receiver is less dynamic and has a resultant neural code less likely to represent the rich and dynamic original acoustic sound scene, as the engineering intent was to focus on the primary speaker, with as little secondary speech sounds and environmental sounds as possible.

Beck (2021) suggested the ideal neural code should avail to the brain

1. Ear-specific acoustic information, allowing the brain to compare and contrast the unique left and right signals (interaural loudness differences (ILDs), and interaural timing differences (ITDs)).
2. Very high-quality sound.
3. Substantial noise reduction with a balanced and prioritized sound scene.
4. A rich acoustic signal fit-to-target without acoustic feedback.
5. A decoding task which requires less listening effort.
6. A maximal Signal-to-Noise Ratio (SNR).

### SELECTIVE ATTENTION

Selective attention (SA) is the ability to attend to, or switch focus to/from the sound source you choose, in the acoustic environment, regardless of a quiet or noisy background. Unfortunately, as hearing loss increases, the ability to selectively attend to the chosen auditory signal decreases. Further,

as one would expect, SA is typically worse in noise (Shinn-Cunningham & Best, 2008).

Multiple studies (Alickovic et al 2021; O'Sullivan et al., 2019; Hausfeld et al, 2018; Puvvada and Simon, 2017) indicate that for humans to “recognize,” untangle, comprehend, or apply meaning to speech sounds, the brain must essentially orient and then focus on the selected sound source. As such, delivering the complete sound scene via the neural code in an “orient, focus, recognize” paradigm is more likely to represent the original acoustic sound scene, making it easier for the brain to decode, while requiring less effort/energy and allowing more advantageous listening.

### DISCUSSING DEEP NEURAL NETWORKS WITH PATIENTS

As Hearing Care Professionals (HCPs), we enjoy knowing the terminology, theories and application of audiology and hearing aid technology. However, using those words, acronyms and theories with patients may cause confusion and frustration. The main goals of a solution-based conversation is to have the patient understand how technology may help them hear and listen better in quiet and noisy environments, and to motivate them to follow your recommendation for amplification.

Unfortunately, there is no “one size fits all” solution. Each patient is an individual, each human brain is unique and each person has their own set of challenges. Meeting them “where they are” while validating their observations

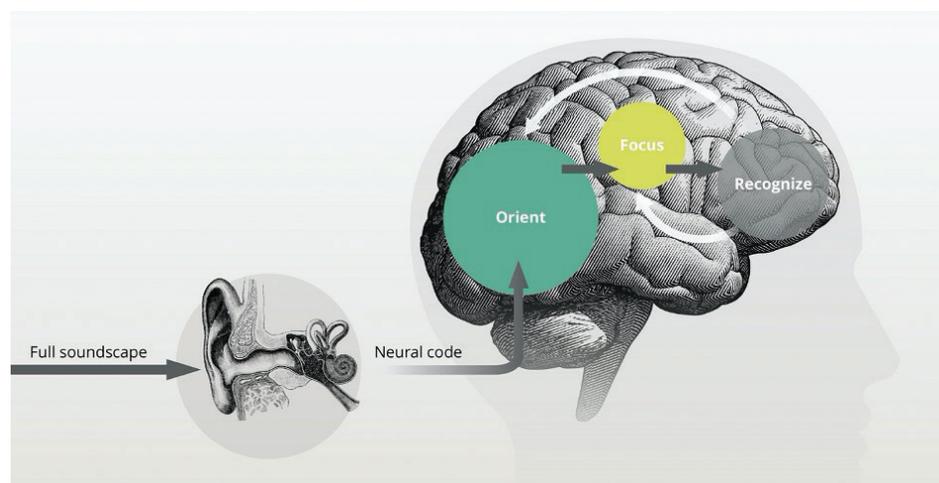


Figure 2: The neural code facilitates the brain's ability to orient, focus and recognize sound.

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and asking about their experiences and difficulties is a quick way to build trust. Indeed, trust is the cornerstone of outstanding patient care. Trust results from the patient perceiving a sense of caring from the HCP. Although each patient is on a hearing healthcare journey and although many journeys share common features, each journey is unique.

Patients seek our help secondary to disruptions in their ability to hear, listen, and socialize. Often, they report struggling in familiar acoustic environments which

previously were easy and comfortable for them. Typical self-discovered solutions, and common coping mechanisms to manage difficult hearing and listening situations include withdrawing, pulling away and socially isolating from social interactions. Recent studies have shown that uncorrected hearing loss and social isolation can lead to other physiological, psychological and other health challenges (Beck, Bant, Clarke, 2020 and Livingston et al, 2017).

### DISCUSSION PROTOCOLS

As such, an important skill for the HCP is to “actively listen” to the patient. Ask open-ended questions such as, “Please

share with me three situations in which you find it difficult to understand what someone said?” or, perhaps, “Can you tell me whose voice is the most difficult to understand?” to engage a deeper conversation and to define and focus on the most challenging sounds, situations and concerns.

A challenge for many HCPs is to avoid jumping in too quickly to “fix” the problem. We may have an urge to push the conversation, as we’ve heard these complaints and descriptions many times before. However, for the patient, this is likely the first time they’ve deeply explored their hearing and listening observations. Further, although many people listen in order

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to know when to speak, we must listen to understand as we need to build trust prior to offering solutions.

### **PATIENT-CENTERED ASSESSMENT TOOLS**

There are many tools which can help assess, define, and focus on the patient’s hearing, listening and communication difficulties. The Client Oriented Scale of Improvement (COSI) has the patient identify situations in which they have trouble hearing, listening, and communicating. The Hearing Handicap Inventory in the Elderly (HHIE), the International Outcomes Inventory (IOI), the Speech, Spatial, and Qualities of Hearing Scale (SSQ) and other assessment tools help facilitate an excellent, robust, and trusting relationship between the HCP and the patient.

Motivational Interviewing (MI) is an interview technique that encourages the patient to describe and reveal situations in which they have difficulty. MI helps patients focus, accept and often, initiate and request a solution. The Ida Institute ([www.idainstitute.com](http://www.idainstitute.com)) offers a wealth of information on Motivational Interviewing. Additional insight regarding MI can be found via Beck & Harvey (2018). The 2020 Oticon Inc. recording titled “Patient-Centered Care” with Cherilee Rutherford Au.D., Senior Audiologist at The Ida Institute can be found at <https://www.oticon.com/practice-support>.

After completing hearing, listening and/or communication assessments, the HCP’s task is to motivate the patient to act. A key factor to motivating the patient to act is to specifically associate the solution

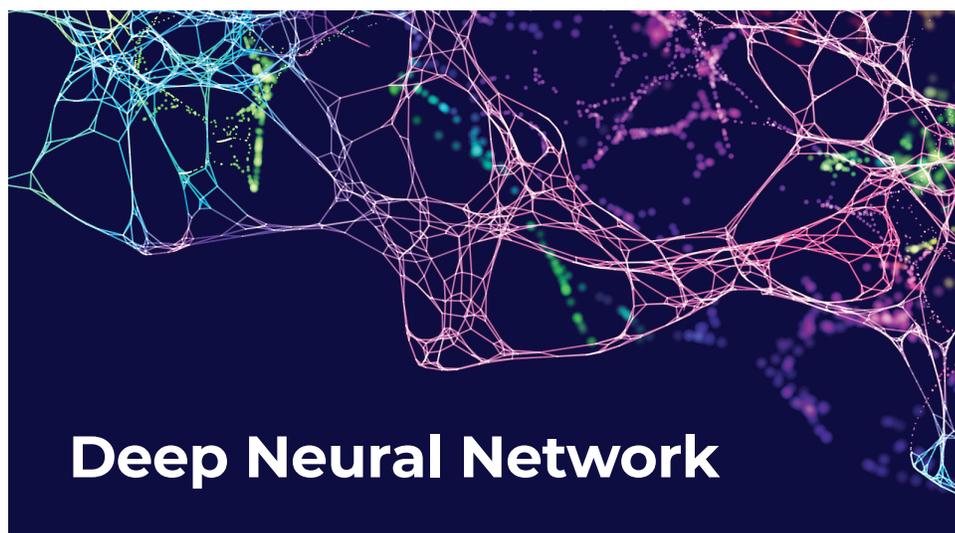
you recommend with the patient’s specific areas of difficulty, as identified via the selected assessment tool.

### **THE DNN DISCUSSION**

Admittedly, the term “DNN” is relatively unknown in the mainstream. Therefore, we suggest not using acronyms and high-tech words unless the patient requests a more technical discussion. A collaborative approach between the HCP and the patient is usually the best approach. Easy-to-digest words and sentences might include:

If you elect to use the term “DNN” in selected discussions, one might say something like...

“With this new technology, the DNN has been trained on millions of real life sounds and has learned in ways similar to how the brain learns. The DNN helps distinguish between speech and background noise and balances sounds to make it easier to understand while maintaining environmental sounds so you can choose who to focus on. The DNN helps your brain make sense of



“Hearing aids with DNN technology are very sophisticated. They are designed to make a distinct separation between the speech you want to hear, as compared to the other competing sounds and background noise. This technology allows you the freedom and confidence to go from a quiet coffee shop to a busy restaurant. The best thing is that these devices make it easier to listen. You won’t have to work so hard to follow and participate in the conversation.”

sounds more easily. You won’t have to work as hard to hear and listen, and you can enjoy participating in the conversation.”

Of note, offering a “positive listening experience” rather than “making sounds louder” can help motivate your patient to make a more informed decision.

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### FINAL THOUGHTS

DNNs represent the most sophisticated approach to sound processing in commercially available hearing aids. Devices with an embedded deep neural network (DNN) solution have been shown to be significantly advantageous when compared to traditional sound processing technologies.

Nonetheless, the term “DNN” is a relatively new concept in hearing healthcare, and technology-based conversations with patients may be overwhelming for many. We suggest approaching the patient as a unique individual and working with them at their level. We urge the use of MI as well as listening and communication assessment tools to evaluate, document and better understand the patients’ hearing and listening difficulties and to build trust.

Finally, we recommend offering solutions which are based on and specifically address the specific difficulties revealed via MI and the listening and communication assessment. ■



#### **Douglas L. Beck, AuD, Vice President of Academic Sciences, Oticon Inc.**

Dr. Beck began his career at the House Ear Institute (LA) in cochlear implant research and intraoperative cranial nerve monitoring. Within a few years, he became Director of Audiology at St Louis University. Beck joined Oticon in 2005. From 2008 through 2015 he also served as Web Content Editor for the American Academy of Audiology (AAA). In 2016, he became Senior Editor for Clinical Research at the Hearing Review and Adjunct Clinical Professor of Communication Disorders & Sciences at the State University of New York at Buffalo. In 2019, he was appointed Vice President of Academic Sciences at Oticon. Dr. Beck is among the most prolific authors in audiology with 188 publications and more than 1250 abstracts, interviews and op-eds.



#### **Denise McLeod, AuD, Manager, Field Training, Oticon Inc.**

Denise McLeod is the Manager of Field Training at Oticon. She previously worked in Texas, Louisiana, and Mississippi, as an account manager, where she taught classes at audiology programs. McLeod has served on the Board of the Texas Academy of Audiology and has been heavily involved with audiology in the State of Texas. She holds a Doctor of Audiology degree from the University of Florida.

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# IHS Continuing Education Test

Talking to Patients about Deep Neural Networks in Hearing Aids, article on page 48.

1. Artificial intelligence is a subset of deep neural networks.
  - a. true
  - b. false
2. Selective attention
  - a. typically improves in noisy situations.
  - b. typically increases as hearing loss increases.
  - c. is the ability to attend to attend to the sound source of choice.
  - d. occurs only in a noisy background.
3. Dogs', cats', and dolphins' ability to listen is superior to that of human's.
  - a. true
  - b. false
4. Deep neural networks are
  - a. exclusively used in the listening process.
  - b. extremely sophisticated digital processing systems.
  - c. exclusively offered in Oticon hearing aids.
  - d. none of the above.
5. The following is often based on deep neural networks:
  - a. interactions and suggestions from Google
  - b. facial recognition
  - c. speech recognition
  - d. all of the above
6. In comparing listening and hearing: listening is the foundation and hearing is the structure built upon that foundation.
  - a. true
  - b. false
7. A human's hearing begins at the tympanic membrane and ends at the superior temporal lobes
  - a. true
  - b. false
8. For a human to converse in a noisy situation
  - a. billions of neurons are engaged.
  - b. the occipital lobe is involved.
  - c. the amygdala is sometimes engaged.
  - d. all of the above
9. In discussing DNN technology with clients, it's best to say
  - a. it helps your brain make sense of sounds more easily.
  - b. it helps make sounds louder.
  - c. you'll still need to work hard to participate in conversations.
  - d. none of the above.
10. When you are listening to a client discuss their hearing, you should
  - a. quickly offer solutions to their problems.
  - b. keep listening so that you build trust.
  - c. listen to find a break in the client's speech to interject your information.
  - d. All of the above

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## Answer Section

(Circle the correct response from the test questions above.)

1. a b	6. a b
2. a b c d	7. a b
3. a b	8. a b c d
4. a b c d	9. a b c d
5. a b c d	10. a b c d