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Use of Deep Neural Networks in Hearing Aids to Improve Hearing and Listening

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ABSTRACT:

In the past 30 years, hearing aids have seen significant improvements, moving from basic analog sound processing methods to cutting-edge digital technology and Deep Neural Networks (DNNs) "on-the-chip" that provide real-time sound processing. Advanced hearing aids with DNN on-the-chip are more effective at making sounds audible as well as providing clearer understanding of speech in noise, improving recall, maintaining interaural loudness and timing differences, and enhancing the wearer's capacity to selectively attend to the speaker of choice in difficult listening situations. These enhancements are given with extremely high sound quality and without acoustic feedback.

INTRODUCTION:

Patients with sensorineural hearing loss (SNHL) typically express confusion rather than hearing loss as their main complaint. Unfortunately, it is considerably harder to interpret speech in a noisy environment. Hearing is merely perceiving or recognizing sound, to be clear. The majority of SNHL sufferers can hear conversational speech at lower speech frequencies (i.e., 100–350 Hz), hence it makes intuitive sense that they believe they can hear. However, the enormous spectral components of speech are generally unknown to those with mild to moderate SNHL, and of course, they are ignorant of that which they cannot (and do not) hear. Because of this, many people with SNHL are not aware that they have hearing loss in the mid- and high-frequency ranges of speech sounds (i.e., 1500–3000 Hz and/or 3000–6000 Hz). Notably, the mid and high frequencies carry the most crucial information for speech recognition (consonants, fricatives, sibilants, etc.). [1] So it makes sense that a lot of SNHL sufferers come to the same conclusion. This means that, in their eyes, the reason they can't comprehend is that people mumble or don't speak clearly, both of which may be

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plausible inferences for someone with a typical mild-to-moderate SNHL. But it's unlikely that any of these conclusions will be the main obstacle to hearing speech over noise.

Sensorineural Hearing and Listening Loss

Hearing is the foundation of listening, but listening is much more than just hearing. Hearing is among the two most important senses and is of utmost importance (vision and hearing). I do not discount hearing's enormously valuable contribution. I'm arguing it's not sufficient to merely hear or perceive sound.

When we decode, recognize, and assign meaning to spoken sounds, the entire brain is engaged. There is considerably more to listening than the standard definitions with line labels (i.e., the auditory nerve sends information to the temporal lobes where it is processed...). The hippocampus, amygdala, frontal lobe, occipital lobes (speech reading and facial recognition), corpus callosum, anterior commissure, brain stem, and other brain regions all collaborate in a very human fashion during listening to provide meaning to sound. The notion that sensory inputs are processed in particular unimodal cortices (i.e., line-labelled) is out of date [2], and "multi-modality" is quickly becoming recognized as a crucial element in the organization and reorganization of the human brain.

According to Seeto, Tomlin, and Dillon [3], one cannot assume that pediatric assessments of auditory processing abilities and testing of cognitive capacities evaluate different talents because there is a correlation between cognition and listening at the other end of the age span.

Prior to processing, speech sounds need to be audible.

They must, however, be audible at a signal-to-noise ratio (SNR) that is advantageous to the patient and acceptable. Reduced audibility has been linked to lower Mini Mental State Examination results, according to Gaete and colleagues [4], even in cognitively healthy individuals.

Selective Attention

Best & Shinn-Cunningham [5] reported hearing loss reduces the auditory signal (i.e., neural coding), making it harder for the hearing-impaired person to pay attention to certain auditory signals. According to recent studies [6–10], the human brain must first orient and then focus on the sound of greatest interest in order to distinguish, sort out, and absorb speech sounds (i.e., to listen) after hearing sound in the acoustic environment. Multiple crucial aspects appear to be at play when it comes to being able to focus on the sound that interests you the most, especially in loudness.

The ability to shift the image on our retina's fovea by just gazing elsewhere in vision is similar to selective attention in hearing. Surprisingly, selective attention by audition is similar to visual focus. [11] That instance, given generally normal hearing and listening abilities, the

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capacity to shift our focus of auditory attention on a particular individual in a busy backdrop (i.e., cocktail party) is an example of selective attention.

Furthermore, it is doubtful that the brain can decode missing acoustic information if the information encoded in the neural code does not include a complete acoustic sound scene.

Speech-in-Noise Technology and Conventional Hearing Aids

To be clear, millions of people all around the world have benefited from traditional hearing aid technology, particularly in calm settings where background noise is not a problem. However, the main issue that both those with SNHL and those using conventional hearing aid technologies have is that they can hear but cannot understand, especially in noisy environments. Unfortunately, certain acoustic information is accidentally limited and reduced by conventional hearing aids. For instance, conventional hearing aids employ a variety of compression techniques to keep the volume of the sound between tolerable and uncomfortable levels.

The listener receives a 10 dB dynamic range at a 3:1 compression ratio, significantly lowering the overall quality and quantity of the neural code. Based on amplitude modulation (i.e., loudness fluctuation) and other acoustic parameters, many commercially available hearing aids use fixed or adaptable directionality (or beam-forming) to focus amplification on the talker who is most likely to be the principal person the listener would prefer to attention to.

A smaller window to the surrounding acoustic sound scene (from directional microphones or beam-forming) is desired or required, and acoustic feedback needs to be reduced by lowering gain. Unfortunately, many traditional hearing aid designs assume the most important sounds are frequently in front of the wearer, non-speech sounds are undesirable, a reduced dynamic range is desirable, and a smaller window to the surrounding acoustic sound scene. [12] These presumptions, however, tend to attenuate the neural code rather than enrich it and give the brain less real-world auditory clues.

Deep Neural Networks

In recent years, Deep Neural Networks (DNNs) have greatly enhanced technical capabilities. The most advanced processors in the artificial intelligence industry are DNNs (AI). What and how DNNs do is what makes them so impressive. Similar to how a human brain would, DNNs look for patterns amid massive volumes of information and then recognize and decode those patterns. Without specialized permutation programming, DNNs process enormous data sets. In other words, DNNs run independently of any given event-driven software. Without a precise stated methodology for each and every decision point, DNNs generate a solution and then self-verify that their solution (the output) is the most accurate one based on the incoming input.

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There are numerous instances of DNNs in the biological world.

Without explicit step-by-step directions, a huge number of amazing things can occur. For instance, after 12 to 18 months of intense sensory input, babies generally learn to walk and talk, much as fish and birds learn to swim and fly.

Technology-based DNNs make an effort to resemble biological DNN by employing digital tools created by humans to process data more effectively and find the most likely advantageous solution to the issue at hand.

Lesica According to [13] hearing aids should ideally restore the neural activity patterns that the brain receives in order to lessen the effort and energy required by the brain to process a neural code that has been damaged. The best DNN processor should enable a full and balanced sound scene with the most significant sounds appearing in the foreground and the background noises being attenuated (yet still available). [12]

DNNs in hearing aids

The first hearing aid incorporating "on-the-chip" DNN technology was made commercially accessible in 2021 by Oticon Inc. The 12 million sound samples used to train the Oticon MoreTM DNN allowed for improvements in speech in noisy environments, recall and memory, delivering extremely high sound quality, and improving selective attention. It is based on the hypothesis that enhancing the neural code improves the brain's capacity to interpret sound. The DNN in Oticon More is a cutting-edge method of sound processing for use in custom hearing aids.

Furthermore, the DNN provided 30% more effective access to the entire acoustic sound scene (in comparison to our finest previous hearing aid technology, the Oticon Opn S). The DNN hearing aid users showed general gains in their capacity to remember spoken words more easily and to understand speech in noisy environments. [14]

CONCLUSION:

Hearing and listening have well-established and distinct disparities in 2021. However, the two ideas are frequently confused by both experts and patients, which is bad for everyone. Using commercially available life-changing technology to enable a better understanding of speech in noise (listening) while enhancing selective attention and reducing listening effort secondary to an improved neural code seems appropriate to us as professionals in order to broaden and clarify our thoughts and explanations from simply making things louder/audible (i.e., hearing). It was a great and timely idea to start with simple analog sound processing methods and protocols from the previous century in order to alleviate hearing loss through improved audibility.

Deep Neural Networks (DNNs) "on-the-chip" have been demonstrated to specifically offer real-time sound processing, a clearer understanding of speech in noise, improved recall, can

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maintain interaural loudness differences, and can improve the wearer's ability to selectively attend to the speaker of choice in difficult listening situations.

Early research has shown that users of hearing aids based on DNN have greater access to the entire soundscape, enabling them to concentrate more effectively on the sounds they chose for the front without losing out on important background sounds. [19]

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