The Neuro-Compensator®: A hearing compensation algorithm based on cochlear modeling and machine learning

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In this technical brief, we will describe the design and testing results of a novel hearing aid based on the Neuro-Compensator® algorithm. The Neuro-Compensator® employs neurocomputational models of the pathophysiology of hearing loss to optimize the gain calculation in a hearing aid so as to generate a more normal pattern of neuronal firing in the auditory nerve of the hearing impaired listener.

Moderate degrees of noise-induced or age-related hearing loss are associated primarily with degeneration of outer hair cells in the cochlea, while severe hearing loss involves pronounced degeneration of both inner and outer hair cells. The inner hair cells (IHCs) are involved in the transduction of travelling waves on the basilar membrane into neuronal firing of frequency-tuned auditory nerve fibers. The outer hair cells (OHCs) are responsible for loudness compression, as well as modulating the frequency response of the auditory nerve fibers, contributing to optimal frequency sensitivity under varying loudness levels, and also to contrast enhancement for complex sounds in the presence of noise. After a hearing loss, even when wearing a conventional hearing aid, the hearing impaired listener frequently reports difficulty hearing sounds in noise or tracking a person's speech in the presence of multiple competing talkers. The key shortcoming in conventional hearing aids is that they calculate how much gain to apply within each frequency channel without taking into account the total spectral content of the sound coming in, thus ignoring how multiple frequencies interact to produce a normal sound percept. To overcome this limitation, we take a novel approach to hearing aid design using the Neuro-Compensator® algorithm. The Neuro-Compensator® employs sophisticated computer models of the cochlea to determine the optimal gain calculation for a given hearing impaired listener. The auditory models are used to simulate how the auditory nerve of a hearing impaired person would respond to a given level of amplification across all frequency channels. The resultant auditory neuronal firing pattern for the impaired ear model is compared to that of a healthy ear model. Machine learning methods are used to iteratively adjust the gain calculation performed by the Neuro-Compensator®, until a normal pattern of neuronal activity is restored. Once this training procedure is completed, the Neuro-Compensator® no longer requires the complex auditory model, and the final gain calculation can then be incorporated into a conventional hearing aid microprocessor. In the resulting hearing aid, rather than calculating the gain separately within each frequency channel, the gain of each channel is dynamically calculated as a function of the entire spectral content of the signal. The Neuro-Compensator® thereby has the ability to restore the non-linearities and cross-channel modulatory functions normally achieved by the outer hair cells. Computer simulations indicate that compared to the widely used WDRC gain calculation, the Neuro-Compensator® is better able to restore intelligibility of higher frequency components of speech signals. Preliminary subjective reports from hearing-impaired individuals indicate that compared to conventional hearing aids the Neuro-Compensator®-based hearing aid restores a much more natural sound for both speech and music, while sound perception in noise and sound localization are greatly enhanced.