Effect of Small Changes of Acoustic Energy on Real World Performance with Hearing Aids

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Decoding human utterances into meaningful information requires the coordination of a multitude of sensory, neural and cognitive processes. These processes can be disrupted in a variety of ways resulting in reduced intelligibility. Noise added to the environment will reduce speech intelligibility for those with normal auditory function.

Individuals with hearing impairment have more than a mere hearing loss. Such individuals, in addition to having a loss of acoustic sensitivity (loss of audibility), have a reduced ability to understand speech, especially in the presence of noise, even when their loss of audibility has been corrected.

A most consistent finding in all studies correlating sensory, neural or cognitive processing and their relation to speech intelligibility in the hearing impaired is the broad distribution of the performance of individuals on all such tests. This reduced speech intelligibility is due to unique individual differences and deficits in the operation of their sensory, neural and cognitive processing.

As a consequence, attempts to correct individual speech intelligibility performance with hearing aids using targets to correct for the loss of audibility or applying global speech-feature processing algorithms fail to demonstrate statistically significant improvement in speech intelligibility, especially in noisy places.

The only publication of a highly significant improvement in speech intelligibility in noise required individually programming hearing aids to address each individual's sensory, neural and cognitive capacities (Magilen & Greenberg, 2005). It reported in -5dB SNR conditions using the same directional hearing instrument that speech intelligibility was improved by 48% over the standard method of hearing correction. The global noise reduction and speech processing algorithms and other "advanced features" incorporated into current digital hearing aid devices, on the other hand, do not improve speech intelligibility by even 1% significantly, in noise over the old non-digital aids.

A Case Study

This paper presents a case study that demonstrates the unique character of an individual's hearing impairment and the need for subtle, individual, detailed correction to provide functional benefit. It demonstrates variation in the spectral, temporal, intensity, spatial, cognitive and experiential dimensions.

The patient is a 59-year-old woman who was told hearing aids would not help. She complained of having difficulty understanding her friends in crowds, on hikes and at shows.

She had normal/near normal bilateral hearing thresholds through 1.5 kHz, then a precipitous drop to a moderate level at 2kHz and above. She had normal middle ear function. Her speech discrimination for high intensity speech was 95% on the right and 85% on the left.

The hearing aid on her right side was dynamically programmed to address her speech intelligibility capabilities under a variety of conditions. Correction of her hearing impairment on her right side resulted in an ability to understand whispered speech and speech at 0 dB SNR. The patient reported a 'natural" experience of sound.

The right hearing aid was turned off and its programming was transferred to the left ear. When turned on, it resulted in an immediate response, “I hear two of you…I hear two of me.” “There is a second, higher pitched voice.” She pointed to a location of the “second voice” as being just over her left shoulder. The second voice occurred with a short temporal delay, “like an echo”.

The hearing aid on her left side was then programmed to address her speech intelligibility capabilities under as variety of conditions. Correction of her hearing impairment on her left side also resulted in an ability to understand whispered speech and speech at 0 dB SNR. The “second voice” remained.

When both hearing devices were turned on, the “second voice” disappeared. The phenomenon was repeatable. Using both hearing aids she had little difficulty understanding speech in babble or cocktail party noise at -5 dB SNR.

The patient returned to the office a week later. The L side still had the spatially and spectrally separate “voice”, but it was no longer temporally delayed. To test the sensitivity of the “second voice” phenomenon, a 3 dB drop in the two (of the 12) gain channels around 2.4 kHz eliminated the unilateral “voice” experience on the L side. The 3 dB drop in gain also resulted in loss of the binaural benefit in speech intelligibility and in speech separation from noise. To compare the phenomenology to excessive gain on each side, the gain above 2 kHz was raised by 3 dB. Unilaterally raising the gain on the right resulted in, “a scratchy noise”; raising the gain on the left resulted in an additional and “louder hi-pitched voice”. The following week, the patient reported similar phenomenology, was using the devices regularly, and “now understanding her female friends in her convertible with the top down”.

Discussion

This case presents a hearing impaired woman’s unique speech processing difficulties. It describes how small local changes in acoustic energy have large effects on her perception of a desired signal, the perception of noise, signal location, sound quality, binaural processing, speech intelligibility, speech separation from noise, personal comfort and the perceived value of a hearing aid.

“Hearing-impaired” individuals have unique disturbances throughout their auditory and language processing space. Speech processing is a purposeful, simultaneous, multi-level, multi-modal, multi-dimensional, multi order scalar, operation on acoustic spectrotemporal information. Age reduces the speed and accuracy of brain processing. It consequently affects the coordinated temporal processing necessary to make rapid speech intelligible and separated from environmental sounds. The disturbances become more complicated as the individual ages.

Hearing loss unmasks a multitude of auditory processing deficits that otherwise go unnoticed due to the otherwise robust capabilities of normal speech decoding mechanisms. This appears to explain why a small loss in audibility can have large loss in speech perception. Prior to their speech perception difficulties, certain individuals depended greatly upon those fine elements of acoustic energy.

This observation reinforces the concept that optimal speech intelligibility and speech separation from noise for hearing-impaired individuals is dependent upon the detailed placement of fine elements of acoustic energy uniquely for each individual ear. It argues against the indiscriminate manner in which hearing aids are currently provided.

Magilen, G. & Greenberg, S. (2005) "The Missing Link - The Importance of Diagnostic and Fitting Strategies for Clinical Amelioration of Hearing Loss Using Digital Hearing Aid Technology." Twenty First Danavox Symposium