CrossLink Directionality: Facilitating true binaural auditory processing

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Hearing instrument manufacturers make significant investments in research and development to create hearing instruments that provide speech intelligibility, localization, environmental awareness, and comfort while maintaining audibility. Hearing in noise continues to be a challenge for end users while providing excellent speech intelligibility in noise continues to be a challenge for manufacturers. The benefit provided by directional microphones in improving signal to noise ratio is well known, however, current directional technologies utilize bilateral synchronization strategies rather than binaural strategies that facilitate the auditory processing occurring in the brain. Beltone’s CrossLink Directionality is a true binaural strategy, utilizing Beltone’s 2.4 GHz technology, in which bilateral communication between the two hearing instruments allows them to be adjusted to an optimal combination of directional microphone technology. This enables binaural processing, ensuring audibility while providing intelligibility.

Directional microphone technology has come a long way in the last 10 years, and although directionality is the most effective algorithm to improve the signal to noise ratio for hearing impaired users; consumers continue to be dissatisfied with their ability to hear in noise. This is primarily because day to day situations can be very dynamic and fixed microphone configurations in individual hearing aid programs would require constant switching between programs to achieve maximum benefit. For instance, a hearing impaired listener may not hear a speaker in a noisy environment when they are approached from the rear with currently available microphone configurations. If the hearing aids were set to omnidirectional, the hearing aids would pick up too much noise. A directional configuration on the other hand would attenuate the speaker. In an asymmetrical configuration, the listener would still miss hearing the speaker if the speaker were coming from behind and ipsilateral to the directional microphone. Beltone’s CrossLink Directionality was developed precisely for dynamic situations such as these. It continually monitors the acoustic environment and uses a unique integrated bilateral steering strategy to improve speech understanding in noise while maintaining environmental awareness.

Directional microphone technology: Drawbacks

Directional microphones are the industry standard for improving speech understanding in noise. They accomplish this by increasing the signal-to-noise ratio for speech originating from the front or “look-direction” of the hearing aid user and attenuating off-axis signals or noise. This works well if the speaker is in front of the listener, however if the speaker is off-axis or off to the side, the directional microphones will actually attenuate the signal of interest making it even harder for the user to hear. Other drawbacks of traditional directional technology include the introduction of equalization noise in attempting to compensate for the low frequency roll-off inherent in directional microphone technology, over-amplification of near-field signals resulting in increased wind noise, poorer sound quality, and diminished localization. In addition to these, there are disadvantages to the hearing aid user in that the end user may or may not appropriately switch programs to take advantage of the directional technology. Even successful users spend more time in their “default” omnidirectional program than in other programs (Nelson et al, 2006).

Solutions

Beltone has been a leader in offering innovative solutions to the drawbacks associated with conventional directional microphones. The audibility issue was addressed by using asymmetric directional processing - fitting one ear (the focus ear) in the directional mode and the opposite ear (the monitor ear) in the omnidirectional mode as in Monitored Directionality. The problems with equalization noise and comfort were resolved in Beltone True with Spatial Directionality, which includes band-split directionality (processing low frequencies omnidirectionally and high frequencies directionally) and synchronization of the omnidirectional signal. Synchronization of the signal is necessary to maintain the interaural timing differences between the two ears. This provided amplification that has a more natural sound quality along with improved speech intelligibility, environmental awareness and localization ability.

However, there are situations in which the hearing impaired user may benefit from bilateral directional processing or a reverse asymmetric fit (omnidirectional in the focus ear and directional processing in the monitor ear) as mentioned earlier. Hornsby and Ricketts (2007) have shown directional benefit to be dependent on the location of the noise source. When the speech was presented from the front and the noise from the sides or behind the listener, bilateral directional mode was preferred over an asymmetric or omnidirectional fitting. Coughlin et al in 2008 showed that performance was equally poor for an asymmetric fit as with a bilateral directional fit, when a speech signal was presented from the rear, ipsilateral to the ear with the directional microphone. This indicates the need for switching the laterality of the omnidirectional microphone when the speech signal is ipsilateral to the directional microphone but not coming from the front or the “look direction.” The goal is to provide directionality that is more precise and less variable. In order to achieve this, we need to understand auditory scene analysis and binaural processing.

Binaural processing and auditory scene analysis

The human auditory system has representation in both auditory cortices by virtue of the auditory nerve fibers crossing over to the contralateral cortex. Binaural processing allows for sounds from
both ears to be analyzed and processed together so that the individual can determine which sounds they want to listen to (signal) and what sounds they want to ignore (noise). The process by which we can perceptually organize the sound environment and determine the signal of interest is called Auditory Scene Analysis. This is aided by the brain's ability to take advantage of the interaural level and timing differences between the two ears to extract the signal from the noise (also called the better ear strategy). Hearing aids today are able to perform Acoustic Scene Analysis, a method that classifies acoustic events as they occur based on a pre-defined set of characteristics, and attempts to predict the auditory scene that might exist for a listener at a given moment. Based on these predictions, automatic changes are applied to the hearing instruments to provide maximum hearing benefit. However, acoustic scene analysis can be highly variable and does not take user intent into consideration. In addition, hearing aids make digital signal processing decisions independent of each other i.e. they bilaterally process the acoustic environment as opposed to binaurally processing it. In order to mimic the auditory system, we need technology that can steer or switch the laterality of the directional microphone to facilitate the binaural processing capability of the auditory system. This has been made possible with Beltone's new line of hearing instruments, Beltone Promise.

CrossLink Directionality

With the introduction of Beltone's 2.4 GHz Ear to Ear Technology, i.e. wireless communication between the two hearing instruments in Beltone Promise, analysis of the sound environment has become more sophisticated. The hearing instruments together monitor the environment using speech and noise detectors. Each instrument has a front and rear speech detector to evaluate the presence of speech in front and behind the end user, and a noise detector to evaluate the presence of noise in the environment.

Steering of the directional system is determined by analyzing the detector responses. Input from the instrument's front and rear speech detectors on a bilateral fitting is used to obtain a rough estimate of speech location around the head. Microphone mode switching decisions are based on whether the speech and noise is to the front, rear or side of the head. These modes are steered based on evidence of benefit into one of four possible bilateral states:

1. Omnidirectional | Omnidirectional
2. Omnidirectional | Directional
3. Directional | Omnidirectional
4. Directional | Directional

The omnidirectional and directional configurations continue to use Synchronized Omni and Band-split Directionality. Depending on the location of speech, the microphone modes of both devices can change in order to provide an omnidirectional or directional response. The transition time between microphone mode changes is between ten to twenty seconds to avoid perceptual switching artifacts.

The hearing aids remain in a bilateral omnidirectional mode in a quiet environment with or without speech. In a noisy environment with speech dominance in front of the user, a bilateral directional mode is selected. In all other situations, in the presence of noise, an asymmetric microphone mode will be selected. Depending on the presence and location of speech, one of the ears will switch to a directional mode and the other to an omnidirectional mode. The algorithm provides directional coordination and synchrony between devices allowing the listener to use the “better ear advantage” to maximum effect, regardless of the signal or noise locations. This method of automatic wireless steering is consistent with research that indicates that binaural processing is the most effective means of maximizing the signal to noise ratio when the acoustic conditions allow it. CrossLink Directionality overcomes the disadvantages of the currently available directional systems by allowing the hearing instrument wearer to decide what to attend to rather than letting the hearing instruments make this decision. It not only provides hearing loss compensation, it ensures audibility of sounds coming from all directions. This allows for environmental awareness and in turn improves speech intelligibility.

CrossLink Directionality in Solus Pro 1.4

The SolusPro fitting software applies CrossLink Directionality as the default starting program in the hearing instruments. The improved Focus Ear Calculator II calculates the focus ear and monitor ear based on the word recognition scores and degree of hearing loss in each ear. Although the software initially determines the focus and monitor ears, the speech and noise de-
tectors in both the hearing aids communicate with each other continually using Ear to Ear Synchronization and identify situations in which a different microphone configuration may be more beneficial. As mentioned previously, the possible combinations can be omni/omni, omni/directional, directional/omni, and directional/directional. The directionality defaults to Automatic for both instruments in the fitting software.

There is an option to permanently set the focus and monitor ears in the hearing aids if the clinician so chooses. In that case CrossLink Directionality becomes inactive and automatic switching of the microphone modes is inhibited.

In the figure above, the right ear has been chosen to be the focus ear and the left one as the monitor ear. In the reverse case, the right ear would be the monitor ear and the left one the focus ear. See Figure 6 below.

Summary
The human auditory system is capable of performing operations a hearing instrument cannot. By ensuring the full sound picture is delivered to the brain, CrossLink Directionality allows the patient to take advantage of the fact that while hearing may be impaired, the brain is still capable of accepting, analyzing, and organizing sound. It is a true binaural strategy that affords the end user an automatic program of which he/she is in control rather than the hearing instruments. This facilitates binaural processing, providing improved speech understanding in noise without compromising the audibility of surrounding sounds.

References
