# Localization: Give your patients a listening edge

For those of us with healthy auditory systems, localization skills are often taken for granted. We don't even notice them, until they are no longer working.

Localization skills are essential to our understanding of sounds, and make listening more natural and enjoyable. They make it easy to focus on a speaker and pinpoint where a sound is coming from, and improve our environmental awareness. When our ability to localize is impaired, our quality of life suffers. It's time for hearing healthcare professionals to recognize localization for what it is—"a major aspect of auditory functioning and quality of auditory experience."[1]

This paper will outline the benefits of localization, its process and potential impairments, and opportunities for its repair.

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Favorite sound: waves breaking on the shore

## More than a location

Localization provides a listening edge by helping you separate the sounds you want to hear from those you don't. When you meet a friend for coffee, it's your localization abilities that let you hold a conversation in a noisy café. We call this an auditory figure-ground effect, and it's the auditory equivalent of "I Spy"—where we pick out one thing amongst a background of others. But it's also known as the cocktail party effect, and includes the ability to not only find the voice of a speaker, but focus our auditory attention on one speaker in the midst of others and background noise (as you'd find at a cocktail party).

Localization, as demonstrated by the cocktail party effect, makes it easier to participate in social situations. It's especially useful in noisy places. Many of us take this ability for granted; we don't even recognize when we separate conversation from noise. But hearing healthcare patients report conversations in background noise as difficult, whether or not they use hearing instruments.[2]

Localization skills also help map out auditory scenes. They allow you to know where your cat is, or where you left the cordless telephone. Externalization of acoustic images gives the impression that a sound appears outside the head, providing a realistic awareness of our environment.[3] Environmental awareness helps in many different aspects of daily life: safety, navigation, and social participation.

Having environmental awareness allows you to avoid being hit by a car as you cross the street. However, there are additional benefits you might not notice. People need to be able to tell where things are to walk safely. If they suddenly see something that they didn't hear, they may react in an exaggerated way, which can affect their balance.[4] Indeed, a "poor awareness of the auditory and spatial environment" has been suggested as a possible contributor to falls.[5] In fact, auditory localization is especially important to those with visual impairments "who use auditory localization to reconstruct inside their heads the world around them."[6]

With environmental awareness, we can see again how important localization is to social situations. Turning toward your communication partner is not only socially appropriate, it's a known enhancer of communicative effectiveness. Without localization, it's difficult to know who you should face, or that someone is speaking to you at all. The environmental awareness we derive from localization can make us hear and experience sound in a much more natural way, improving our life overall.

## How does localization work?

The ability to hear sounds binaurally allows us to locate the source of a sound. Localization is impaired if there is difficulty in any of the following areas of the auditory pathway: the outer ears (including pinnae and ear canals); the middle and inner ears; the auditory nerve and brainstem; the central auditory pathways and cortex.

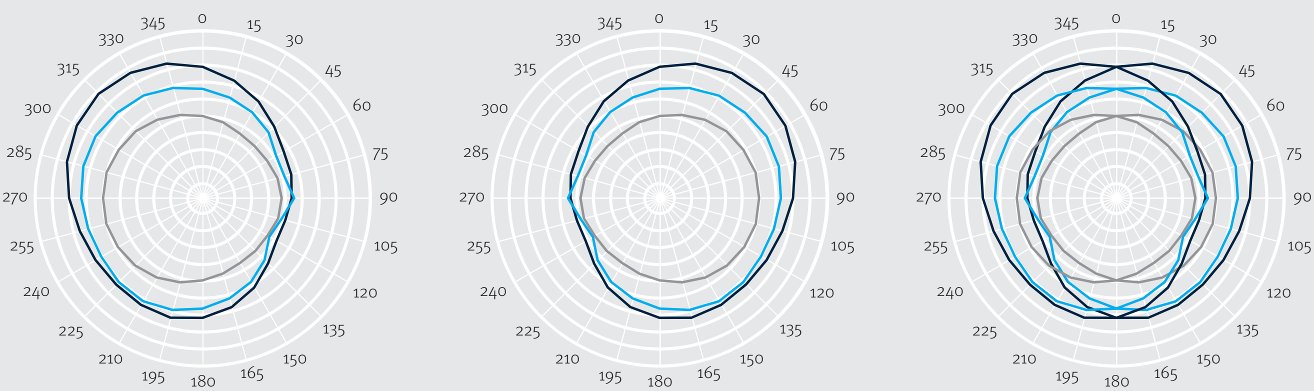
The outer ears (along with the head) shape the sound that enters the rest of the auditory system. Since it's created by our unique pinna and ear canal geometry, the shaping of sound is specific to each individual. Just as they cast a shadow of light, the head (and pinnae) cast a shadow of sound. This is shown in a Head-Related Transfer Function (HRTF), which shows the Sound Pressure Level (SPL) transform from a sound source in free field to the ear canal. (See Fig. 1.)

The cocktail party effect is made possible through binaural and spatial processing, and requires the integrity of the entire auditory pathway. The auditory system uses information from both ears to perceptually separate a signal of interest (a conversation partner) from noise (background speech and noises).

In addition, signal-to-noise ratio (SNR)—the ratio of the primary speech signal to the background noise—can be improved by the normal auditory system using the difference in SNRs between ears to improve the overall SNR. These binaural processes provide an improvement in speech intelligibility compared to the monaural condition.

**Fig. 1 –** Various angles of incidence of sound produce varying levels of loudness at all pitches. Below, we have simplified HRTFs with 3 pitches highlighted in particular: high=dark blue, medium=cyan, low=gray. Each ear's HRTF is shown separately but, in reality, they occur at the same time (see combined). When they are combined they produce the interaural information that allows the auditory system to determine the sound's origin. E.g., at 45 degrees there is a 15 dB difference in sound between the two ears at the high (dark blue) pitch.

High pitch
Medium pitch
Low pitch




**Left ear** **Right ear** **Left ear / right ear combined**

HRTFs provide the cues we need for localization. Although both localizations below are in the horizontal plane, they use different cues. The principal cues for localizing left-to-right tend to be binaural, and based on loudness and timing differences. Front-to-back cues tend to be monaural, and based on spectral differences as the pinna reflects sounds. Those reflections, along with the direct sound, result in a sound spectrum. (See Fig. 2.)

In left-to-right localization, depending on the location of the sound source, the head and outer ears form a 'baffle', which creates a shadow of sound for higher frequencies with shorter wavelengths (generally above 1500 Hz, where the wavelengths are small relative to a person's head size). The 'baffle' also causes a diffraction or bending for lower frequencies with longer wavelengths (generally below 1500 Hz where the wavelengths are large relative to a person's head size).

The physical realities of having a head and two ears result in differences in loudness between the ears (interaural level differences, ILD), as well as interaural time differences (ITD) which lead to interaural phase differences (IPD). All together, these differences provide frequency-dependent cues (affecting the higher [ILDs] and lower frequencies [ITDs and IPDs]).

Your brain learns to use these cues to determine the location of a sound source (even with your eyes closed).

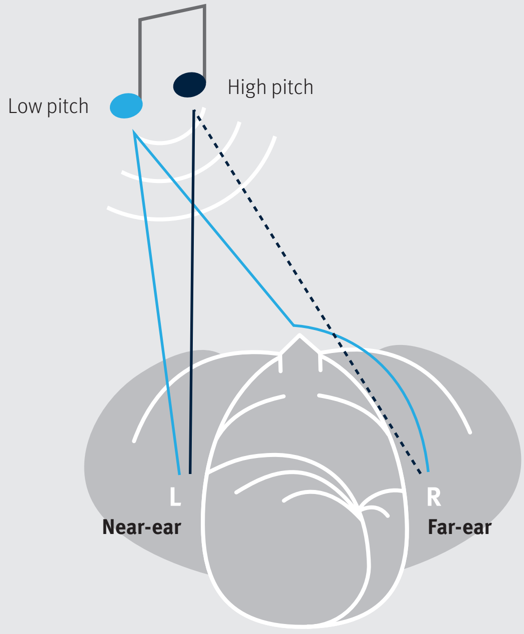



**Fig. 2 –** When displaying the ILD or ITD, the effects on pitches are often shown separately. In reality, the sounds we hear are complex, and the ILDs and ITDs occur at the same time. As you can see, the 'Near-ear' (nearest the sound source) has a greater level of high-pitched sounds and a similar level of low-pitched sounds to the 'Far-ear' (farthest from the sound source). The low-pitched sounds reach the Far-ear later, and have a different phase than the Near-ear sounds.

Front-to-back localization uses the differences in high-frequency sounds, which occur between the front and back of the pinna. (See Fig. 3.)
The outer ear is more directional in high frequencies: when the sound is in front of the listener, there's an accentuation of the high pitches due to the shape and reflections of the pinna and ear canal. In comparison, when the sound is directly behind the listener's head, the 'baffle' is provided by the auricles only.

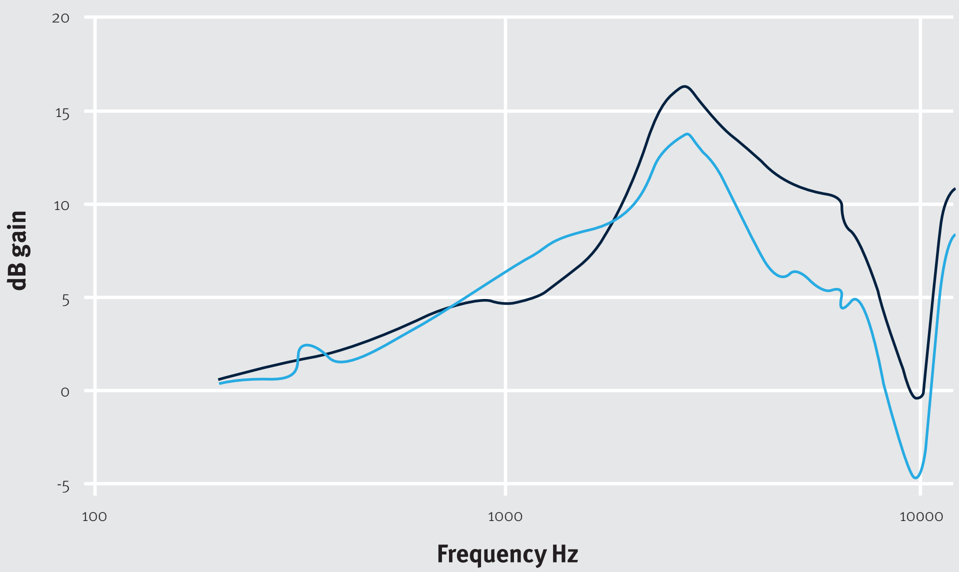



**Fig. 3 –** Unaided gain in KEMAR demonstrates the information for front-to-back localization, by comparing 0° (dark blue) to 180° azimuth (cyan). This is the information listeners receive by nature, helping them perform front-to-back localization.

Figure is based on Shaw data (1974)[7]

Because of its reliance on high-frequency cues, front-to-back localization is traditionally expected to be difficult, even for normal hearing listeners. The presence of high-frequency hearing loss and the placement of microphones where the pinna cues are no longer accessible does not help in this process.

## Impairments in localization

Processing difficulties can occur in older adults, due to changes in neurophysiology: "Aging is associated with both decreases and increases in brain activity. Whereas age-related decreases usually reflect neural decline, some age-related increases have been linked to functional compensation."[8]

Changes can also be the "direct consequence of an impaired cochlea sending deficient signals to the brainstem."[9] The outer hair cells (OHCs) and inner hair cells (IHCs), found in the cochlea's Organ of Corti, provide sensitivity to the level of sound, as well as frequency (OHC) and temporal (OHC & IHC) specificity cues. Frequency and temporal cues can also diminish with the cochlear dysfunction that often accompanies hearing loss.

Hearing instruments can be a help with localization. They provide amplification for audibility, and can balance an asymmetric hearing loss. However, they may also impair the natural cues of the pinna and ear canal.[10] Your brain is used to hearing sounds via the specific shape of your ears. Imagine trying to make sense of unconscious localizations with someone else's outer ear canal geometry—or no ear canal at all, as is the case with some fittings. It would be like trying to deal a deck of cards with different-sized hands, or a gymnast performing on a balance beam with bigger feet—completely unnatural and unreliable. Interaural cues would be inaccurate or absent.

## Opportunities in localization

Hearing instrument wearers are waiting for the benefits of improved localization—even if they don't know it. In a follow-up to his MarkeTrak V survey, Sergei Kochkin reported that poor benefit and performance in noise were the top two reasons for hearing instrument non-usage.[11] More recently, in MarkeTrak IX, we learned that "the listening situation with the lowest satisfaction level across all groups is trying to follow a conversation in the presence of noise."[12]

**We could make conversations enjoyable again.**

Hearing instrument wearers could benefit from improved SNR and emphasis of ILDs, improving the localization of sounds from left, right, and behind the ears. Quick and accurate cues would aid in the cocktail party effect, helping them follow and focus on conversations in challenging environments.

**We could improve front-to-back localization and intelligibility from behind.**

In real life, it's not always possible to turn towards a talker. There may be safety or logistical considerations, like driving a car with a back-seat passenger, or participating in a classroom-style meeting. Remote microphones are helpful, but wouldn't it be best if the hearing instrument could do this work for us?

**We could make environmental awareness more natural.**

Using a system that mimics the open ear response, we could get the hearing instrument out of the way, letting localization and listening happen naturally. Since no two ears are alike, we could take the extra step of personalization, which would be more beneficial for safety, natural listening, and externalization.

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