# The SAGE Encyclopedia of Human Communication Sciences and Disorders

## Binaural Hearing

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Binaural hearing refers to the fact that humans and other animals use information arriving at the two ears to perceive sounds. Binaural hearing helps localize sounds in the horizontal plane (left–right dimension) and understand speech in noisy environments. A hallmark of binaural hearing is the interaction between the head and sounds that arrive at the ears from different locations in space. This entry discusses the acoustic cues that give rise to binaural hearing, anatomical pathways involved in processing these cues, and perceptual phenomena experienced by humans and other animal species.

Binaural cues arise from the fact that sounds occurring at each angle relative to the head produce different binaural cues. Sources from directly in front reach the two ears with zero difference in timing and with the same amplitude, or intensity. Sources on one side of the head reach the nearer ear before the farther ear, creating an interaural difference in time (ITD) of arrival of the sounds. The ITD depends on the size of the head because of the amount of time it takes a sound to reach the two ears and is therefore larger for bigger heads.

For a sound that occurs from 90 degrees to the side, an average human adult head produces an ITD of 650 to 700 μsec. ITDs are particularly robust at low frequencies, where the wavelength of the sound is relatively long compared with the size of the head and the sound coming from the side can easily bend around the head to reach the other ear. As frequencies increase (above ~1,500 Hz for an adult), timing of sounds between the ears becomes ambiguous.

At higher frequencies, the wavelength of the sound is too short to bend around the head, and an “acoustic shadow” is created whereby the amount of energy in the sound is reduced in the far ear compared with the near ear. The interaural difference in level (ILD) also depends on the distance of the source from the ears; the “inverse square law” renders sounds that are farther away less intense, and the head shadow has less impact at larger distances.

The physiological and anatomical basis of binaural hearing has been studied extensively in a variety of non-human mammalian species, revealing numerous similarities across species. A ubiquitous feature of auditory brainstem nuclei is the existence of separate nuclei that process ITDs and ILDs in parallel pathways and then integrate ITD and ILD processing at higher levels in the auditory pathway. Auditory information is organized by frequency, hence the term *tonotopic organization*. From the cochlea in each ear, information is tonotopically transmitted to the auditory nerve (also known as the VIII nerve) and then to the initial point of contact in the brainstem known as the cochlear nucleus.

Subsequently, the pathways diverge into two parallel processing stages. Low-frequency ITDs are processed in a circuit thought to detect coincidence in the timing of inputs arriving from the right and left auditory nerves and enable a mechanism for coding information about space. Over the years, numerous renditions of models have made various assumptions about the importance of excitatory and inhibitory circuits in the brainstem that modulate the sharpness of tuning to ITD cues. Studies in animals that have been deprived of hearing, in one or both ears, have revealed that neural plasticity plays an important role in the establishment, refinement, and integrity of the ITD pathway.

Parallel to the ITD pathway runs the ILD circuit, which contains neurons that are mostly sensitive to high-frequency stimuli and through combinations of excitatory and inhibitory inputs provide the animal with information about differences in intensity for sounds that arrive from different locations. The ITD and ILD information is the crux of what is known as binaural hearing, and the two pathways are recombined at higher stages in the auditory system to convey integrated information about sound location. Higher order centers in the auditory system also act as integrative and relay centers that enable listeners to perform complex tasks involving learning, memory, and directing attention to important sources.

When the two sounds arrive at the ears concurrently, the auditory system uses two separate processes to separate them. One process is nonbinaural, known as the *better ear listening effect*, and the other process is the *binaural unmasking effect*. In this way, binaural hearing plays a key role in the ability to function in a "cocktail party" situation, where the goal is to obtain information from important stimuli or talkers (targets) while ignoring information from other sources that can cause interference (interferers). When targets and interferers occur from the same location, the target is much more difficult to detect and understand than when the sources are separated in space.

Binaural hearing in a cocktail party environment is directly linked to the effect mentioned earlier whereby ITDs and ILDs provide cues necessary for localizing sounds. If the auditory system can provide information about source locations of two different sound sources, the listener is able to extract information from the target source and separate that information from background interferers.

ITDs are especially important and useful in the *binaural unmasking effect*: Whereas sounds that arrive from the same locations have a statistical coherence as stimuli reach the two ears, sounds arriving from different locations cause statistical incoherence or decorrelation as stimuli reach the two ears. Listeners are sensitive to these binaural incoherences or decorrelations and can use them to select the target signal in the presence of background noise.

Finally, when considering the impact of hearing loss, successful hearing in the cocktail party environment is maximized when listeners can hear with both ears; individuals who are deaf in one ear find this task much more challenging. Binaural hearing is therefore considered to be a necessary component of treating children and adults who are hearing impaired or deaf.

***See also*** Anatomy of the Hearing Mechanism and Central Audiology Nervous System; Auditory Scene Analysis; Psychoacoustics

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### Further Readings

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