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Hearing

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Hearing, also known as audition, is a modality of sensory perception in which one detects and differentiates things and features in the environment by transducing and extracting information from pressure waves by means of a dedicated sense organ such as the ears. While the study of sense perception historically has focused predominantly on vision, hearing is also a significant area of research in the cognitive science of perception. Such research addresses which things human beings are capable of perceiving auditorily, in which respects hearing differs from vision, and how audition contributes to perception overall. Three main topics have occupied the focus of research on hearing: spatial hearing, nonspeech hearing, and speech perception. Attention to auditory perception extends and challenges vision-based theorizing about perceptual capacities, processes, and awareness. New developments concern the role of hearing in multisensory perception and draw broader theoretical connections to research on object perception and disability studies.

History

Hearing and auditory perception played a key historical role in the development of psychophysics (Helmholtz, 1877), language cognition (Liberman, 1996), and multisensory perception (McGurk & MacDonald, 1976). Nevertheless, such research was eclipsed by the attention devoted to vision during the 20th century. Marr's (1982) landmark book *Vision* is a paradigm example [see Visual Cognitive Neuroscience].

Auditory perception emerged as a central research topic spurred in part by Bregman's (1990) groundbreaking book *Auditory Scene Analysis* (see also Handel, 1993). Auditory perception has recently generated sustained debate in empirically oriented philosophy of perception. Hearing is important theoretically because it differs from vision in several notable respects, including its spatial and temporal characteristics and its perceptual objects. It thus presents unique challenges in developing a comprehensive, general understanding of perception.

Core concepts

The study of hearing has focused on three main subareas: spatial hearing, nonspeech hearing, and speech perception. The primary questions animating each area concern what humans are capable of perceiving auditorily, how auditory perception takes place, and how auditory perception differs from perception in other sensory modalities.

Spatial hearing

Auditory perception is robustly spatial. Human hearing is capable of detecting direction and distance by means of slight differences in the arrival time of sound waves at the two ears (*inter-aural time delay*) and by means of distinctive ways the head and pinnae (outer ears) transform incoming sound waves (*head-related transfer function*).

Nonetheless, spatial hearing is not as accurate or detailed as spatial vision. Auditory spatial resolution is roughly an order of magnitude less than that of vision (Blauert, 1997). This difference stems from the physical nature of sound waves and of the human ear as compared with light and human eyes.

Auditory temporal resolution, however, is significantly greater than that of vision. Indeed, it has been proposed that time plays a role in audition that is analogous to that of space in vision (Kubovy, 1988). While the objects of visual perception (things we see) are organized and identified by means of their spatial structure, it is plausible that the objects of auditory perception (things we hear) are organized and identified by means of their temporal structure (O'Callaghan, 2008).

Nonspeech hearing

Sounds are sometimes understood as pressure waves that move through the atmosphere. However, it is not obvious that perceivers represent sounds as waves that travel through the air. Much like things we see, sounds typically appear to be located at a distance in some direction.

Nonetheless, sounds are unlike the ordinary objects we see. Sounds have qualities such as pitch, timbre, loudness, and duration, which differ from those of corresponding ordinary objects. Sounds are more fleeting than the bells and horns that make them. Accordingly, scholars say sounds are generated or caused by what takes place in one's surroundings. Some maintain that sounds are events located at a distance (Casati et al., 2020; O'Callaghan, 2007). Others hold that sounds are properties of objects or events such as clapping hands or vibrating strings (Pasnau, 1999; Kulvicki, 2008).

Auditory perception is a way to become aware of things like collisions, clapping, and vocalization—the sources of sound. One important question is whether or not human beings, strictly speaking, hear such objects or events. If so, such awareness counts as belonging to auditory perception. If not, it is instead a matter of extra-perceptual cognition or inference.

A distinct question concerns the range or variety of features that human beings are capable of perceiving auditorily. According to a sparse account, auditory perception represents only relatively basic acoustical features such as pitch, timbre, and loudness. According to a more liberal account, auditory perception also represents higher-level features such as categories or kinds. For instance, one may hear footsteps, specific animals, or particular melodies as such—that is, one may auditorily attribute properties such as *being a footstep* (Di Bona, 2017). This connects questions about auditory perception to broader debates about the "richness" or "thinness" of perceptual content (Siegel, 2010).

Speech perception

It is particularly significant that human beings have developed a distinctive capacity to perceive spoken language. In many cultures, perceiving speech auditorily plays a predominant role in communication. Speech perception is a highly specialized area of study. A primary aim of this research is to discover the degree to which perceiving spoken language is continuous with general, nonspeech hearing and the

degree to which it involves special or dedicated capacities (Liberman, 1996). This research also helps illuminate whether language itself is uniquely human (Fitch, 2018).

Questions, controversies, and new developments

Hearing does not stand alone. Instead, it works in concert with the other senses. Crossmodal perceptual illusions have demonstrated that the senses not only operate in parallel but also interact extensively with each other. *Ventriloquism* involves an auditory spatial illusion sensitive to the visible location of an apparent sound source (Bertelson, 1999). The *McGurk effect* shows that seeing the movements of a mouth can alter the way spoken utterances sound (McGurk & MacDonald, 1976). The *sound-induced flash* demonstrates that hearing two quick beeps can make a single visible flash look like two flashes (Shams et al., 2000).

Hearing may also cooperate with other senses to enable the perception of novel features that could not be perceived with any single sense operating on its own. Potential examples include perceiving intermodal causal, spatial, and temporal relations as well as phonological features that rely jointly on hearing and vision (O'Callaghan, 2019).

An open question concerns whether and to what extent the capacity to perceive certain features auditorily may depend crossmodally on other senses. For instance, could the capacity to auditorily perceive a certain spatial feature require a prior capacity to visually perceive that feature?

Broader connections

Hearing and auditory perception interface with several noteworthy areas in cognitive science, including object perception, perceptual content, the senses, multisensory perception, music perception, language and cognition, attention, and disability. For example, there is debate about whether a more general notion of *perceptual object* applies not just to three-dimensional, extended, bounded, cohesive bodies that we see but also to sounds and other audible events that we hear. The notion of an individual composed of a structured complex of parts has been proposed to play this role (O'Callaghan, 2016; Green, 2019). Another example concerns how a hearing disability, such as deafness, impacts a person's overall perceptual capacities, either by impairing or enhancing perception with one's other senses.

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