

# Spatial Hearing

During our evolution, the ability to locate the source of a sound has been critical for our survival. Since the appearance of mammals as primarily nocturnal animals more than 200 million years ago, they have relied heavily on their sound localization abilities for locating friends, foes, and food. Locating the source of a sound remains an important sensory ability for prey and predator alike. Even for humans in modern times, spatial hearing is extremely useful and important for orientation in one's environment. Sound sources are often localized with relatively good accuracy by our hearing, even in cases when the sources are not visible.

The mechanisms of how localization is performed are, however, not generally understood by the layperson. Many of them have been uncovered largely by science. There is actually a plethora of complex, robust, and accurate mechanisms for spatial hearing that are based on signal analysis of either binaural or monaural inputs. For example, the JND in the detection of delays between binaural signals is of the order of  $20\ \mu\text{s}$ , which is amazingly accurate when one remembers that it is obtained using neurons whose latency times and output spike lengths are of the order of 1 ms.

Spatial hearing develops substantially through learning and adaptation to gain more accuracy and better performance in complex environments. The fundamental role of learning is easy to understand because spatial hearing is dependent on individual factors, such as the size and form of the head and geometries of the pinnae. The auditory system learns to analyse sound environments by utilizing the properties of direct sound, reflections from surfaces and objects, and reverberant sound arriving at the two ear canals of the subject.

## 12.1 Concepts and Definitions for Spatial Hearing

### 12.1.1 Basic Concepts

We begin the discussion by defining some basic concepts related to spatial hearing. The term *localization* is the process by which the location of an auditory event in the auditory space is associated with the attributes of a sound event in an acoustic environment. In general, the human auditory system represents the external sound environment by an internal auditory