Key mechanism in the brain's computation of sound location identified

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New York University researchers have identified a mechanism the brain uses to help process sound localization. Their findings, which appear in the latest edition of the journal *PLoS Biology*, focus on how the brain computes the different arrival times of sound into each ear to estimate the location of its source.

Animals can locate the source of a sound by detecting microsecond (one millionth of a second) differences in arrival time at their two ears. The neurons encoding these differences—called interaural time differences (ITDs)—receive a message from each ear. After receiving these messages, or synaptic inputs, they perform a microsecond computation to determine the location of the sound source. The NYU scientists found that one reason these neurons are able to perform such a rapid and sensitive computation is because they are extremely responsive to the input's "rise time"—the time it takes to reach the peak of the synaptic input.

Existing theories have held that the biophysical properties of the two inputs are identical—that is, messages coming from each ear are rapidly processed at the same time and in the same manner by neurons.

The NYU researchers challenged this theory by focusing on the nature of the neurons and the inputs—specifically, how sensitive they are in detecting differences in inputs' rise times and also how different are these rise times between the messages arriving from each ear.

Buoyed by predictions from computer modeling work, the researchers examined this process in gerbils, which are good candidates for study because they process sounds in a similar frequency range and with apparently similar neuro-architecture as humans.

Their initial experimental findings were obtained through examination of the gerbils' neuronal activity in charge of this task. This part of the brain was studied by stimulating directly the synaptic pathways. The researchers found that the rise times of the synaptic inputs coming from the two ears occur at different speeds: the rise time of messages coming from the ipsilateral ear are faster than those driven by the contralateral ear. (The brain has two groups of neurons that compute this task, one group in each brain hemisphere—ipsilateral messages come from the same-side ear and the contralateral messages come from opposite-side ear.) In addition, they found that the arrival time of the messages coming from each ear were different. This finding was not surprising as the distance from these neurons to the each ear is not symmetric. Other researchers had assumed that such asymmetry existed, but it was never measured and reported prior to this study. Given this newfound complexity of the way sound reaches the neurons in the brain, the researchers concluded that neurons did not have the capacity to process it in the way previously theorized.

Key insights about how these neurons actually function in processing sound coming from both ears were obtained by using the computer model. Their results identified that neurons perform the computation differently than what neuroscientists had proposed previously. These neurons not only encode the coincidence in arrival time of the two messages from each ear, but they also detect details on the input's shape more directly related to the time scale of the computation itself than other features proposed in previous studies.

"Some neurons in the brain respond to the net amplitude and width of summed inputs—they are integrators," explained Pablo Jercog and John Rinzel, two of the study's co-authors. "However, these auditory neurons respond to the rise time of the summed input and care less about the width. In other words, they are differentiators—key players on the brain's calculus team for localizing a sound source."

More information: Jercog PE, Svirskis G, Kotak VC, Sanes DH, Rinzel J (2010) Asymmetric Excitatory Synaptic Dynamics Underlie Interaural Time Difference Processing in the Auditory System. PLoS Biol 8(6): e1000406. doi:10.1371/journal.pbio.1000406

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