Principles of auditory grouping in the presence of multiple sounds.

Ilana B. Witten[1], Phyllis F. Knudsen[1], and Eric I. Knudsen[1]

[1]Stanford University School of Medicine, Stanford, CA, 94305

The auditory system uses many cues to group and segregate sounds, including timing, spectral, and localization information [1]. When these cues conflict, timing cues are particularly powerful in grouping auditory input, and will tend to override localization information. For example, in humans, when two sounds are presented simultaneously from different horizontal positions, the timing cues cause the sounds to be grouped, and only the location of the lower frequency sound is perceived [2]. We investigated the effect of timing cues on discrepant localization cues in the barn owl, using behavioral and neurophysiological experiments.

We trained two barn owls in a simple task to assess their localization of two simultaneous sounds originating from different locations. During an initial training period, the owl was rewarded for first fixating a zeroing light and then generating a head orienting movement to a subsequent sound, which was either a low (3-5kHz) or a high (7-9kHz) frequency sound. During the test period, either one sound was presented alone, or else both sounds were presented at the same time from different locations. The owl was rewarded for any short latency head movement following the onset of the sound. We found that, in agreement with the results from humans, the barn owls preferentially oriented to the low frequency sound when the sounds were separated in azimuth. In contrast, when the sounds were separated in elevation, the barn owls oriented exclusively to the high frequency sound.

To identify the neural basis of this localization bias, we recorded neural activity in response to the same sounds in the barn owl's optic tectum (OT; homolog of superior colliculus), which contains a map of auditory space and is involved in generating orienting head movements to sounds. We found that although both the low and high frequency sounds generated spatially restricted responses in the OT on their own, when the two sounds were presented together with a spatial separation in azimuth, the center of mass of the responses was shifted towards the location of the low frequency sound (n=45). The dominance of the low frequency representation developed dynamically, stabilizing about 25 ms following sound onset. The direction and magnitude of the owls' head movements in the behavioral experiments correlated with the center of mass of the neural activity. Additionally, we found an agreement between the behavioral performance and neural activity when the sounds were separated in elevation as well: in this case, the responses corresponding to the high frequency sound dominated in the space map.

We hypothesize that the localization bias is related to the resolution and spatial ambiguity of the localization cues. The bias towards the low frequency sound for sounds separated in azimuth may be related to the greater spatial ambiguity inherent to the high frequency sound in azimuth, while the bias towards the high frequency sound for sounds separated in elevation may be related to the lack of spatial resolution provided by the low frequency sound in elevation.

References

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