Neural Codes for Representing Target Distance in Bat Sonar

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Abstract:

Animals that rely on active sensing present powerful models for investigating the neural substrates of behavior, as their actions directly influence the very signals they use to represent the environment. Echolocating bats, for example, transmit high frequency sounds and process information carried by returning echoes to determine the 3D location of objects. Bats estimate the distance to a target from the time delay between a sonar pulse and its echo return, and they can discriminate echo arrival time differences of less than 60 μsec, or 1 cm in target range. The neural basis for microsecond sonar ranging accuracy in bats has eluded researchers for decades, and motivated the studies presented in this talk. To investigate the neural representation of echo delay in the bat sonar receiver, we conducted extracellular recordings in the midbrain of passively listening and actively echolocating animals. First, we discovered precisely timed premotor activity associated with each sonar vocalization, which could serve as the start signal of an internal stopwatch to measure echo delay. We also found that the synchronous firing of auditory neurons in the bat midbrain can reliably register the timing of acoustic events with microsecond precision. Finally, we characterized spatial response profiles of single auditory neurons in the midbrain superior colliculus of free-flying bats engaged in natural echolocation tasks. Our data show that midbrain neurons respond selectivity to both the direction and delay of sonar echoes from physical objects along the bat's flight path. Further, we discovered that 3D auditory spatial tuning and response areas of midbrain neurons are both modulated by the bat's temporal patterning of its echolocation calls. Collectively, these findings indicate that the representation of echo delay (target range) in the bat's sonar receiver is dynamic and tightly coupled to its active production of echolocation signals.