Cogs 107b – Systems Neuroscience

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Lec8_02022010 – the auditory system II – timing is everything

principle of the week – ‘active sensing’
ascending pathways of the mammalian auditory system
the ‘where’ of sound – sound source localization by comparison of inputs to the left and right ears

interaural time difference (ITD)

not useful for persistent high frequency sounds (>2000 Hz) as hair cell responses do not oscillate in response to high frequency tones

interaural level difference (ILD)

not useful for low frequency sounds as their amplitude is less impacted by the head

what about sound source height?
Brainstem processing of auditory information yields sound source localization. The organization of cochlear nucleus outputs to the brainstem yields responses to interaural time differences in medial superior olive neurons and interaural level differences in lateral superior olive neurons.
timing of spikes in A1 can be very consistent even for highly complex auditory sequences
multiple sub-regions of auditory cortex: most contain a tonotopic map – responses to different sound intensities are heterogenous
A1 preferred frequency map (tonotopy)
preferred frequency = pitch for which amplitude necessary to give a response is lowest

A1 preferred ‘sweep direction’ map
preferred direction = ordering (low→high vs. high→low) of frequencies in a frequency sweep that produces the strongest response to the preferred frequency

timing matters: A1 responses to pure tones are modulated by the frequency ordering of preceding tones
history-dependence of A1 response fields: order-dependent excitation
history-dependence of A1 response fields: order-dependent suppression
temporal dependence of response to preferred frequencies means that auditory ‘objects’ can be registered by the patterns of firing of A1 neurons. A1 responses to vocalization of a monkey can be considered an auditory object (similar, in principal, to a spoken word). Both the ordering of tones and their temporal relationships alter A1 responses.
bat echolocation: finding and tracking the location of prey through comparison of sound time signatures
What Can the Bat Tell from an Echo?

Distance to target – FM delay

Absolute target size - amplitude

Azimuth and elevation- ITD, ILD

Velocity of target- CF Doppler shift

Flutter of target (i.e., wing beat) – modulation of echo delay
stiffness of basilar membrane

best frequency for membrane oscillation

60 kHz
62 kHz
target proximity: utilization of the FM component delay

bat cortex area 4 contains neurons which recognize the FM component of a call AND register its delay from the time of the call
target speed: utilization of changes in pitch of the CF component between call and echo (i.e., detecting the Doppler shift in frequency)
take-homes:

• A1 neurons respond best to sounds at particular frequencies, but those responses can vary greatly according to:
  • sound amplitude – neurons may exhibit a linear increase in response to increasing amplitude of a preferred-frequency tone or may exhibit highest firing at some intermediate amplitude and less at lower and higher amplitudes
  • the temporal ordering of sound – neurons may exhibit very different responses to a preferred-frequency tone depending on the tones that precede and accompany it
• the basilar membrane of a bat has extra space devoted to regions responding to sounds near 60 kHz (in the range of its calls) – in this sense, it can be considered the bat’s auditory fovea
• bats use long ‘CF’ calls to assess Doppler shift and, in turn, the movement speed of their prey
• bats use shorter ‘FM’ sweeps to assess their proximity to their prey
• prey size can be determined by the echo amplitude (closer = louder)