Audio-Vocal Integration in Awake, Behaving Echolocating Bats

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Introduction

The hallmark of biological organisms is the ability to integrate information from multiple sensory modalities in a robust, real-time situation with low power consumption. The processed sensory information is subsequently used to update and initiate species specific motor behaviors.

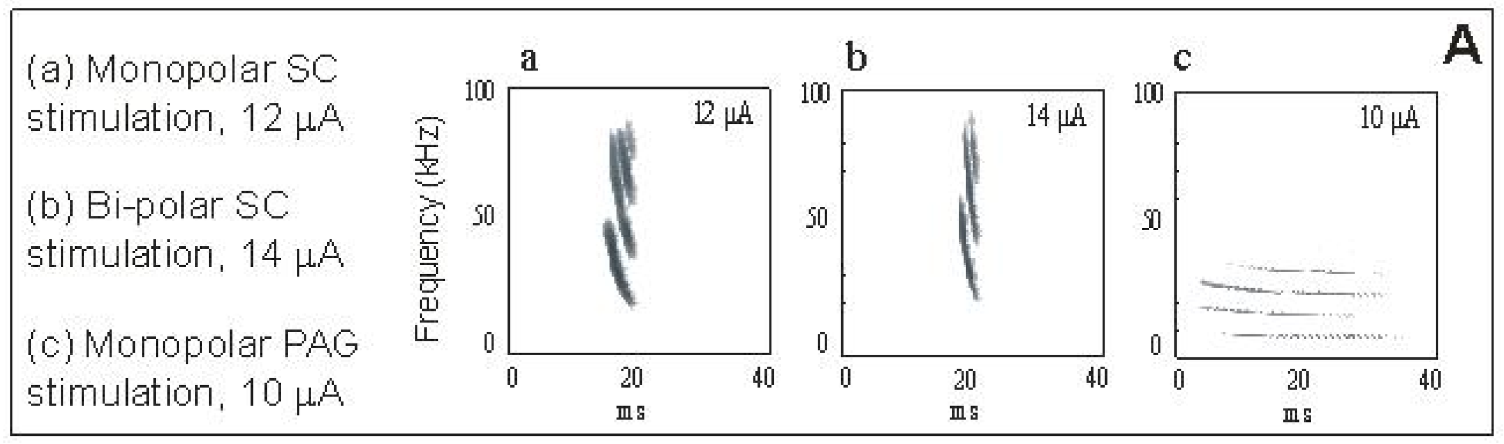
One form of sensori-motor transformation occurs in the auditory guidance of sonar vocalizations observed in echolocating bats. For bats, orienting behaviors that are generated to follow a target are dependent on the interplay between sonar vocalizations and the resulting auditory cues from echoes. Thus, the choice of echolocation call parameters, and the sequence of calls produced, will impact the acoustic cues used for target identification and localization.

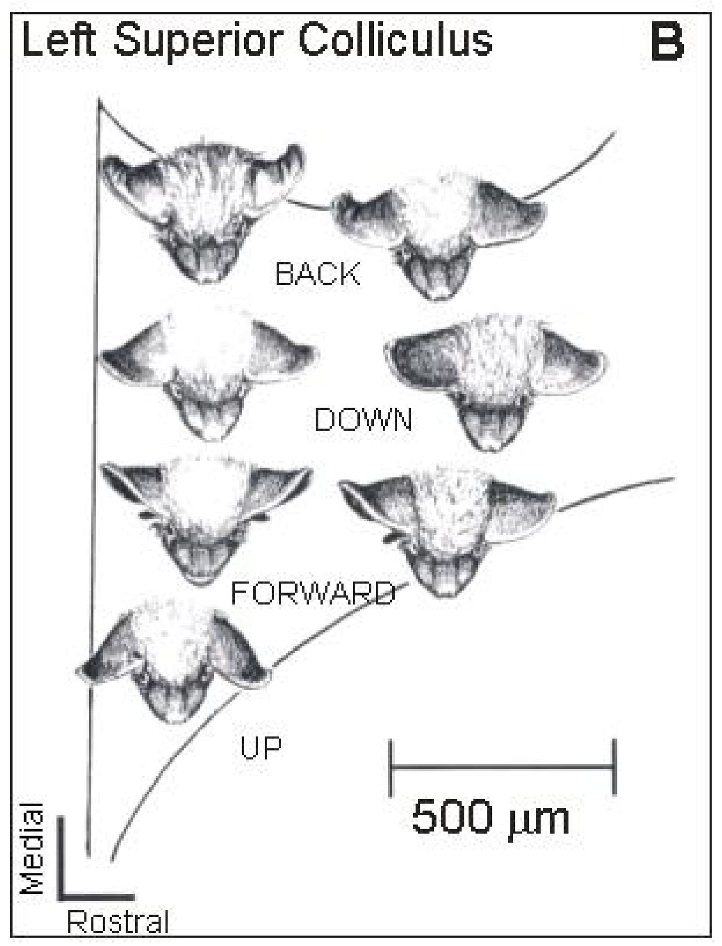
Background

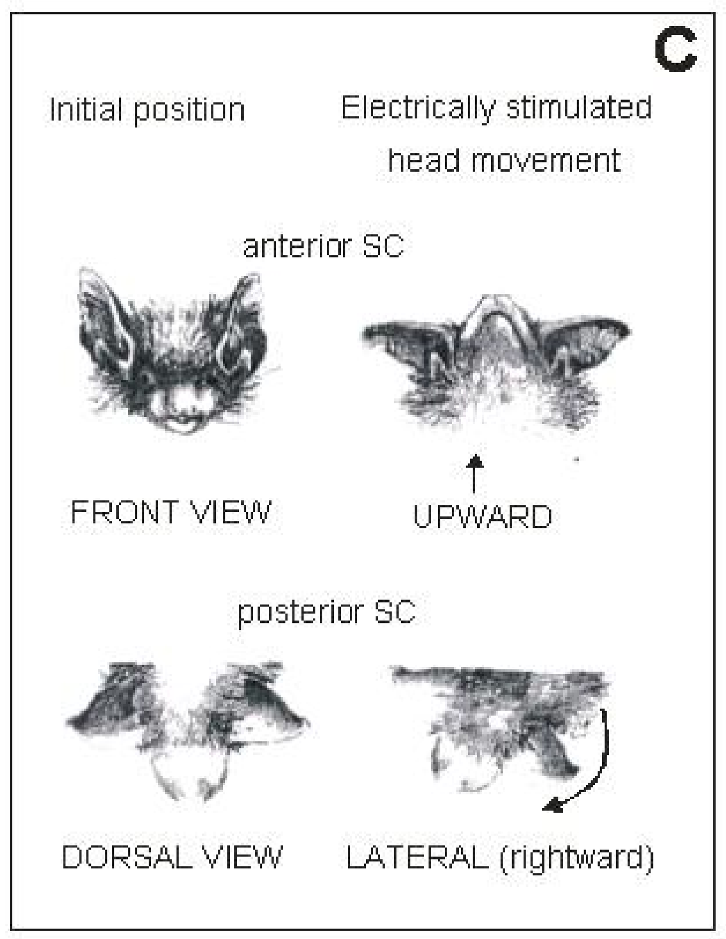
We conducted a series of experiments in the superior colliculus (SC), an identified sensori-motor structure in the midbrain of mammals. These experiments focused on:

(1) The representation of auditory information in the SC,1
(2) The motor behaviors the SC is able to initiate, and
(3) Pathways that allow the SC to mediate these behaviors.

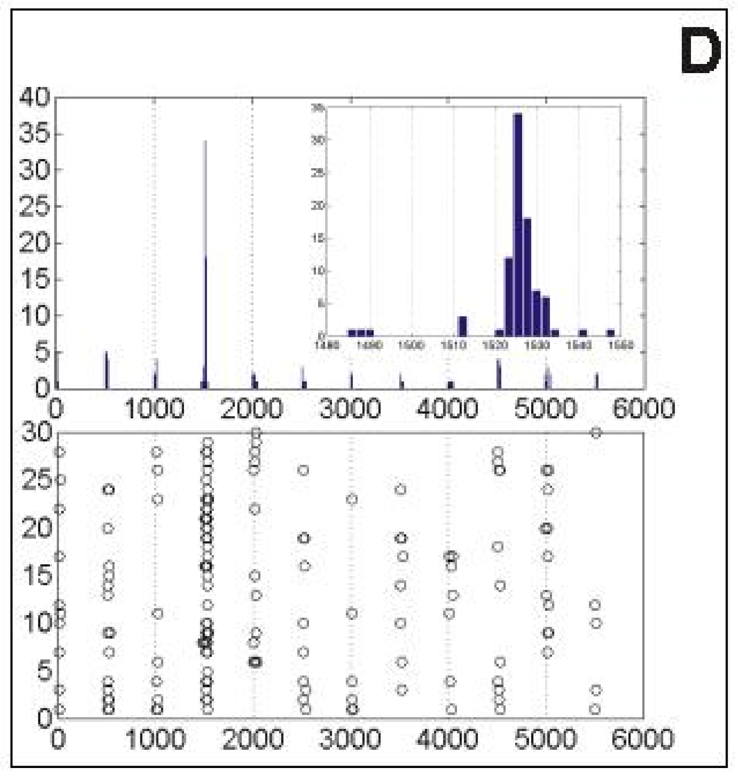
On the *motor* side we demonstrated that microstimulation of the SC elicits sonar vocalizations (A), pinna (B) and head (C) movements.

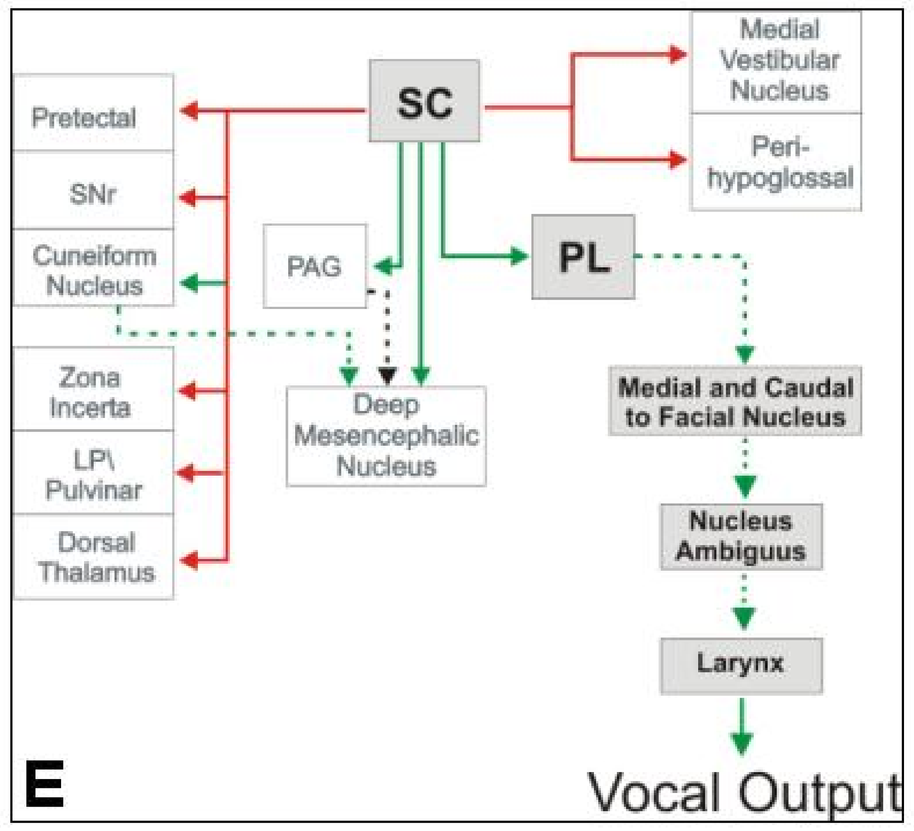






On the *sensory* side we have demonstrated two population of neurons with spatial receptive fields. The first population has 2-D receptive fields sensitive to a target location in azimuth and elevation. The second population has 3-D receptive fields, sensitive to target azimuth, elevation, and distance (**D**). Additionally, we have identified anatomical connections between the SC and pre-motor vocal control nuclei (**E**).





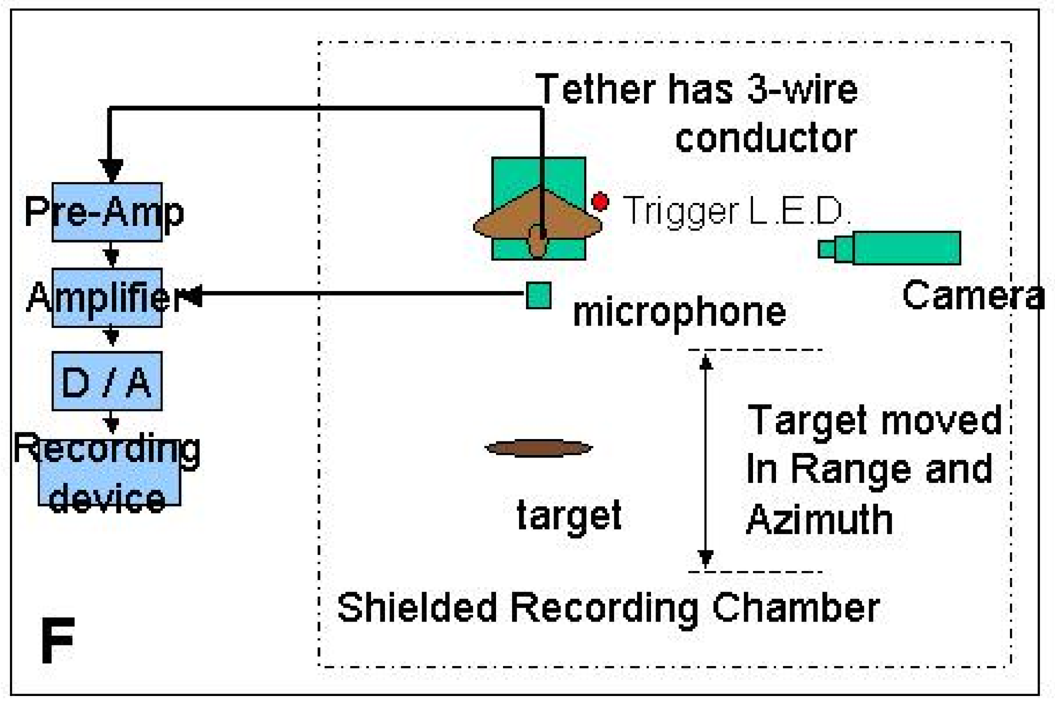
Neural Recordings from Behaving Bats

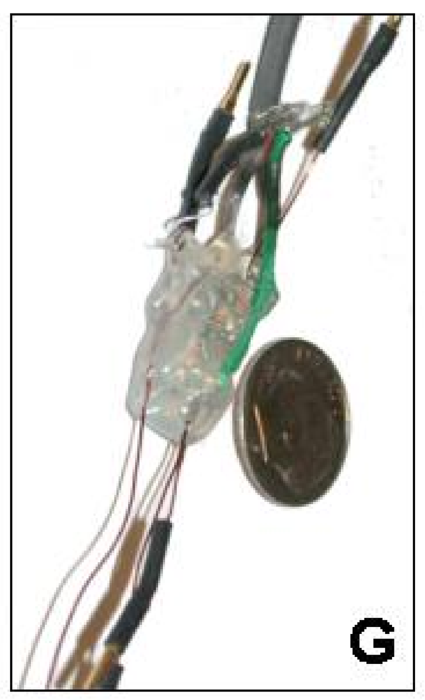
We have conducted experiments using *chronic neural recording techniques* in the SC of bats performing a behavioral task (see **F** for set-up and **G** for picture of amplifier to be used).

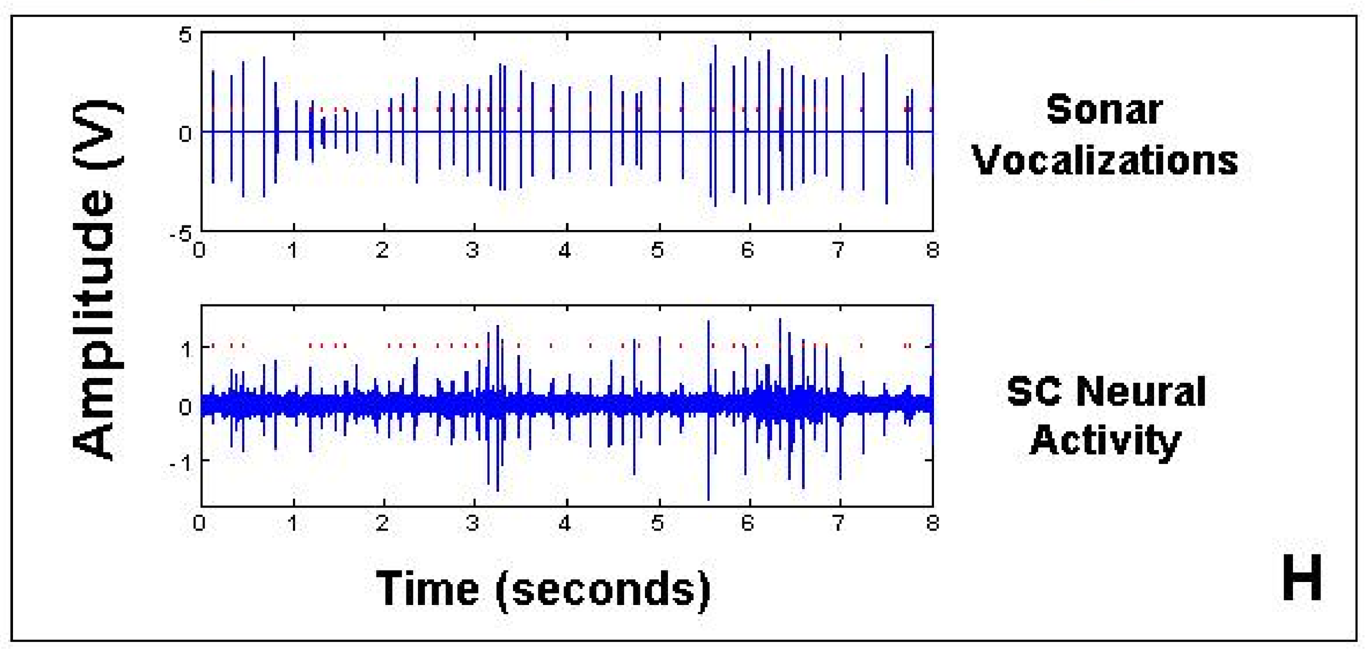
•The bats were trained to remain on a platform and track a moving target using echolocation.

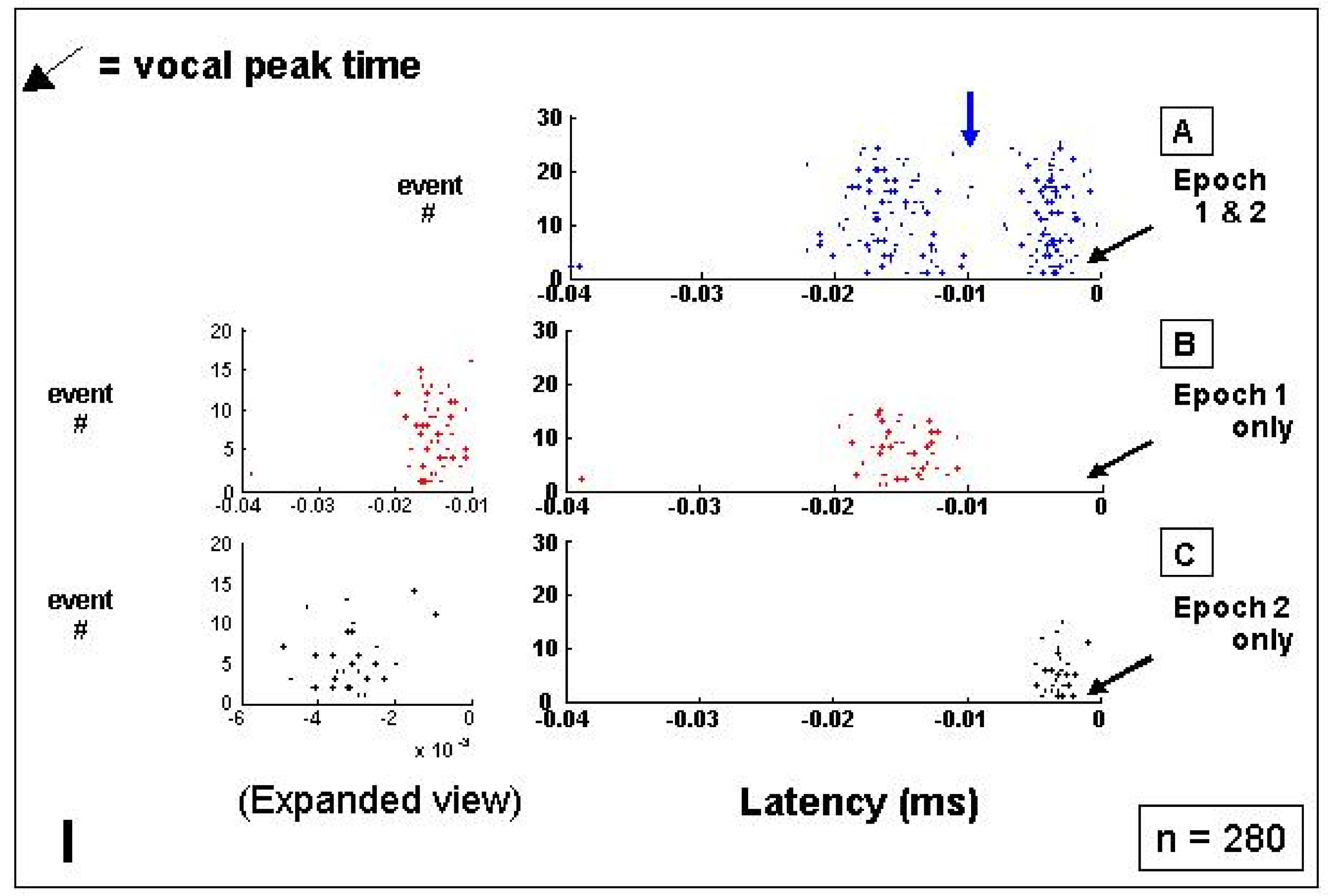
• The vocalizations were simultaneously recorded with neural activity in the deep SC (see **H** below).

• Data was collected in 8 second blocks, with 6 MΩ tungsten electrodes.



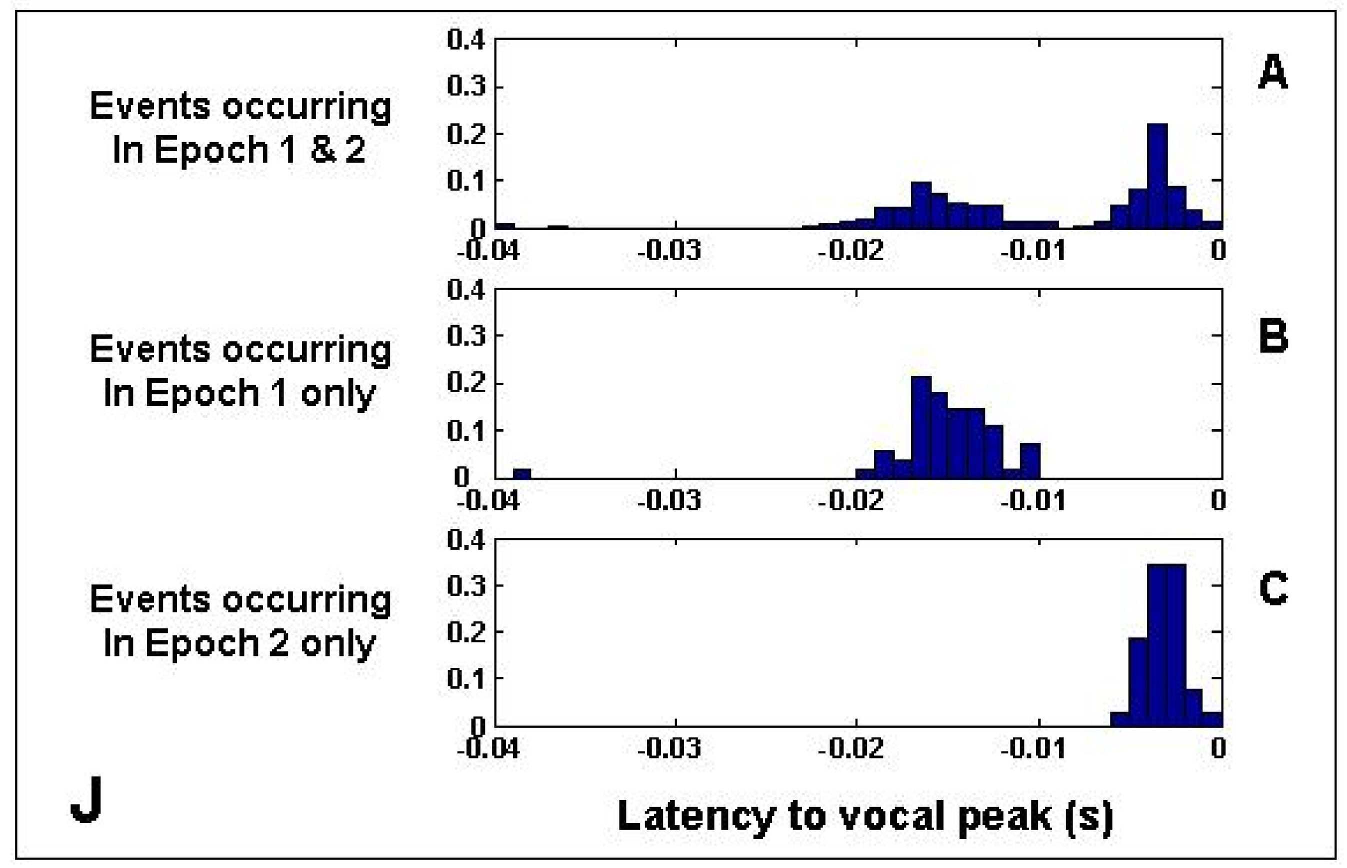






The neural activity preceding the vocalizations showed different latencies, and could be classified into: (1) a long latency group, peaks > 8 ms latency to vocal peak, and (2) a short latency group, peaks < 8 ms latency to vocal peak.

Peaks in the waveform above a 2 SD threshold were used. The level was measured at the recording site, on the day of each experiment, during a non-vocalizing period. (**I**)



The histograms show the frequency of peaks with different latencies relative to the vocal peak. All histograms are normalized in frequency within their category. *Note* that the histograms for Epoch 1 only, and Epoch 2 only, show an increase in frequency when compared with corresponding frequencies in the Epoch 1 and 2 histogram. This is suggestive of an interplay between the activity in the two epochs. (**J**)

The chronic recording technique allows us to investigate questions related to competition among auditory object representations and selection of orienting behaviors as measured by pre-motor neural activity and the behavioral choice of vocal parameters. The mechanisms identified in these studies are likely to prove of interest in developing devices that employ rapid audio-motor feedback.