Motion–Dependent Object Representation in *Eptesicus fuscus*

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INTRODUCTION

Echolocating bats emit ultrasonic sounds and listen to the returning echoes in order to navigate their environment, avoid obstacles, and detect prey.

Previous experiments have demonstrated that bats have the capability to use echolocation for fine discrimination, identification, and possibly even categorization of objects in their environment. These studies have shown bats to discriminate:

- • mechanically projected disks vs. mealworms^1^·
  - • plates with different hole depths^2^·
  - • physical objects of different shapes^1,6^·
  - • computer-generated stimuli^3,8^·

We examine the discrimination abilities of *Eptesicus fuscus* in free flight using inedible physical targets.

We demonstrate the validity of this new behavioral paradigm by testing bats’ texture discrimination.

We then design new stimuli to determine whether bats can combine information about their own motion with echo information to build a motion-dependent object representation of the targets.

METHODS

Experimental Paradigm

We trained bats to discriminate between two tethered beads under low IR illumination, one designated the positive stimulus (S+) and the other the distracter (S-). The bats were trained to seek out and hit S+ suspended from the ceiling and avoid hitting S−, also suspended from the ceiling. The positions of the targets in the room changed with every trial, and the target positions were randomized. S+ and S− were suspended for the full duration of each trial.

Training

Using operant conditioning, the bats were trained in the following order, with some modifications per bat:

1. Train bat to catch mealworms from tether
2. Associate bridge stimulus with food reward while bat on platform
3. Allow bat to learn to land on platform
4. Train bat to connect physical contact with S+ (either on platform or hanging in the room) to the bridge stimulus and food reward on platform
5. Introduce S− to teach bat to prefer S+ and avoid S−

![Inspects targets](Image)

"Captures" target

![Lands on platform](Image)

Food reward

Experiments were run in a large carpeted flight room (6.4 x 7.3 x 2.5m) lined with acoustic foam in low light, long wavelength conditions.

Sonar vocalizations were recorded using ultrasonic microphones and analyzed off-line.

The bat’s 3-D flight path was reconstructed using stereo images taken from high-speed video recordings.

An array of 16 microphones was used to record the directional aim of the sonar beam of the bat as it flew.

![Echo Recordings](Image)

Echo recordings showing the changes in echo strength (dB) along frequency at different angles to the vertically oriented grooved bead

Bats can integrate object related information from multiple echoes during discrimination

RESULTS

Can bats obtain object related information from sonar echoes?

Smooth spherical beads were used as S+. Differently textured beads were used as S−, each presented at one time as an alternate to S+.

Bats can discriminate physical objects of different textures

Can bats integrate echoes over time to discriminate sonar targets?

We used the same behavioral paradigm with newly designed stimuli. Smooth spherical Delrin balls were machined with a groove cut 1 mm in depth around their circumferences. Holes were drilled to hang them from the ceiling. Each bead was machined identically, but presented horizontally (S+) or vertically (S−).

![Variation in Bat Flight Height](Image)

Variation in flight altitude between experimental conditions shows flight behavior between conditions to be similar.

Preliminary findings suggest that bats did not alter their own flight altitudes when presented with stimuli at different heights.

Potential Issues

Bat flight is variable from one trial to the next, while bead heights were separated by only a few centimeters. The variable flight paths could have washed out the critical timing when the bat is inspecting the beads (a relatively small portion of time), and the close proximity of the beads could make any differences in flight path within the noise.

FUTURE WORK

Separate the targets by greater amounts of height. Do differences in flight path become more obvious when the beads are separated by greater distances? Hang grooves at different angles. At what point are bats unable to distinguish the groove orientations? Examine the flight pattern of the bats as they inspect the targets by using auditory data to determine where the bats increase their sonar repetition rate. Do bats change their flight pattern to keep the most salient difference in echo returns constant, or is their representation less abstract? Examine the angle of the bats to the grooves of the two targets as the bats inspect the targets. Do bats get a complete sampling of echoes from the two targets or is the sampling of echoes restricted to only a subset of angles?