INTRODUCTION

Echolocation is the process of emitting high frequency sounds and listening to the return echoes in order to sense the environment. Microchiropteran bats rely on echolocation for the detection, localization, and categorization of objects in their environment (Schmidtner and Kalko 2001). The extent to which bats can discriminate texture and the specific cues bats use to discriminate texture have not yet been established.

Past studies of bat’s discrimination abilities have examined its performance discriminating:

- Mechanically projected disks and mealworms (Griffin 1967)
- Plates with different hole densities (Haberstetter and Vogler 1983; Simmons et al 1974)
- Physical objects of different shapes (Bradbury 1970, Simmons and Vernon 1971)
- Computer generated stimuli (Gnawald et al 2004; von Helversen 2004; Weilenbacher & Wiesem 2003)

In these past studies, the bat performed its discrimination stationary on a platform or in flight along a restricted path. None of these studies examined the bat’s discrimination of targets similar in size to their prey or in true flight.

We use a new behavioral paradigm to test the bat’s discrimination ability.

QUESTIONS

1. Can the bat discriminate between two objects that differ only in texture?
2. What behavioral strategies does the bat employ to discriminate a smooth surface from a textured surface?

HYPOTHESES

1. The bat’s discrimination performance will vary with the texture difference between S+ and S-.
2. A) The bat will direct its sonar beam to examine both targets simultaneously and use the interference patterns from the echoes of the two targets to make its discrimination.
3. OR
   B) The bat will direct its sonar beam to sequentially inspect each target individually.

METHODS

Experimental Setup

During discrimination testing, targets were suspended 80 cm from the ceiling by monofilament fishing line (.1 mm diameter). Figure 1 shows a top-down view of the experimental setup.

Training and testing

Using operant conditioning we trained the bat to discriminate between two tethered beads, one designated the positive stimulus (S+) and the other the distracter (S-). The bat was trained to seek out and hit positive stimulus (+S) suspended but not spinning from the ceiling. The bats needed to avoid hitting the distracter (S-) suspended from the ceiling. The positions of the targets in the room changed with every trial, and the target positions were randomized within the calibrated space of the flight room. S+ and S- were suspended for the full duration of each trial.

Stimuli

Two smooth spherical beads, both 16 mm in diameter, remained the S+ throughout the entire experiment. We switched between the two S+ from one day to the next and, on occasion, between trials. Ten different bead types of different textures and sizes were ensonified to determine their acoustic properties. Of the ten different beads, five were chosen for the experimental S-.

Echo Recording

In order to determine the acoustic characteristics of the different stimuli, echo recordings of each of the stimuli were taken. The signal swept from 10 to 10 Hz and was broadcast at a rate of 200 Hz from a custom-made loudspeaker. The outgoing signal and the echoes returning from the beads were recorded using an Ultrasonic Advice microphone. Six five-second recordings were taken for each bead, three at 90° and three at 180°. The beads were spun slowly during the recordings to ensure that the entire surface area of the bead was ensonified. Each recording contained 1200 echoes.

Echo Recording Analysis

Transfer functions for each of the stimuli were calculated to understand how each stimulus shapes the outgoing signal and to compare between stimuli their acoustic properties. For each of the 1200 echoes within the echo recordings, a transfer function was generated. The five beads returned echoes within 5 dB of S+.

RESULTS

Performance data were collected from the bat. The performance, measured in the percent of trials the bat hit S+, varied with which S- was presented (Fig. 4).

The variation in intensity was graphed against the bat’s overall performance for the beads (Fig. 5).

The bat’s discrimination performance varies with texture. Hypothesis 1 confirmed.

The 3-D flight path of the bat was reconstructed from stereo images recorded at high frame rates and the sonar beam pattern was reconstructed using the microphone array.

In the example trial, the bat makes two passes around the flight room before choosing S+, and increases its repetition rate of its vocalizations to inspect S- before hitting S+.

DISCUSSION

Training the bat using operant conditioning permitted us to separate the food reward from the task. Our methods allow more control of acoustic properties of the stimuli.

Performance data, coupled with the echo recording analysis, show that the bat discriminates the stimuli more reliably when the S- and S+ are more texturally distinct.

Microphone array data show the bat inspects both objects sequentially before making its decision.

The bat increases the repetition rate of its vocalizations as it inspects the targets. The bat may be attempting to increase its acuity by increasing its repetition rate.

FUTURE PLANS

Train more bats to perform the task and test the bats with beads of different groove depths and groove patterns.

Observe and record behavior of bat with only one target to determine the difference in how the bats inspect one target versus the two target discrimination.

ACKNOWLEDGEMENTS

We would like to thank Wei Xian and Amaya Perez for their help with the data analysis. We would also like to thank the HHMI, University of Maryland Senior Summer Scholars, and NSF Research Experience for Undergraduates for their funding for this project.