Discrimination of texture via Echolocation in bats

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Introduction

A longstanding question about echolocating bats is how they are able to recognize their prey or obstacles by the sounds of echoes. Free-tailed bats emit frequency-modulated (FM) biosonar pulses and are able to reconstruct their auditory scene based on the timing, amplitude and fine acoustic features of the returning echoes. It is hypothesized that the shape or texture of a target can be inferred by the presence of spectrotemporal interference patterns that emerge in the echoes bouncing off of irregular shaped objects. The precise pattern of the notches in the bats' echoes may be used to deduce target shape. To test this, we trained bats to discriminate between different types of sandpaper using their echolocation. The bats investigated targets by emitting pulses and evaluating the returning echoes, and were rewarded for approaching whichever sandpaper possessed the courser grit size. Sandpaper grit sizes differ by the average particle size, which allowed us to investigate how finely bats can discriminate differences in texture.We challenged bats with sandpaper grit sizes ranging from very course (40 grit, 425 microns) to very fine (240 grit, 65 microns) to determine what the smallest perceivable difference was.

Figure 1: Bat Echolocating to find target

Figure 2: Bats living together in colony

Bats live in colonies together and are able to unique discern their own voices from others. They use the echo of their unique voice off their target to hunt them as displayed in the above figure. Through their echo, their target's location and size can inferred, but in this experiment we aim to test if a Mexican Free Tailed bat can be trained to detect texture with their echo.

Methods and Materials

In order to do the experiment the bats were trained to walk across a Y-maze, rather than fly. After the bats were comfortable crawling around the Y-maze, they were given the choice between two textures. The bats would be rewarded with a treat when they approached the rougher choice of sandpaper.

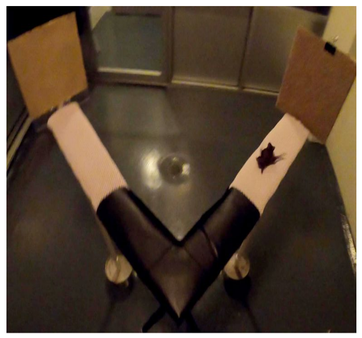


Figure 3. The Y maze for the bats to make a decision

Results

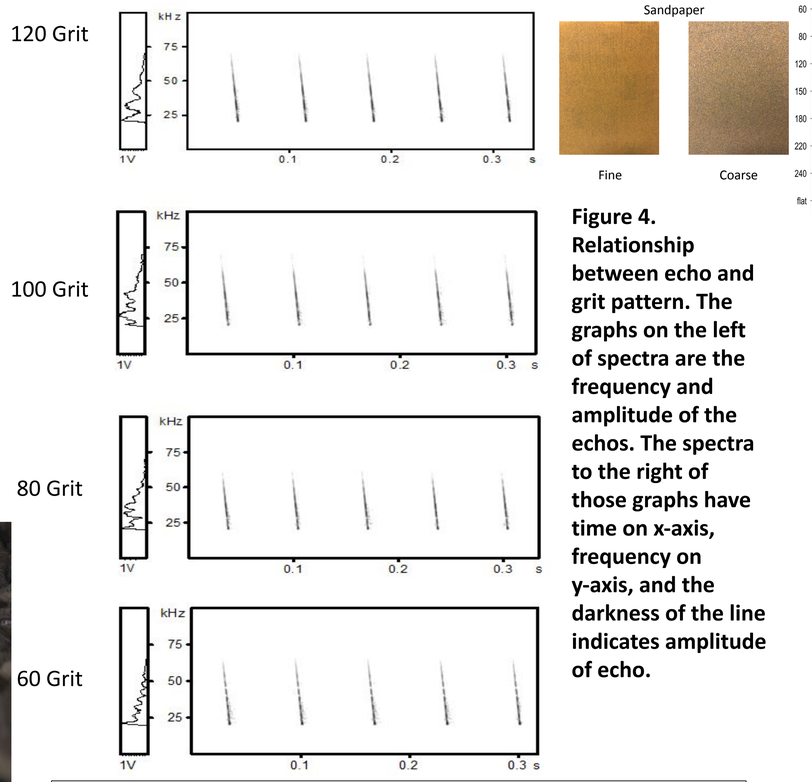
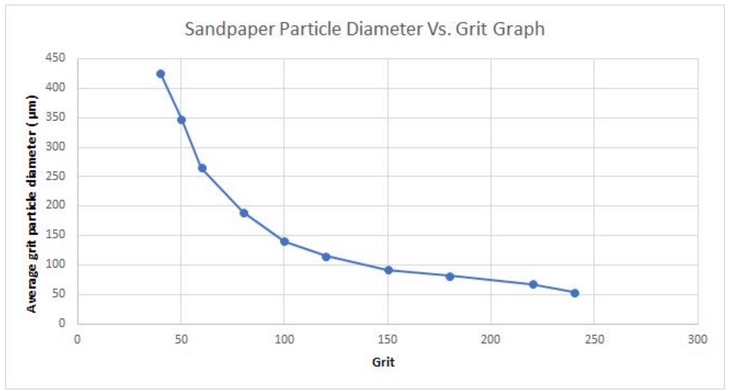


Figure 4. Relationship between echo and grit pattern. The graphs on the left of spectra are the frequency and amplitude of the echos. The spectra to the right of those graphs have time on x-axis, frequency on y-axis, and the darkness of the line indicates amplitude of echo.

In order to test if bats can discriminate textures, we must first prove that echoes are changed by differences in textures . As we go down the grit sizes, and the sand paper becomes rougher, and the power spectra shows a pattern of "rougher" peaks in their graphs. As evident when comparing the peaks of the of 60 grit vs the 120 grit, there are many more peaks and troughs in the 60 grit. In this experiment it is hypothesized the bats can make use of these differences in peaks to discriminate between two different sandpaper grits.

Next the bats were subjected various combinations of sandpaper to discriminate. Starting with the roughest and smoothest. The bats could easily discriminate between extremes. A full array of grits were tested to discover the limit of discrimination. As seen in figure B, the higher grit numbers have less of a particle diameter difference than lower grits which have a high difference in size between grits. At this point the discrimination is either based on relative difference or a discrete unit of difference.

Figure 5. The particle diameter of the particles on sandpaper followers a logarithmic scale as grit size increases.



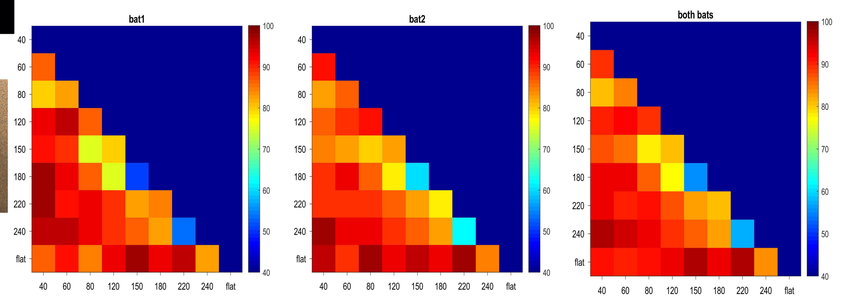


Figure 6. Above is a matrix on the success of the bats when discriminating two different grits.

As seen by the data (Figure 6) the bats were unable to discriminate 150 vs 180 and 220 vs 240. This struggle to discriminate the grits could have been indicative of a Weber-Fechner relationship or a simple struggle of how few microns apart the two grit sizes were. A Weber-Fechner relationship is discrimination based on relative difference. To test if Weber-Fechner was in play, a 40 grit and 50 grit was tested. The results are seen in Figure Z The bats struggled to tell apart 40 vs 50 despite a 77 micron difference between the grit sizes.

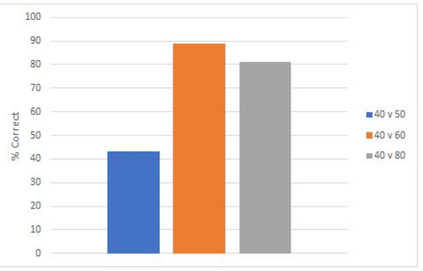
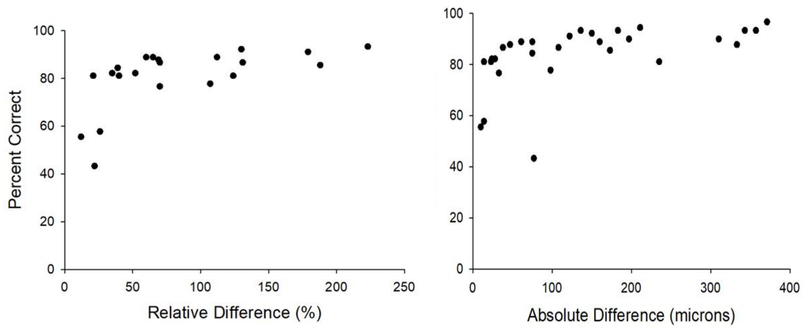


Figure 7. This figure shows the success of the bat between discriminating 40 grit vs 50, 60, 80.

Figure 8. Comparing the success of the trials between relative difference of the particle diameter vs the absolute difference of particle diameter. As seen by the graph, the ultimate predictor of success is having a relative difference above 20%.



Conclusions

The bats were found able to discriminate surfaces based on texture, due to the changes in echoes that the different particle sizes cause. The bats were able to distinguish a difference of 14 microns of sandpapers (180 grit vs 220), but were not able to do a difference of 77 microns (40 grit vs 50 grit). This inability suggests the bats' discrimination follows a Weber-Fechner law with a threshold of approximately 20%. Overall this experiment was successful as a training model for providing evidence for this theory and as a model to train Mexican Free Tailed bats.

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References: