Comparison of Sonar Behavior During Landing in Laryngeal and Lingual Echolocating Bats, *Eptesicus fuscus* and *Rousettus aegyptiacus*

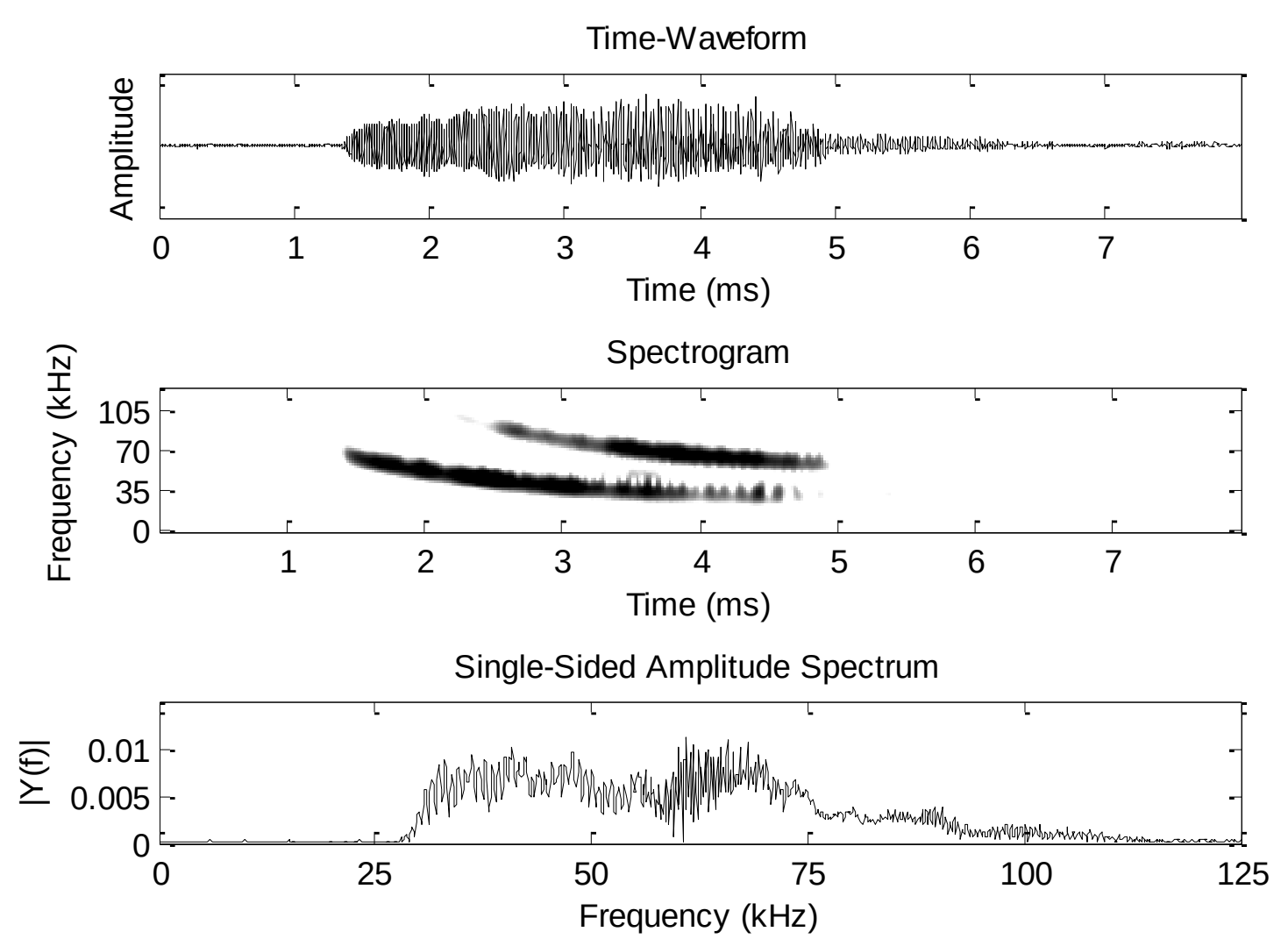
Ben Falk[1,2], Yossi Yovel[3], Scott C. Livingston[4], and Cynthia F. Moss[1,5,6]

[1]*University of Maryland, College Park,* [2]*Neuroscience and Cognitive Science Program,* [3]*Department of Neurobiology, Weizmann Institute of Science, Rehovot, Israel,* [4]*California Institute of Technology,* [5]*Institute for Systems Research,* [6]*Department of Psychology*

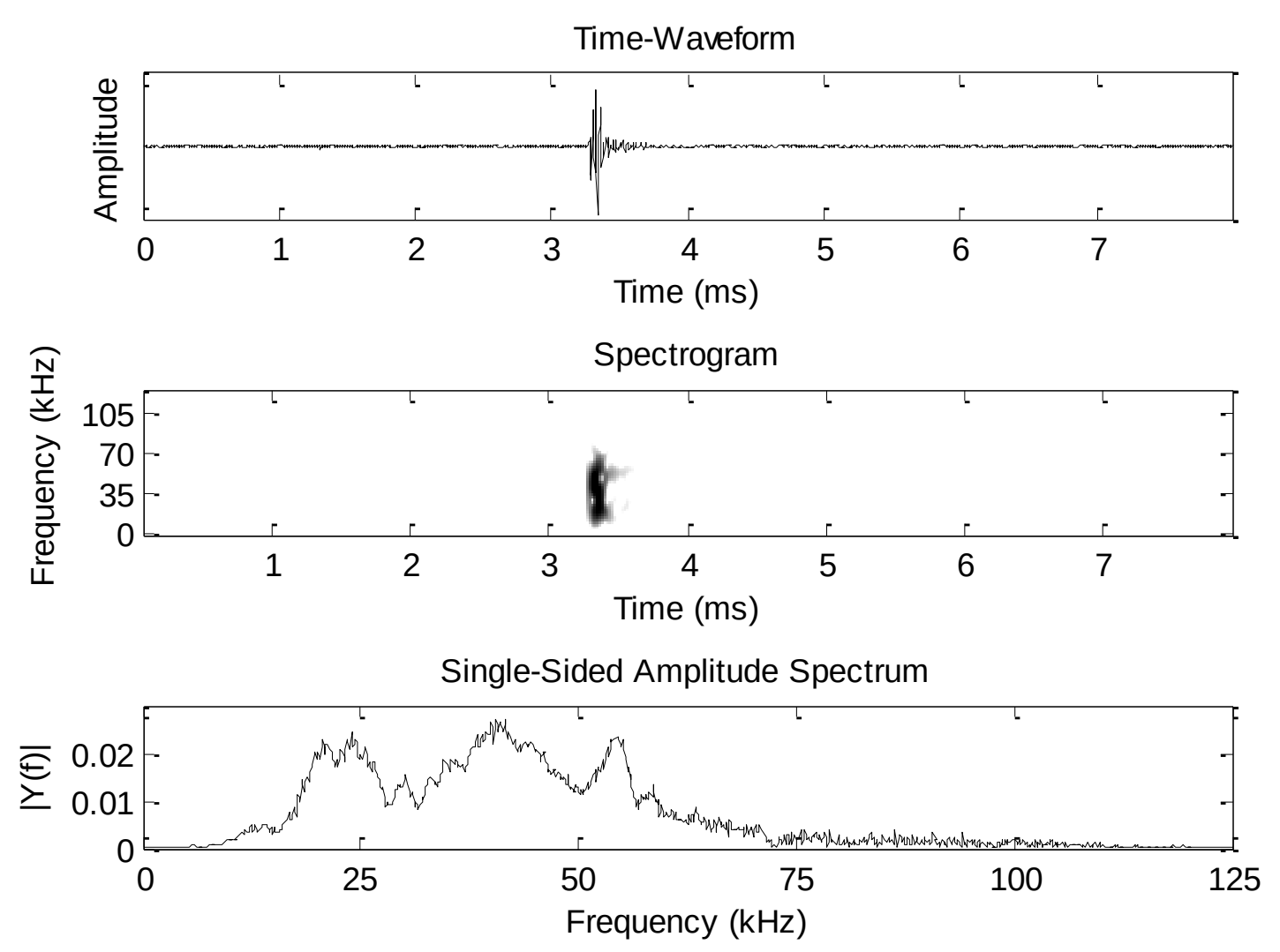
INTRODUCTION

Echolocating bats use biological sonar to determine the spatial location of objects in the environment. Central to an echolocating bat's spatial perception is directional control of its sonar signals with respect to objects in the environment. The extent to which bats of different species employ different sonar beam-directing behaviors to localize objects in the environment is the focus of this study.

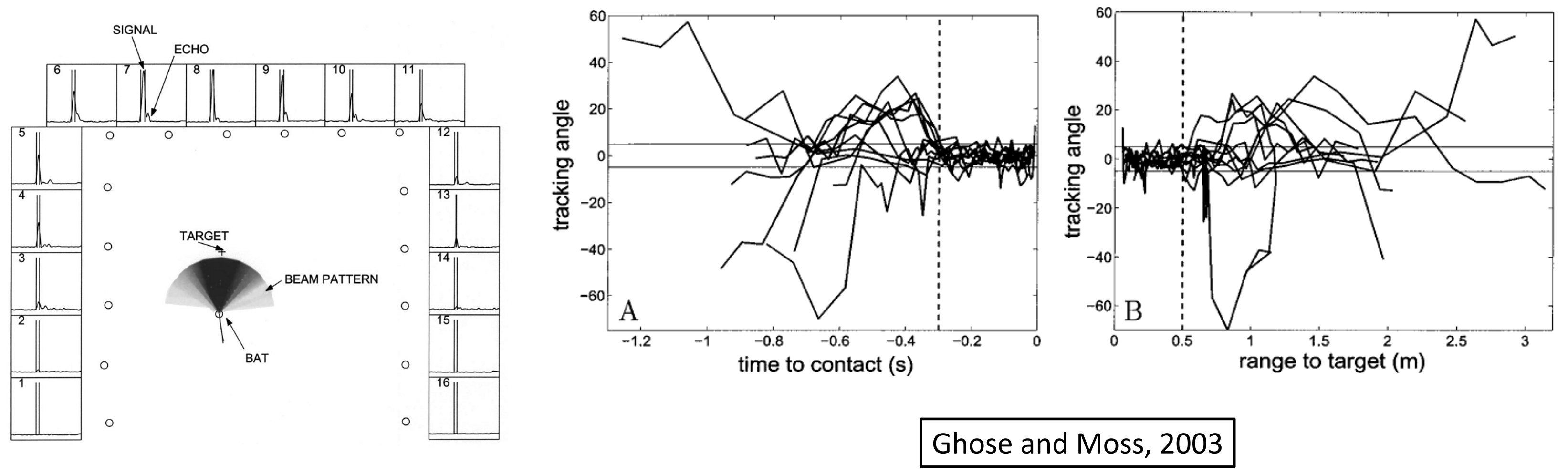
Eptesicus fuscus, the big brown bat, is a laryngeal echolocator and uses a frequency-modulated call structure (1-4 ms duration).



Rousettus aegyptiacus, the Egyptian fruit bat, produce very short (50-100 µs duration) tongue clicks in pairs (second click not shown).

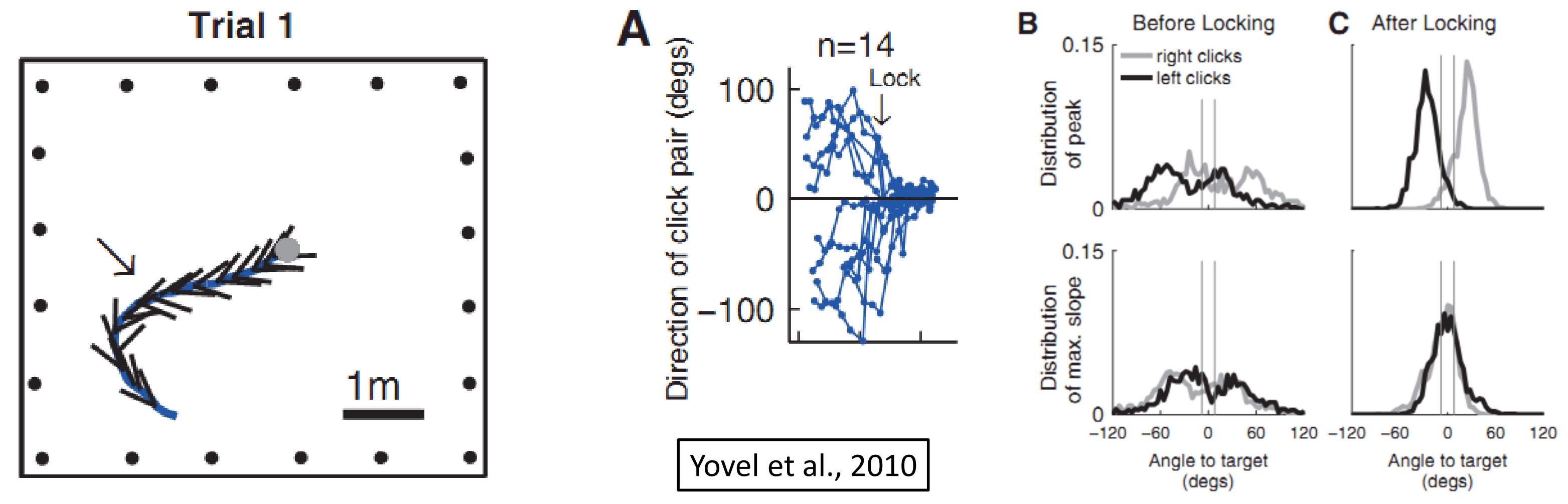


E. fuscus has been shown to aim the maximum intensity of its sonar vocalizations at insect prey as it prepares to intercept (Ghose and Moss, 2003).



Ghose and Moss, 2003

In a landing task investigated with the same microphone array, *R. aegyptiacus* placed the maximum slope of intensity of each click towards the landing target (Yovel et al, 2010).



Yovel et al., 2010

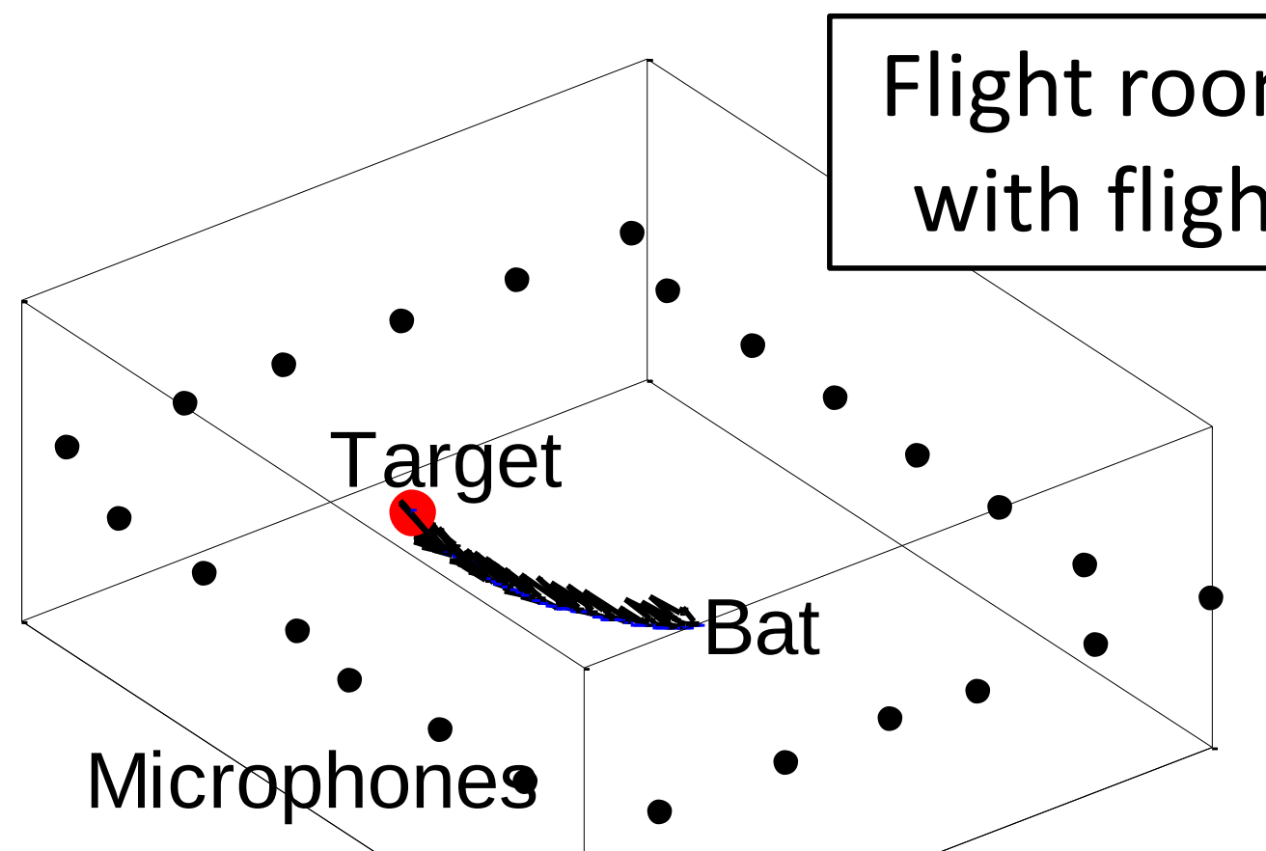
Do these differences in beam-directing behaviors of *E. fuscus* and *R. aegyptiacus* arise from the task (landing vs. insect capture) or their sonar production mechanisms (laryngeal vs. lingual) and structure (frequency modulated sweeps vs. clicks) of their echolocation calls? To begin to address these questions, we studied the beam directing behavior of *E. fuscus* as it performed in a landing task comparable to the one studied previously in *R. aegyptiacus* (Yovel et al., 2010).

METHODS

Five *E. Fuscus* were trained to land on a ball (*target*) mounted on the end of a 1 meter pole positioned in a laboratory flight room (7.3m x 6.4m x 2.5m). The room was lined with acoustic sound-absorbing foam. The bat's 3-dimensional position in space was tracked using high-speed infrared video cameras (250 fps). The bat was given a food reward upon landing on the target. Trials were performed in low light conditions. The target was repositioned in between trials.

Image of *E. fuscus* prior to landing on target

Flight room schematic with flight trajectory

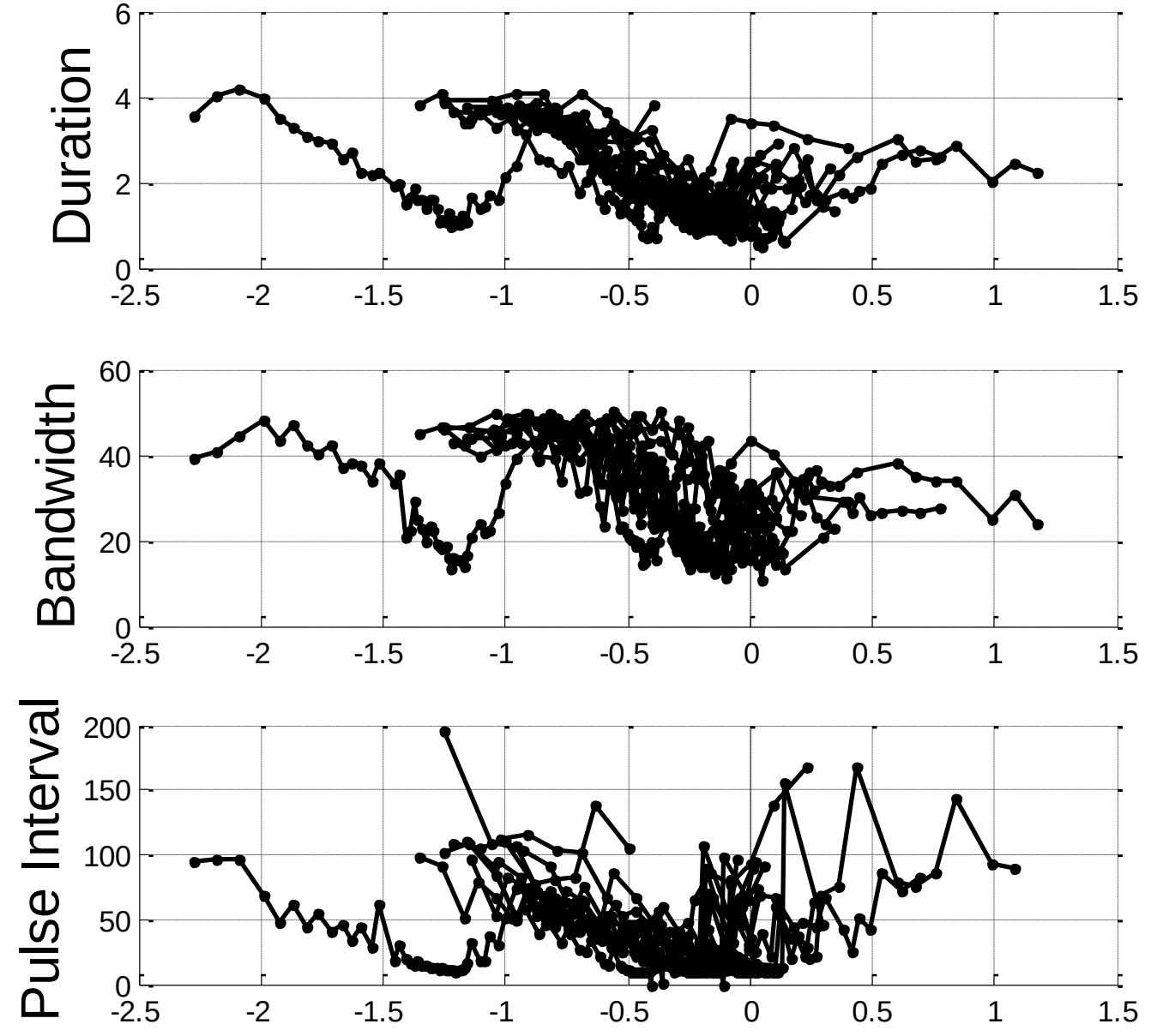


Sonar vocalizations were recorded using a 24-channel linear microphone array, expanded from the same array as in Ghose and Moss, 2003 (16 channels) and Yovel et al, 2010 (20 channels). Microphone array recordings were bandpass filtered (center frequency, 35 kHz; 3 dB down, 28 and 42 kHz) and enveloped, yielding the intensity of the sound within that frequency band.

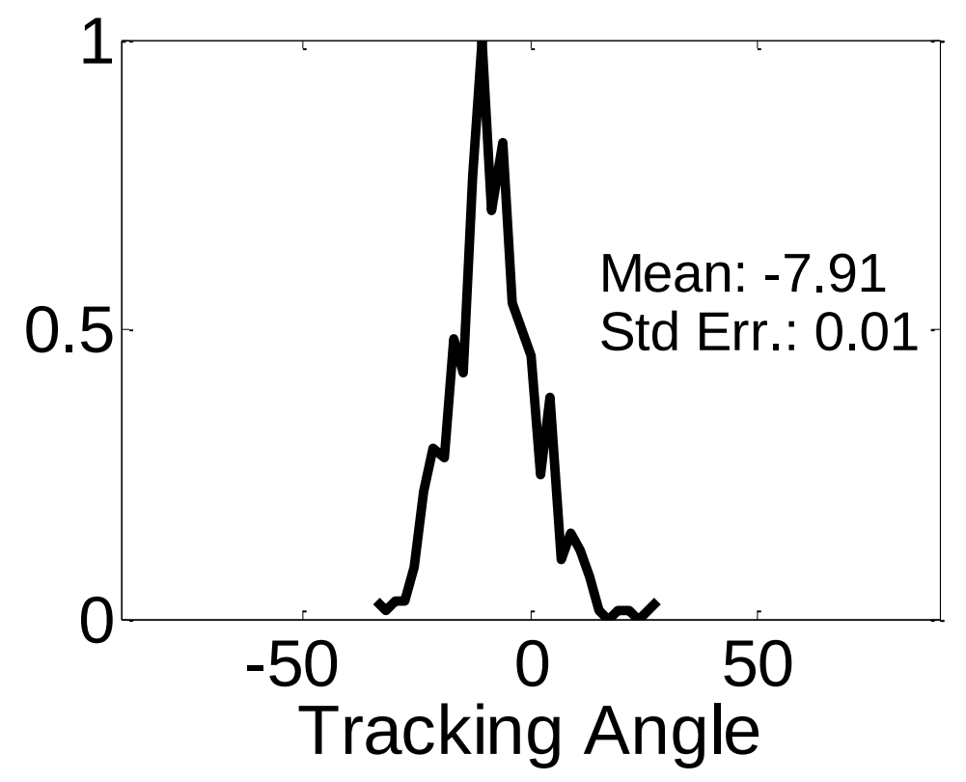
The sonar beam direction of each vocalization produced by the bat was calculated as the vector average of the intensity recorded at each microphone (after corrections for atmospheric attenuation and spherical spreading loss). The tracking angle is the angle difference between the sonar beam axis and the direction to the target. A total of 40 trials and 714 vocalizations were analyzed, pooled across bats. 14 representative trials were chosen for analysis of duration, bandwidth (of the fundamental sweep), and pulse interval of the vocal behavior.

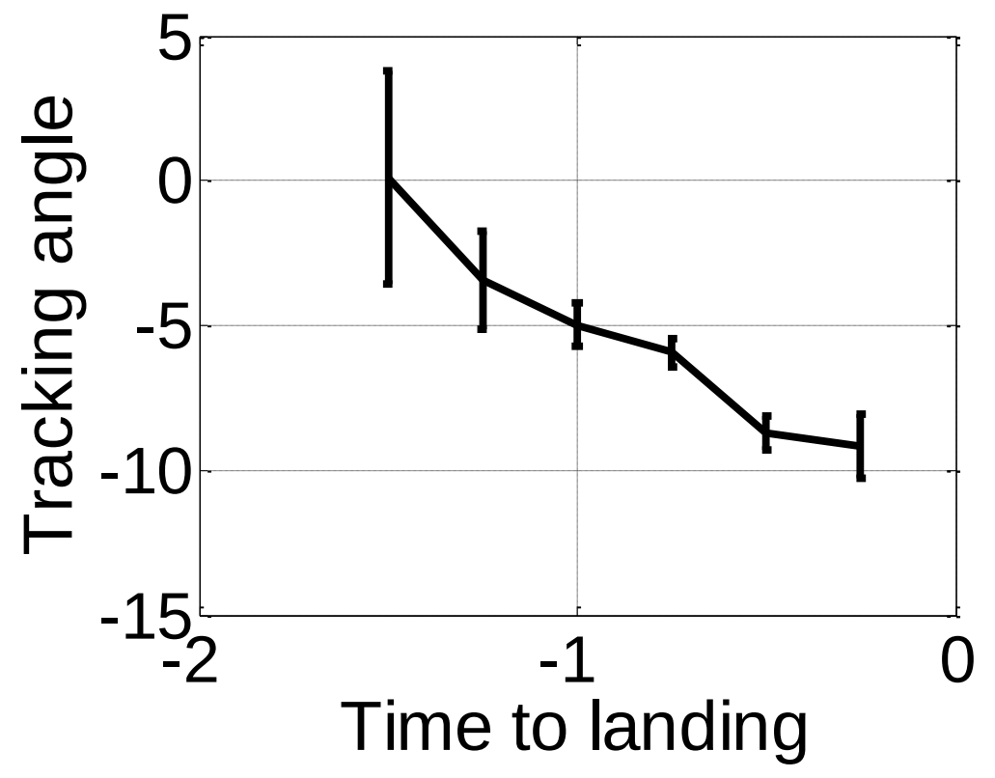
RESULTS

14 trials

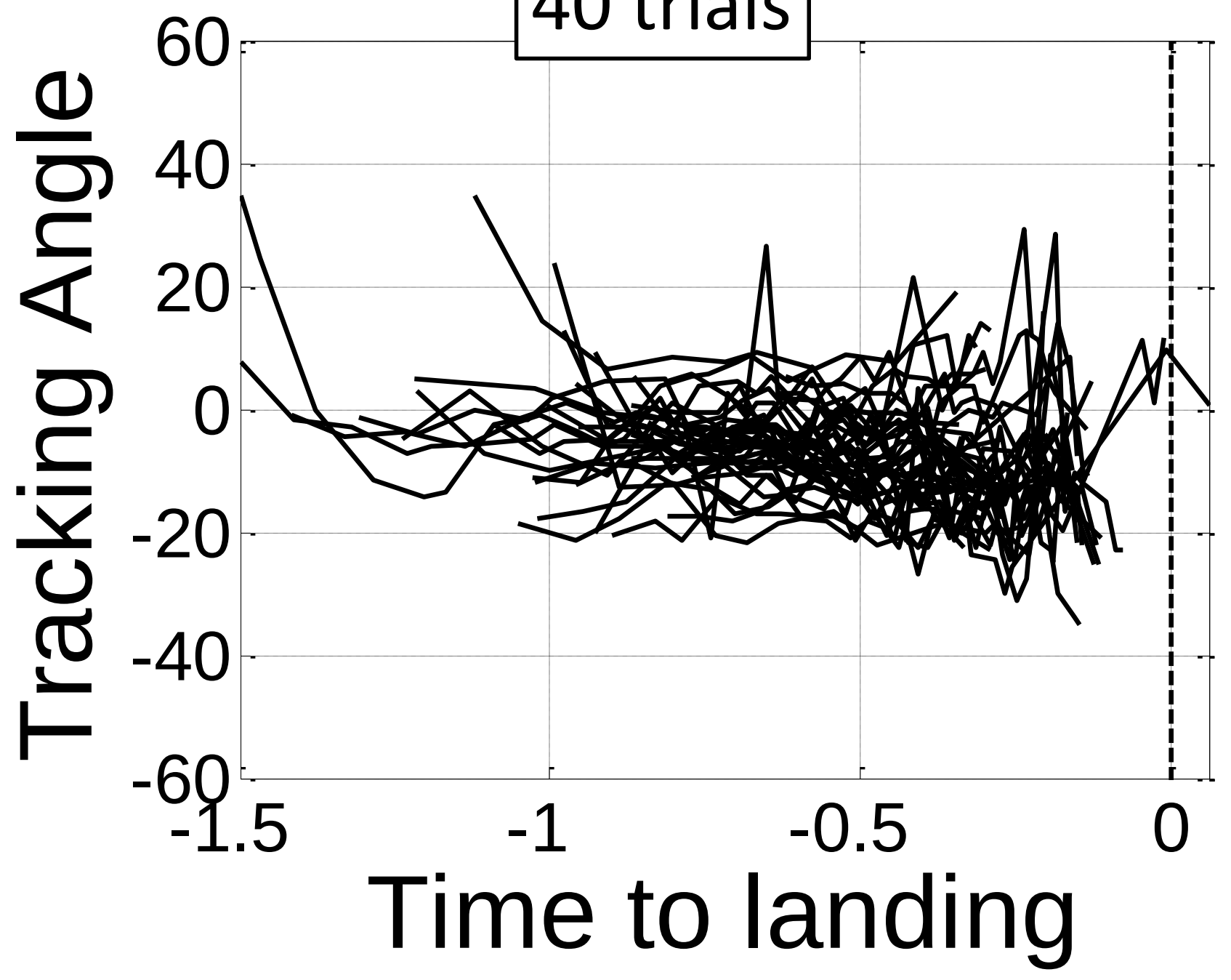


Tracking angle histogram
Last 700 ms prior to landing

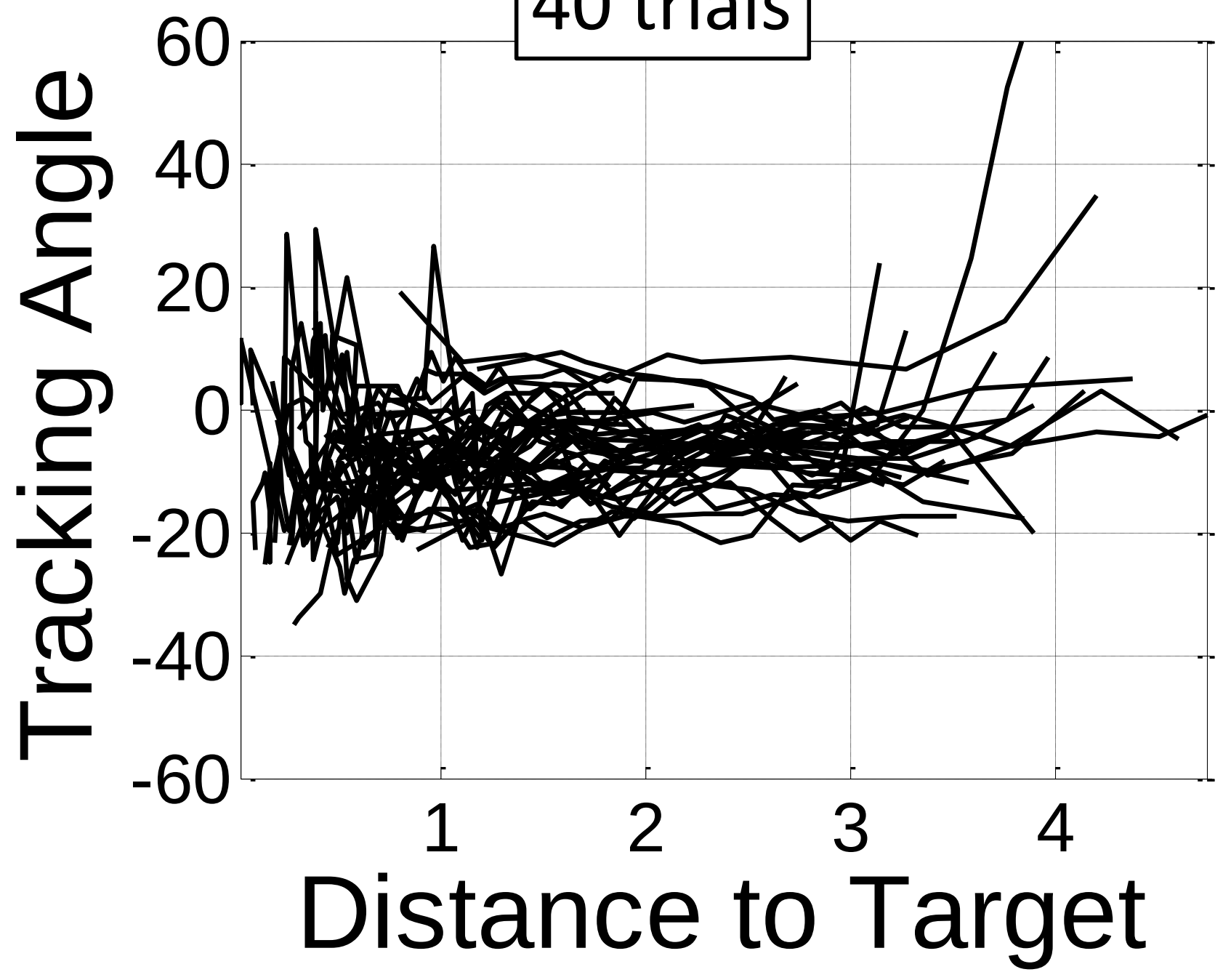




40 trials



40 trials



SUMMARY

Within the set of frequencies measured by our microphone array, the bat's beam direction lies off-center of the target. Further analysis is needed to determine whether the bat is aiming the maximum slope of its sonar beam on the target or if the skew is due to some other cause.

E. fuscus directs its sonar beam at the target from as far as 4 meters. This is in contrast to measurements of the sonar beam direction of *E. fuscus* when tracking insect prey, in which the tracking angle did not converge to the target until as close as 0.5 meters (Ghose and Moss, 2003). The landing target is much larger in comparison to an insect, returning a much stronger echo which is easier to localize.

The accuracy with which *E. fuscus* directs its sonar beam towards the landing target is less than reported for insect capture. The flight maneuvers required for landing on the target are likely not as complex and might not require as accurate a sonar aim by the bat. The width of the sonar beam of *E. fuscus* has been measured to be 70° (Hartley and Suthers, 1989), so less accurate sonar tracking may still be sufficient for landing.

FUTURE DIRECTIONS

Use a wide-bandwidth microphone array to measure the sonar behavior of *Eptesicus fuscus* during landing and prey capture. Using these recordings, analyze the sonar directing behavior outside of the 28 to 42 kHz band previously reported. *E. fuscus* may use a different strategy at higher frequencies, including changing beam width or beam shape.

REFERENCES

Ghose, K., & Moss, C. F. (2003). The sonar beam pattern of a flying bat as it tracks tethered insects. *The Journal of the Acoustical Society of America*, *114*(2), 1120-1131. doi:10.1121/1.1589754

Hartley, D. J., & Suthers, R. A. (1989). The sound emission pattern of the echolocating bat, Eptesicus fuscus. *The Journal of the Acoustical Society of America*, *85*(3), 1348-1351. doi:10.1121/1.397466

Yovel, Y., Falk, B., Moss, C. F., & Ulanovsky, N. (2010). Optimal Localization by Pointing Off Axis. *Science*, *327*(5966), 701-704. doi:10.1126/science.1183310

ACKNOWLEDGEMENTS

We would like to thank Kaushik Ghose for building the microphone array, and Nachum Ulanovsky for suggestions and discussion. We would also like to thank Joe Kasnadi and Tanvi Thakkar for their help with data processing.

FUNDING

This work was supported in part by NIDCD training grant fellowship to Ben Falk (DC-00046, Arthur Popper and Robert Dooling, PI's) and NIMH R01 MH56366 and NSF CRCNS IOS-1010193 to Cynthia Moss and Timothy Horiuchi.