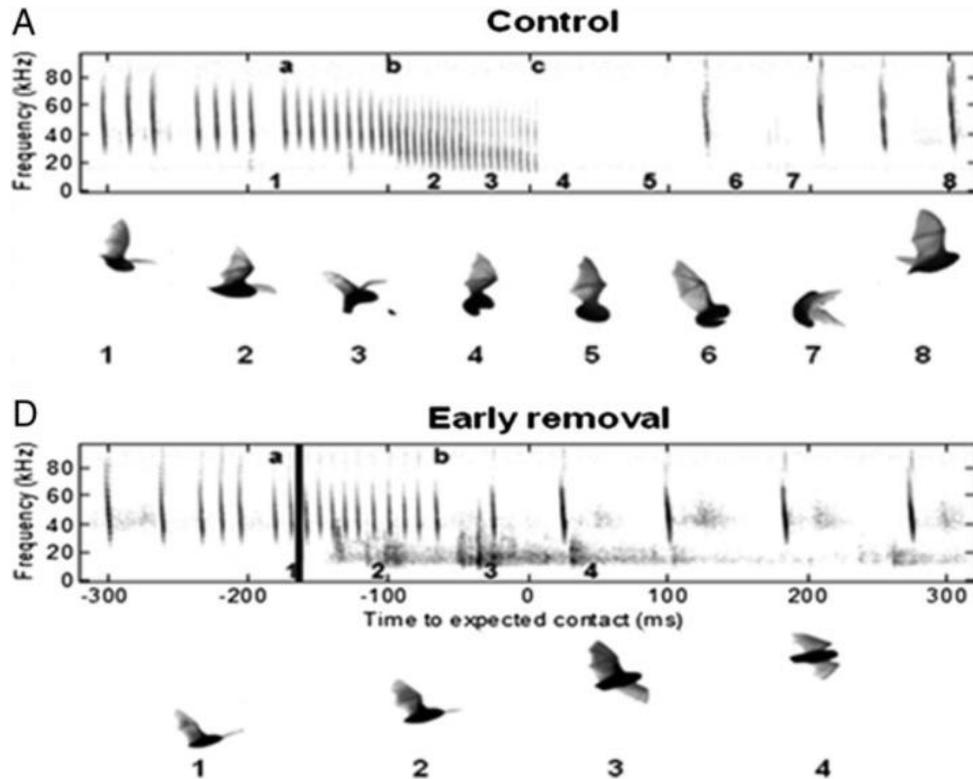




HOW TO USE THIS RESOURCE

Show the figure below to your students along with the caption and background information. The “Interpreting the Graph” and “Discussion Questions” sections provide additional information and suggested questions that you can use to guide a class discussion about the characteristics of the graph and what it shows.



Caption: Spectrograms and corresponding video snapshots (indicated by numbers) show the physical and acoustic behaviors of bats as they attempt to capture prey. Figure A shows a bat successfully capturing prey, while Figure D shows the bat's behavior when the prey is removed early in the hunt, indicated by the solid black vertical line. The echolocation signals emitted by the bat appear as near-vertical lines on the spectrogram. When these occur in quick succession as a bat approaches its prey, it is called a buzz. Three points during the buzz sequence are labeled: (a) start of buzz I, (b) end of buzz I/start of buzz II, and (c) end of buzz II. In Figure D, where the prey is removed, the bat does not emit a buzz II sequence.

BACKGROUND INFORMATION

Many bats use an acoustic behavior called echolocation to perceive the world around them. During echolocation, bats emit ultrasonic sound waves and analyze the echoes returned when those sound waves bounce off of another object, such as a moth. The bat can then interpret this feedback to gauge distance and adjust its physical movements to capture the moth. During prey capture, bats emit echolocation signals at a variable rate. Before they detect prey, they are in “search” phase and emit signals infrequently. After they detect prey, they enter the “approach” phase and emit signals at an increased rate. The final phase is the “terminal buzz” in which signals are emitted in a rapid sequence to receive information frequently. In many species of bats, the terminal buzz consists of two distinct subphases: buzz I and buzz II. When signals are emitted slowly, bats have time to process each echo before sending the next signal, but the short interval between calls in the buzz likely does not leave enough

time for the bat to process and react to information. Some scientists have argued that the buzz is not used to help during the current capture attempt but rather to help analyze what went wrong when prey escapes. In this study, researchers tested whether bats change their behavior during the buzz phase based on feedback. If so, the result would support the notion that the terminal buzz is used to respond to changes during prey capture rather than for evaluating failed captures afterward. In the control trials (Figure A), bats were recorded by audio and video as they were allowed to catch their prey. In the experimental trial shown in Figure D, researchers removed the prey early in the buzz I phase.

INTERPRETING THE GRAPH

The spectrograms display the frequency of acoustic signals over time. Each marking on the spectrogram represents a call emitted by the bat, separated by periods of silence. The fact that each marking is nearly a vertical line shows that the call is very short and covers a range of frequencies.

Figure A shows a successful capture in which buzz I and buzz II were completed. Buzz I calls have very short intervals between them. In buzz II, the frequency drops and the calls are emitted at even shorter intervals than during buzz I. After buzz II, there was a gap in calls followed by search phase echolocation calls that are spaced out at long intervals. The video stills show the bat lowering its hind legs (3), scooping up the prey with its tail membrane (4), forming a ball to transfer the prey to the mouth (5), and uncurling (6-8).

Figure D shows the behavioral response when the prey was removed >150 ms before the researchers expected the bat to reach its prey. In this sequence, buzz I is completed but neither buzz II nor the physical capture behavior is initiated. These results show that the terminal buzz sequence is used to gather feedback during a hunt and bats respond to that feedback by aborting capture attempts when they don't catch their prey.

Teacher Tip: Prompt your students to explain the parts of the graph as applicable:

- Figure Type: Spectrogram
- X-axis: Time in milliseconds (ms) before and after expected contact between bat and prey
- Y-axis: Frequency of the bat calls (kHz)
- Buzz Sequence Labels: Letters on the top of the spectrogram indicate (a) start of buzz I, (b) end of buzz I/start of buzz II, and (c) end of buzz II.
- Video Still Labels: Numbers on the bottom of the spectrogram indicate when the corresponding video stills were recorded.

DISCUSSION QUESTIONS

- What differences can you see in the buzz sequences between Figure A and Figure D?
- What differences can you see in the video snapshots between Figure A and Figure D?
- What do you notice about the buzz sequence at the moment the bat contacts the prey in Figure A? What happens next?
- Using Figure A as a comparison, at what point after the prey is removed in Figure D do you think the bat responds? Provide evidence.
- The answer to the previous question is called a “reaction time.” It takes a human about 230-400 ms to respond to a visual cue (e.g., raising your hand when you see your instructor raising their hand). How does this reaction time compare to a bat’s reaction time?
- The researchers used this experiment to test whether bats use the buzz sequence to gather information and react during prey capture. Based on the results in Figure D, what conclusions can you draw? Provide evidence.

- Humans hear sounds between 20 Hz and 20 kHz. Are any of the sound waves emitted by the bats audible to humans? Provide evidence.

SOURCE

Figure 2A and 2D from:

Cornelia Geberl, Signe Brinkløv, Lutz Wiegrebe, and Annemarie Surlykke. (2015). Fast sensory–motor reactions in echolocating bats to sudden changes during the final buzz and prey intercept. *Proc. Natl. Acad. Sci. USA* 112(13): 4122-4127; doi:10.1073/pnas.1424457112

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