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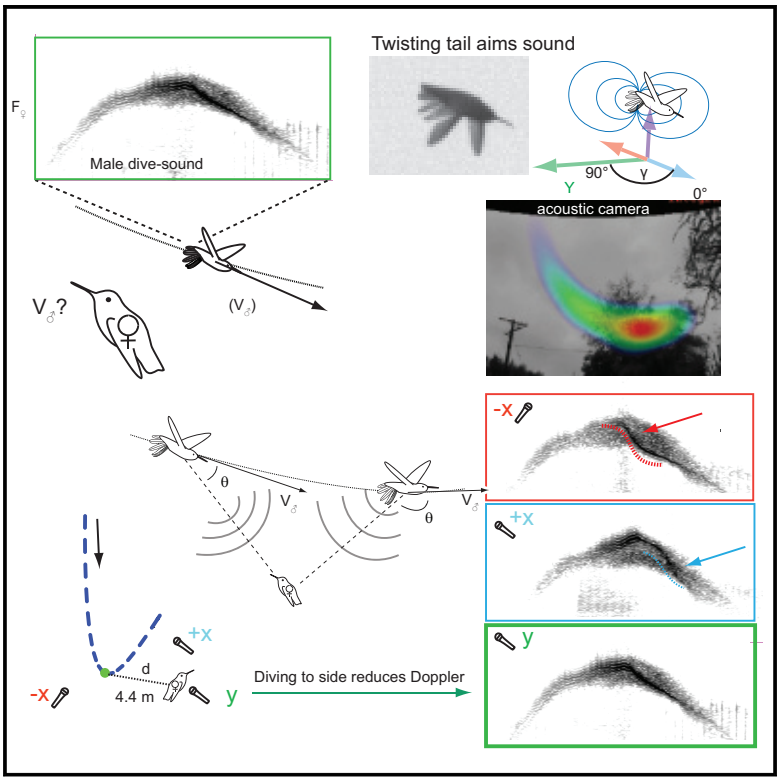
Strategic Acoustic Control of a Hummingbird Courtship Dive

Graphical Abstract



Highlights

- Motor displays showcase male dynamic attributes such as speed or acceleration
- Costa's hummingbirds dive off to a female's side, concealing their Doppler curve
- Their dive sound is directional, so they twist their tail to aim toward the female
- Concealing the Doppler curve deprives females of one way of measuring male speed

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In Brief

Clark and Mistick examine how male Costa's hummingbirds control female reception of their dive sound. Males dive to a female's side, which conceals their Doppler curve, and as the sound is directional, they twist their tail to aim the dive sound toward the female. These results show a way courting males manipulate reception of their display.

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Strategic Acoustic Control of a Hummingbird Courtship Dive

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SUMMARY

Male hummingbirds court females with a high-speed dive in which they "sing" with their tail feathers. The male's choice of trajectory provides him strategic control over acoustic frequency and pressure levels heard by the female. Unlike related species, male Costa's hummingbirds (*Calypte costae*) choose to place their dives to the side of females. Here we show that this minimizes an audible Doppler curve in their dive sound, thereby depriving females of an acoustic indicator that would otherwise reveal male dive speed. Wind-tunnel experiments indicate that the sounds produced by their feathers are directional; thus, males should aim their tail toward females. High-speed video of dives reveal that males twist half of their tail vertically during the dive, which acoustic-camera video shows effectively aims this sound sideways, toward the female. Our results demonstrate that male animals can strategically modulate female perception of dynamic aspects of athletic motor displays, such as their speed.

INTRODUCTION

Many male animals perform athletic motor displays for females, who evaluate male performance in the course of choosing a mate. When courting, a male has strategic choice over when, where, and how intensely to perform [1, 2]. This provides him control over his audience's reception of his display. For instance, male bowerbirds arrange bower objects to produce forced perspective, a visual illusion that enhances females' perception of the size of his ornaments [3, 4]. In an acoustic case, tree frogs tune their songs to exploit tree-hole resonance as an acoustic amplifier of their fundamental frequency, enhancing the sound that females perceive [5]. These examples demonstrate ways in which males may favorably manipulate static (time invariant) aspects of display, such as amplitude or size, when the physics of signal production permits it.

In comparison to static components of display, the role that dynamic (time-varying) components of motor display play in mate evaluation is less understood [2, 6, 7]. Here we examine a motor display in which males appear to specifically manipulate audience reception of dynamic aspects of display.

Although all displays intrinsically have both static and dynamic attributes, we define motor displays as displays in which the dynamic (time-varying) components of motions, such as the animal's speed, accelerations, or forces attained, are a prominent feature. In motor displays, these dynamic components may be the specific target of, and have evolved in response to, female preferences. For example, recent studies of spiders [8], crabs [9], birds [10, 11], and fish [12] suggest a common dynamic feature of displays that females prefer: higher male display speed. These dynamic aspects of display are also what make the display physically demanding or difficult to perform. Ability to perform behaviors with high accelerations, muscle forces, or other physically demanding attributes could correlate with heritable components of male "athletic" ability [6, 10, 13]. If females use dynamic attributes of motor performance to assess a male's genetic quality, the display might evolve to accurately ("honestly") showcase a dynamic aspect such as speed. The alternative is that male displays might instead evolve to control female perception of dynamic aspects of performance per se without respect to honesty, as expected by receiver psychology [14, 15], perceptual bias [16], or aesthetics [17, 18] models of sexual selection. Here we explore how male Costa's hummingbirds (*Calypte costae*) modulate audience reception of their speed and sound pressure levels (SPLs) during an aerial dive, through choice of dive trajectory.

Diving, or descending from a height with the aid of gravity, allows an animal (or aircraft) to briefly attain velocities greater than they can attain in level flight [19]. Males that court females with a dive are thus engaged in a speed-limited display. Like the wailing wing siren of the World War II-era Stuka dive bomber [20], hummingbird dive displays incorporate acoustic performance, albeit one intended to impress rather than intimidate. Similar to a high-pitched version of the Stuka, the dive sound of Costa's hummingbirds rises from 7 to 9 kHz and then falls back to 6.5 kHz as the male's speed increases and decreases (Audio S1). This tone is produced by the male's tail feathers [21, 22], which he holds spread as he dives, causing the back edge of the outer tail feather, rectrix 5 (R5), to flutter (vibrate) in the airflow [23] (Figure 1A).

Here, we replicated this flutter in our new aeroacoustic wind tunnel (Figure 1B), allowing us to characterize how the sound is produced (Figure 1C). As acoustic directionality has rarely been studied (but see [24, 25]), we used these wind-tunnel data to make a spatial model of how dive sound varies according to location and establish how male choice of trajectory modulates the sound heard by the female. We then tested the model

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