Echolocating bats use different pursuit strategies in different contexts

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Introduction

• Insectivorous bats use echolocation to pursue and capture insect prey in the dark (Figure 1 left).

• Bats often encounter conspecifics in the field and sometimes pursue other bats to defend territory or food sources (Figure 1 right).

• This study reveals two different pursuit strategies, classical pursuit (CP) and constant absolute target direction (CATD) used by big brown bats (*Eptesicus fuscus*) when encountering conspecifics and prey, respectively.

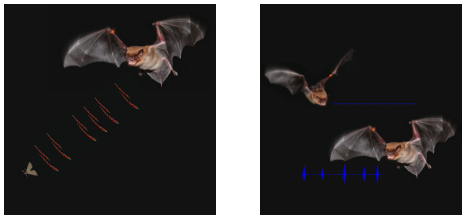

Figure 1. (Left) A bat uses echolocation to pursue insect prey (photo by Jessica Nelson). (Right) A bat pursues another bat in flight (photo by Jessica Nelson).

Two pursuit strategies

• The pursuer and the evader can be each viewed as a point particle in 3-D space and each moves along a certain trajectory (Figure 2).

• The unit tangent vector x_e (x_p) is along the velocity of the evader (pursuer), and y_e (y_p), z_e (z_p) spans the normal plane to x_e (x_p). The vector r_e (r_p) points from the origin of the coordinate system to the position of the evader (or the pursuer), and baseline r is the vector that points from the pursuer to the evader.

• Bat chases prey
  – Pursuer: bat
  – Evader: insect prey
  – The role of pursuer or evader CANNOT be switched.

• Bat chases another bat
  – Pursuer: following bat
  – Evader: leading bat
  – The role of pursuer or evader CAN be switched.

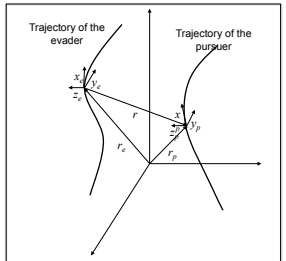

Figure 2. Schematic of flight trajectories of the pursuer and the evader. The unit tangent vector x_e (x_p) is along the velocity of the evader (pursuer), and y_e (y_p), z_e (z_p) span the normal plane to x_e (x_p). The vector r_e (r_p) points from the origin of the coordinate system to the position of the evader (or the pursuer) and baseline r is the vector point from the pursuer to the evader. Data analysis in this section followed the equations and algorithms in Justh and Krishnaprasad (2005); Reddy et al. (2006, 2008); Reddy (2007) and Wei et al. (2009).

Classical pursuit (CP)

• The pursuer's velocity vector is pointing toward the evader.

• Cost function

$$\Lambda = \frac{r}{|r|} \cdot x_p$$

• When Λ = -1, the pursuer is in the CP state.

Constant absolute target direction (CATD)

• The pursuer keeps an absolute target direction when pursuing the evader.

• This strategy holds when the baselines are parallel.

• Cost function

$$\Gamma = \frac{r}{|r|} \cdot \frac{\dot{r}}{|\dot{r}|}$$

• When Γ = -1, the pursuer is in the CATD state.

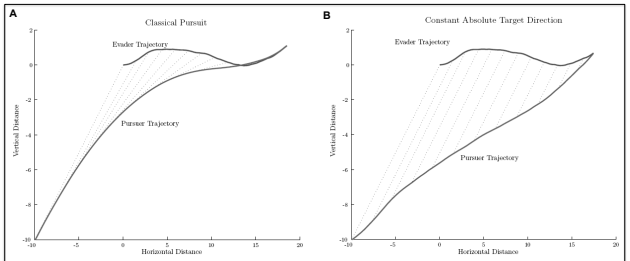

Figure 3. A. An example of classical pursuit: the pursuer aligns its velocity vector with the baseline. **B.** An example of constant absolute target direction: the baselines are parallel. (Wei et al. 2009)

Scenario I: When the bat pursues a prey item

• Bats use a CATD strategy during pursuit of insect prey.

• This strategy minimizes the time it takes for a pursuer to intercept an unpredictably moving target.

• The bat's behavior is similar to the interception strategy implemented in some guided missiles.

• This time-optimal strategy adopted by the bat is in response to the evolutionary pressures of having to capture erratic and fast moving insects.

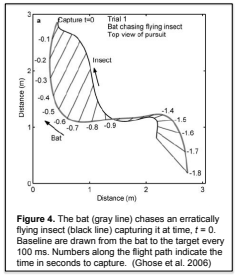

Figure 4. The bat (gray line) chases an erratically flying insect (black line) capturing it at time, t = 0. Baseline are drawn from the bat to the target every 100 ms. Numbers along the flight path indicate the time in seconds to capture. (Ghose et al. 2006)

Scenario II: When the bat pursues another bat

• The leading bat is the evader and the trailing bat is the pursuer in this study.

• The bat uses a CP strategy when pursuing another bat.

• The duration a bat pair remained in the CP state was significantly longer than the CATD state (CP state for 50.54±0.07 sec, CATD state for 22.42±0.03 sec, Mann-Whitney test, p<0.001).

• The bat that spent more time in the trailing position over the entire analyzed trial time was more successful in capturing prey.

• The bat in the leading position within the last one second of prey capture showed higher prey-capture success.

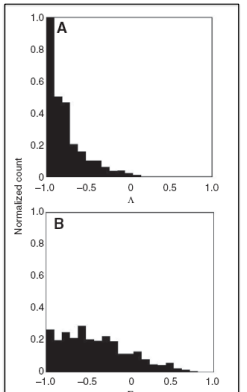

Figure 5. Distribution of the cost function of two pursuit strategies: **A.** classical pursuit (CP), cost function Λ; and **B.** constant absolute target direction (CATD), cost function Γ. The y-axis is normalized according to Λ because Λ has the maximum count. (Chiu et al. 2010)

• The bat's most successful strategy may be to begin a trial in the trailing position and later switch to the leading position when close to the prey.

Conclusions

• Bats use two different pursuit strategies when pursuing different subjects.
  – CATD strategy for pursuing prey
  – CP strategy for pursuing another bat

• The use of different strategies may be due to differences in the nature of predator-prey pursuit behavior and conspecific following behavior.
  – The insect prey often moves slower than its bat predator, but the bat and its conspecifics have similar flight speeds.
  – The bat's goal is not to intercept and capture the other bat, but to reach the prey first.

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