

Luminance modulates sensorimotor delay in refuge tracking of Glass Knifefish

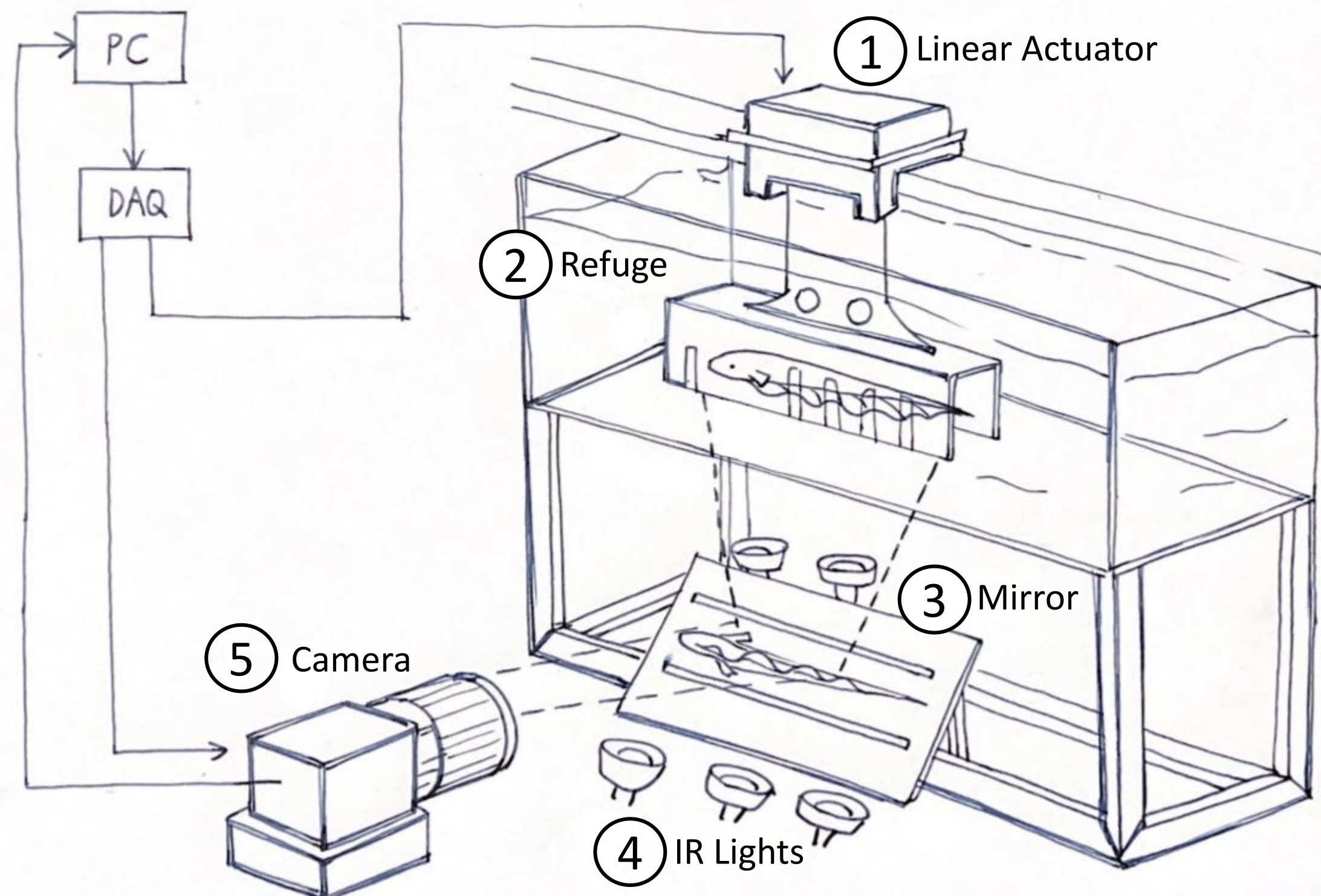
Huanying (Joy) Yeh^{1*}, Yu Yang², Noah J. Cowan²

¹ Department of Electrical and Computer Engineering, Johns Hopkins University; ² Department of Mechanical Engineering, Johns Hopkins University

Introduction

- Weakly electric fish readily track a linearly-moving refuge with high gain and low phase lag
- Visual sensory feedback plays an essential role in tracking
- This research explores changes in fish refuge-tracking locomotion as a function of visual salience

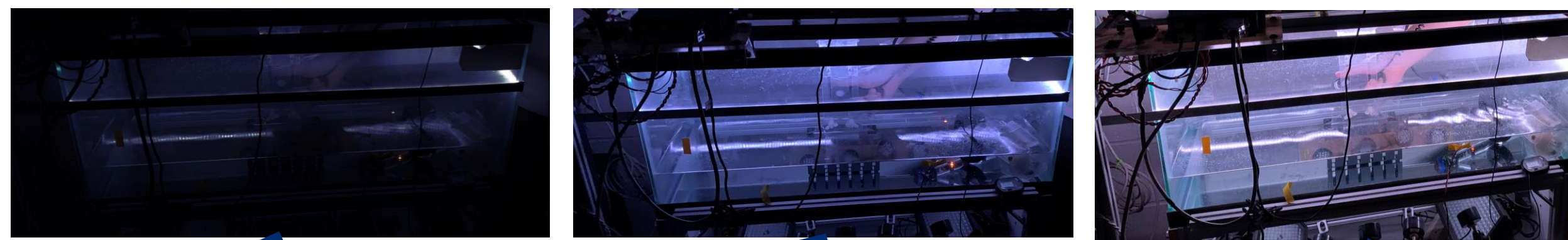
Experiment Tank Set-Up



Experiment Procedure

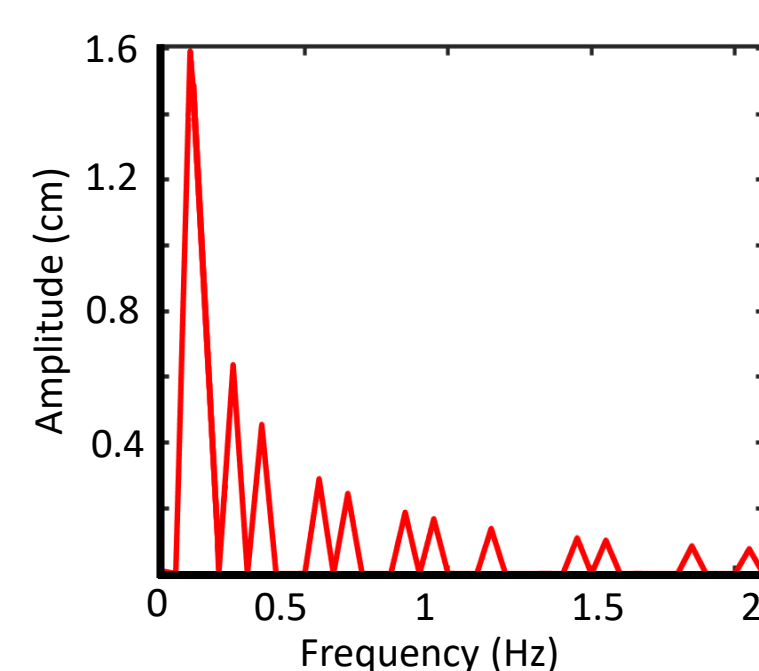
- Sum-of-sines (0.1 – 2.05 Hz) reference trajectory
- 15 - 20 randomized 20s trials with varying illuminance
- Fish movement trajectories tracked with DeepLabCut

Illuminance Range Tested

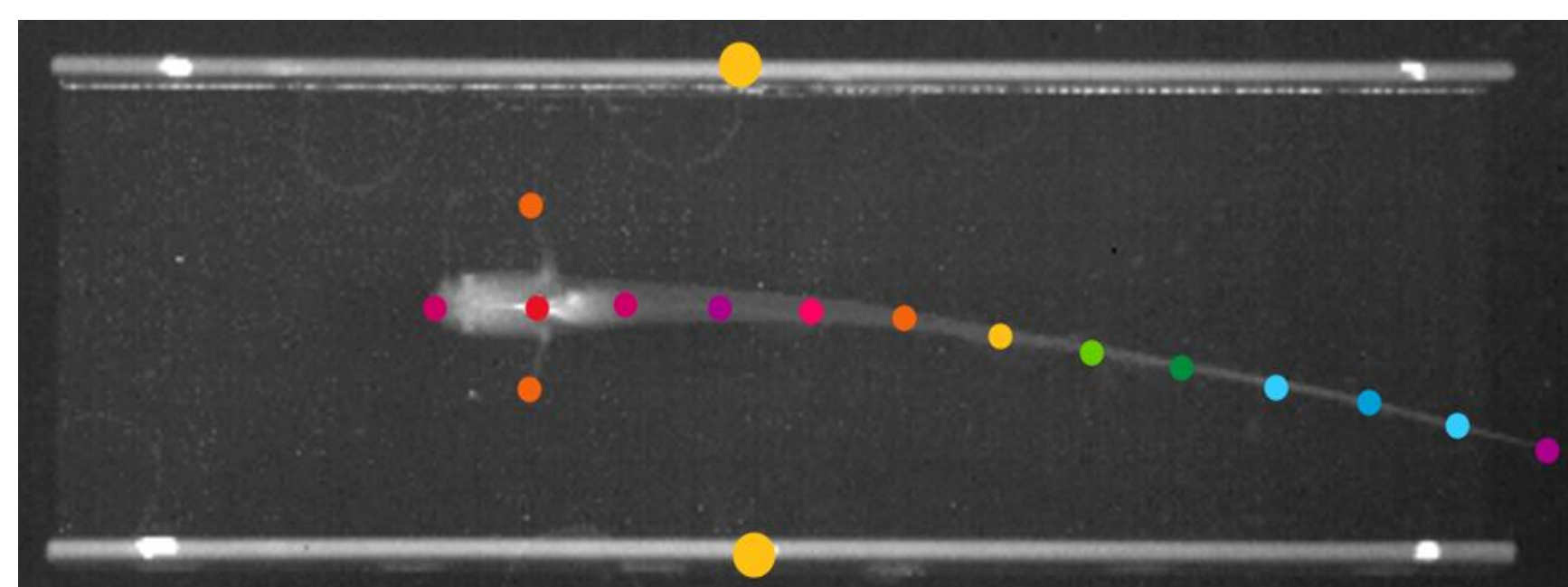


0.1 60 210 (lux)

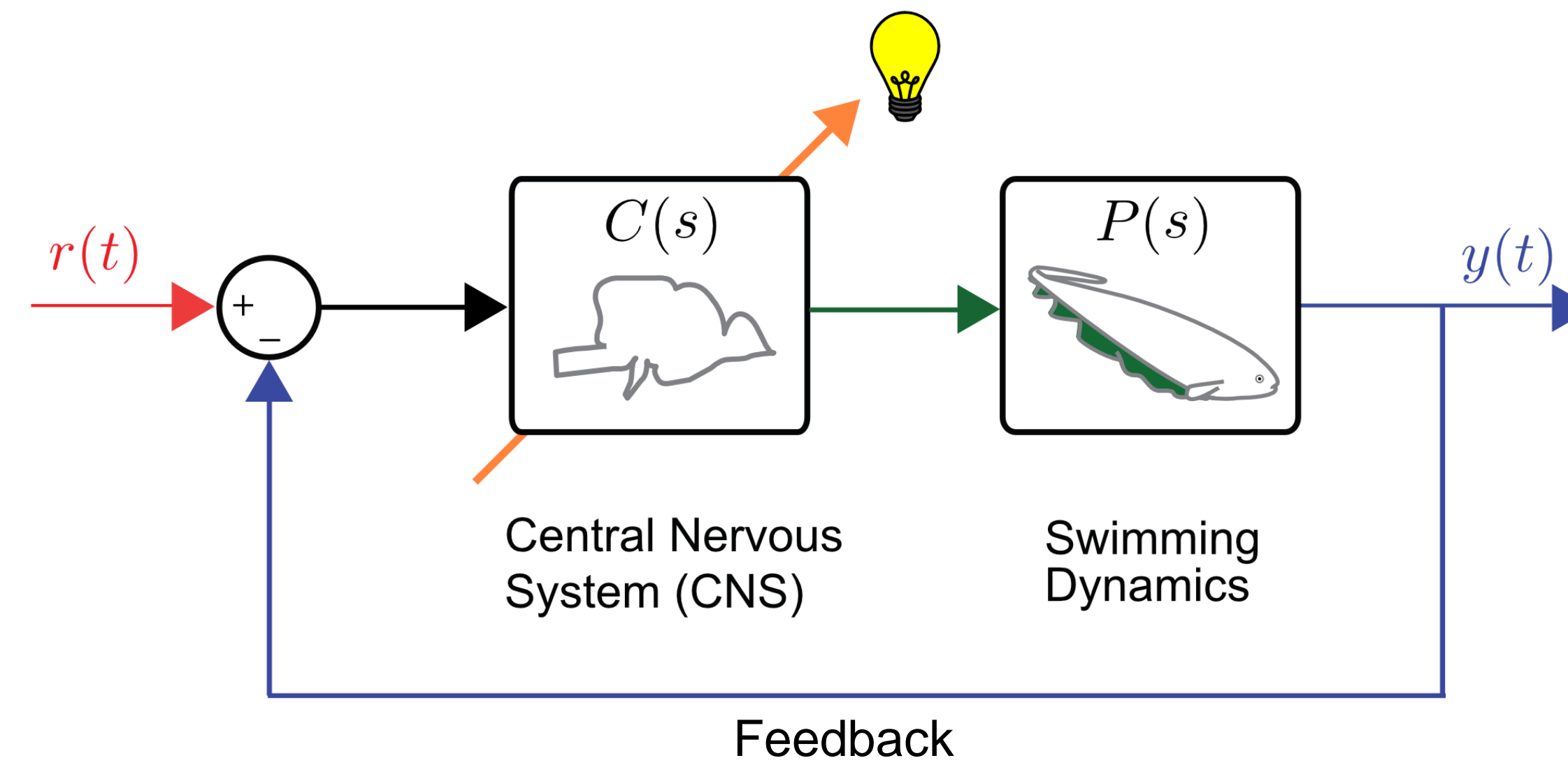
Refuge Input FFT



DLC Tracking



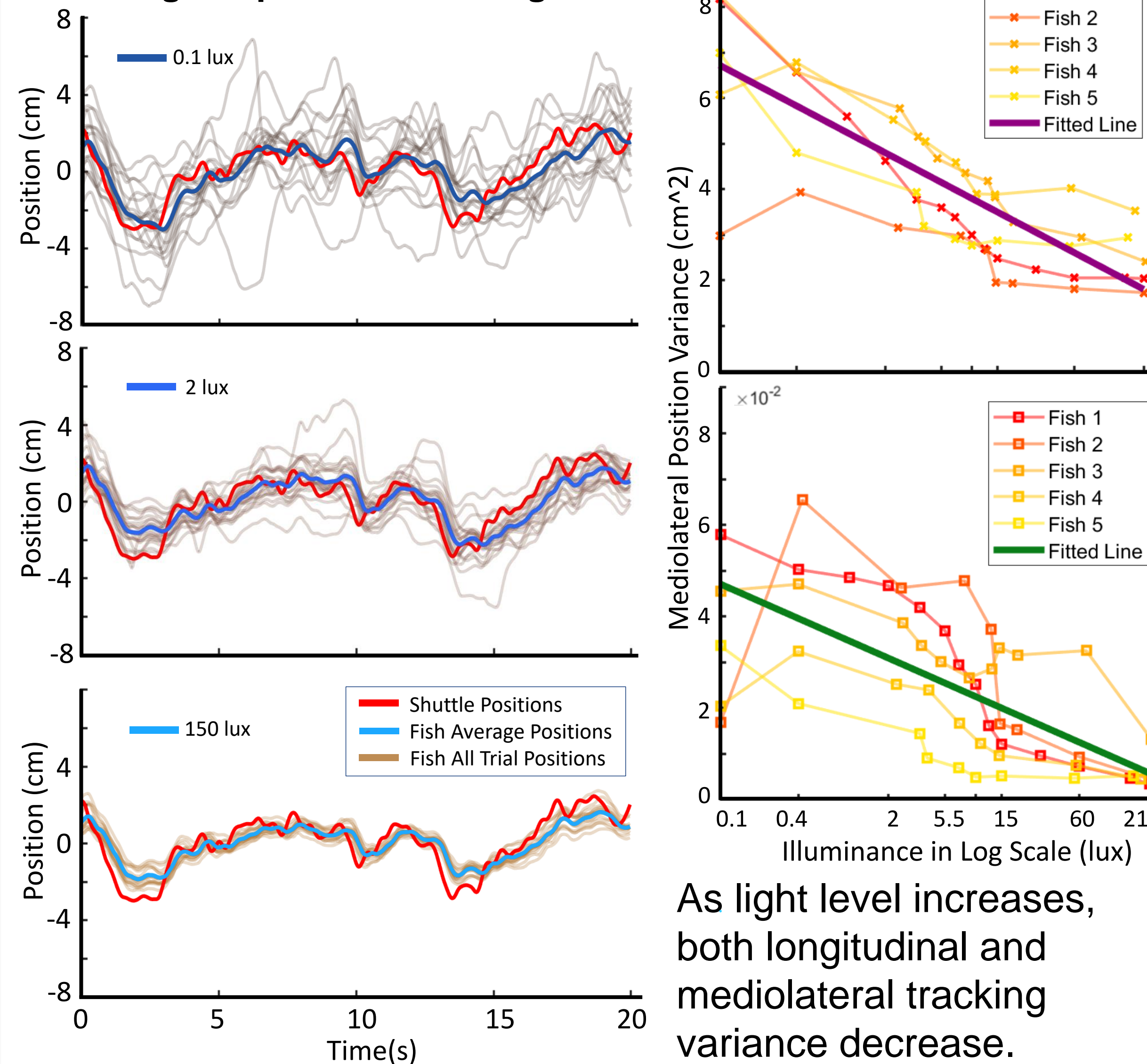
Block Diagram



$r(t)$ = Reference trajectory, sum-of-sines
 $y(t)$ = Fish position

Tracking Variance Decreases with Increased Illuminance

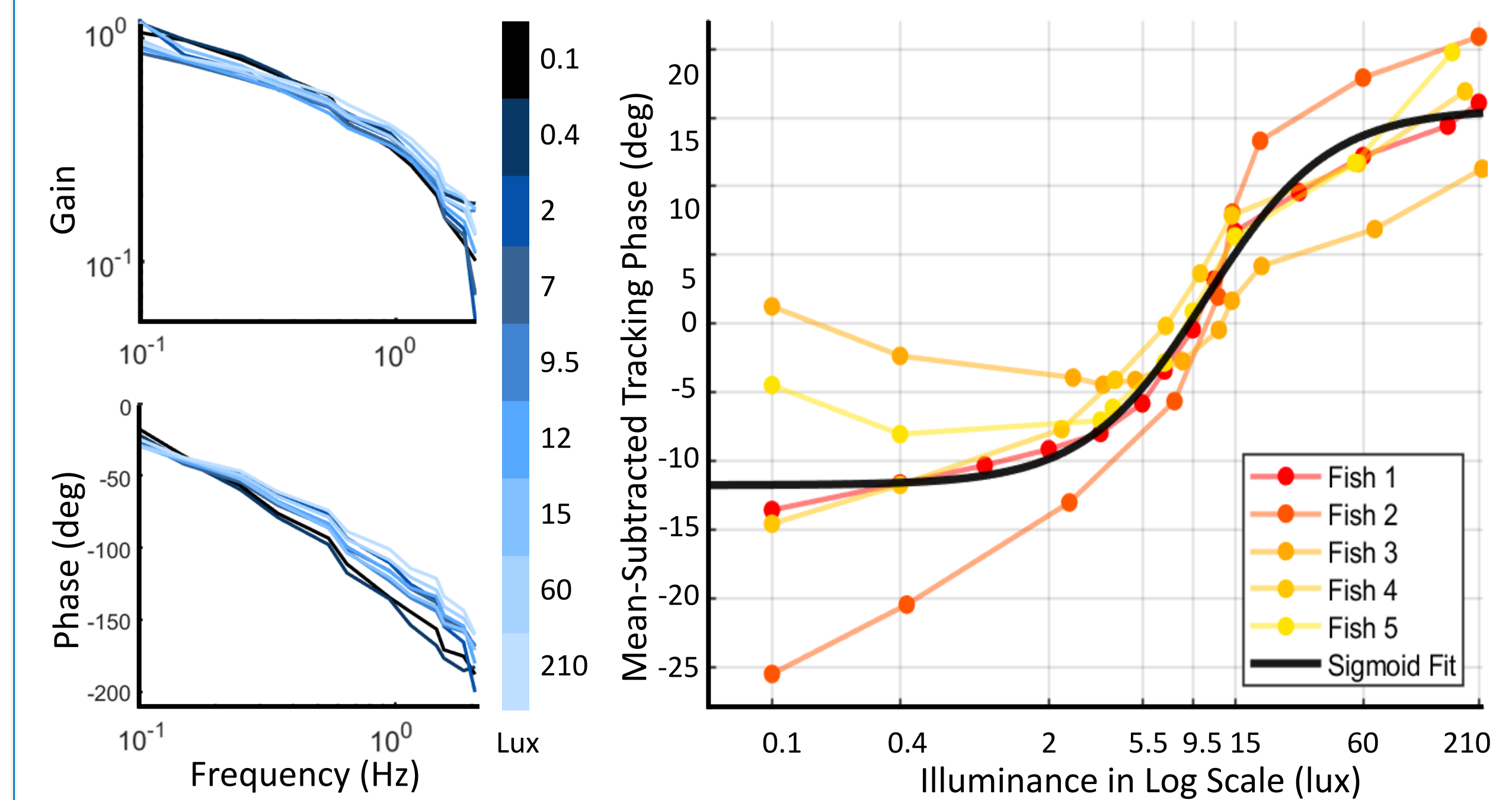
Tracking Responses vs. Refuge



As light level increases, both longitudinal and mediolateral tracking variance decrease.

Luminance-Dependent Switch in Tracking

- At low frequencies, fish track nearly perfectly, but the **gain and phase “roll off”** at increasing frequencies.
- For high-frequency components (1.15 - 2.05Hz), **phase lag decreases** as a function of illuminance.
- This suggests an “illuminance threshold”** at 5.5 – 9 lux, where the fish switches sensorimotor modes.

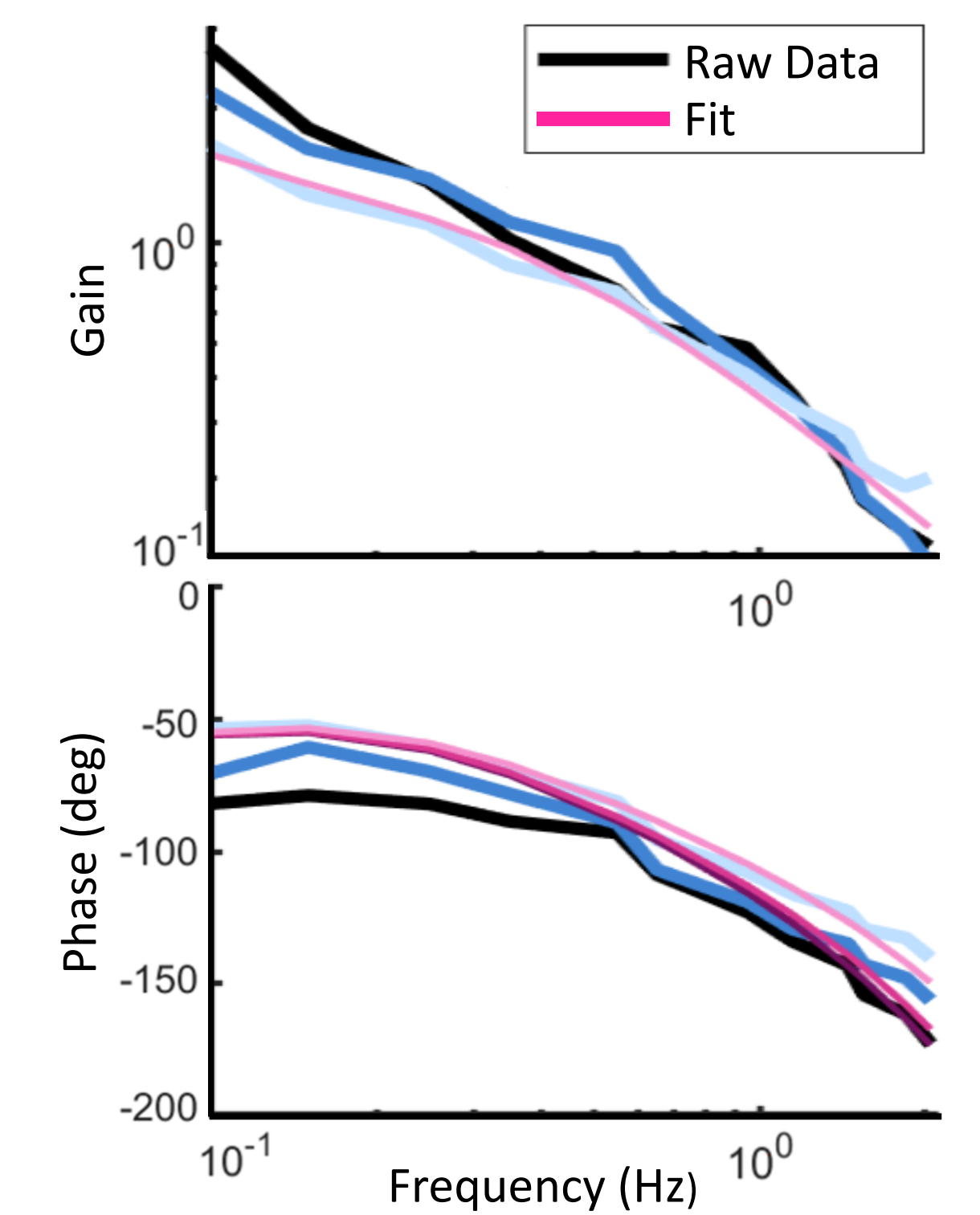


CP Model Fitting

The system²:

$$\frac{k_1 s + k_2}{s^2 + k_3 s} e^{-\tau s}$$

If k_1 , k_2 , and k_3 are kept constant, only changing the delay term¹ is not sufficient for modeling CP changes as a function of illuminance.



Discussion & Outlook

Conclusions:

- Fish movement variance decreases as illuminance increases.
- Above illuminance threshold, tracking lag sharply decreases.

Future work: Investigate changes in tail movement and other system dynamics above and below illuminance threshold.

References:

- Sponberg S et al., Science (2015)
- Uyanik I et al., Elife (2020)