Assessing Canada Goose avoidance behavior to lights of different color and frequency

Ryan Lunn, Brad Blackwell, & Esteban Fernández-Juricic

BIO PURDUE

PURDUE UNIVERSITY

FEDERAL AVIATION ADMINISTRATION

USDA

Canada Geese and Airplane Collisions (2000-2022)

Collisions

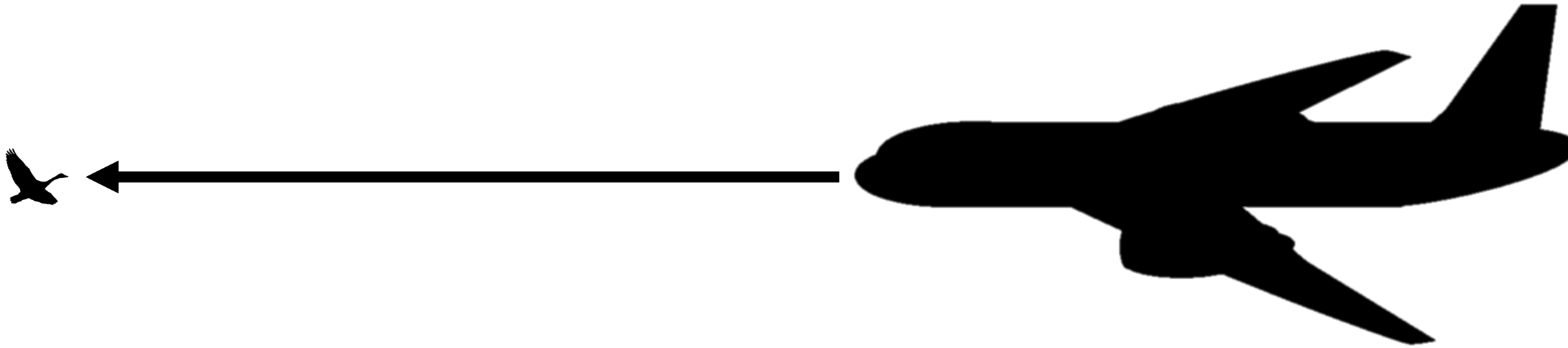
Total Collisions: 1430

Annual Average 65

Cost

Total Cost: $127.52 million

Annual Average $5.8 million



Accessed 07/17/22

Lights could be effective at enhancing bird avoidance responses.

Lustick 1973
Larkin et al. 1975
Blackwell & Bernhardt 2004
Blackwell & Fernández-Juricic 2013

Lights could be effective at enhancing bird avoidance responses.

Special Issue: Conservation Behaviour

No single solution: application of behavioural principles in mitigating human–wildlife conflict

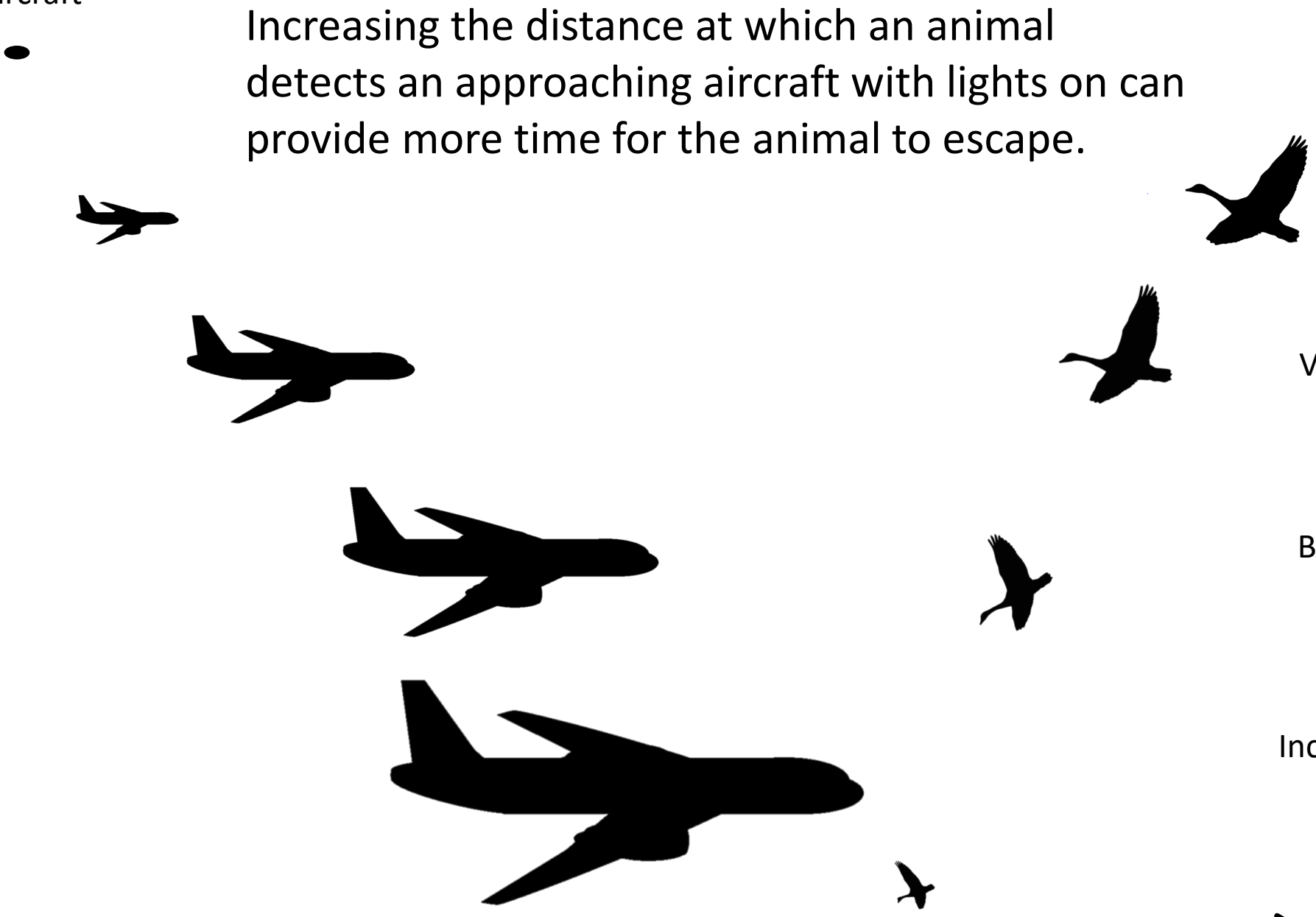
Bradley F. Blackwell [a], Travis L. DeVault [a], Esteban Fernández-Juricic [b], Eric M. Gese [c], Lynne Gilbert-Norton [d], Stewart W. Breck [c]

Lustick 1973
Larkin et al. 1975
Blackwell & Bernhardt 2004
Blackwell & Fernández-Juricic 2013

Aircraft

Animal

Increasing the distance at which an animal detects an approaching aircraft with lights on can provide more time for the animal to escape.



Detection (DD)

Visual attention (AD)

Begin escape response

Increasing the probability of avoidance

Distance to collision

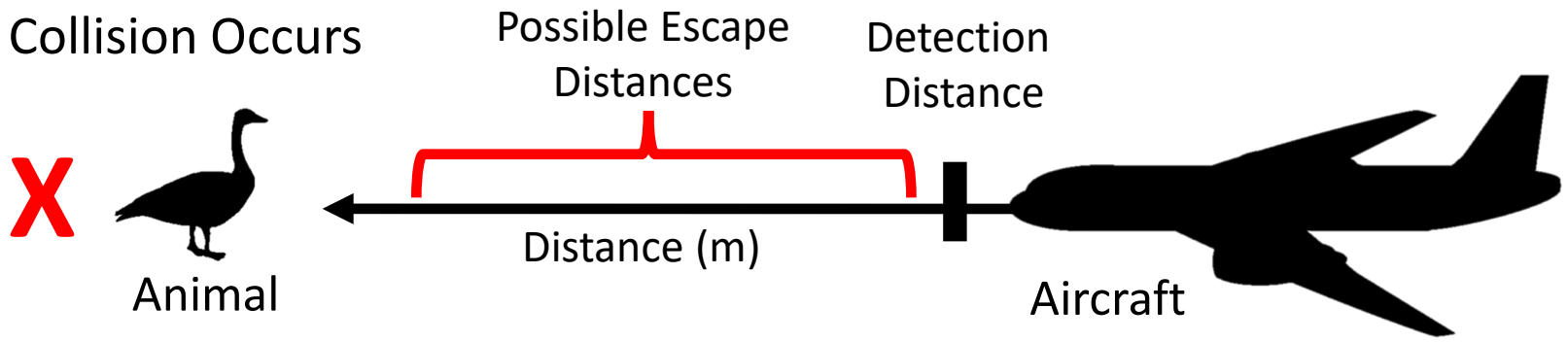
Lima et al. 2015
Blackwell & Fernandez-Juricic 2013

Detection always precedes escape behavior. If an animal cannot outrun the threat, they must escape at a longer distance.

<u>Scenario 1:</u>

Shorter detection distance

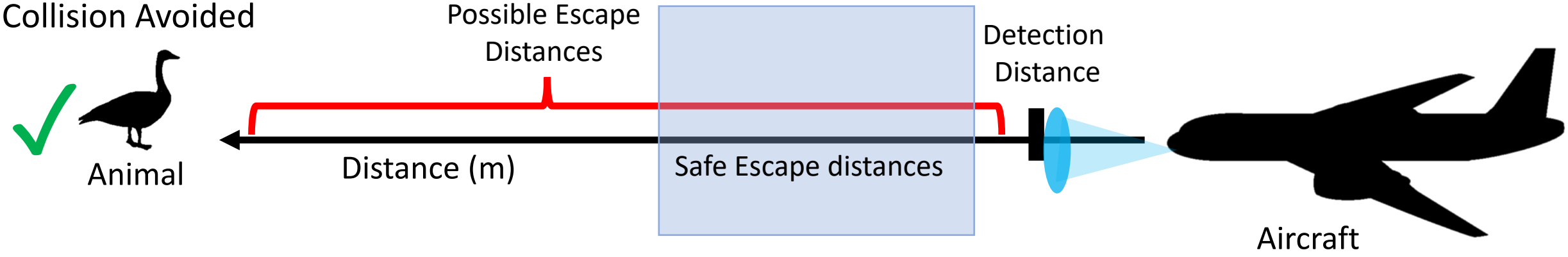
Collision Occurs



<u>Scenario 2:</u>

Longer detection distance

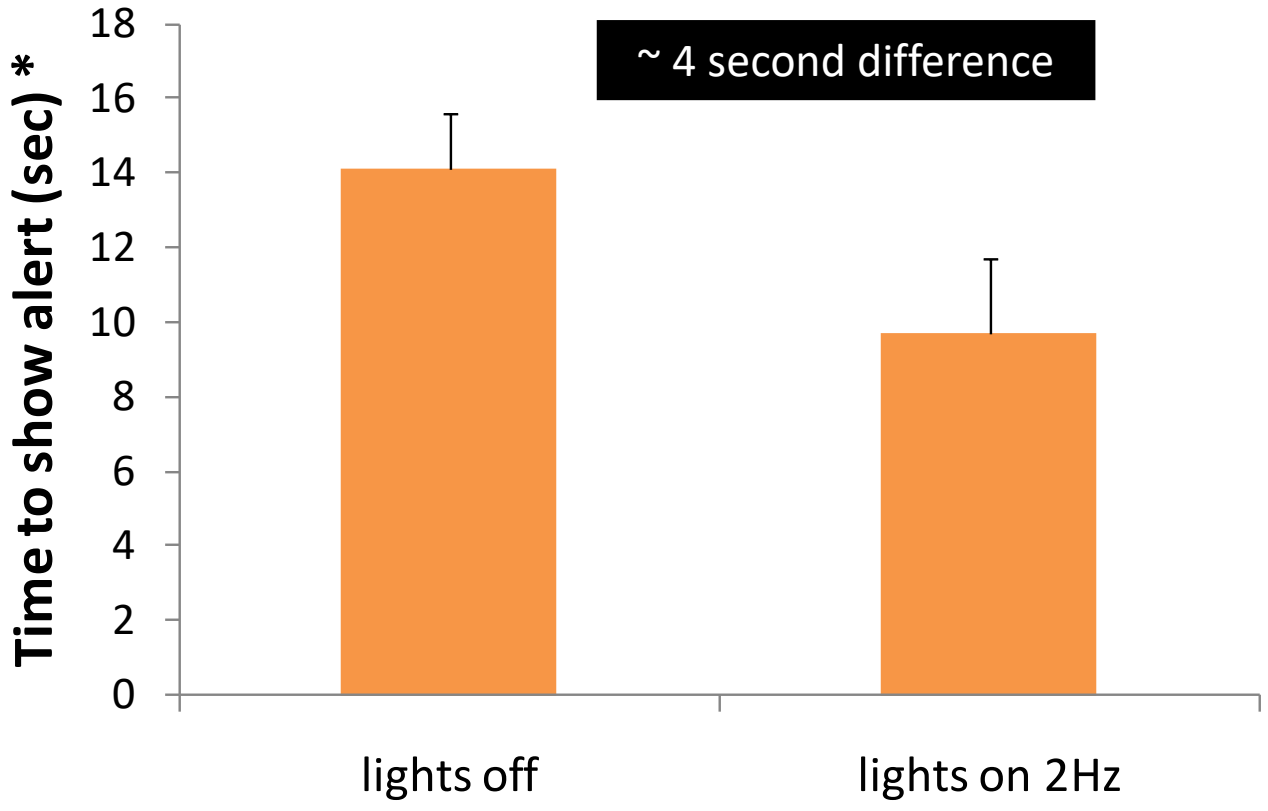
Collision Avoided



Blackwell & Fernández-Juricic 2013

Main Assumption:

- Lights onboard a vehicle will trigger detection and alert response earlier than an aircraft with lights off.



Blackwell et al. 2012

** time from initiation of an alert behavioral response to the vehicle reaching the end point of the approach.*

Goal of the Study:

- **Evaluate the relative performance of LED lights (varied in color (nm) and frequency) tuned to the Canada goose eye at evoking avoidance behavior**

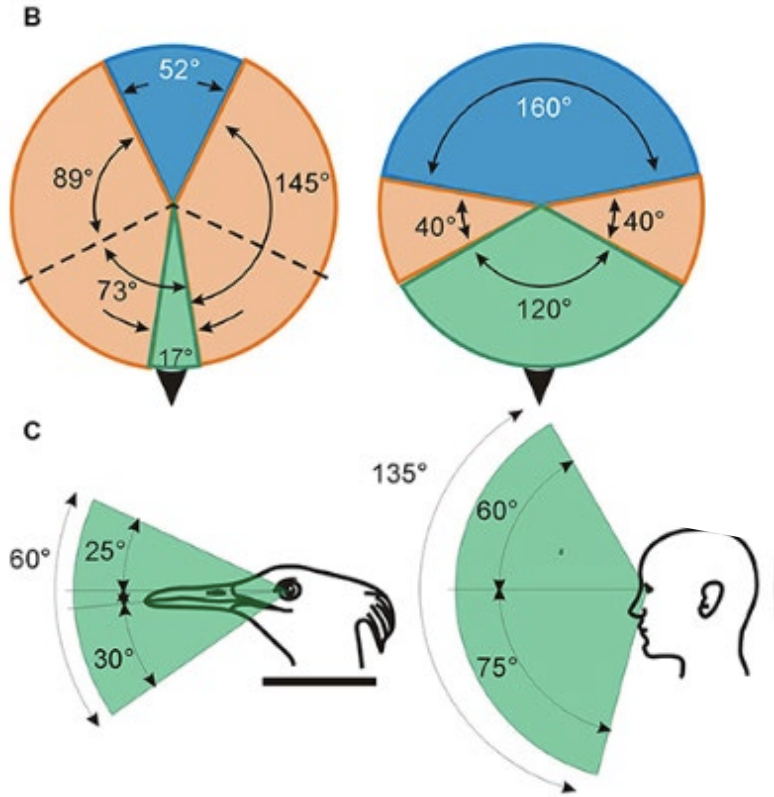
Why tune lights to the bird eye?

Healy et al. 2013
Goller et al. 2019

Avian vision differs drastically from human vision

- Visual Coverage
- Spatial visual resolution
- Temporal visual resolution

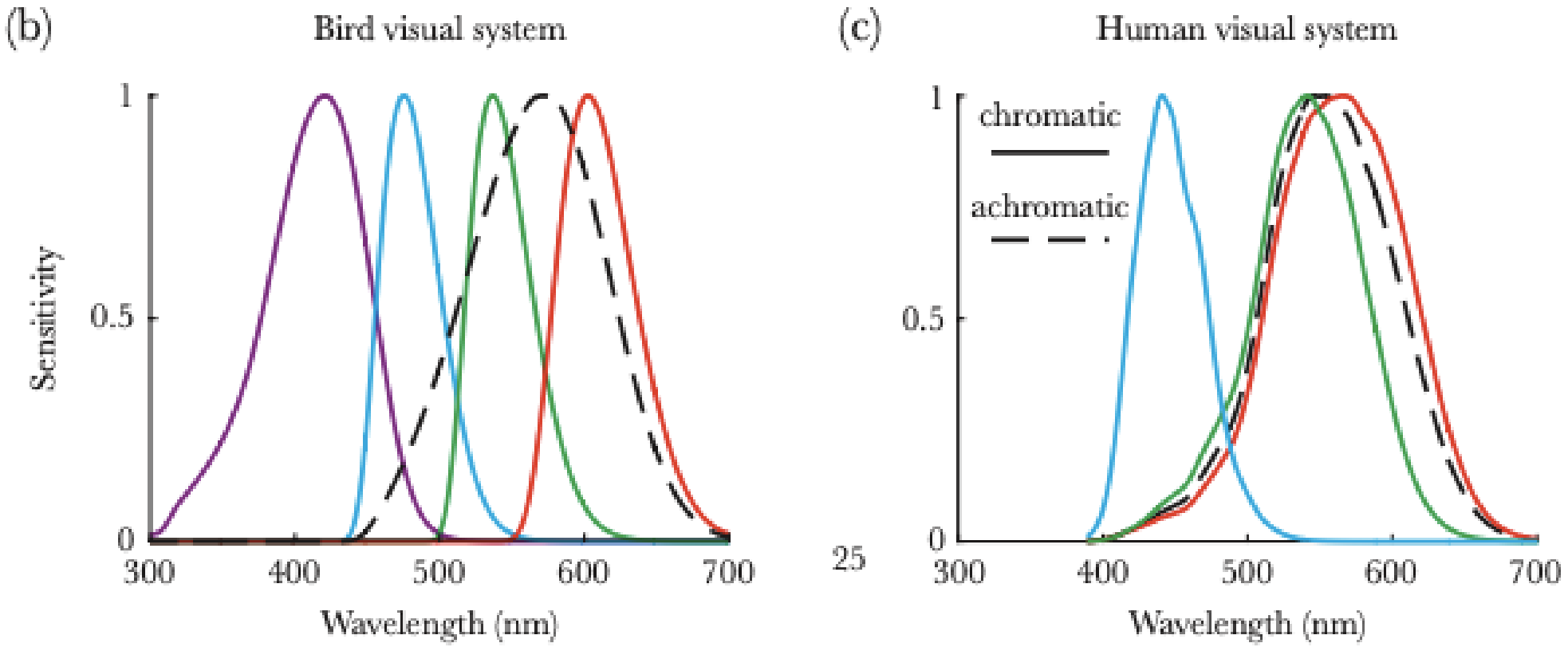
Visual Coverage



Why tune lights to the bird eye?

Avian vision differs drastically from human vision in terms of color perception

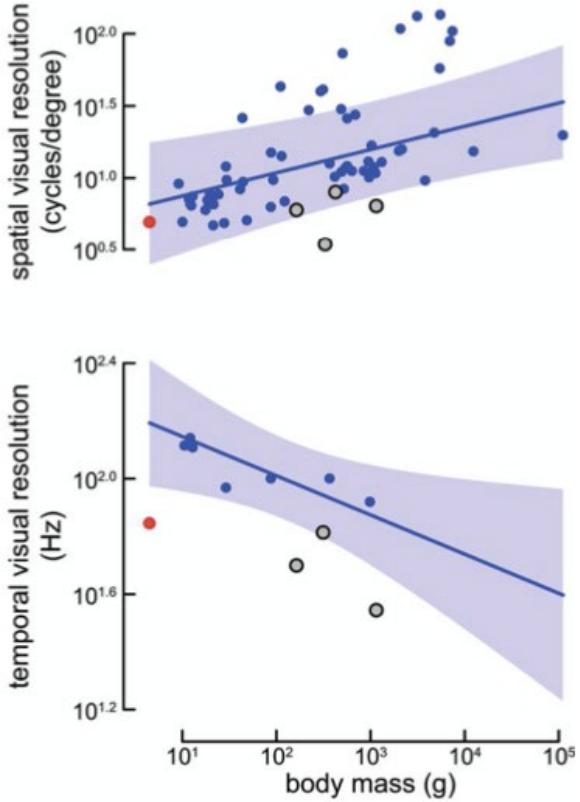
Photoreceptor Sensitivity



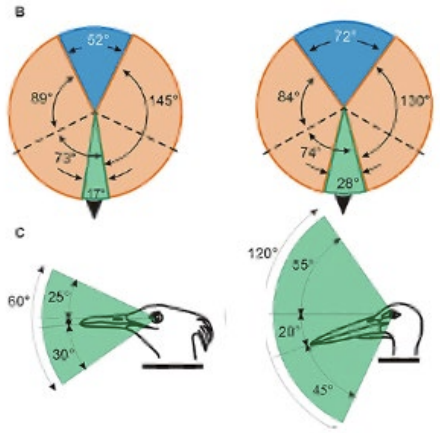
Why tune lights to the Canada goose eye?

Visual perception differs drastically between bird species

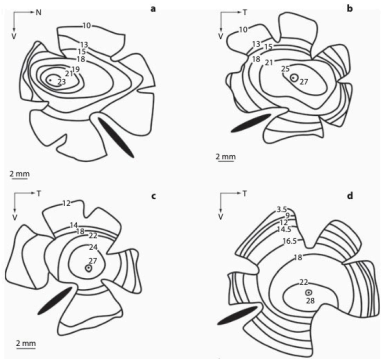
Spatial and Temporal Visual Resolution



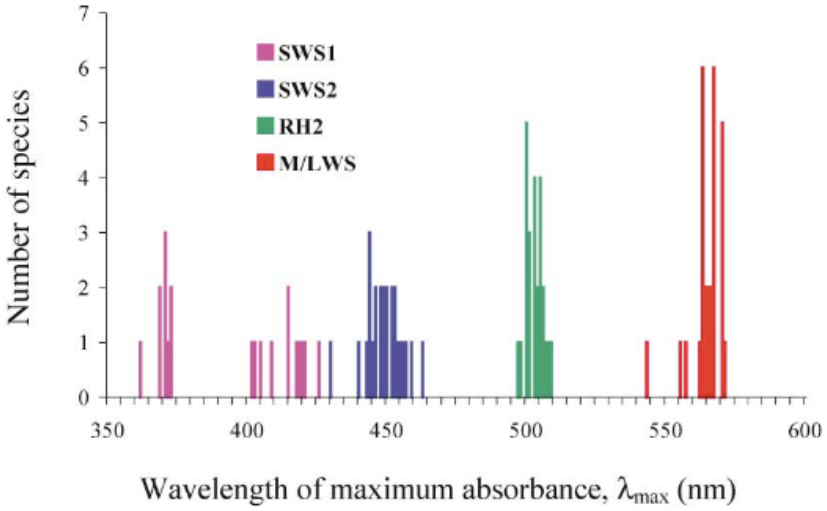
Visual Coverage



Retinal Topography



Peak Absorbance of photoreceptors



Hart 2001
Dolan & Fernandez-Juricic 2010
Goller et al. 2018
Martin et al. 2017

Tuning lights to Canada Goose eye required characterizing its visual anatomy and physiology

Original Paper

Brain, Behavior and Evolution

Brain Behav Evol 2011;77:147–158
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Testing the Terrain Hypothesis: Canada Geese See Their World Laterally and Obliquely

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Bradley F. Blackwell[b] Steven L. Lima[c] Travis L. DeVault[b]

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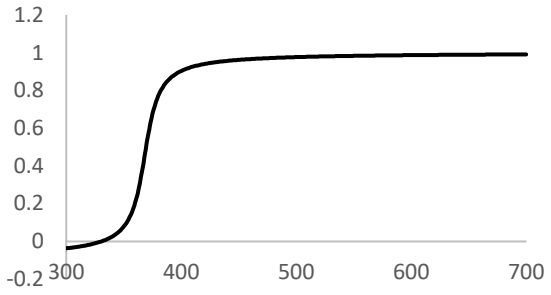
RESEARCH ARTICLE

Oblique color vision in an open-habitat bird: spectral sensitivity, photoreceptor distribution and behavioral implications

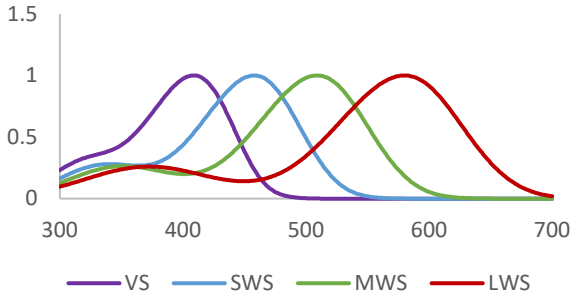
Bret A. Moore[1,*], Patrice Baumhardt[1,*], Megan Doppler[1], Jacquelyn Randolet[1], Bradley F. Blackwell[2], Travis L. DeVault[2], Ellis R. Loew[3] and Esteban Fernández-Juricic[1,†]

We used a Canada Goose visual model

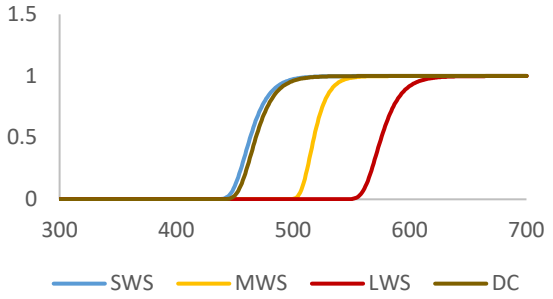
Canada Goose Ocular Media



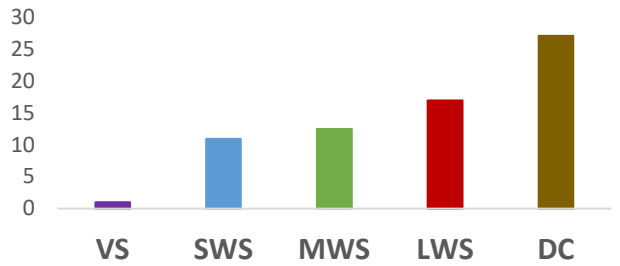
Canada Goose Visual Pigments



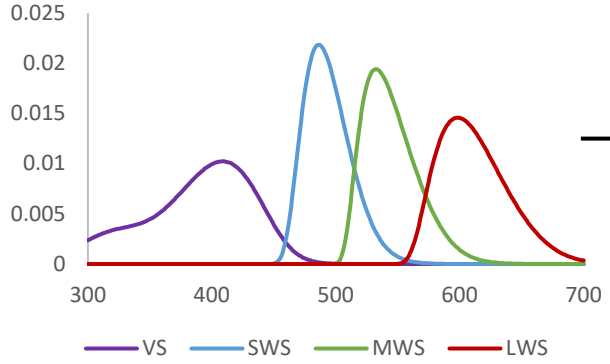
Canada Goose Oil Droplets

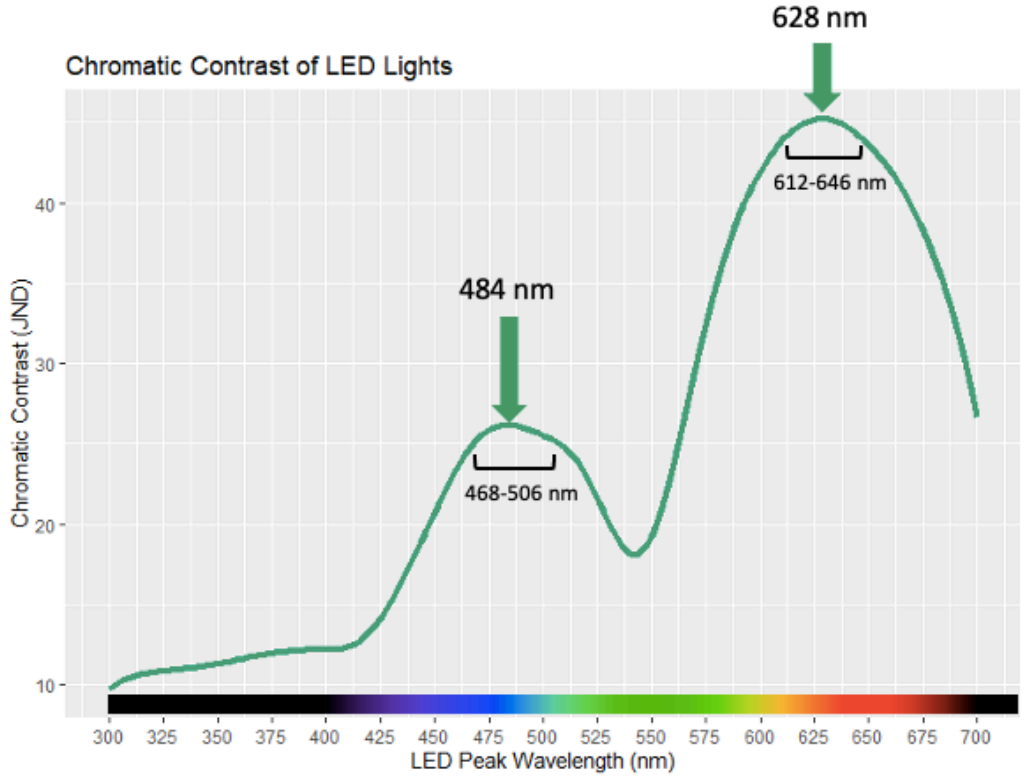


Canada Goose Photoreceptor Relative Densities

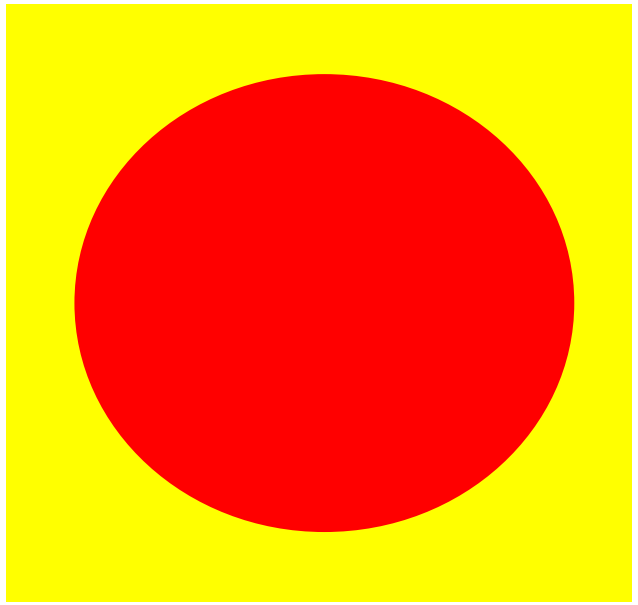


Canada Goose Sensitivity Curves

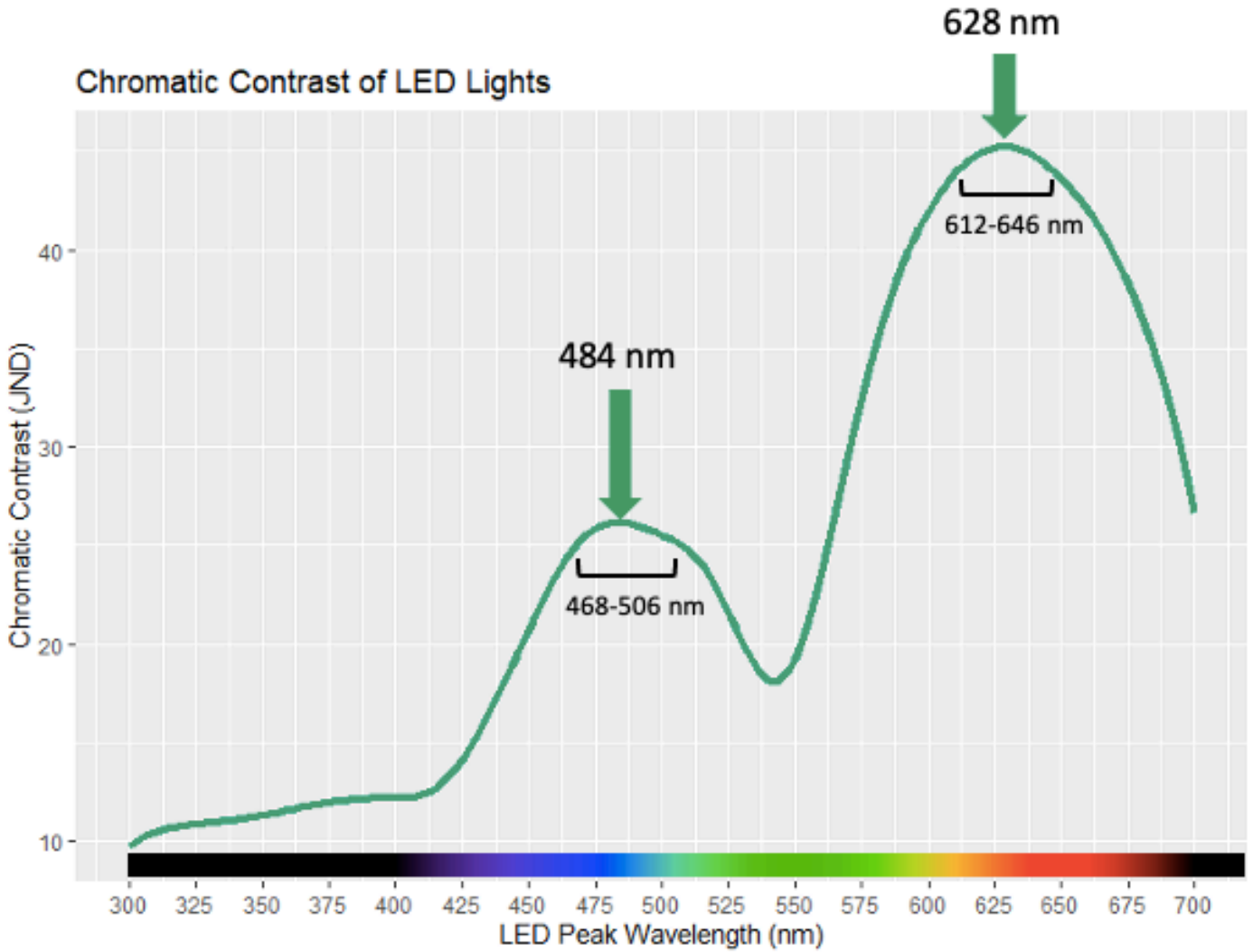




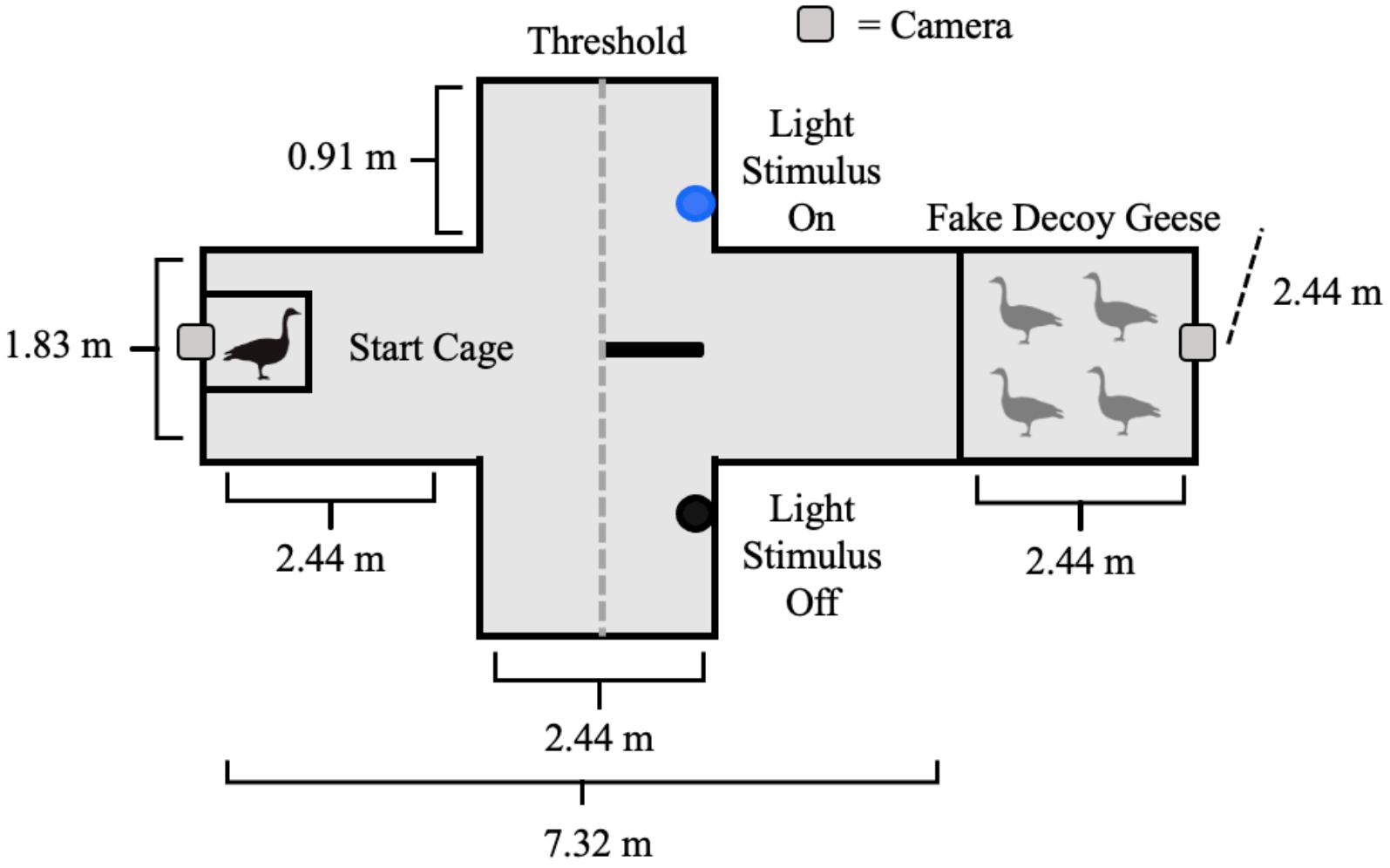
Relatively Higher Chromatic Contrast (Larger JND value)



Relatively Lower Chromatic Contrast (Larger JND value)


Chromatic Contrast of LED Lights
628 nm
612-646 nm
484 nm
468-506 nm
Chromatic Contrast (JND)
40
30
20
10
300 325 350 375 400 425 450 475 500 525 550 575 600 625 650 675 700
LED Peak Wavelength (nm)

Experimental Design: Single Choice Test



Experimental Design: Single Choice Test

Sample Size

- *23 geese,* exposed to different color & frequency treatments

Dependent Variables

- Latency to respond to the lights
- Body movement rate
- Light avoidance
- Survival

Independent Variables

- Light Color (Blue (471 nm) vs. Red (627nm))
- Light Frequency (Steady vs. Pulsing (2 Hz))

Covariates

- Light Position, Trial Order, Light Intensity (Lux)

Blue

Red

Steady

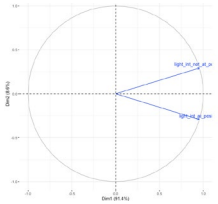
Pulsing

Statistical Analysis: See Me After

1) Data processing and covariate selection

Check Correlations

PCA Light Intensity



2) General and Generalized linear mixed models

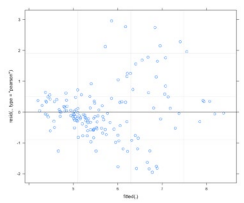
- **Fixed effect:** Color, Frequency, + Interactions
- **Random effects**: Bird ID
- **Covariates:** Light Intensity, Trial Order, Light Position

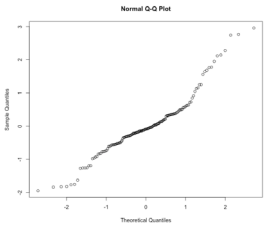
3) Model Selection

Simple → Complex

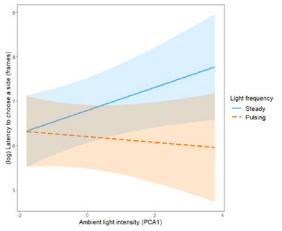
AIC to select model of best fit

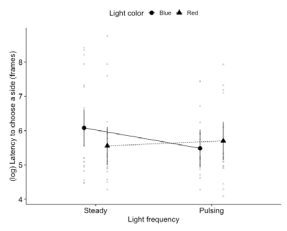
4) Check model assumptions transform if needed



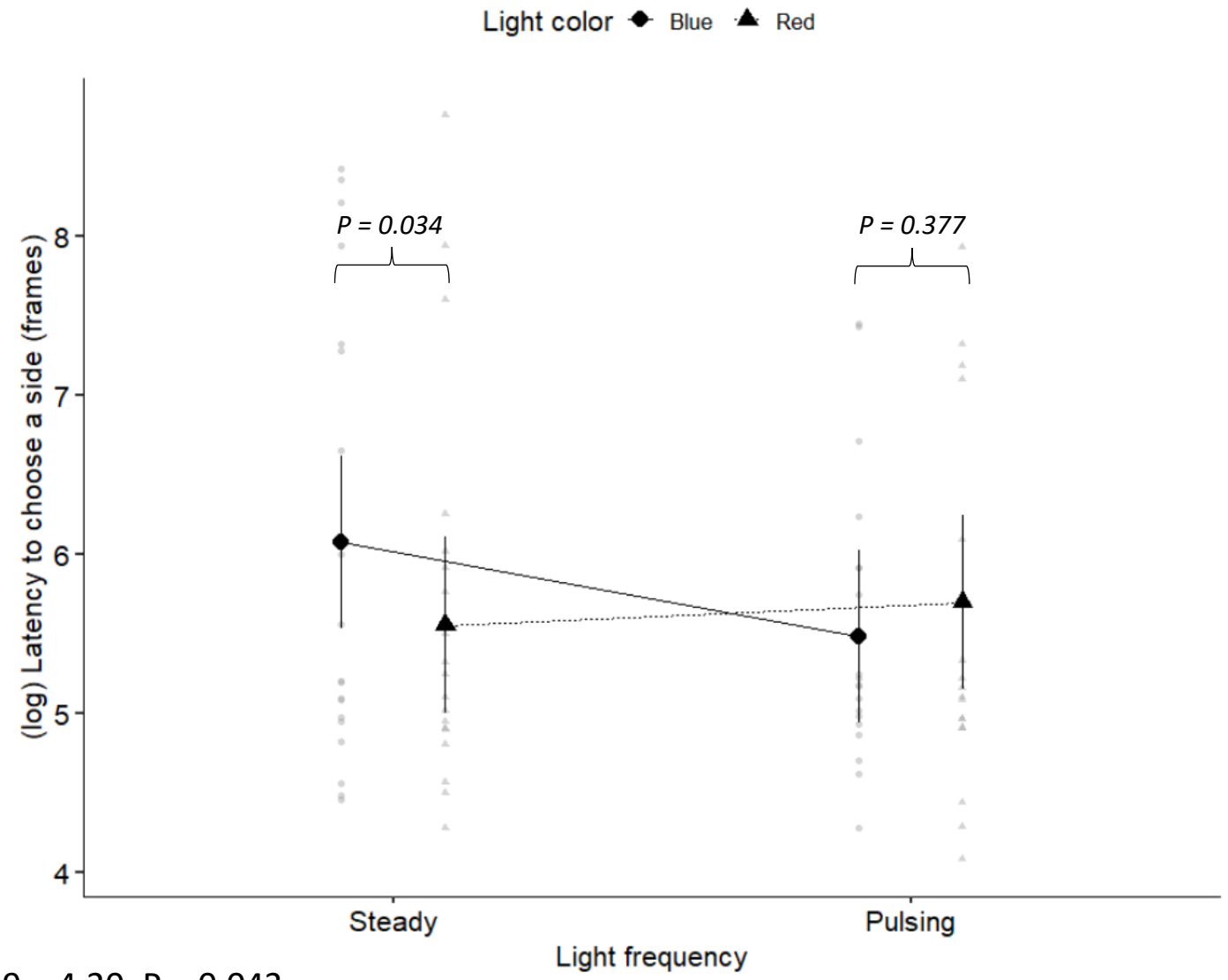


5) Interpreting Fixed and Random effects



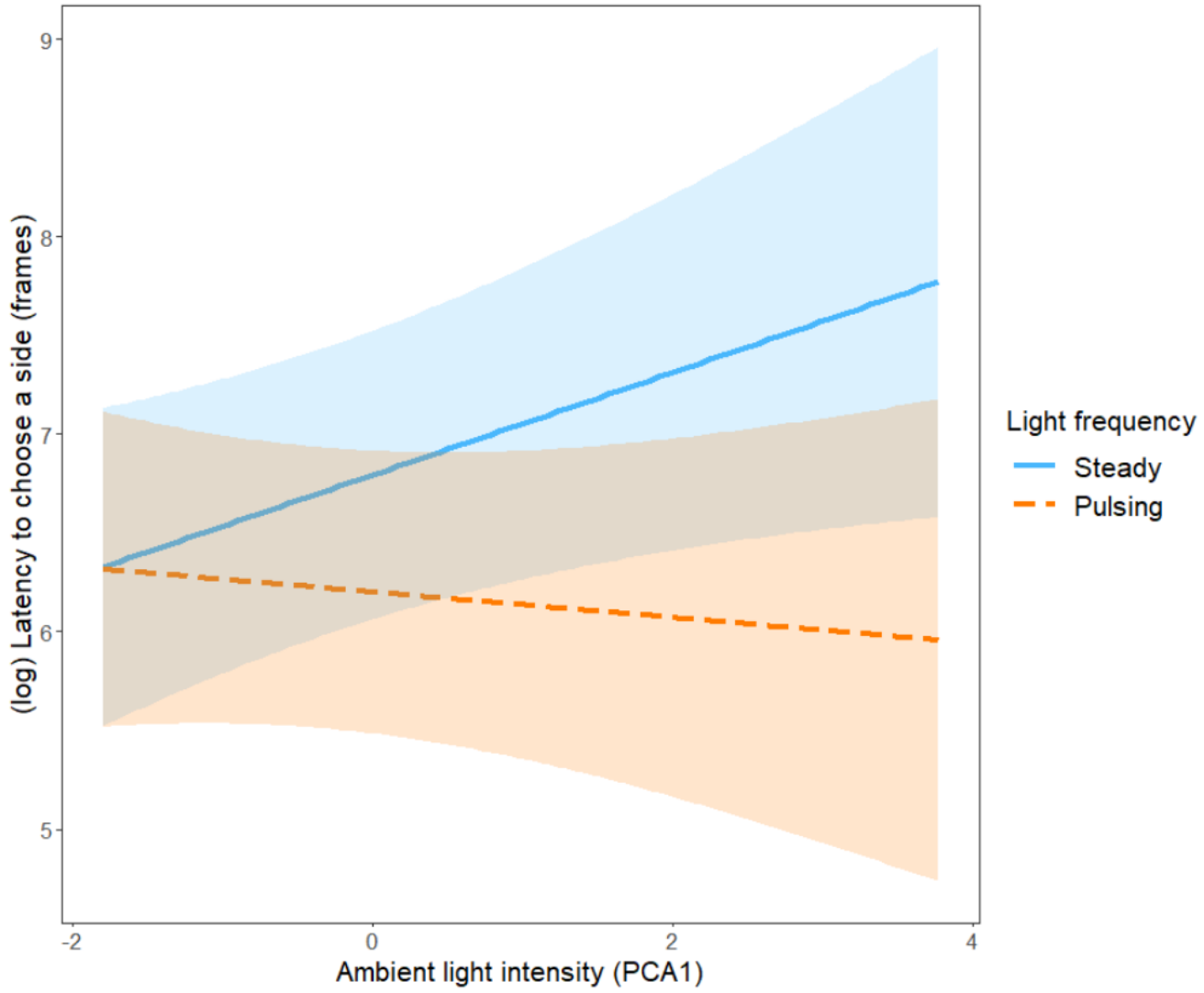


Latency: geese responded sooner to red steady than blue steady lights



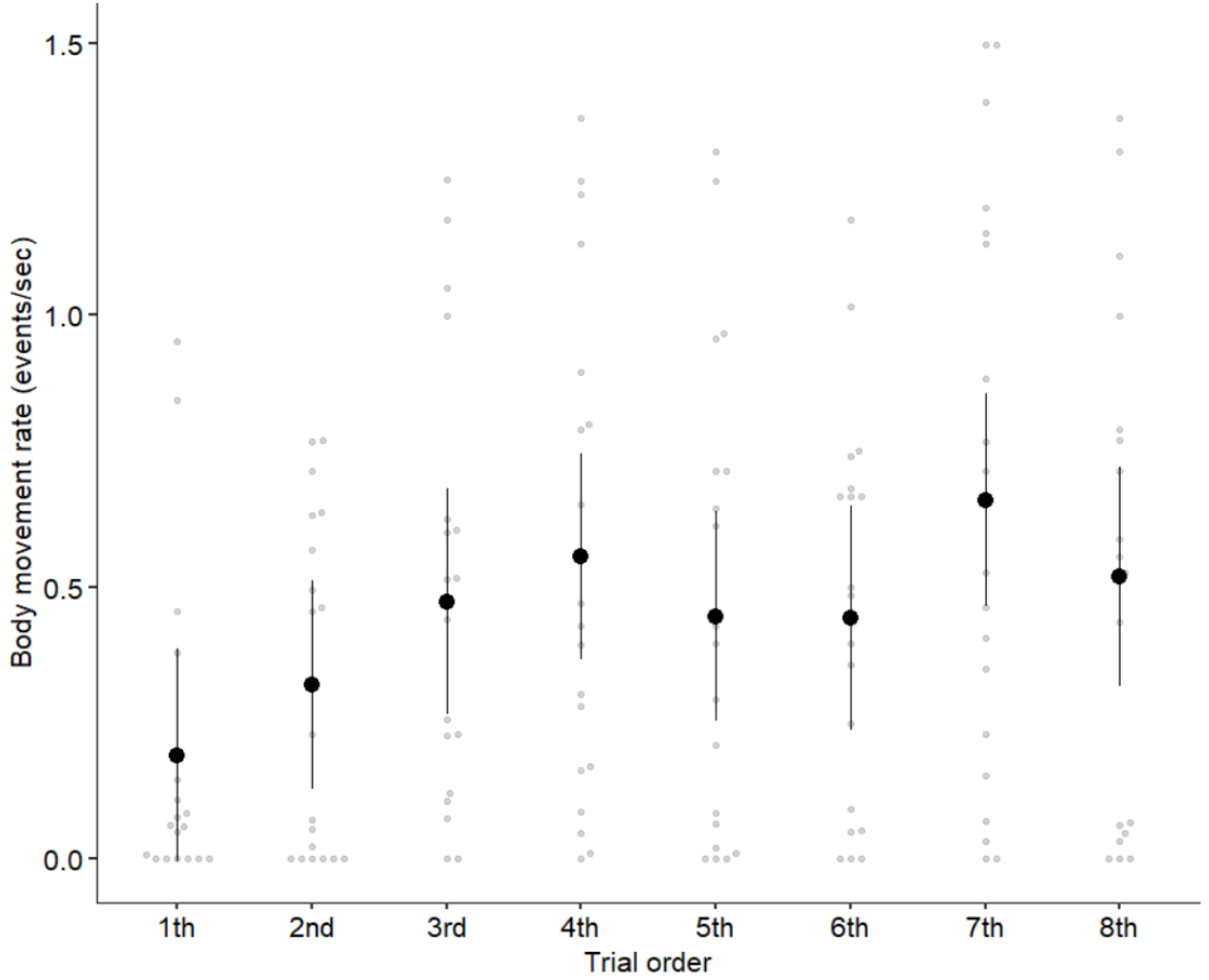
Color X Frequency: F 1, 119 = 4.20, P = 0.043

Latency: geese delayed their responses when the steady light was under higher light intensity



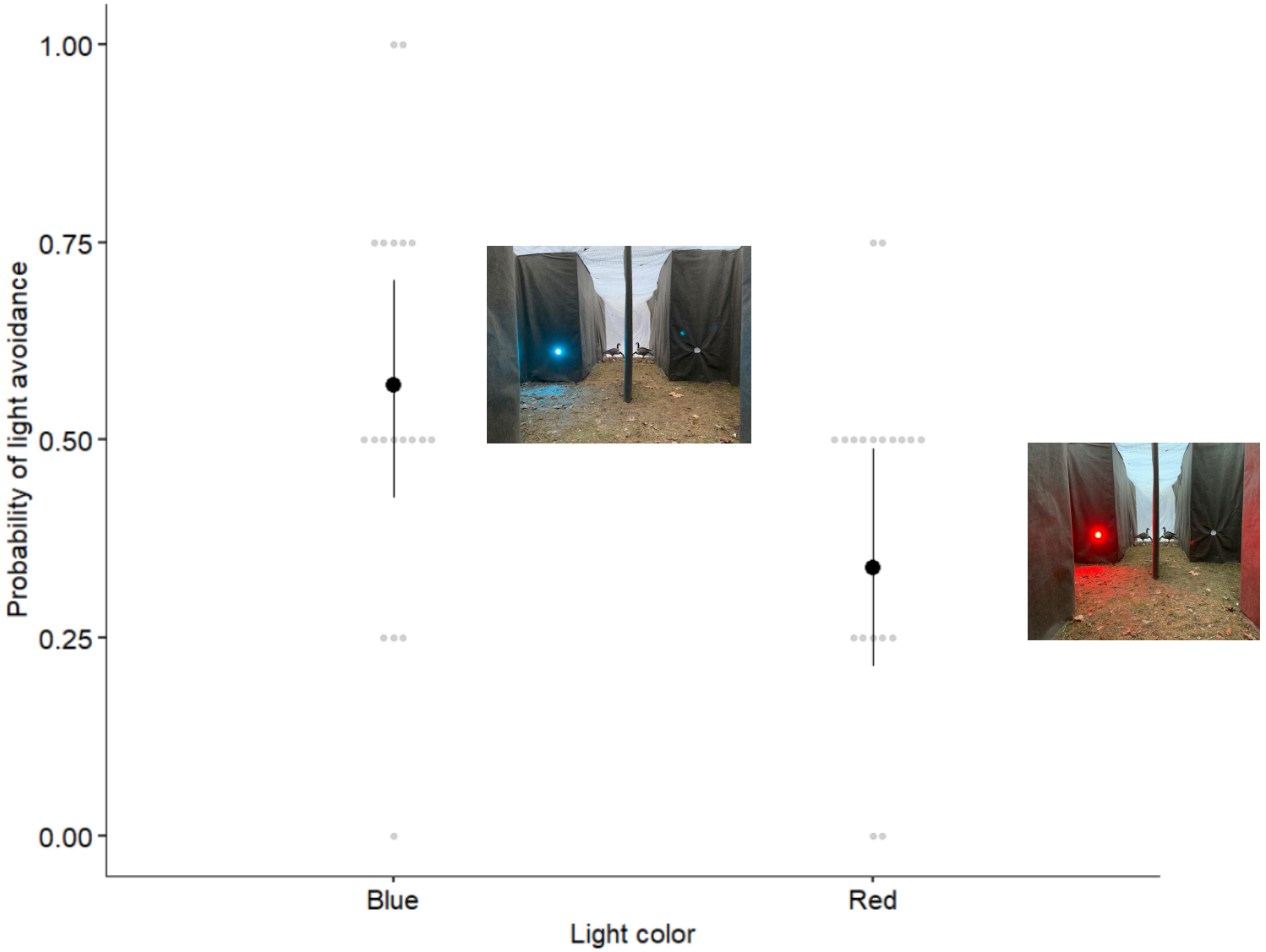
Frequency X PCA1: F 1, 128 = 5.40, P = 0.021

Body movement rate: before making a choice, geese varied the pace of their body movements with the number of exposures to the lights



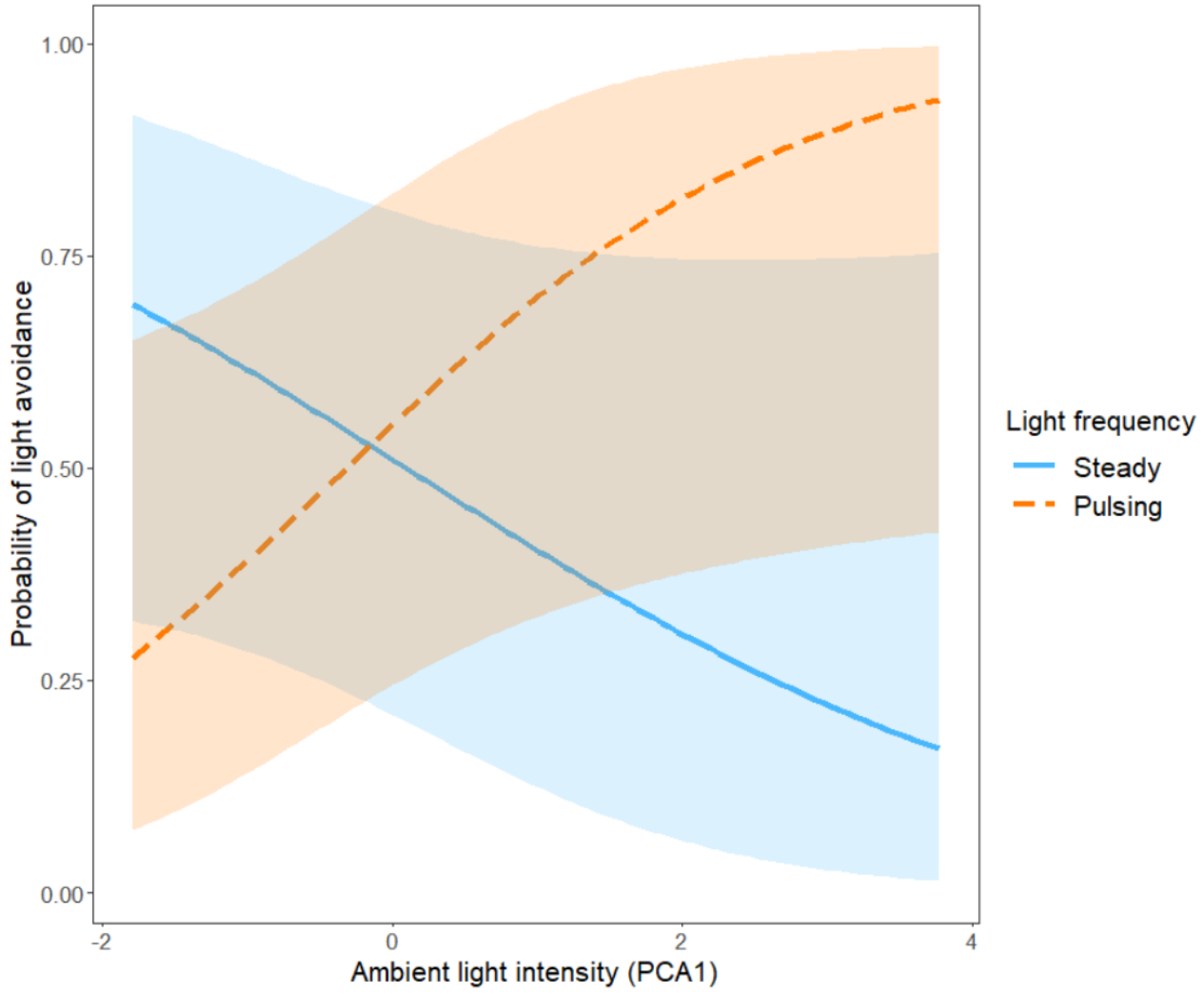
Trial order: F 7, 107 = 2.27, P = 0.034

Avoidance: geese avoided blue lights (471 nm) more than red lights (627 nm)



Color: X^2 1 = 2.27, P = 0.034

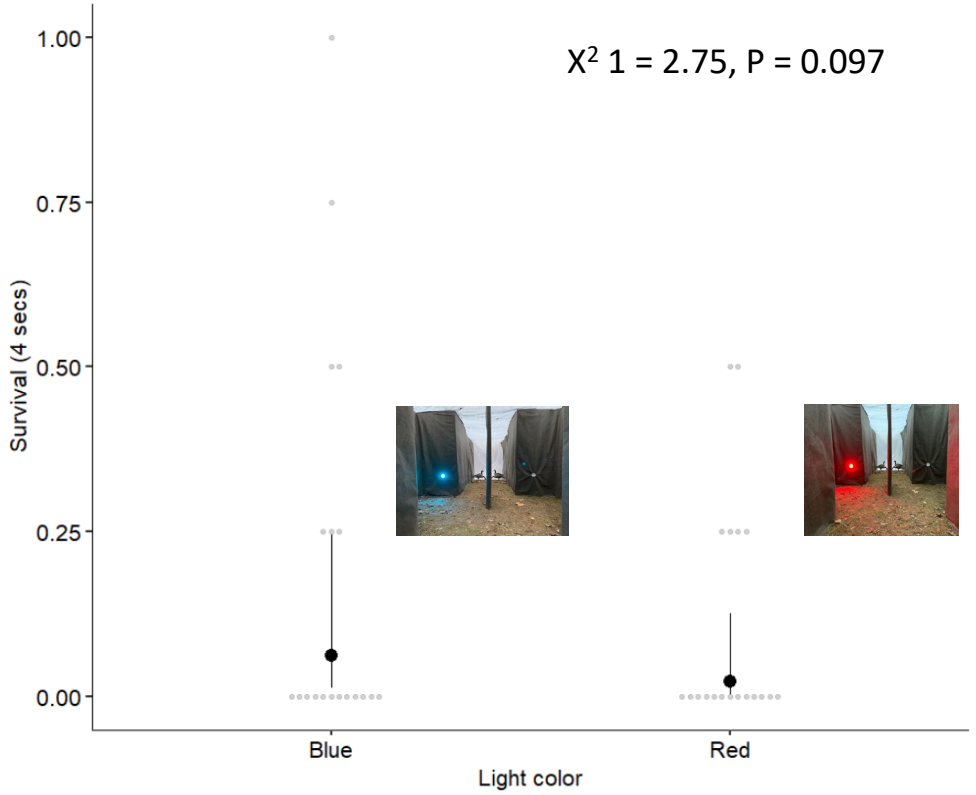
Avoidance: geese had higher chance of avoiding steady lights with low and pulsing lights with high ambient light intensity



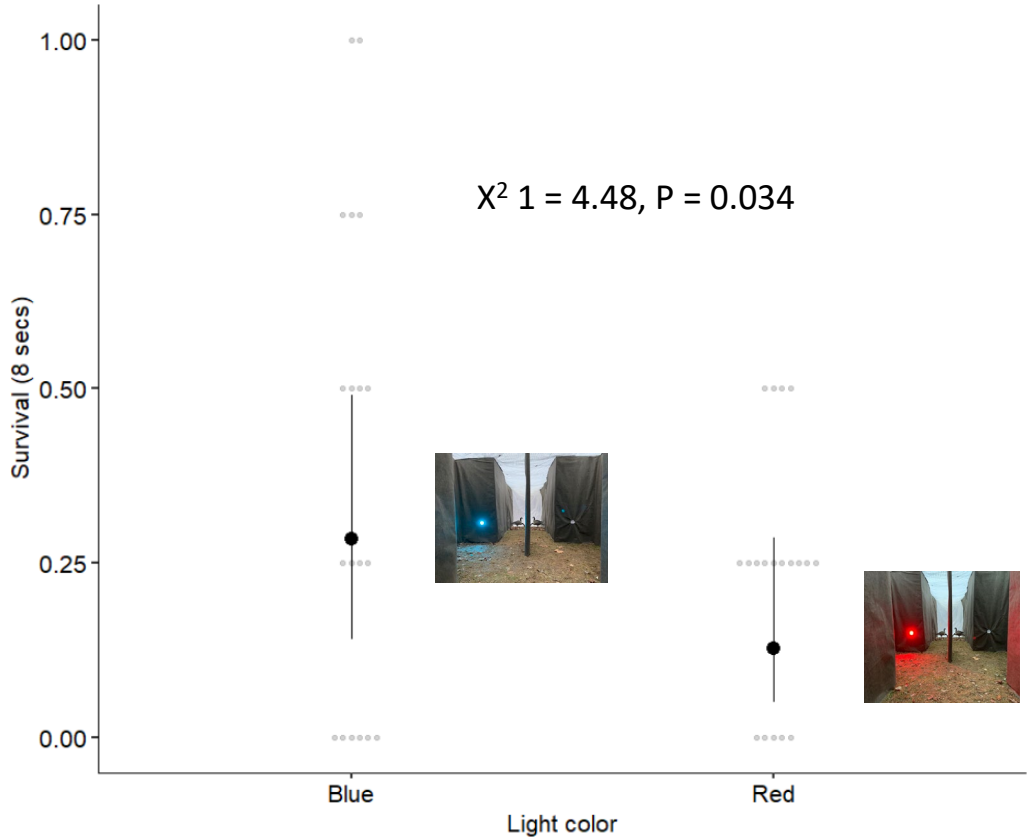
Frequency X PCA1: X^2 1 = 11.59, P < 0.001

The effects of light color on goose “survival” increased with the amount of time the animal had to decide a response to the lights

X^2 1 = 2.75, P = 0.097

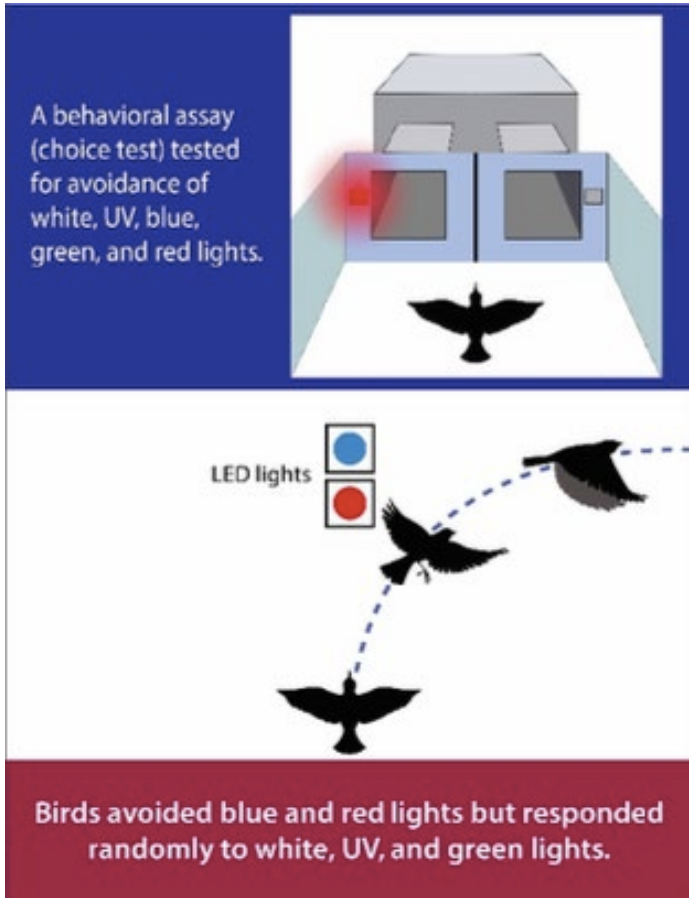


X^2 1 = 4.48, P = 0.034



Conclusions

- Behavioral experiments under controlled conditions are essential to the evaluation the performance of lights.
- Lights tuned to the Canada goose eye with high retinal stimulation do not perform equally.
- Blue lights (471 nm) performed significantly better at generating avoidance behavior than red lights (627 nm)
- Blue lights of (470 nm) generate avoidance response in Brown-headed Cowbirds (Goller et al. 2018)
- Ambient light intensity can have a substantial effect on the performance of lights – this suggests the need for flexibility (steady vs. pulsing lights) depending on environmental conditions (sunny, cloudy).

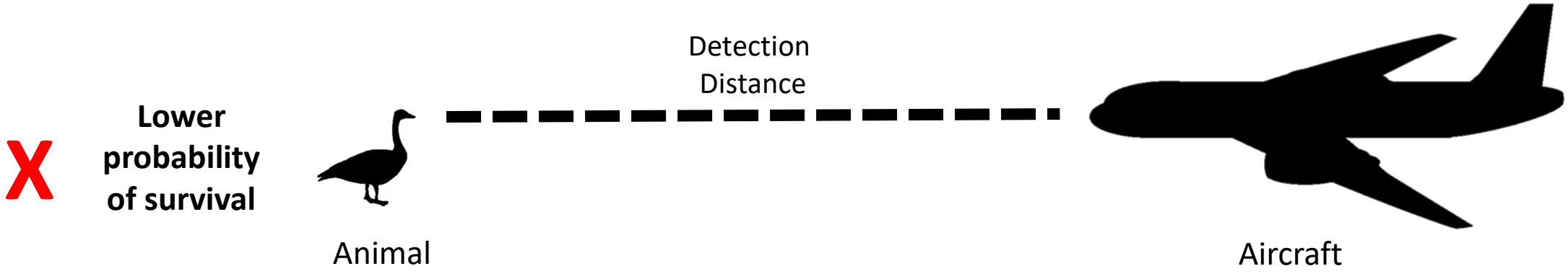


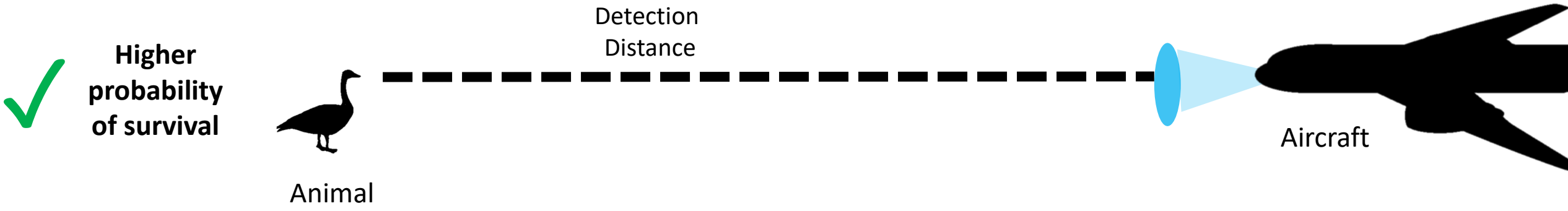
Next Step

1. **Repeated exposures to light can individual birds behaving differently to lights– need to study effects to light sensitization?**
2. **Light intensity could also affect behavior – we chose light intensities not high enough to avoid sensory overwhelming effects (leading to freezing) - need to study LED light thresholds**
3. **Estimate the intensity needed for a goose to resolve a light source given a certain ambient intensity**

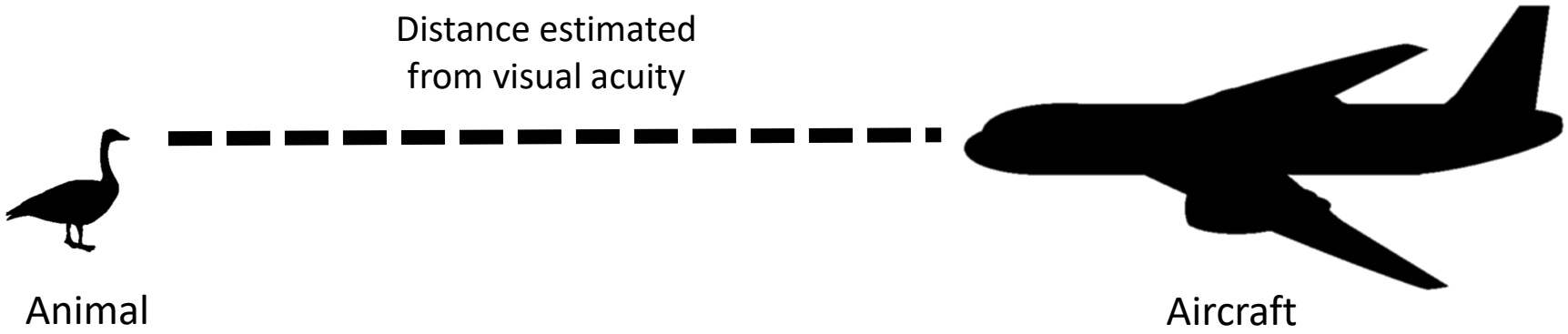
Future Direction

Increasing the distance at which an animal detects the approaching aircraft provides more time for the animal to enact an escape response and avoid the collision.





We have equations to estimate **avian** detection distance of opaque objects



Visual Acuity Formula:

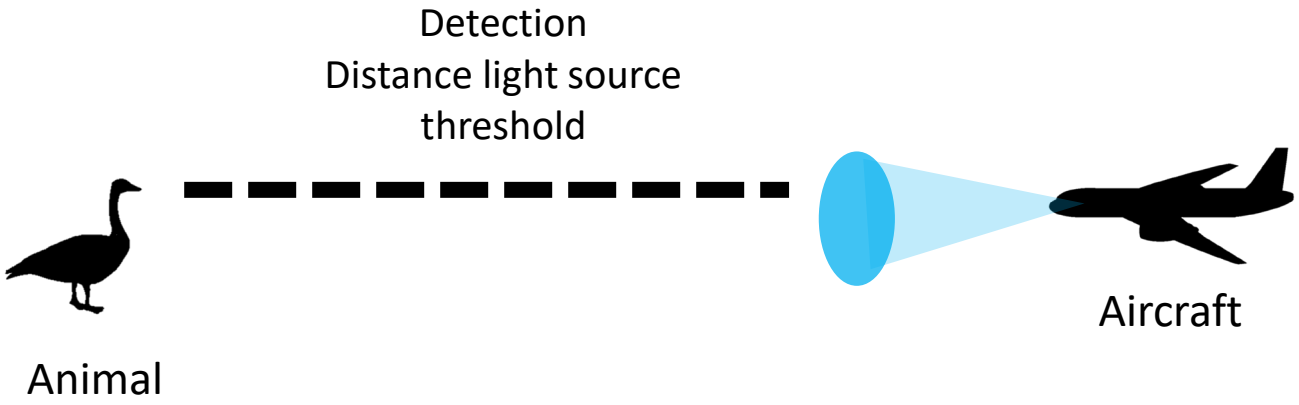
$$RMF = \frac{2\pi PND}{360}$$

$$F_n = \frac{RMF}{2}\sqrt{\frac{2D}{\sqrt{3}}}$$

$$Detection\ Distance = \frac{r}{\tan(\frac{\frac{1}{F_n}}{2})}$$

GAP: we do not have a framework to estimate avian detection distance of light sources

Estimating the detection distance of a light source for the Canada goose



Light Source Detection Formula:

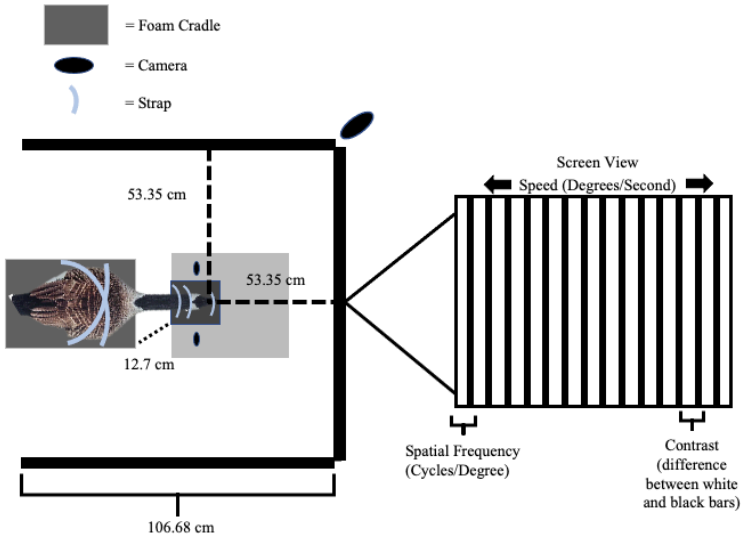
$$r \cong \frac{2}{c} W\left[\frac{cA}{8\sqrt{3}}\sqrt{\frac{E\Delta t}{1+\sqrt{1+\left(2.8d^2N_0+4X\right)\Delta t}}}\right]$$

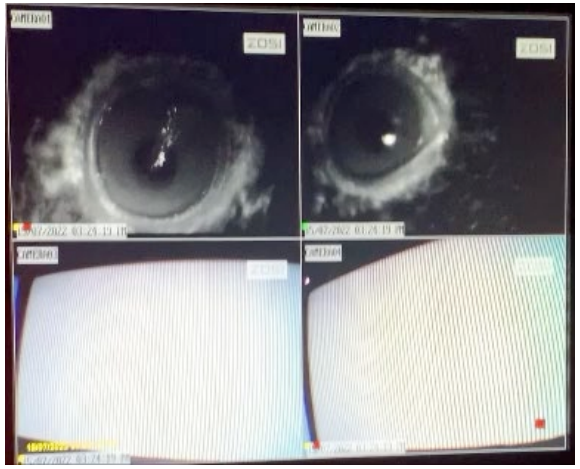
$$N_0 = \left(\frac{\pi}{4}\right) q\tau \int_{\lambda_1}^{\lambda_2} \left(1-e^{-kR(\lambda)l}\right) L_b(\lambda) d\lambda$$

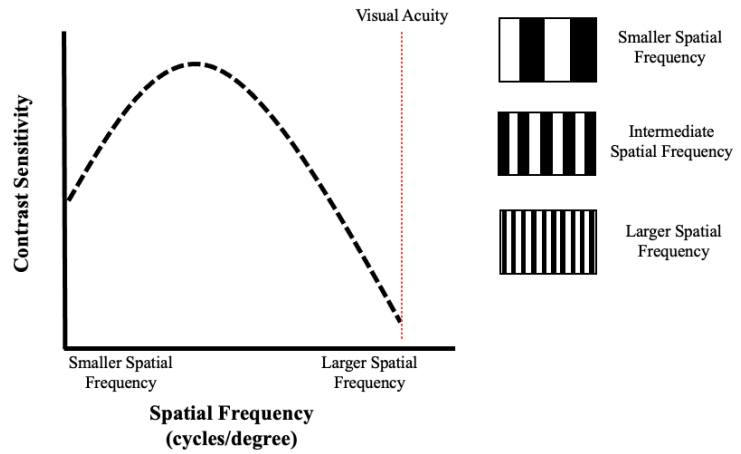
This is a KEY step towards developing new technology

However, we need to characterize two additional Canada goose specific parameters:

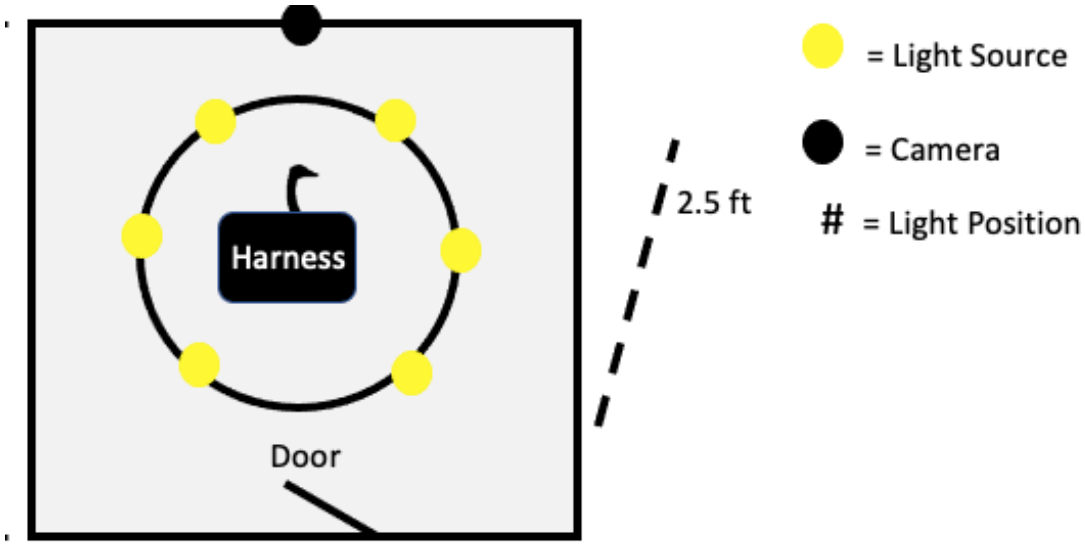
1) Contrast Sensitivity Function



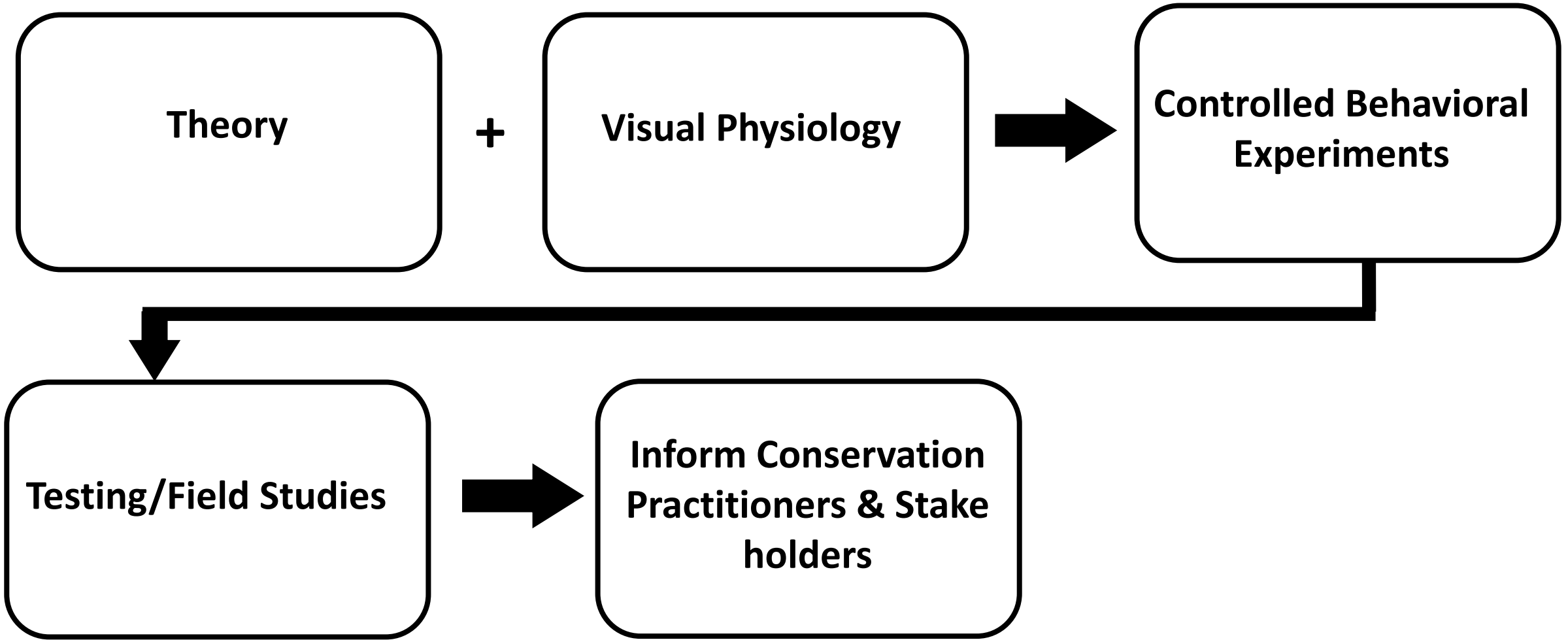




2) Estimate light intensity which evokes a behavioral response



Our general approach: build lights around the avian eye that birds avoid



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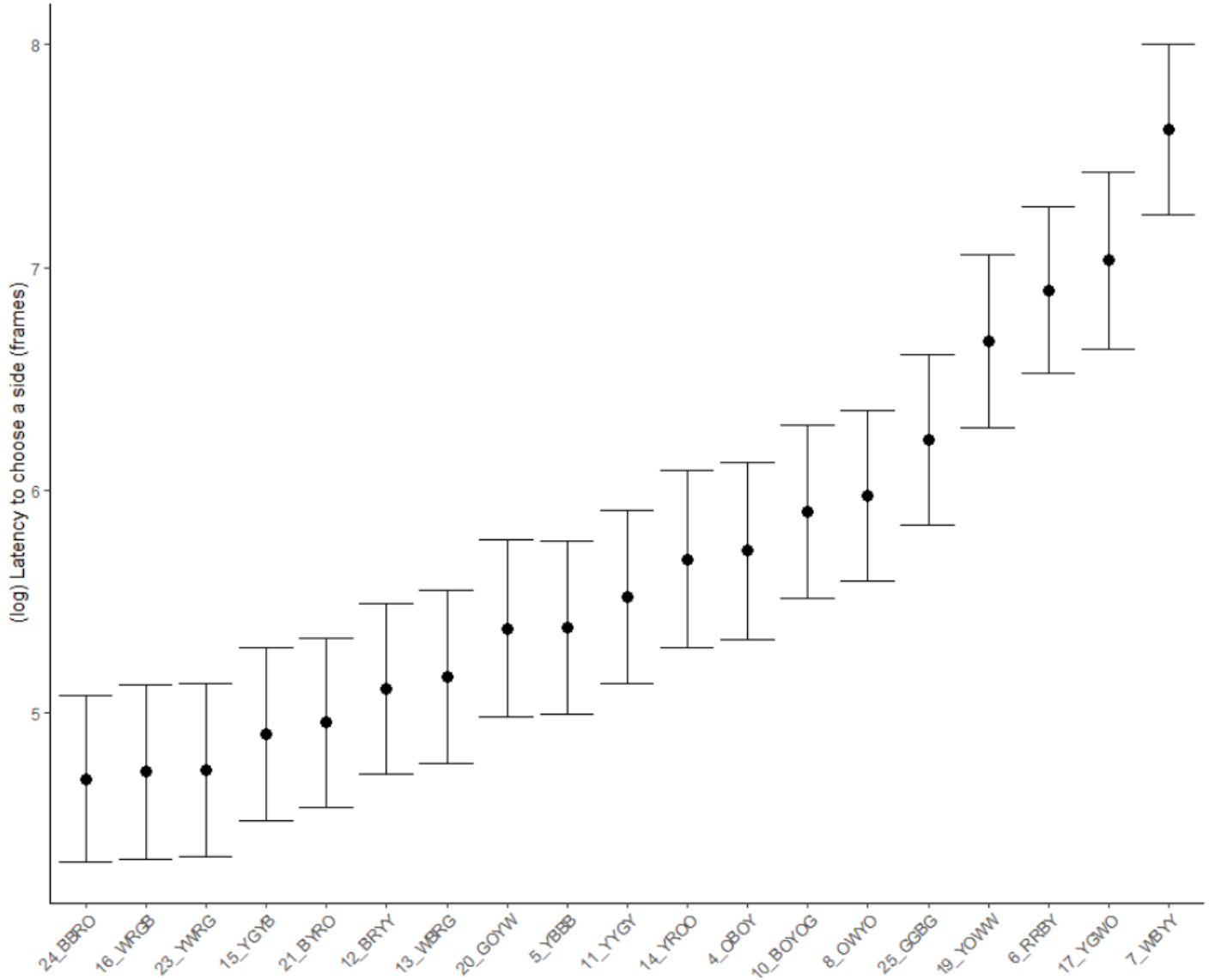
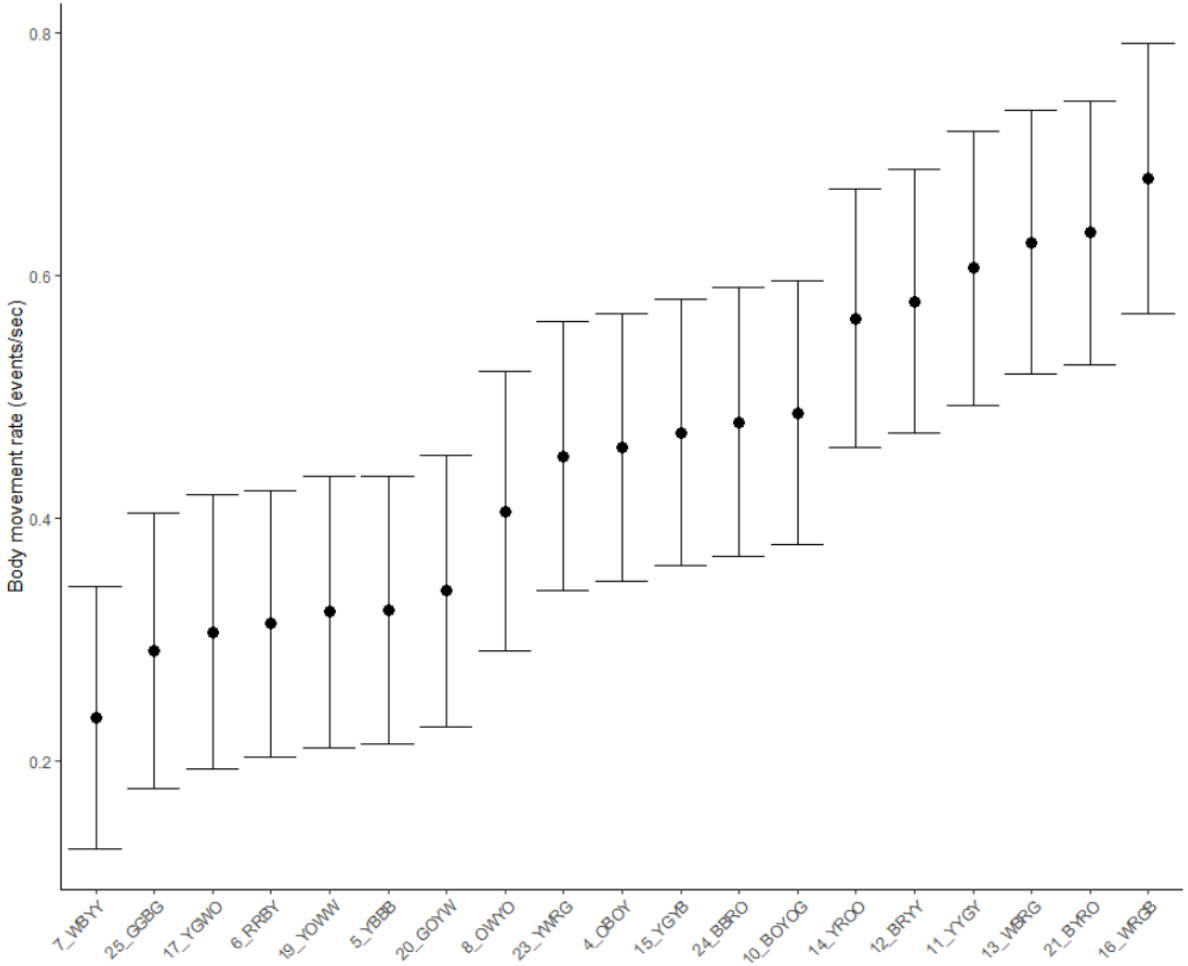
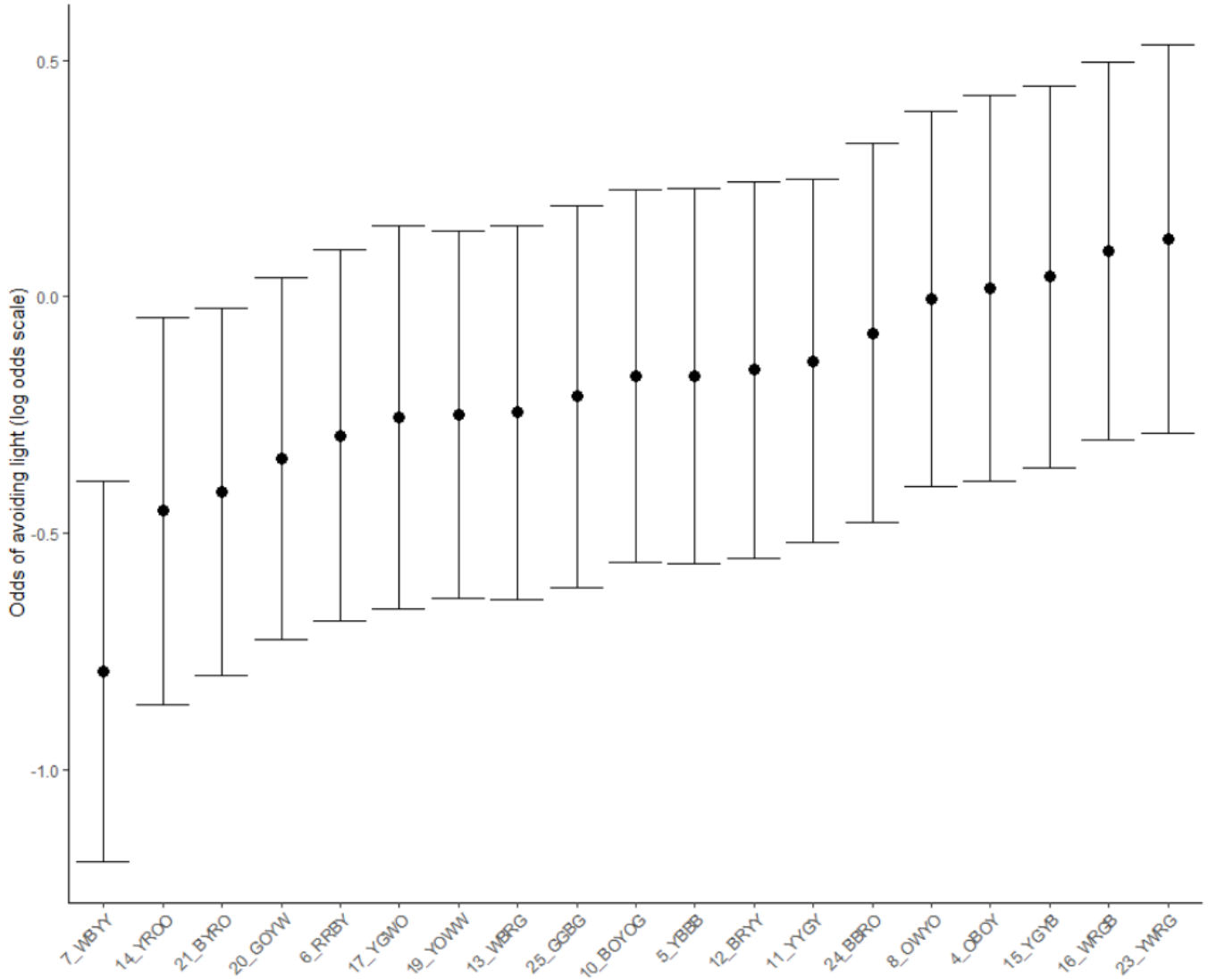
Latency: 46% of the population variance in responses was associated with variation between individuals



Body movement rate: 17% of the population variance in responses was associated with variation between individuals



Avoidance: 6% of the population variance in choice was associated with variation between individuals



Single Choice Test: Experimental Design