# BACKGROUND

### Delayed Visual Feedback

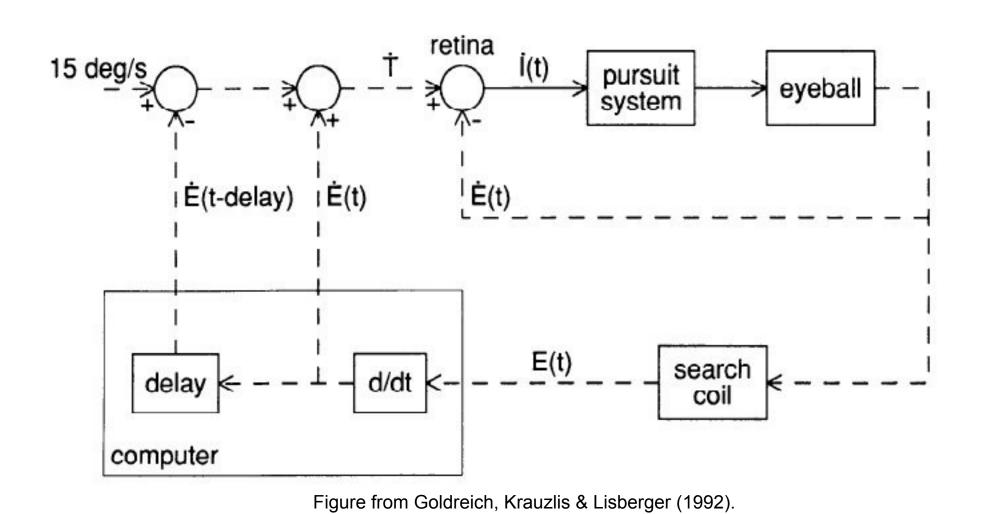
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Effect of Changing Feedback Delay on Spontaneous Oscillations in Smooth Pursuit Eye Movements of Monkeys

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## Theory

e(t)	eye position (EP)
$\mathbf{n}(t)$	target position

 $\dot{\mathbf{e}}(t)$  eye velocity (EV)

 $\dot{\mathbf{p}}(t)$  target velocity

p(t) = e(t)

 $\ddot{\mathbf{e}}(t)$  eye acceleration (EA)  $\ddot{\mathbf{p}}(t)$  target acceleration

$\mathbf{p}(t) = k$	stationary targ

ideal stabilization

 $p(t) = e(t - \varepsilon)$  lab stabilization

p(t) = e(t) + d(t) open-loop

 $p(t) = e(t) - e(t - \delta_2)$  transient stabilization

p(t) - e(t)	retinal position error (RPE)
$\dot{\mathbf{p}}(t) - \dot{\mathbf{e}}(t)$	retinal velocity error (RVE)
$\ddot{\mathbf{p}}(t) - \ddot{\mathbf{e}}(t)$	retinal acceleration error (RAI

# $\ddot{\mathbf{e}}(t) = k_1 \left[ \mathbf{p}(t - \delta_1) - \mathbf{e}(t - \delta_1) \right]$ RPE drives EA

$$\ddot{\mathbf{e}}(t) = k_2 \left[ \dot{\mathbf{p}}(t - \delta_1) - \dot{\mathbf{e}}(t - \delta_1) \right]$$
 RVE drives EA

$$\ddot{\mathbf{e}}(t) = k_3 \left[ \ddot{\mathbf{p}}(t - \delta_1) - \ddot{\mathbf{e}}(t - \delta_1) \right]$$
 RAE drives EA

$$\dot{\mathbf{e}}(t) = k_2 \left[ \mathbf{p}(t - \delta_1) - \mathbf{e}(t - \delta_1) \right]$$
 RPE drives EV

$$\ddot{\mathbf{e}}(t) = k_2 \left| \dot{\mathbf{p}}(t - \delta_1) - \dot{\mathbf{e}}(t - \delta_1) \right|$$
 RVE drive

## **Predictions**

### $p(t) = e(t) - e(t - \delta_2)$ transient stabilization

$$\ddot{\mathbf{e}}(t) = k_1 \bigg[ \mathbf{p}(t - \delta_1) - \mathbf{e}(t - \delta_1) \bigg] \qquad \text{RPE drives EA}$$

$$\ddot{e}(t) = k_1 \left[ e(t - \delta_1) - e(t - \delta_1 - \delta_2) - e(t - \delta_1) \right]$$

$$\ddot{\mathbf{e}}(t) = -k_1 \mathbf{e}(t - \delta_1 - \delta_2)$$

$$\ddot{\mathbf{e}}(t) = -k_1 \, \mathbf{e}(t - \delta)$$

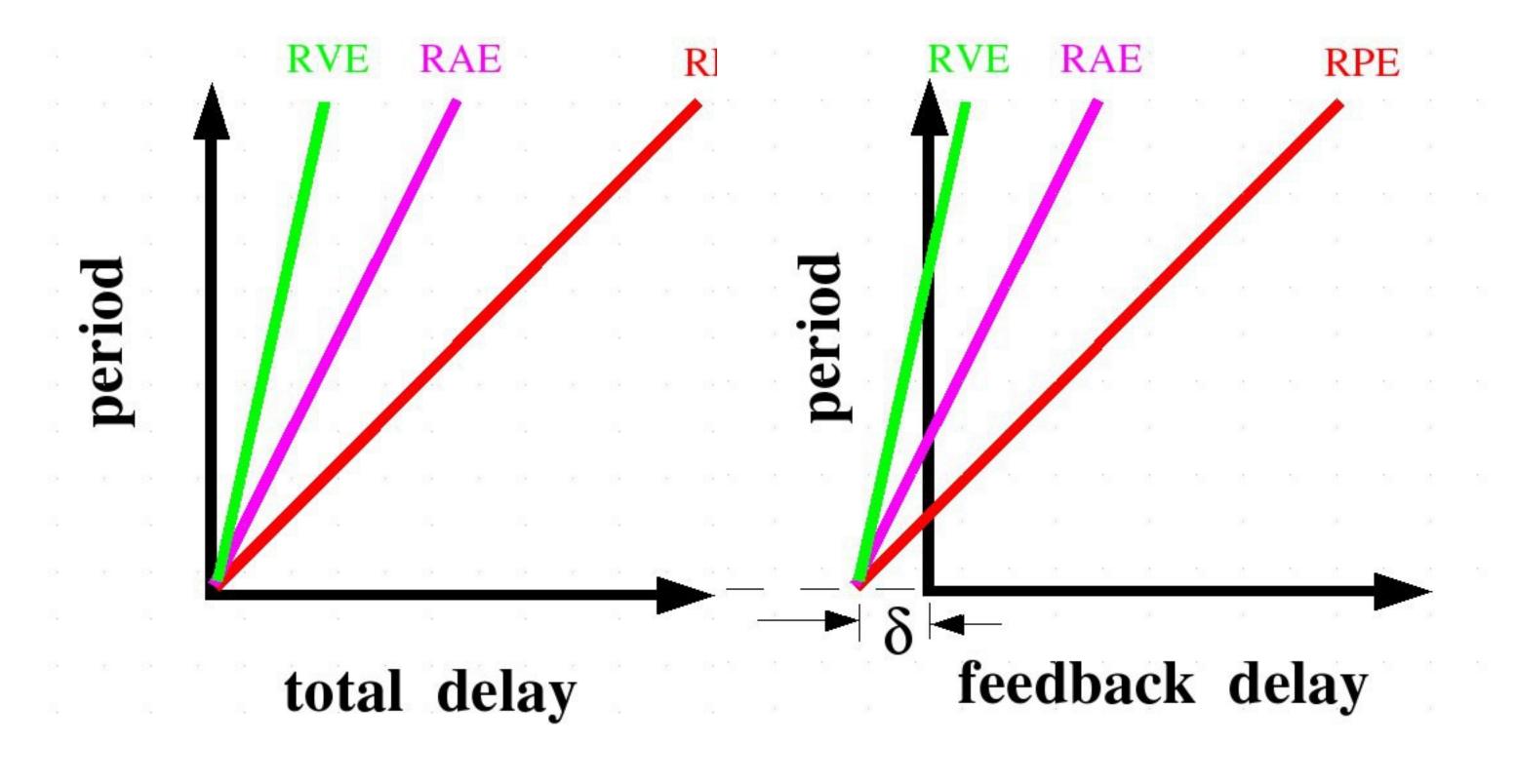
 $\lambda = \delta$  RPE drives EA

 $\lambda = 4\delta$  RVE drives EA

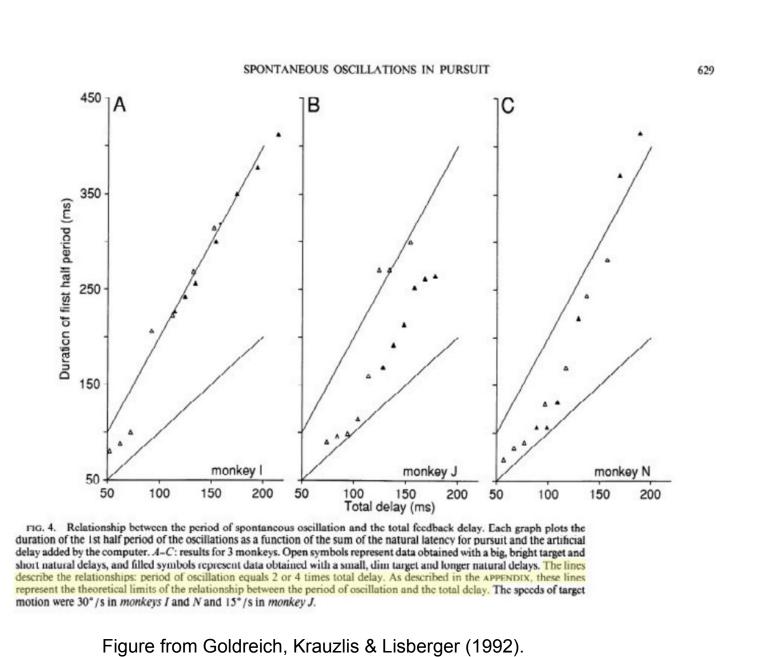
 $\lambda = 2\delta$  RAE drives EA

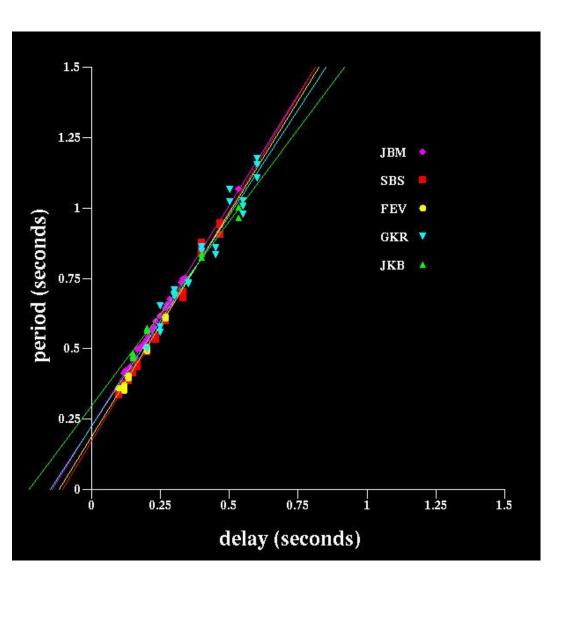
$$\lambda = \frac{4\delta}{4n + 2 - N_d}$$

 $\lambda = \frac{4}{3} \delta$  RPE drives eye jerk



### Results





# tions



BIG QUESTION:

Can we demonstrate a positiondriven pursuit response for certain classes of stimuli?

### Approach:

Delayed Visual Feedback (see Background panel at left)

### Motivation:

Previous work suggests pursiuit responses combine signals from volunatry and reflexive pathways with different properties, which respond to different stimuli.

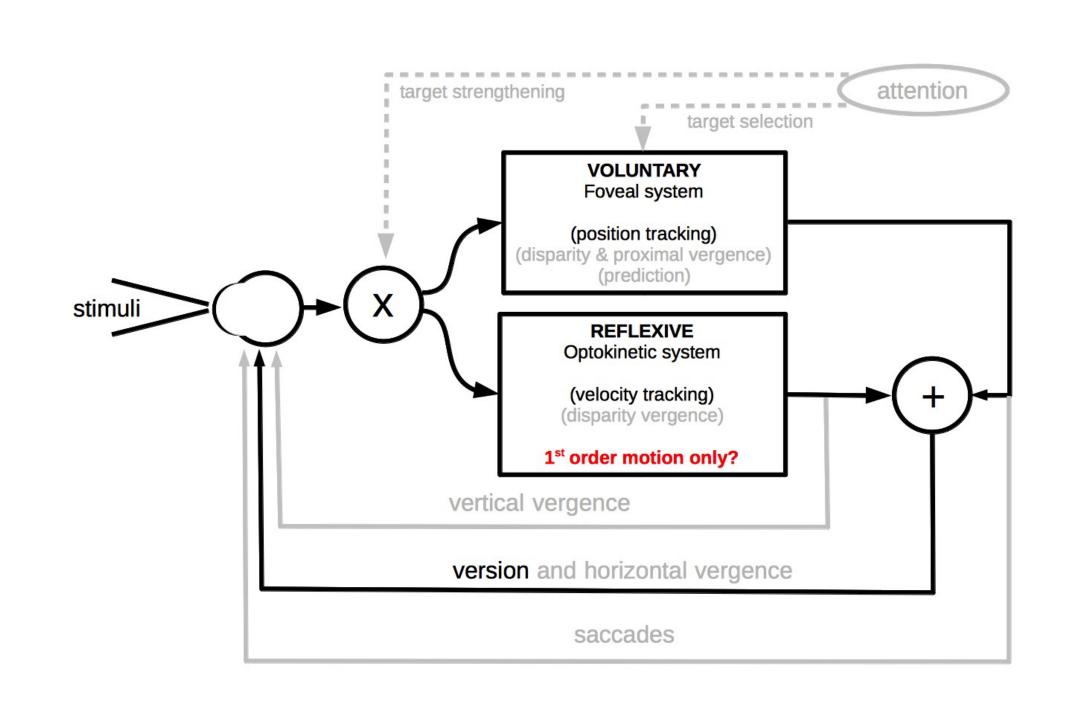


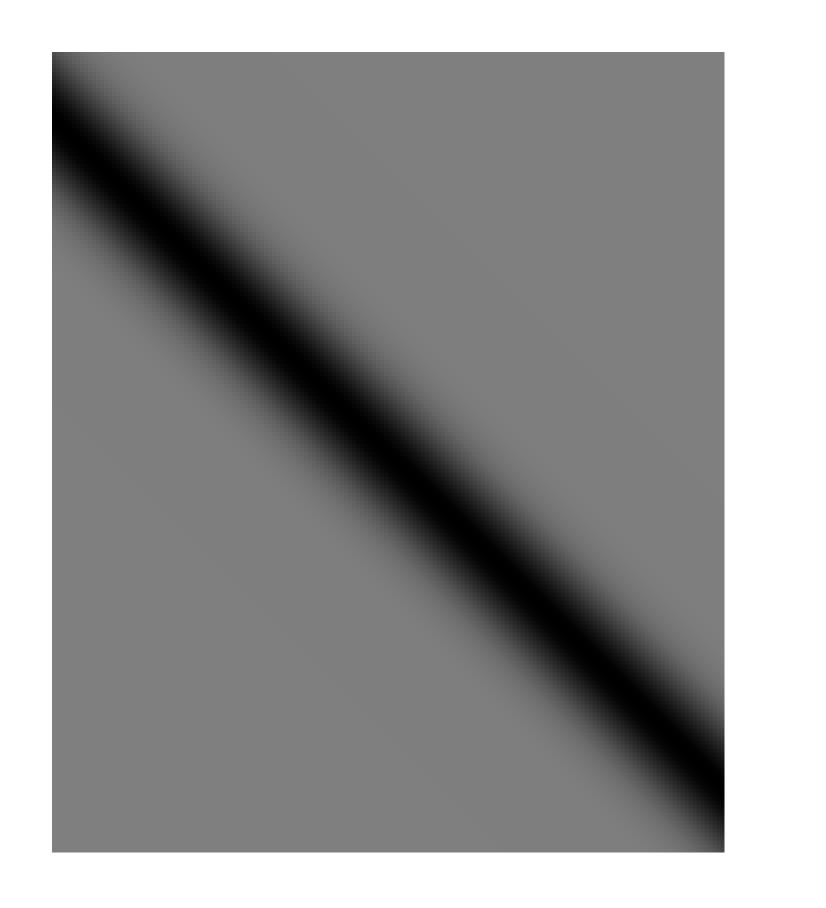
Figure from Mulligan, Stevenson & Cormack (2013), showing proposed architectural model of pursuit control system, with portions relevent to this poster highlighted.

# Stimuli

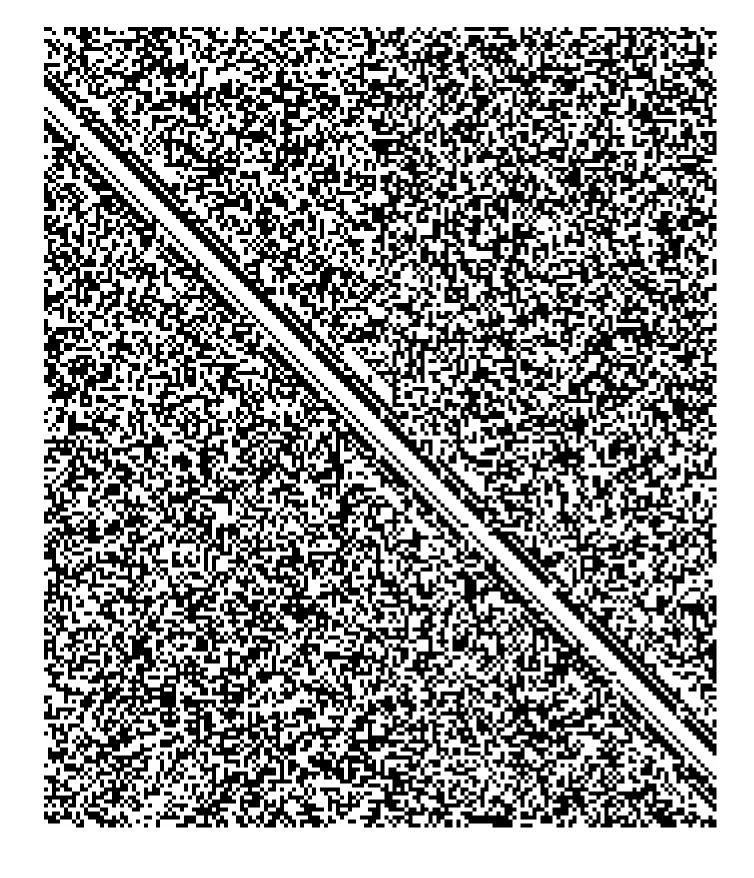
Space-time plots showing time (top-to-bottom), and one spatial dimension for the four classes of stimuli studied.

Jeffrey B. Mulligan

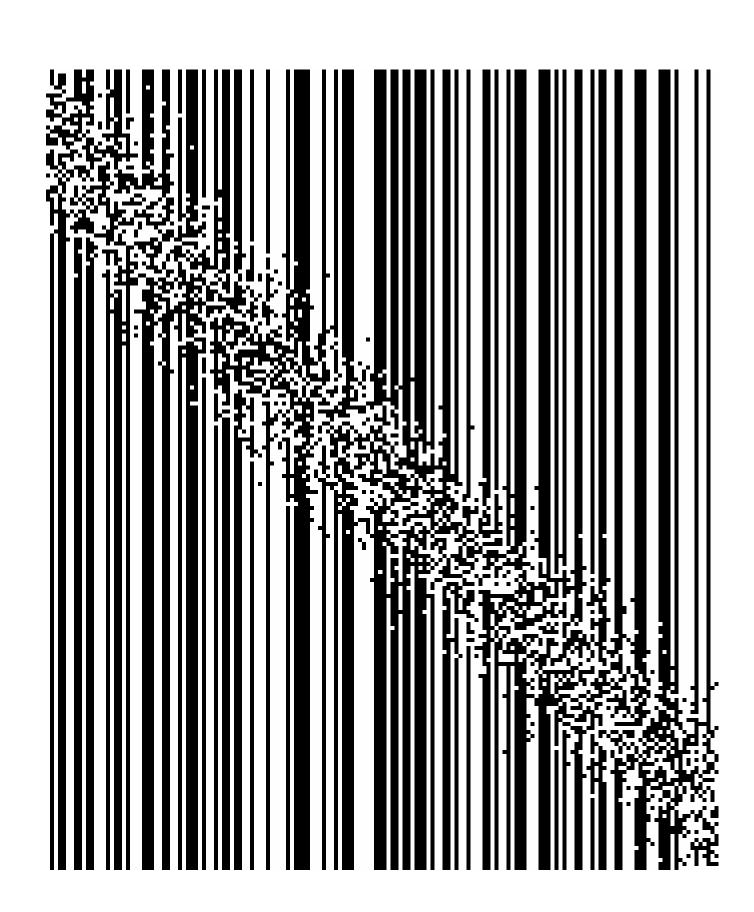
NASA Ames Research Center



black

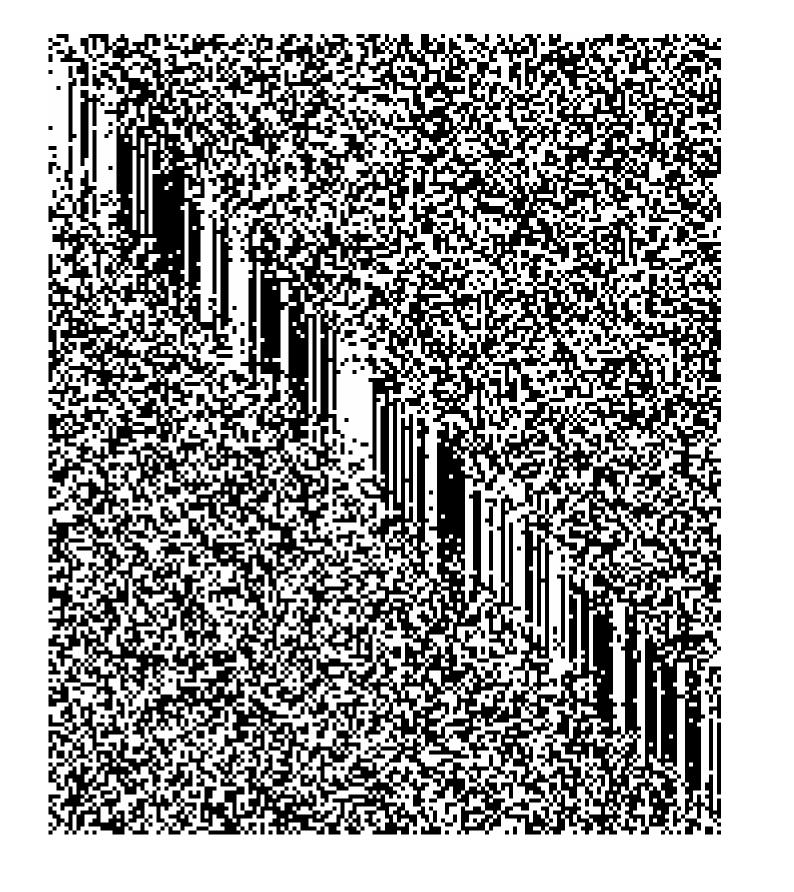


reged"



Smooth pursuit of flicker-defined motion

"Ewille"

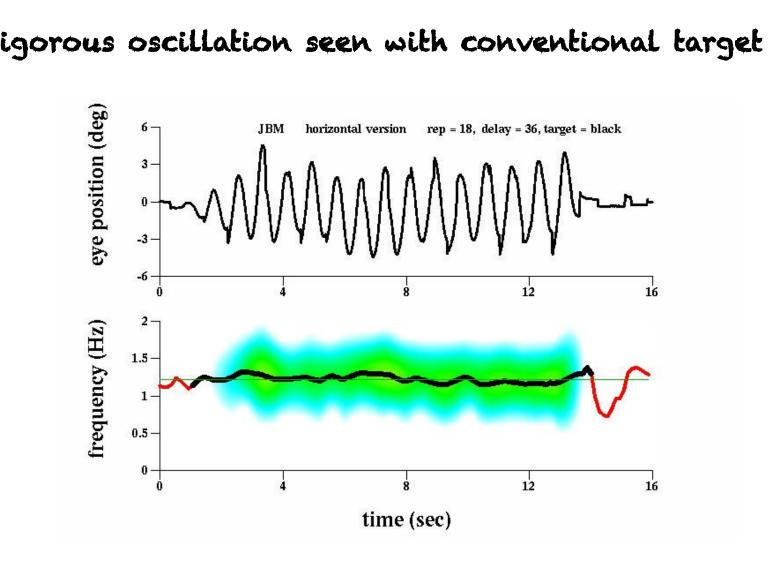


sealic

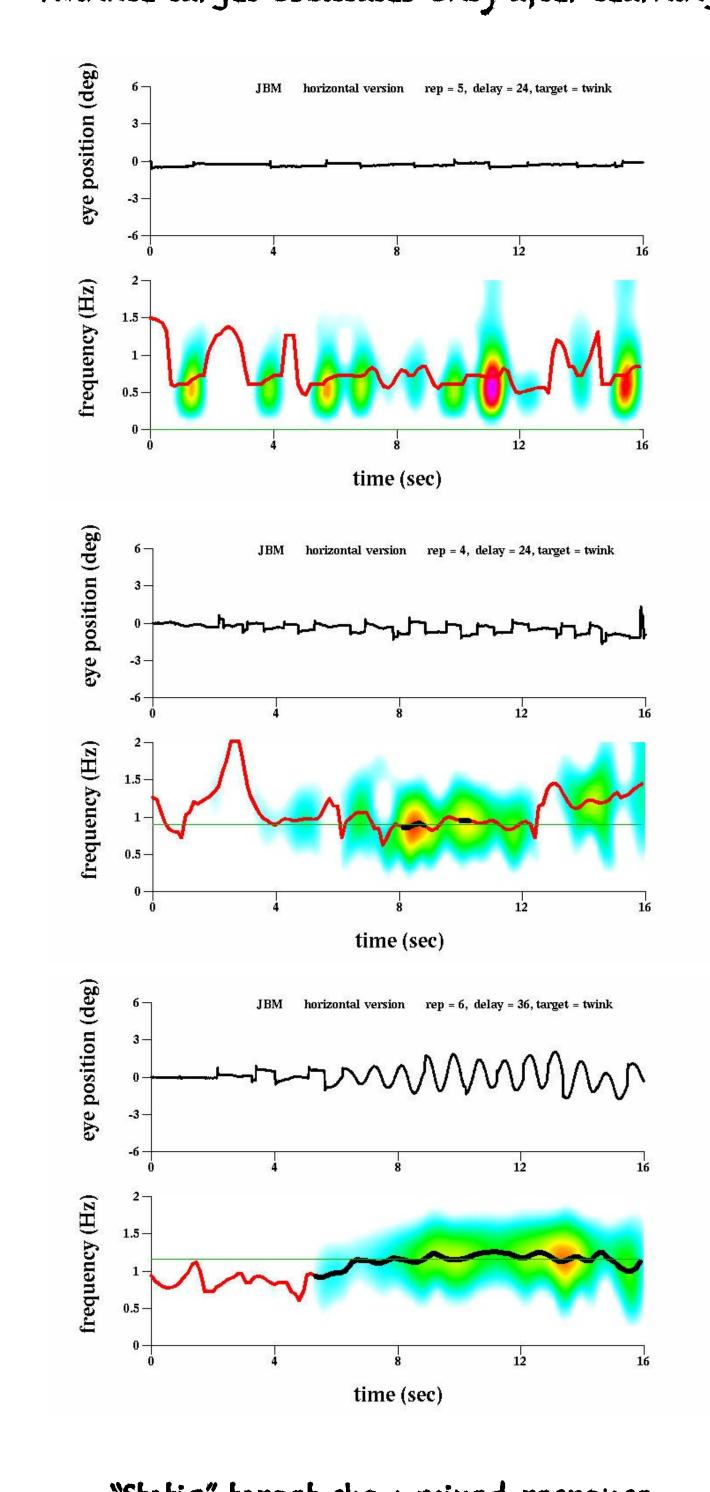
# Trials

Scott B. Stevenson

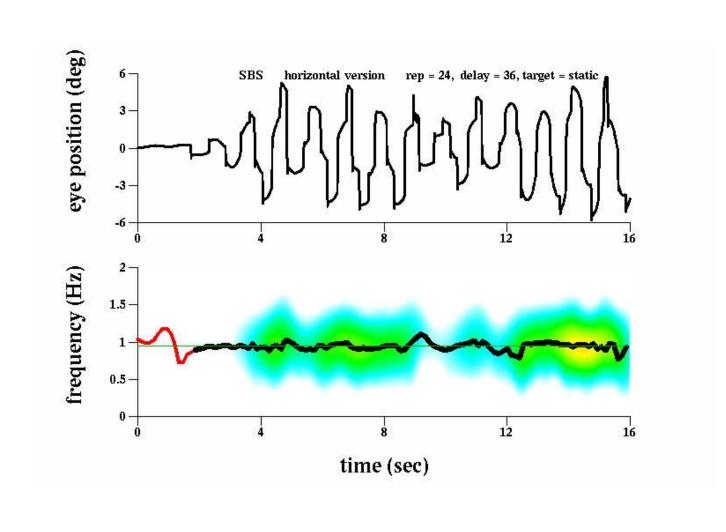
University of Houston College of Optometry



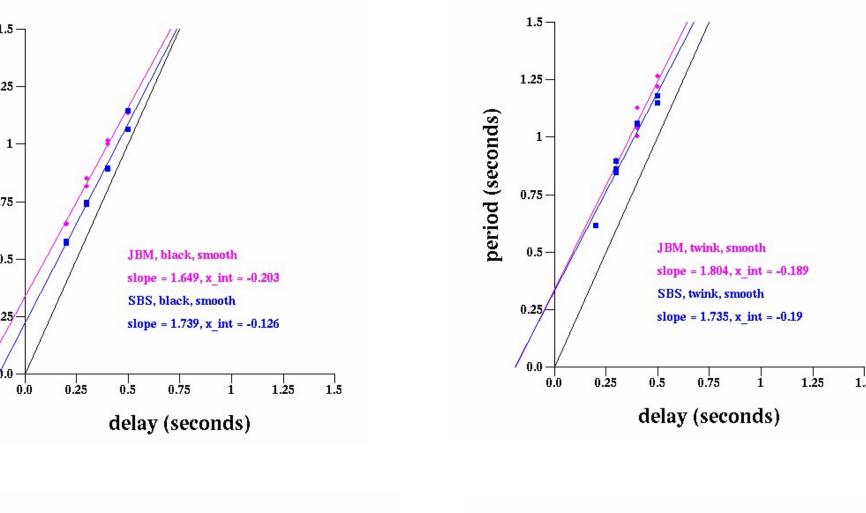
Twinkle target oscillates only after learning

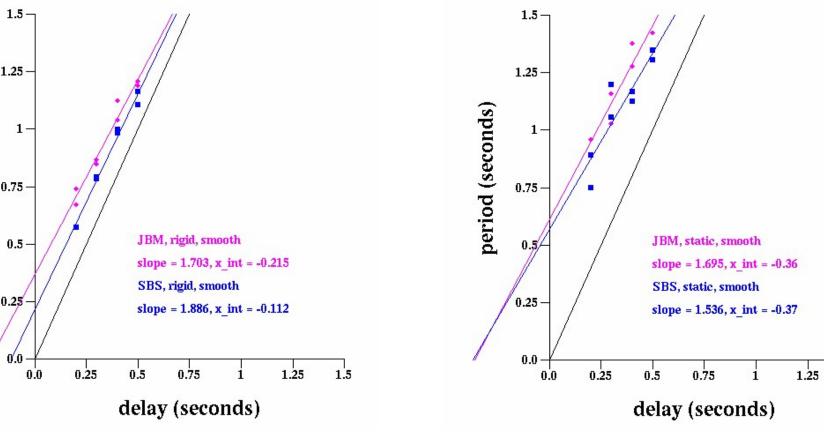


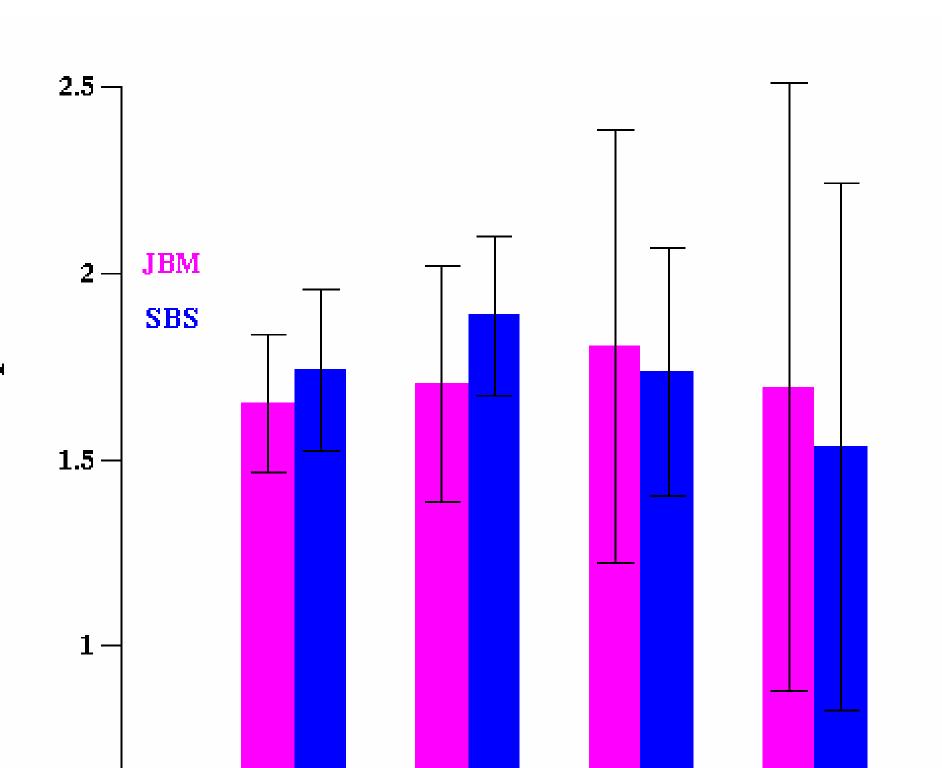
"Static" target show mixed response



# CESULES









# CONCLUSION

Can we demonstrate a position-Driven pursuit response for certain Classes of stimuli?

TODAY'S ANSWER: Not yet...

# Ceferences

oscillations in smooth pursuit eye movements in monkeys." J. Neurophysiol., **67**(3), 625-638.

Mulligan, J. B., Stevenson, S. B., and Cormack, L. K. (2013). "Reflexive and voluntary control of smooth eye movements." in Rogowitz, B.E. Pappas, T.N., and de Ridder, H. (eds.), *Human Vision and Electronic Imaging XVIII*, Proc. SPIE, v. 8651.