Retinal Motion and Visual Sensitivity During Smooth Pursuit

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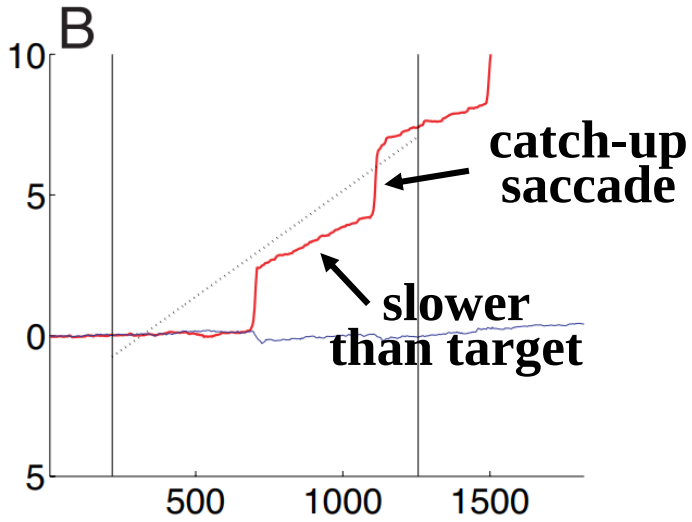
OUTLINE

- Background & Scientific Questions
- Experimental Paradigms & Data
- Characteristics of Retinal Image Motion
- Retinal Image Motion Affects Visual Sensitivity
- Summary
- Inconsistency Issue

Background: What is Smooth Pursuit

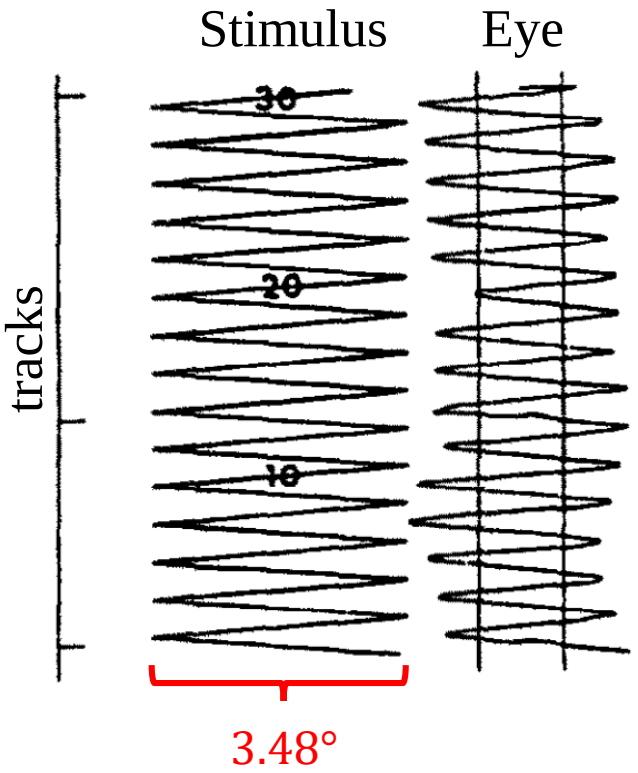
- Smooth pursuit allows the eyes to keep a moving target on the fovea
- Eye velocity is often slower than that of the target (see Lisberger et al, 1987 for review)
  - Result in retinal image slip and catch-up saccades
- How does retinal image motion during pursuit affect visual sensitivity?



Spering et al, *JOV*, 2005

Background: Visual Sensitivity

- Higher target speed => higher retinal image speed
- Higher retinal image speed => lower sensitivity to 5.14 cpd



- Grating: 5.14 cpd, 1.36° × 1.36°

Grating and Target Move Together

Table 2. Mean pattern threshold contrast (%) and retinal image speed of subjects *RS* and *EK* during smooth pursuit of targets moving at several speeds (*stimulus*)

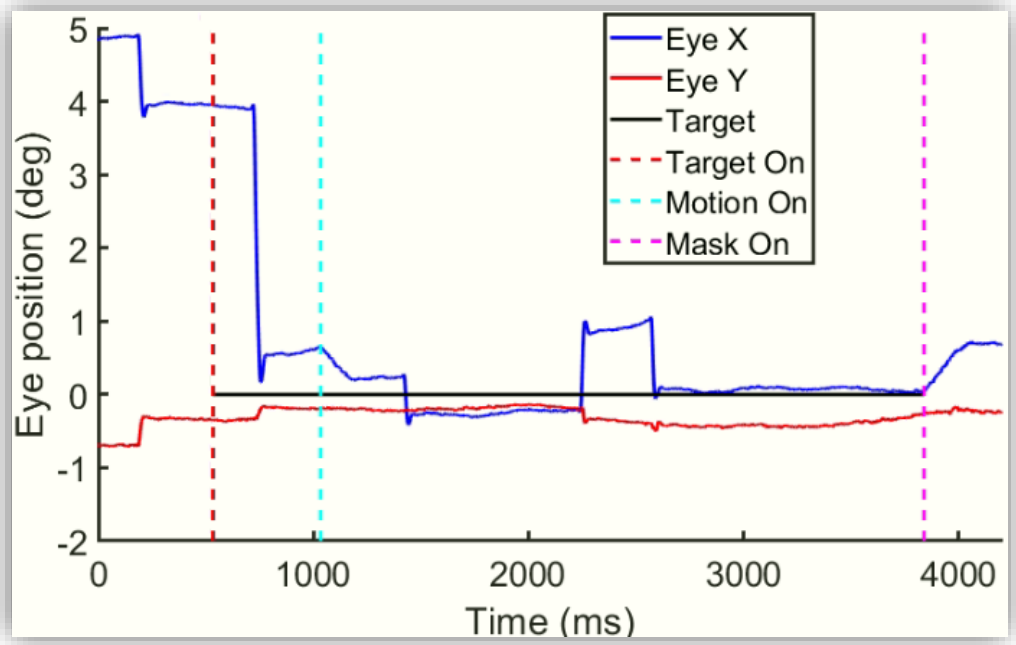
	Stimulus (min arc/sec)	*N*	Image (min arc/sec)	*N*
Subject *RS*	0	18		
	51.1	10	5.4 (3.4)	52
	141.5	10	8.6 (6.9)	77
	232.4	10	21.6 (16.0)	115
	322.5	10	38.1 (23.7)	139
	412.4	10	63.3 (36.4)	159
Subject *EK*	0	21		
	49.5	12	4.7 (3.2)	47
	138.1	12	15.8 (11.2)	83
	226.0	12	27.0 (18.0)	79
	311.6	12	56.0 (36.7)	85
	402.4	12	76.7 (46.0)	97

Murphy, *Vision Research*, 1978

Background: Scientific Questions

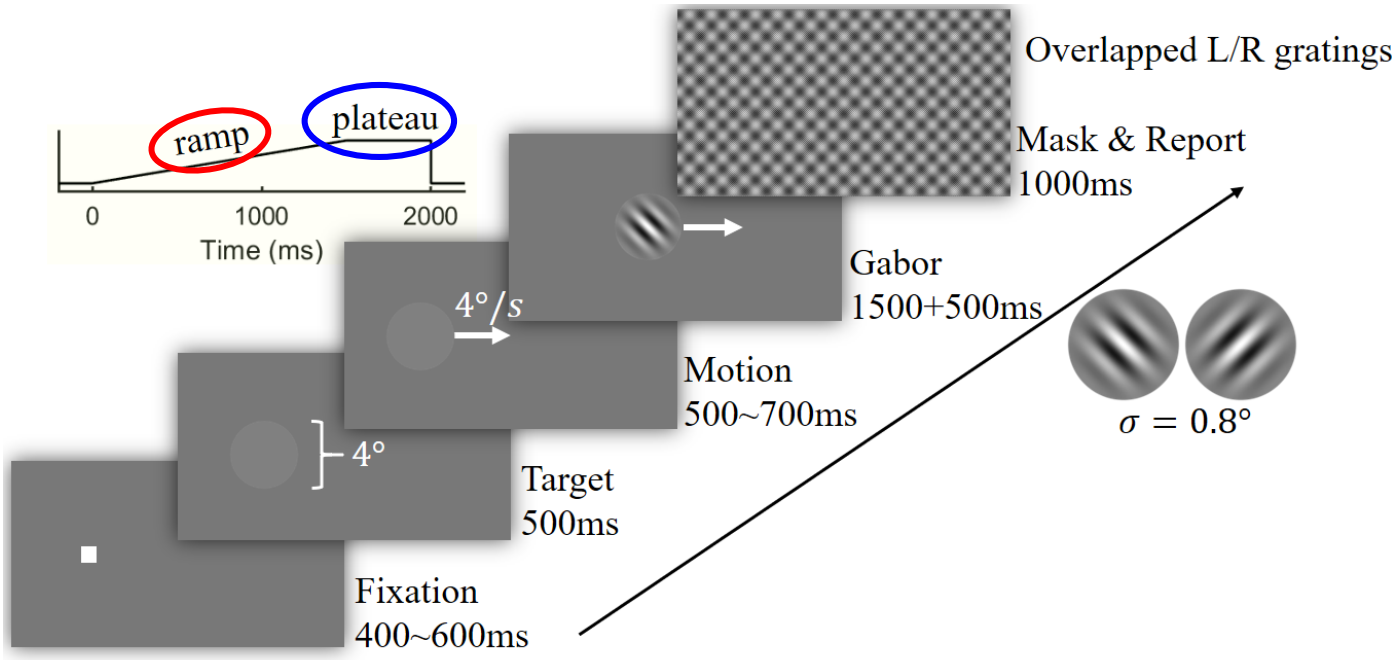
- Contrast sensitivity is modulated by retinal image motion resulted from **inaccurate** pursuit
- However, there are still retinal motion and saccades even when pursuit is very **accurate**

- **What are the characteristics of retinal image motion during accurate smooth pursuit?**
- **For accurate pursuit, how does retinal image motion affect visual sensitivity?**
  - **Hypothesis:** The more the retinal motion, the higher sensitivity to low SF and lower sensitivity to high SF



Experimental Paradigms

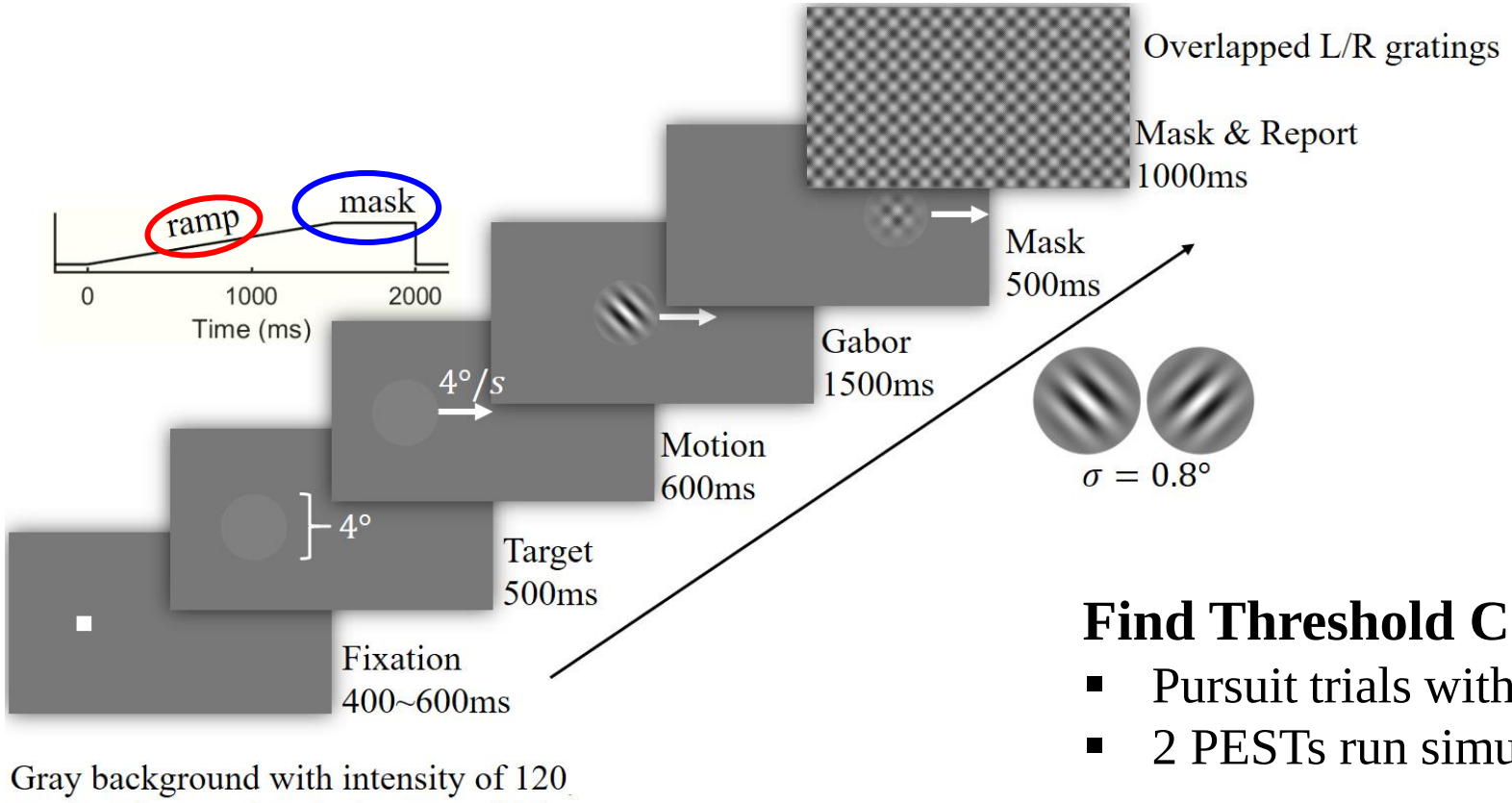
Task 1



Gray background with intensity of 120

Experimental Paradigms

Task 2



Gray background with intensity of 120

Following analyses mainly focus on the **ramp period**

Find Threshold Contrast:

- Pursuit trials with 1cpd / 10cpd interleaved
- 2 PESTs run simultaneously

Collect Data at Threshold:

- Fixation / pursuit with 1cpd / 10cpd interleaved
- Fixed contrast level for 1cdp / 10cpd
- 52 trials each block

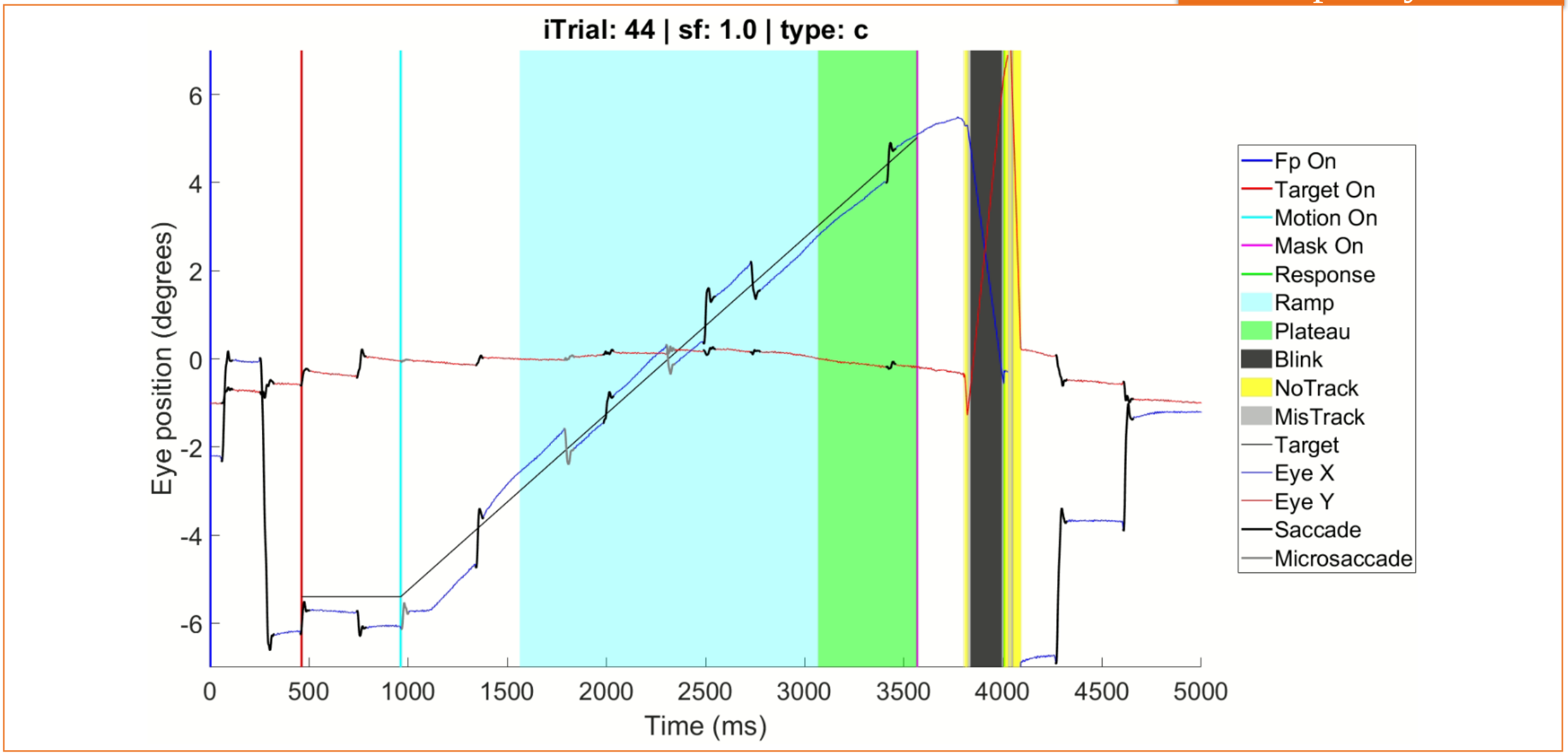
Experimental Paradigms

Data Collected

	Task	Target Ratio	1 cpd		10 cpd	
			Fixation	Pursuit	Fixation	Pursuit
Bin	Task 1	90%	195	168	191	161
Maruti	Task 1	90%	184	140	180	144
Sam	Task 1	90%	321	309	321	306
Paul	Task 2	90%, 80%	107	95	113	106
A123	Task 2	80%	195	185	183	185
A158	Task 2	80%	239	224	239	223
A198	Task 2	80%	163	118	149	98

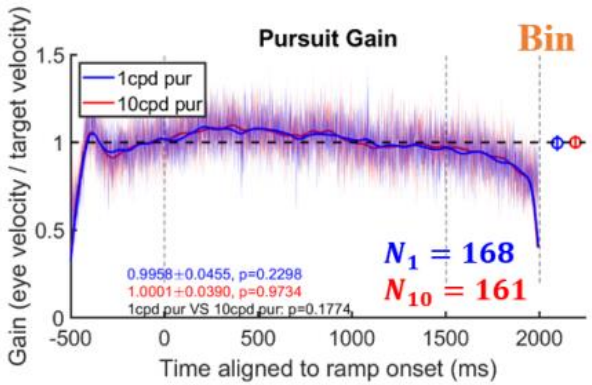
Results: Characteristics of Retinal Image Motion

Example Eye Trace



Results: Characteristics of Retinal Image Motion

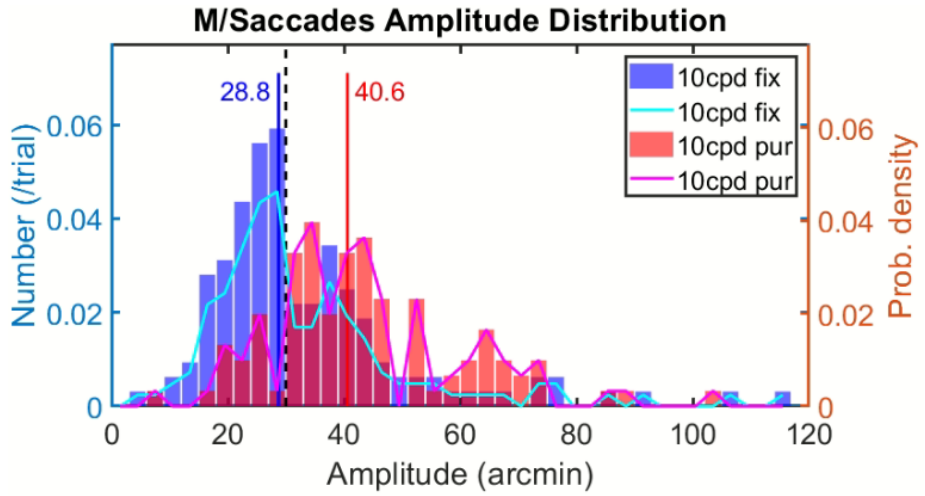
Pursuit Gain: v_E / v_T

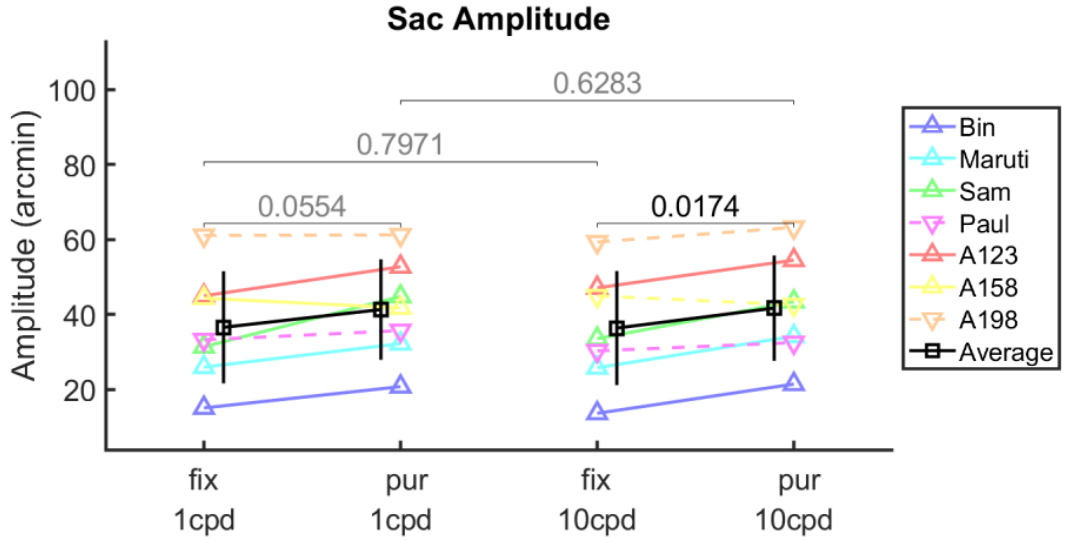


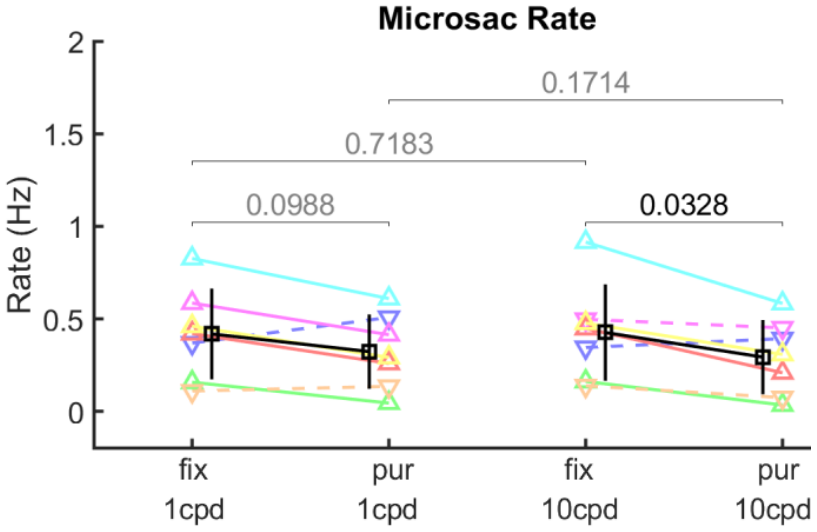
Results: Characteristics of Retinal Image Motion

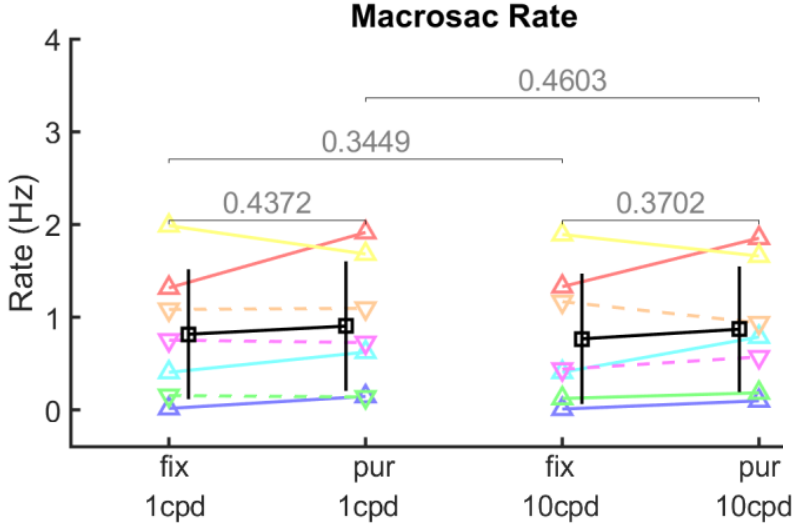
Saccades

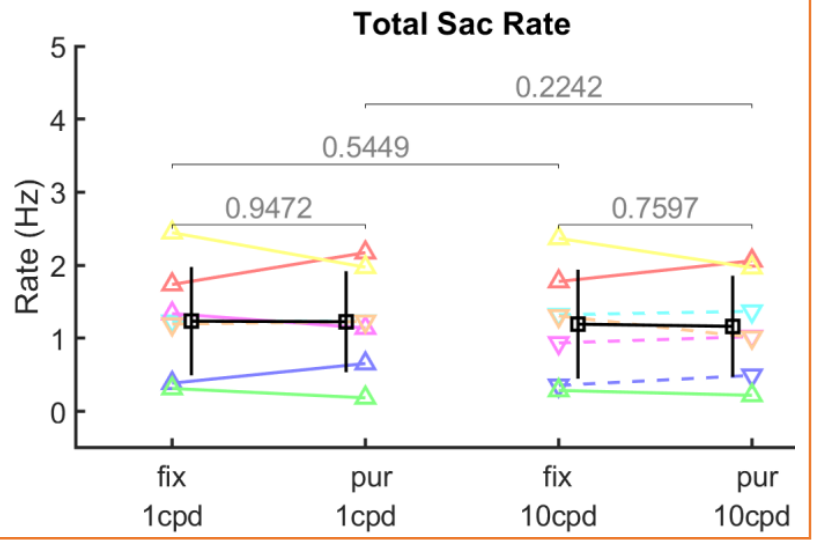
- Pursuit leads to greater saccade amplitude, consistently, less micro- but more macro-saccades







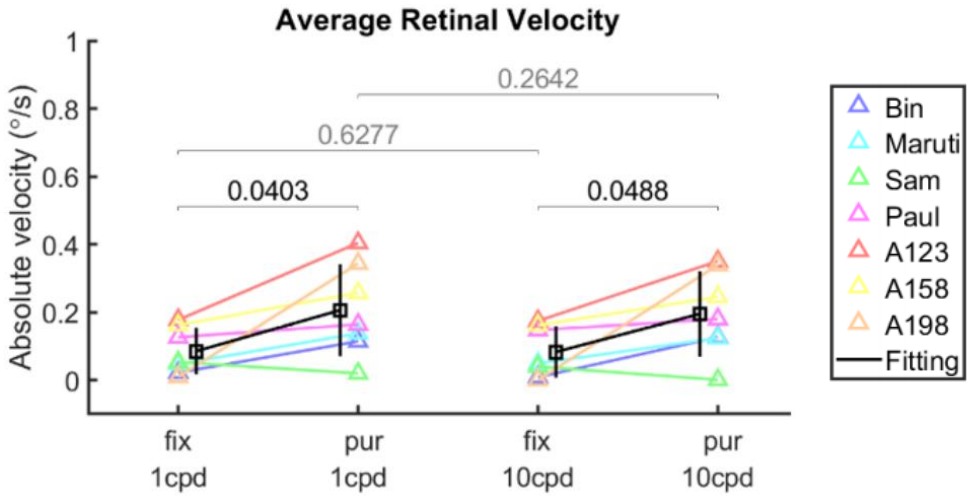


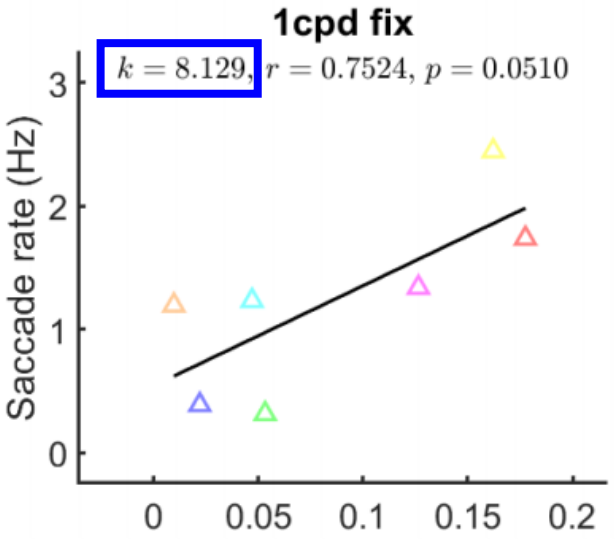


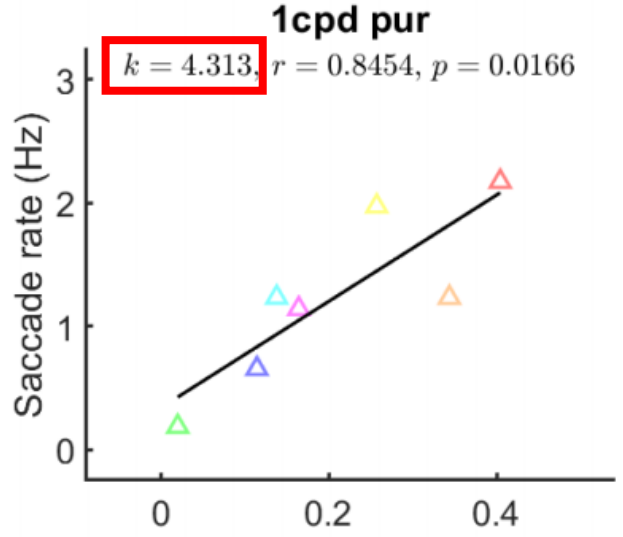
Results: Characteristics of Retinal Image Motion

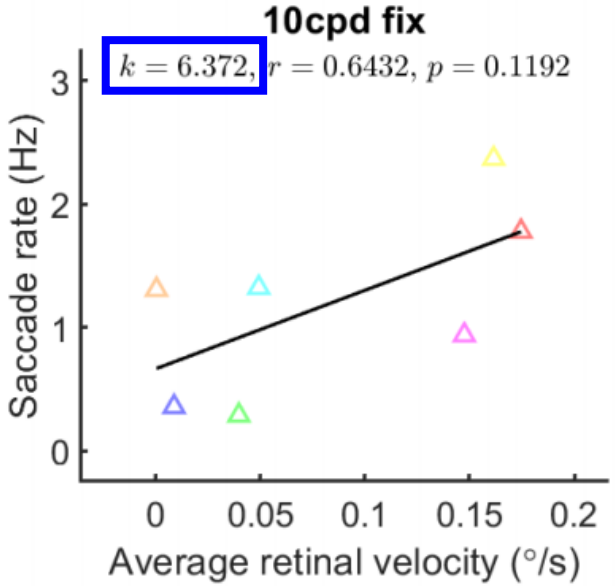
Retinal Velocity

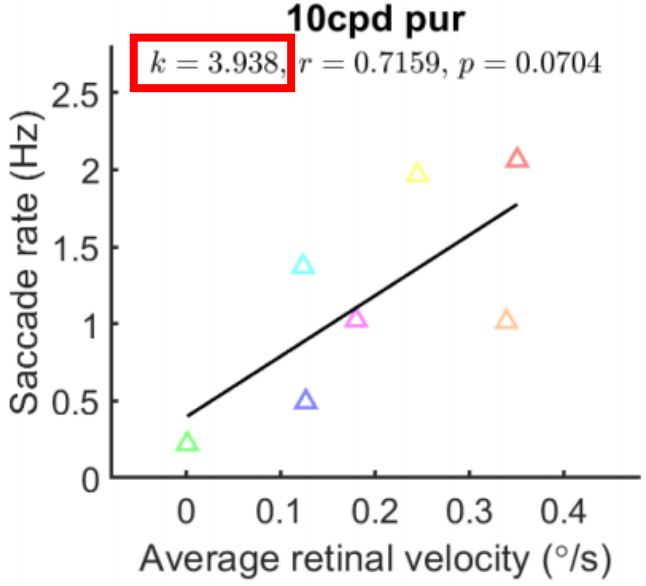
- Retinal velocity is higher in pursuit
- Saccade rate correlates with retinal velocity
- Slope is ~half in pursuit







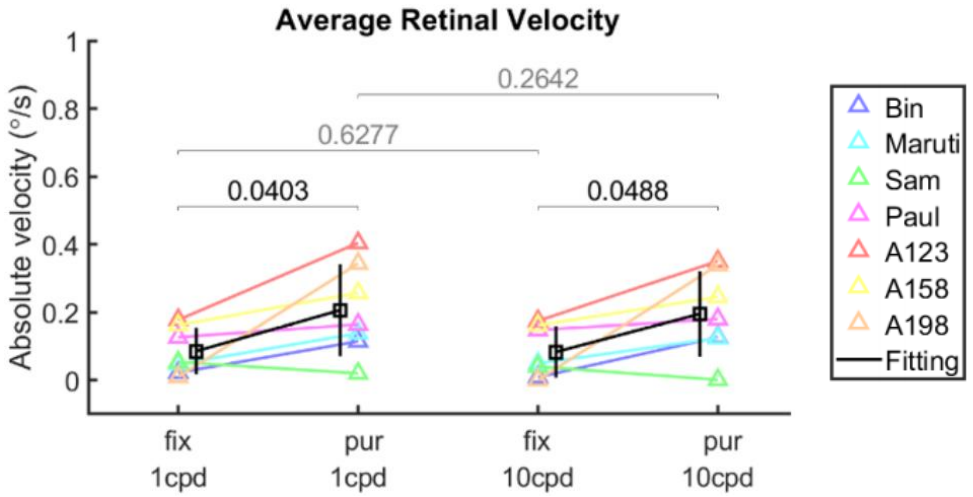


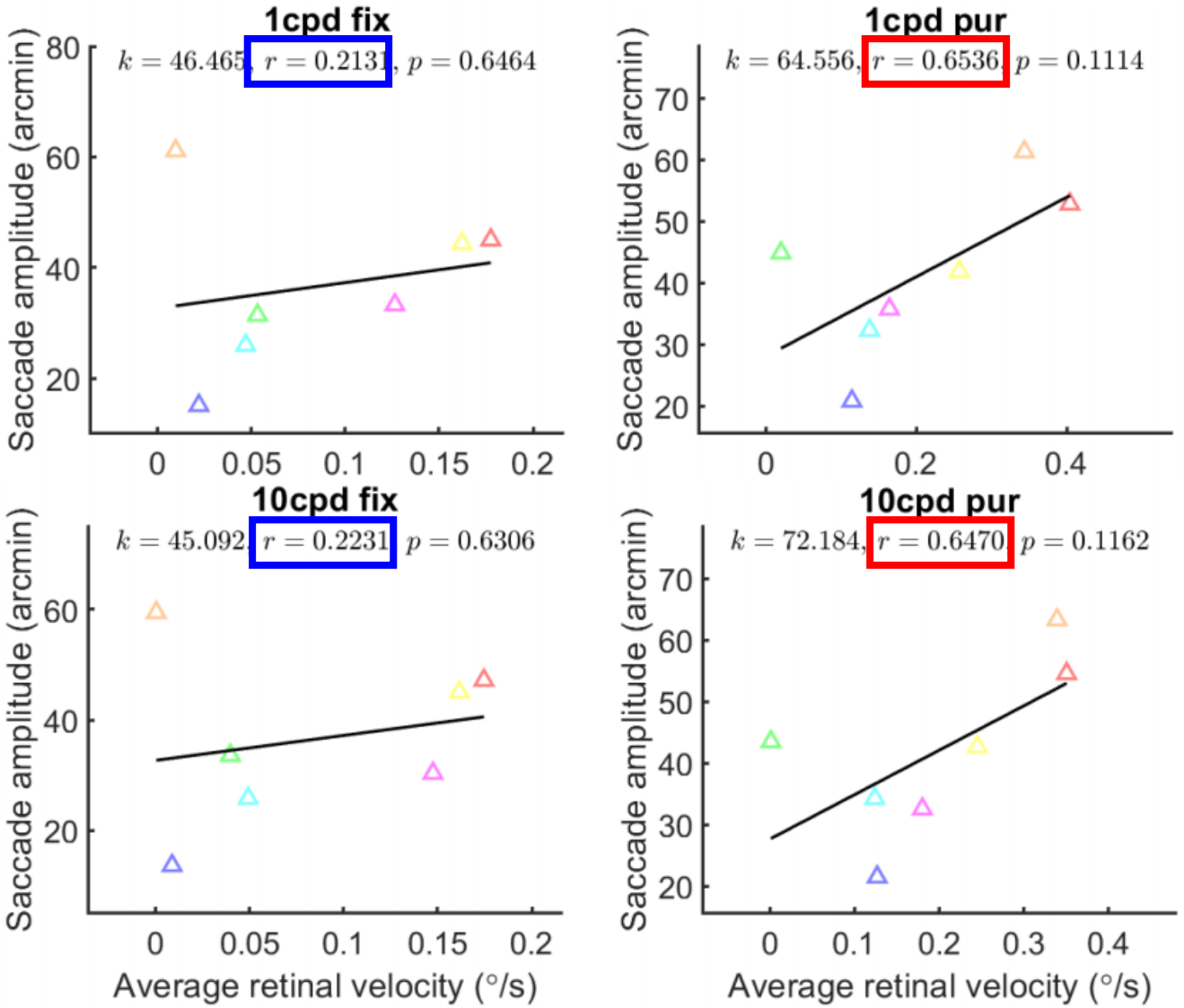


Results: Characteristics of Retinal Image Motion

Retinal Velocity

- Retinal velocity is higher in pursuit
- Saccade amplitude correlates with retinal velocity, especially in pursuit

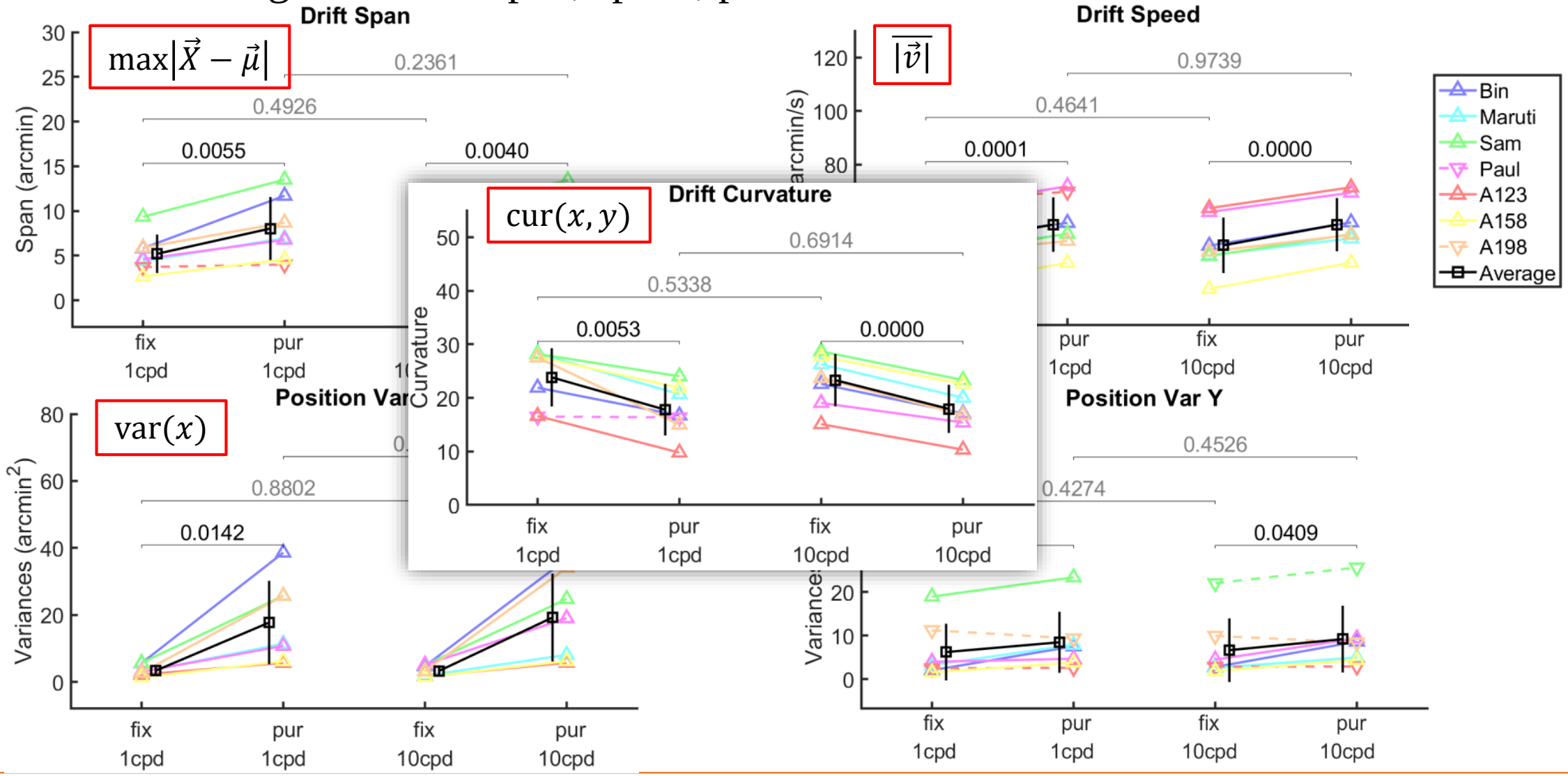




Results: Characteristics of Retinal Image Motion

Drift Characteristics

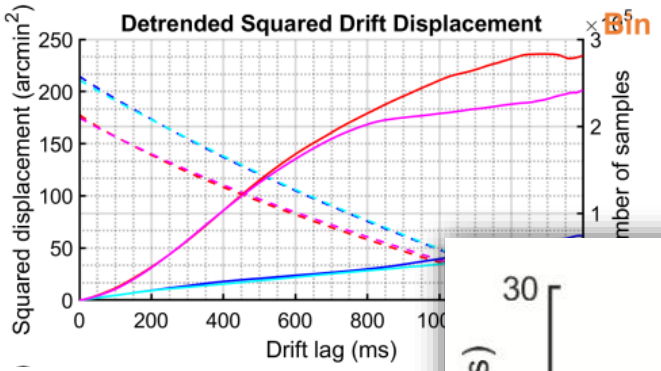
- Pursuit leads to greater drift span, speed, position variance and less curvature

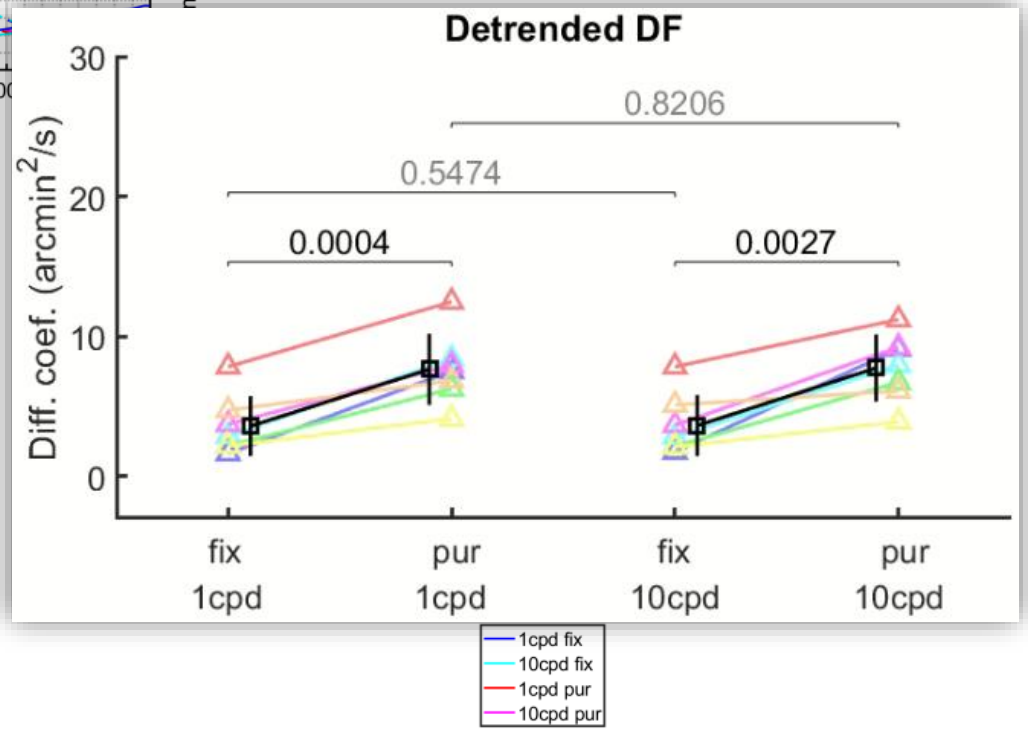


Results: Characteristics of Retinal Image Motion

Diffusion Coefficient

- Brownian motion: $\vec{x}(t) \sim N(0, 4Dt)$ => $\text{mean}(|\vec{x}(t)|^2) \propto t$





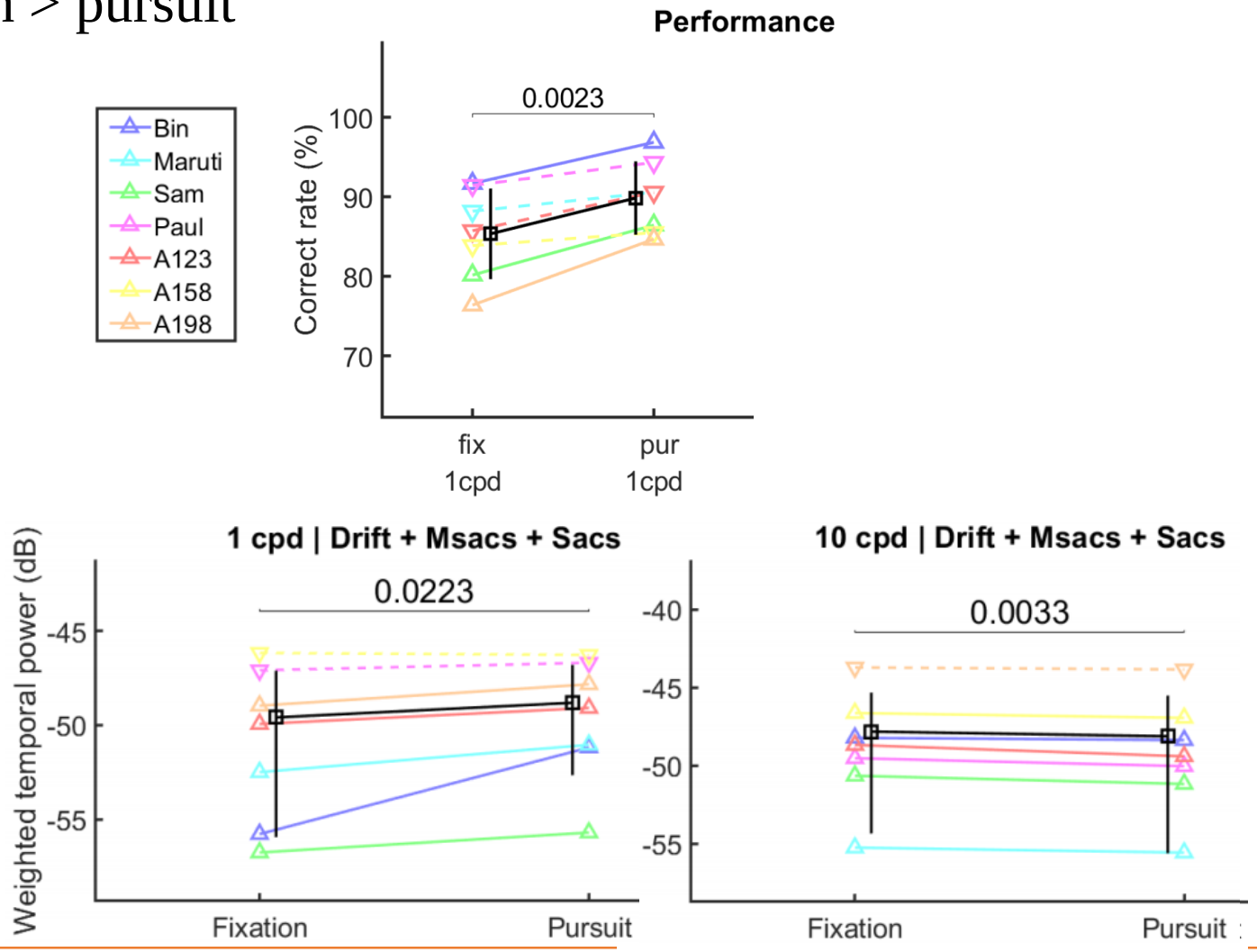
Interim Summary

- Pursuit gain is near unity for all subjects
- Saccade rate correlates with retinal velocity across subjects
- Saccade amplitude is greater during pursuit and correlates with retinal velocity
- Pursuit leads to stronger retinal image motion
- **How does retinal image motion during pursuit modulate visual sensitivity?**

Results: Visual Sensitivity

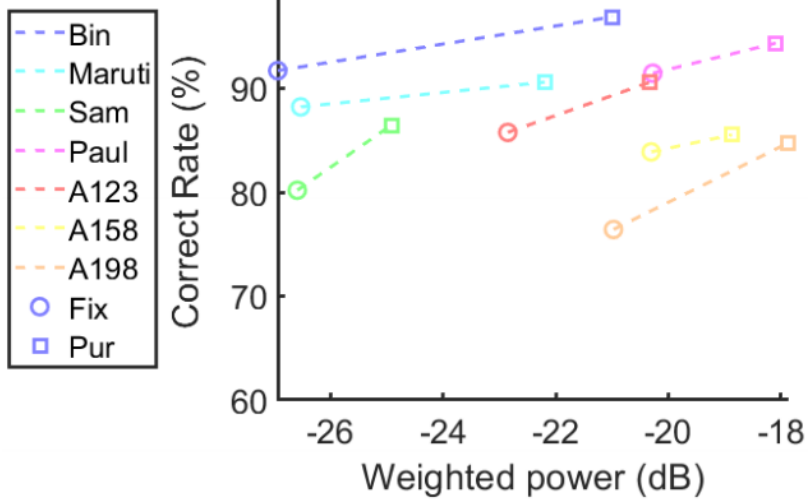
Correct Rate VS Power

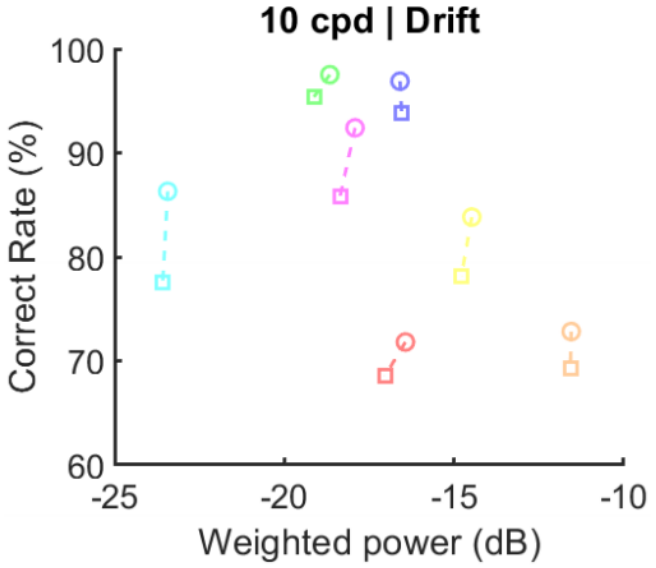
- 1 cpd: pursuit > fixation
- 10 cpd: fixation > pursuit

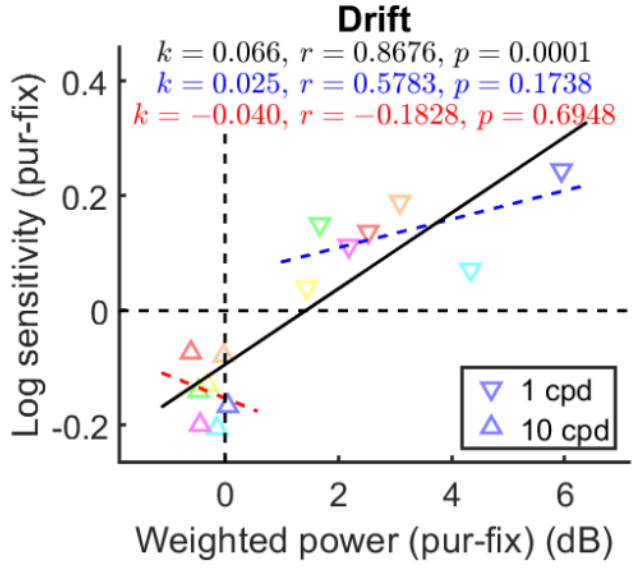


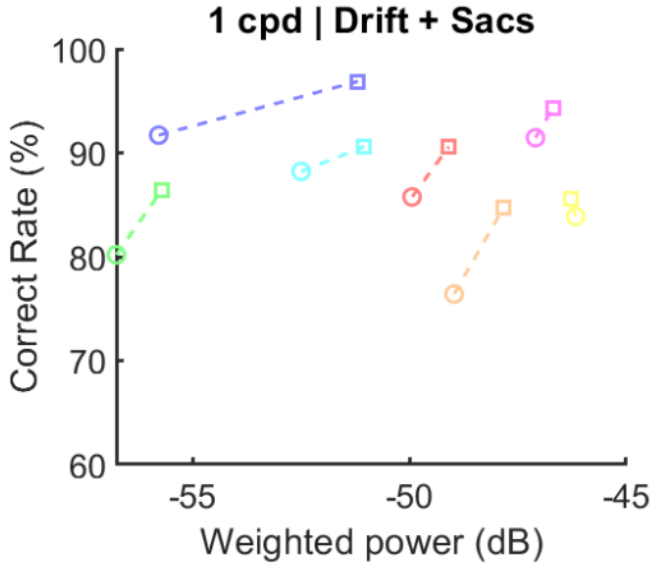
Results: Visual Sensitivity

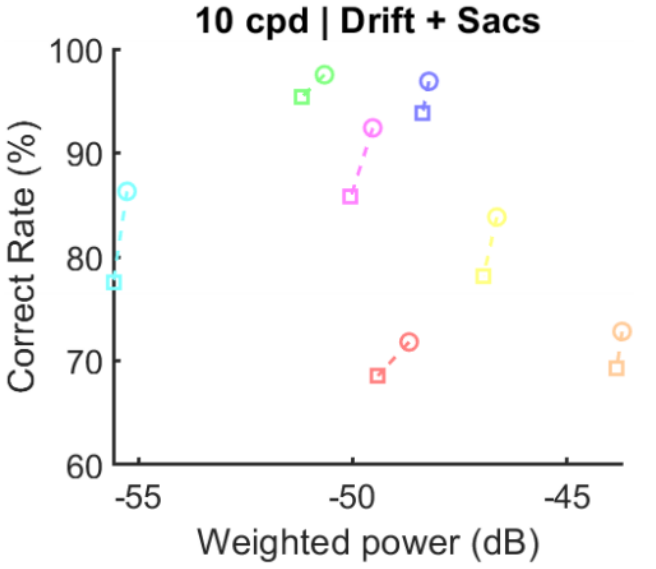
Correct Rate VS Power

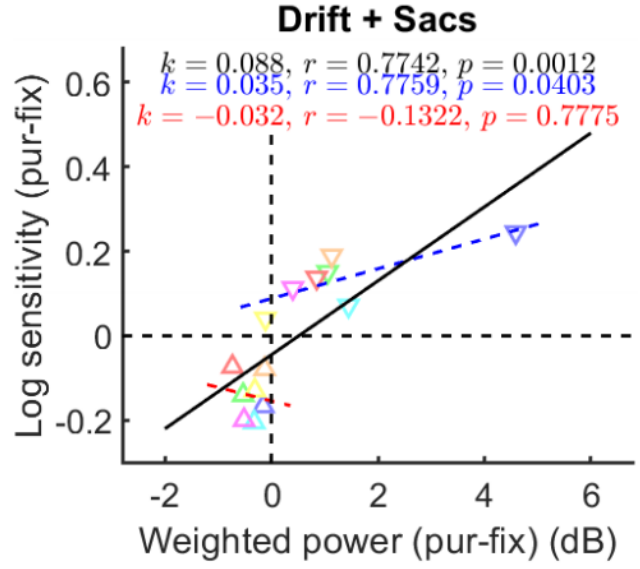






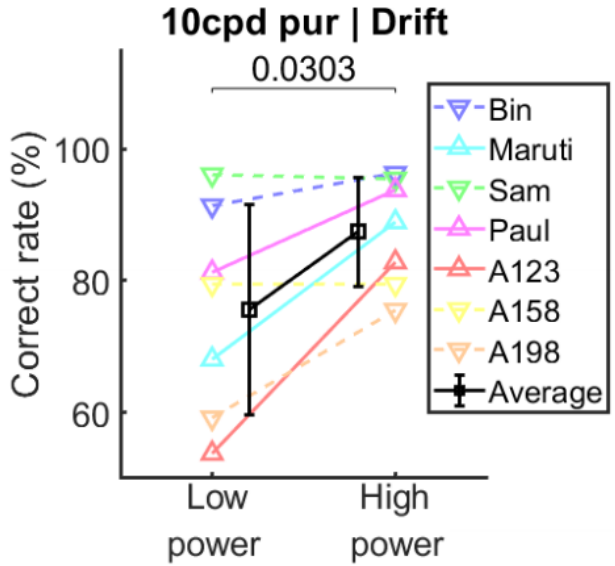






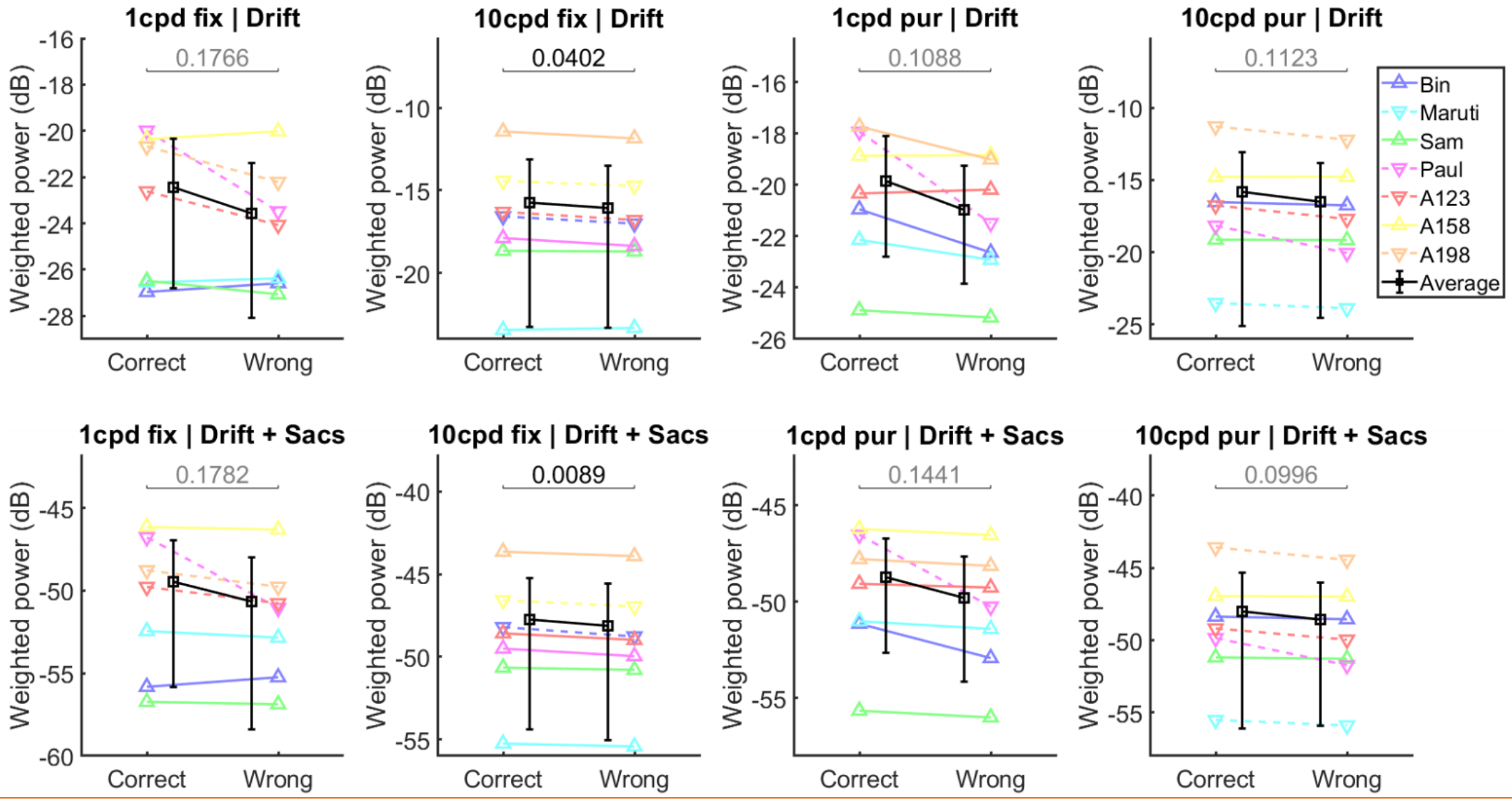
Results: Visual Sensitivity

Correct Rate VS Power



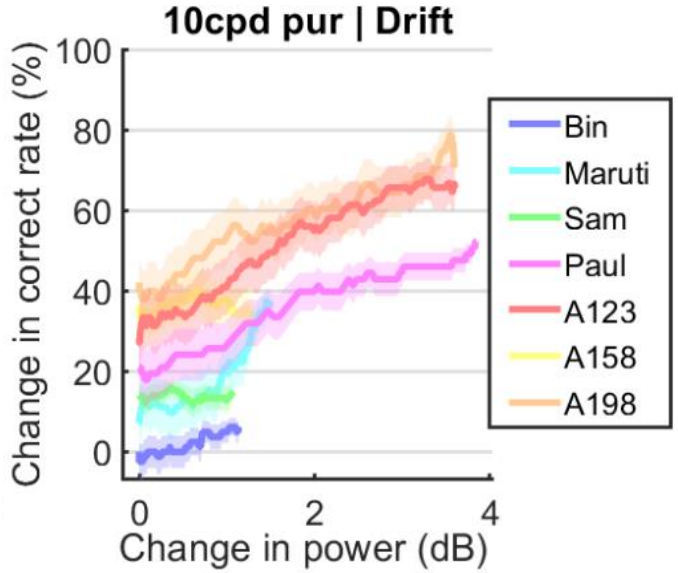
Results: Visual Sensitivity

Correct Rate VS Power



Results: Visual Sensitivity

Correct Rate VS Power



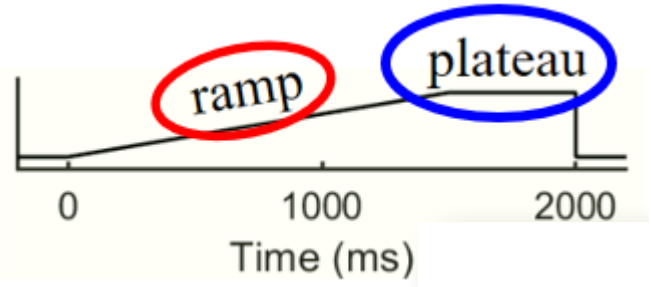
SUMMARY

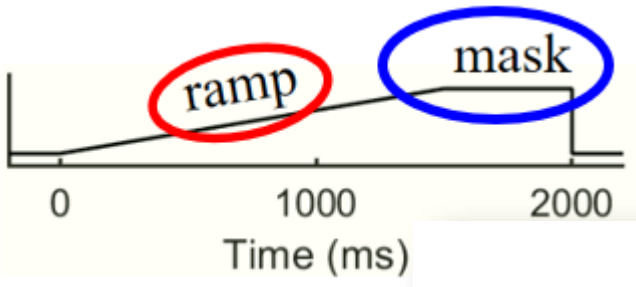
- Pursuit gain is near unity for all subjects
  - Saccade rate correlates with retinal velocity across subjects
  - Saccade amplitude is greater during pursuit and correlates with retinal velocity
  - Pursuit leads to stronger retinal image motion

- Pursuit leads to higher performance at 1 cpd while lower at 10 cpd
  - Consistent with weighted power created by retinal modulation from eye movements

Issue: Inconsistency

New Dataset On Task 2



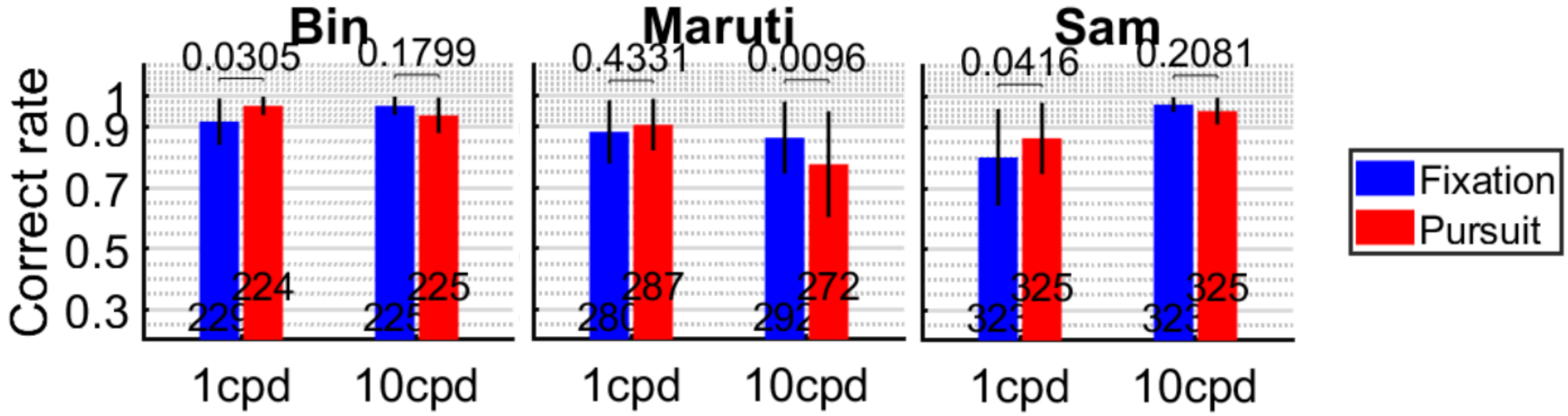


Old Data	**Bin, Maruti, Sam**	**Paul, A123, A158, A198**

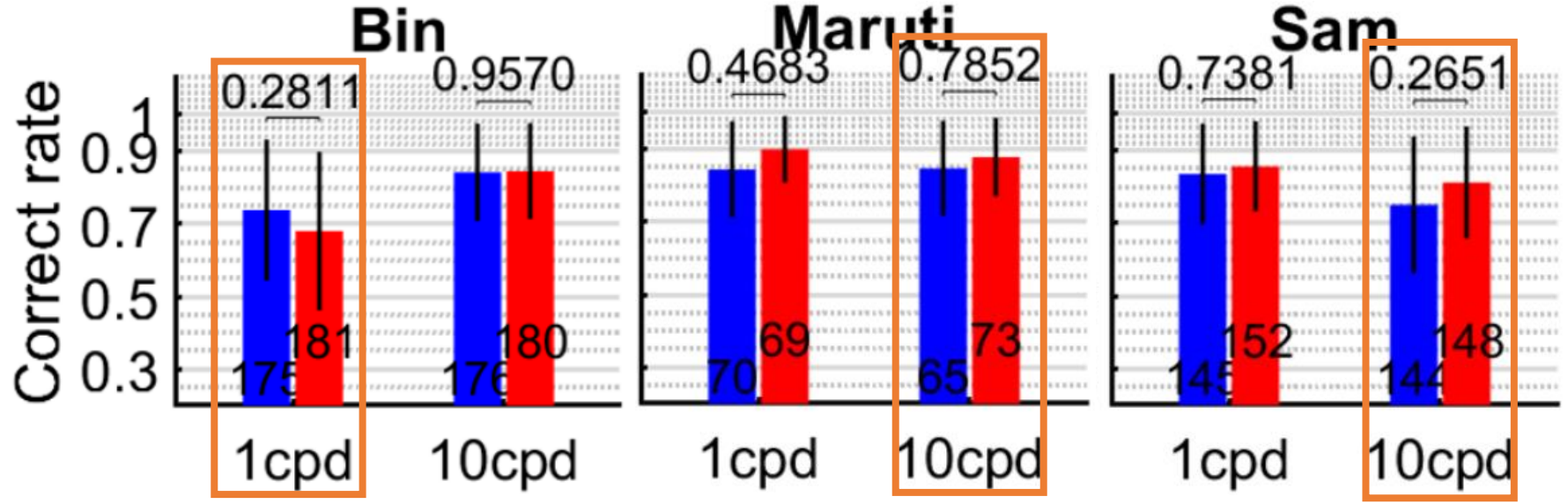
Issue: Inconsistency

New Dataset On Task 2

Old Data



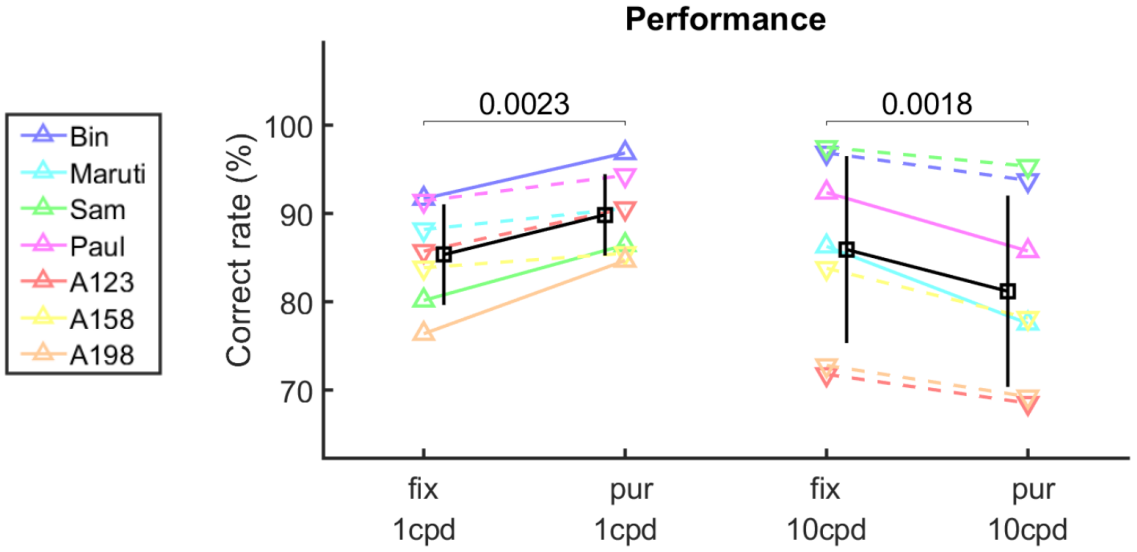
New Data



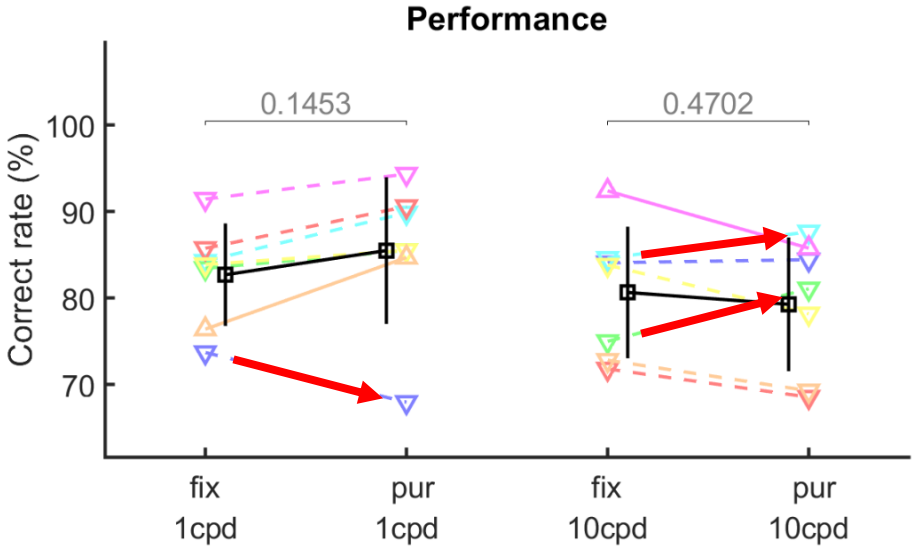
Issue: Inconsistency

New Dataset On Task 2

Old Data



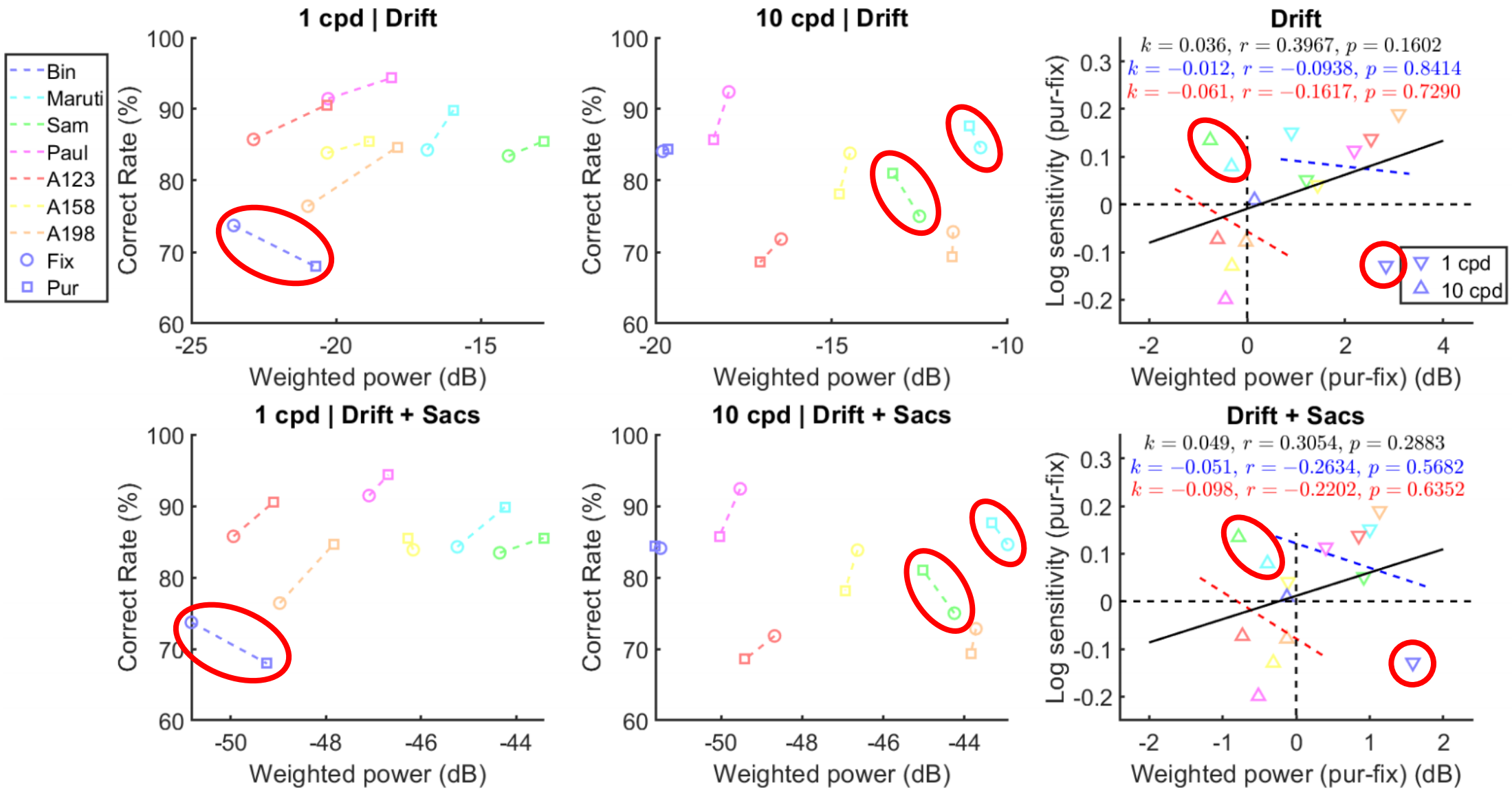
New Data



Issue: Inconsistency

New Dataset On Task 2

New Data



Issue: Inconsistency

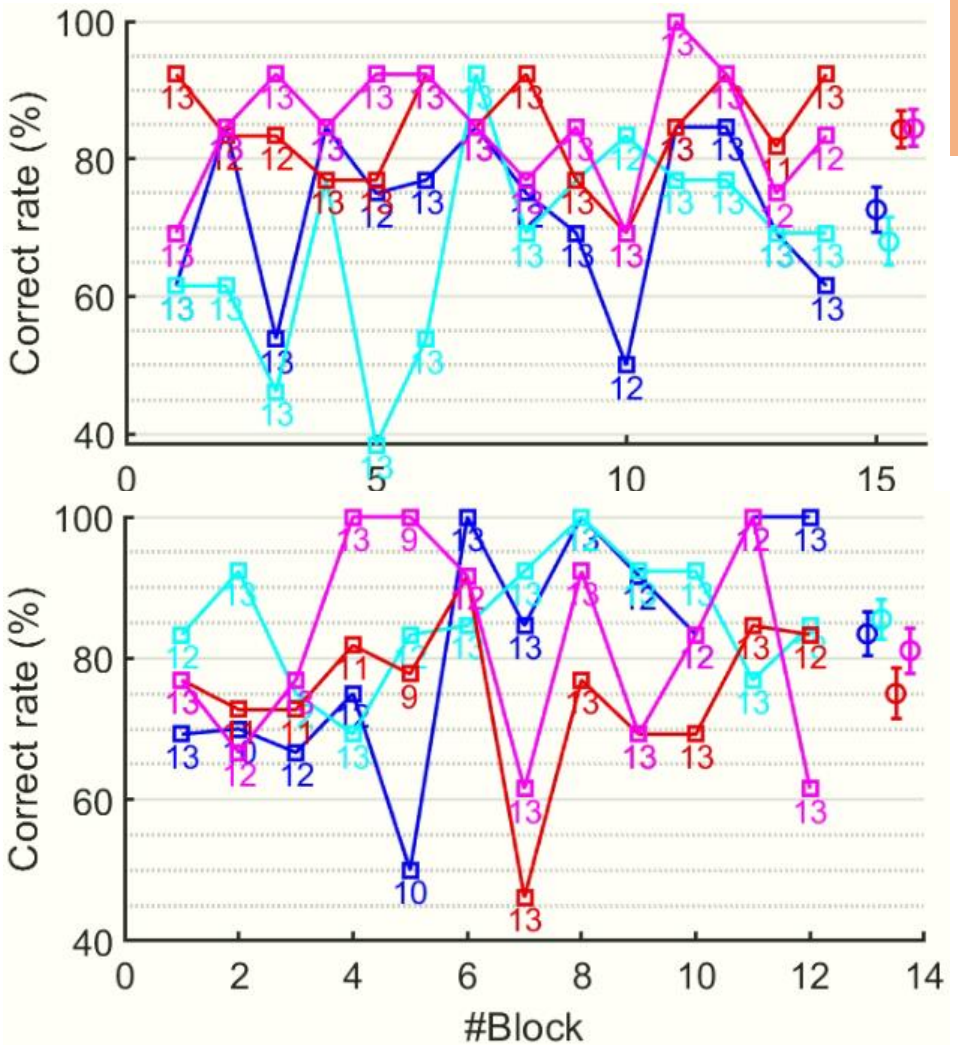
Possible Causes I

- Variability of performance across sessions

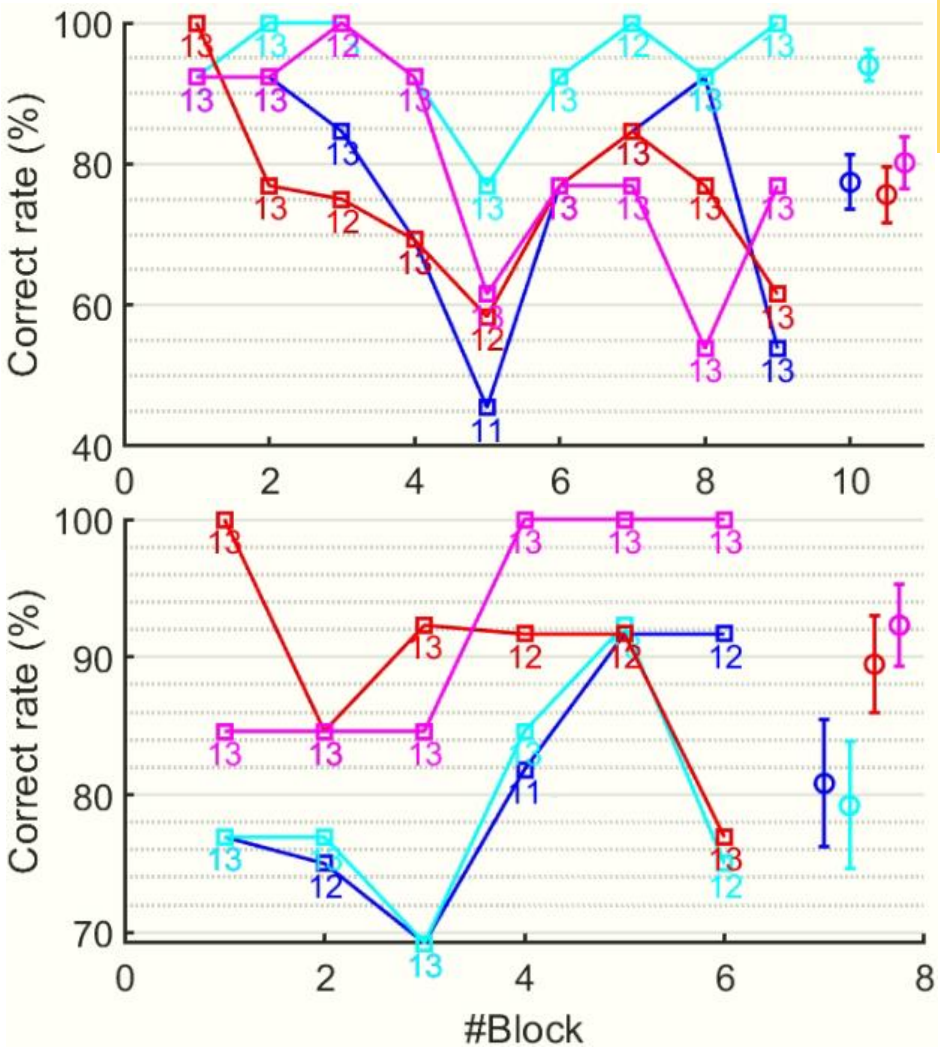
Bin

Sam

New Data



Extra Data



Issue: Inconsistency

Possible Causes I

- Variability of performance across sessions
- **Solution: collect more data**

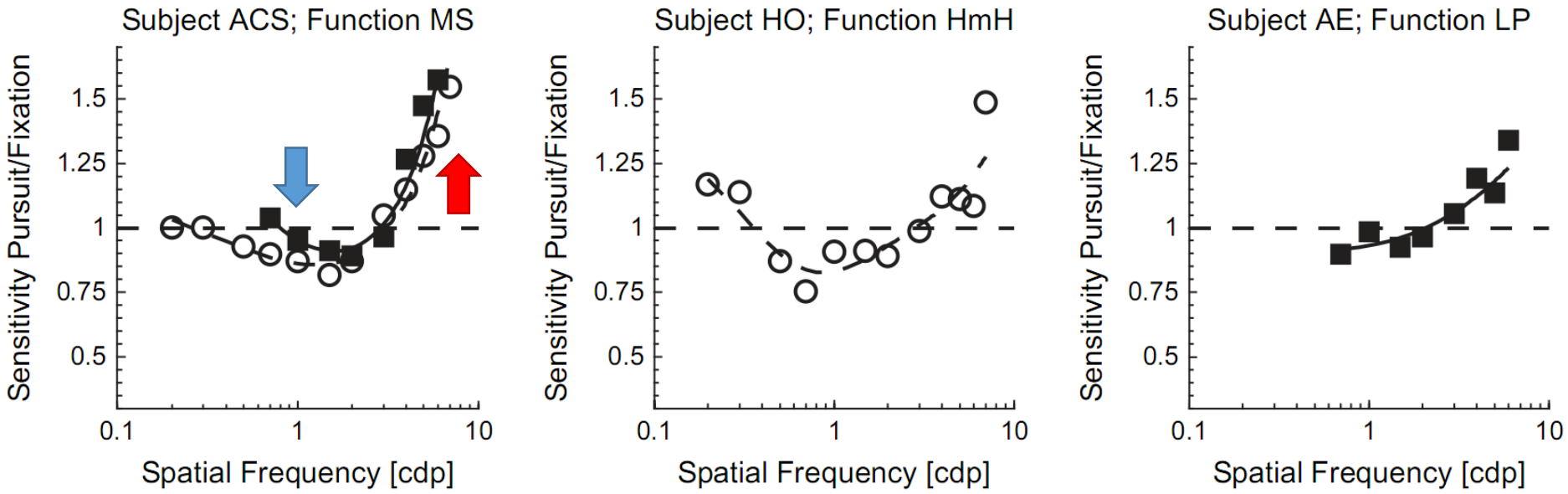
Issue: Inconsistency

Possible Causes II

➢ Extra-retinal modulation during pursuit

Foveal gabor detection task:

- Size:
  - FSG: fixed Gaussian window $\sigma = 1°$
  - FCG: fixed number of sine cycles $\sigma = 4/f$
- Orientation:
  - Horizontal
- Flash for 1 frame (10 ms):
  - When eye reached screen center



Schutz et al, *VisNeu, 2009*

Issue: Inconsistency

Possible Causes II

- Extra-retinal modulation during pursuit
- **Solution:**
  - **Assess the effect of retinal image motion with stabilization of the Gabor**
    - **1 cpd:** $\mathrm{Pur}_{unstab} - \mathrm{Pur}_{stab} > \mathrm{Fix}_{unstab} - \mathrm{Fix}_{stab}$
    - **10 cpd:** $\mathrm{Pur}_{unstab} - \mathrm{Pur}_{stab} < \mathrm{Fix}_{unstab} - \mathrm{Fix}_{stab}$

Issue: Inconsistency

Possible Causes ???

- **More thoughts?**

OUTLINE

THANKS