Post-Saccadic Dynamics of Visual Sensitivity

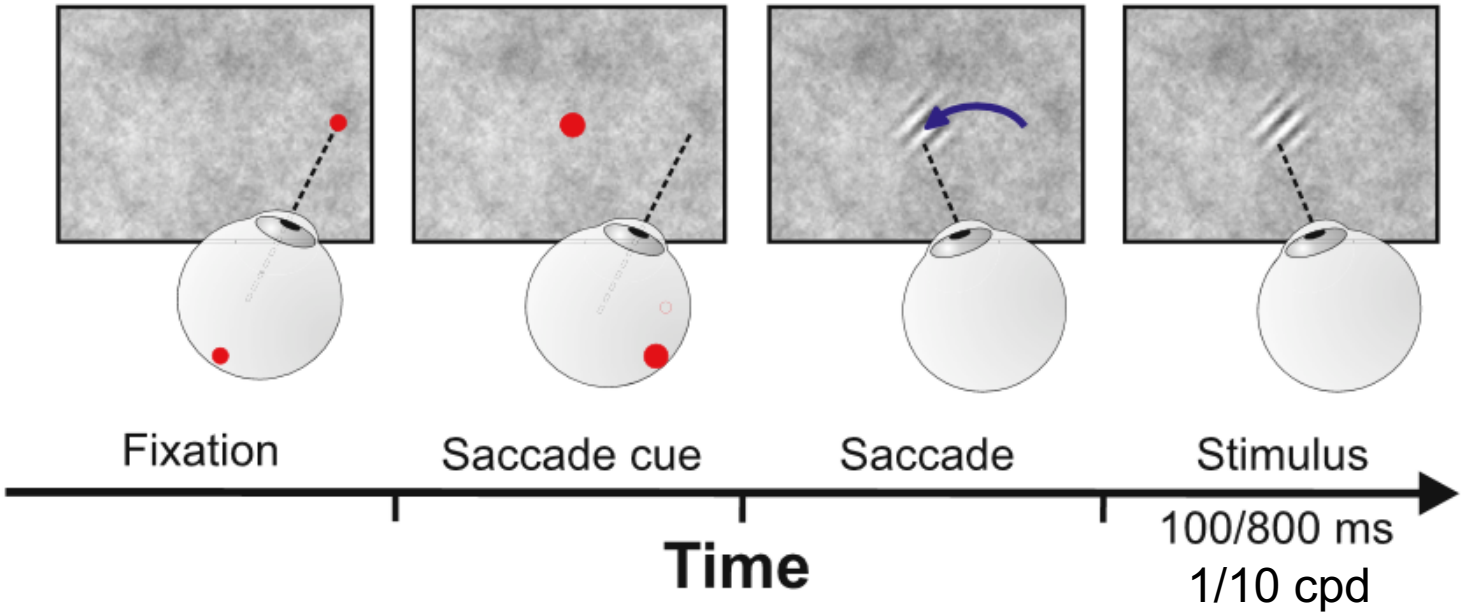
April 9, 2020

Goals

1. Examine natural post-saccadic dynamics of visual sensitivity across the visual field and spatial frequencies.

2. Model dynamics of visual sensitivity to predict visibility at various times following a saccade.

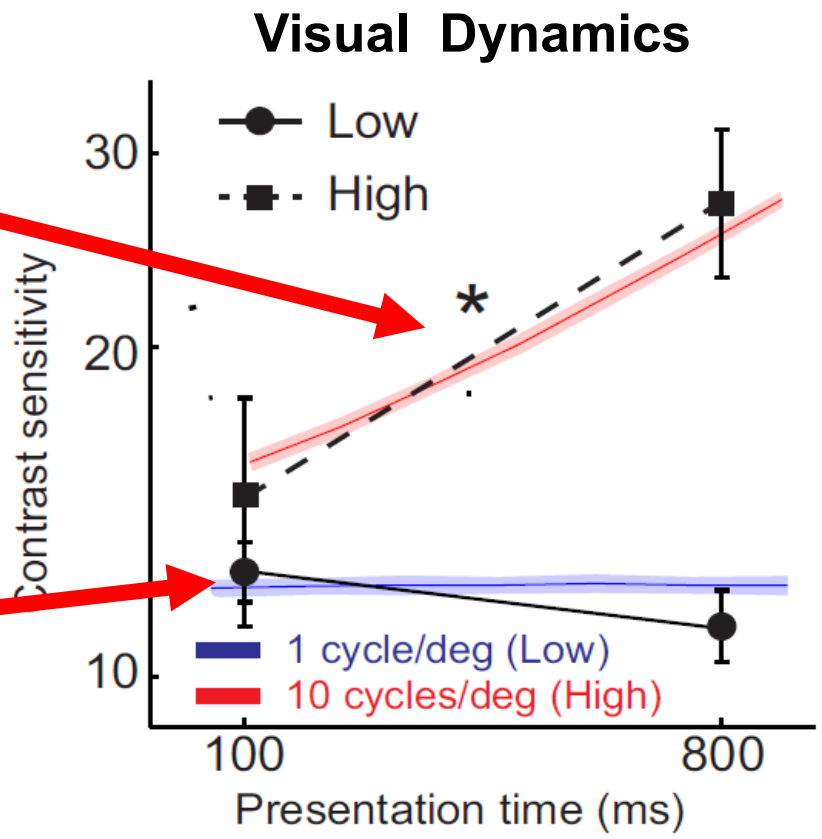
Boi et al 2017 Paradigm



Consequences of Saccades

Relies on modulations
from intersaccadic eye movements

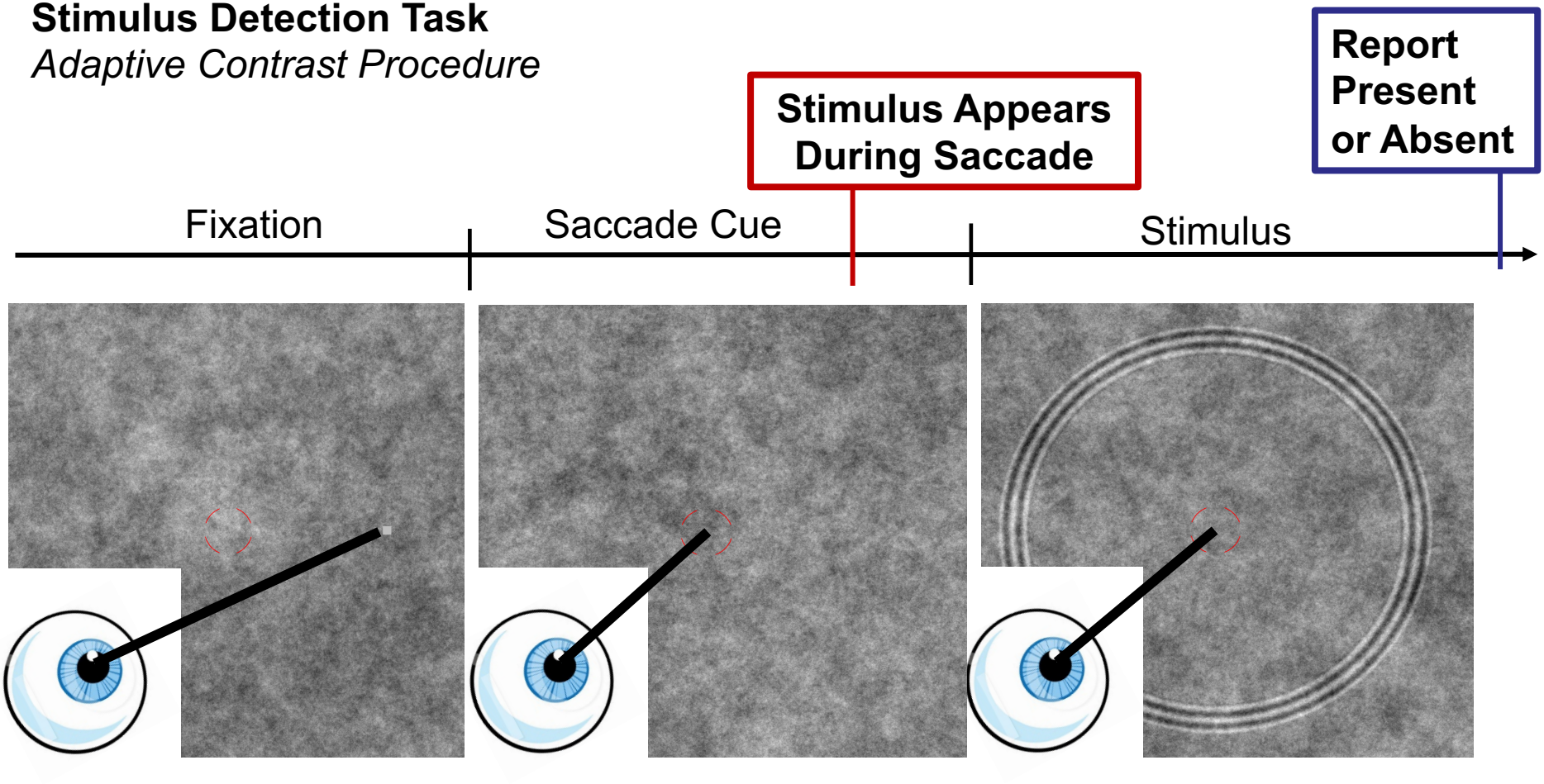
Relies on modulations
from saccades



Boi, Poletti, Victor & Rucci, *Current Biology*, 2017

Stimulus Detection Task

Adaptive Contrast Procedure



Stimulus Parameters: Eccentricity (dva) – 0, 4, 8, 12
Presentation (ms) – 50, 150, 500
Spatial Freq (cpd) – 2, 10

50% Catch trials
No Stimulus

Refined Paradigm

	1.1	1.2
Main Task	Yes/No Detection	Yes/No Detection
Starting Contrast	Fixed	**Method of Adjustment**
Adaptive Method	PEST	**ML PEST**
Rendering	Standard 8bit	**Noisy Bit**
Cue Horz. Positions	[-400 0]	[-200 200]
Saccade Cue	Always White Flashes Off to Cue Saccade	Alternate Light/Dark Gray Flashes Off to Cue Saccade
Saccade Target	Static Red Crosshair Flashed Central Square	Static Red Crosshair Only
Response Cue	Saccade Target Disappears	Auditory
Stimulus: SF	2, 10 cpd	2, 10 cpd
Stimulus: Ecc	0, 4, 8 dva	0, 4, 8, **12** dva
Stimulus: Time	50, 500 ms	50, **150**, 500 ms
Pixel Angle	1.07 arcmin / pixel	1.52 arcmin / pixel

Data Collection

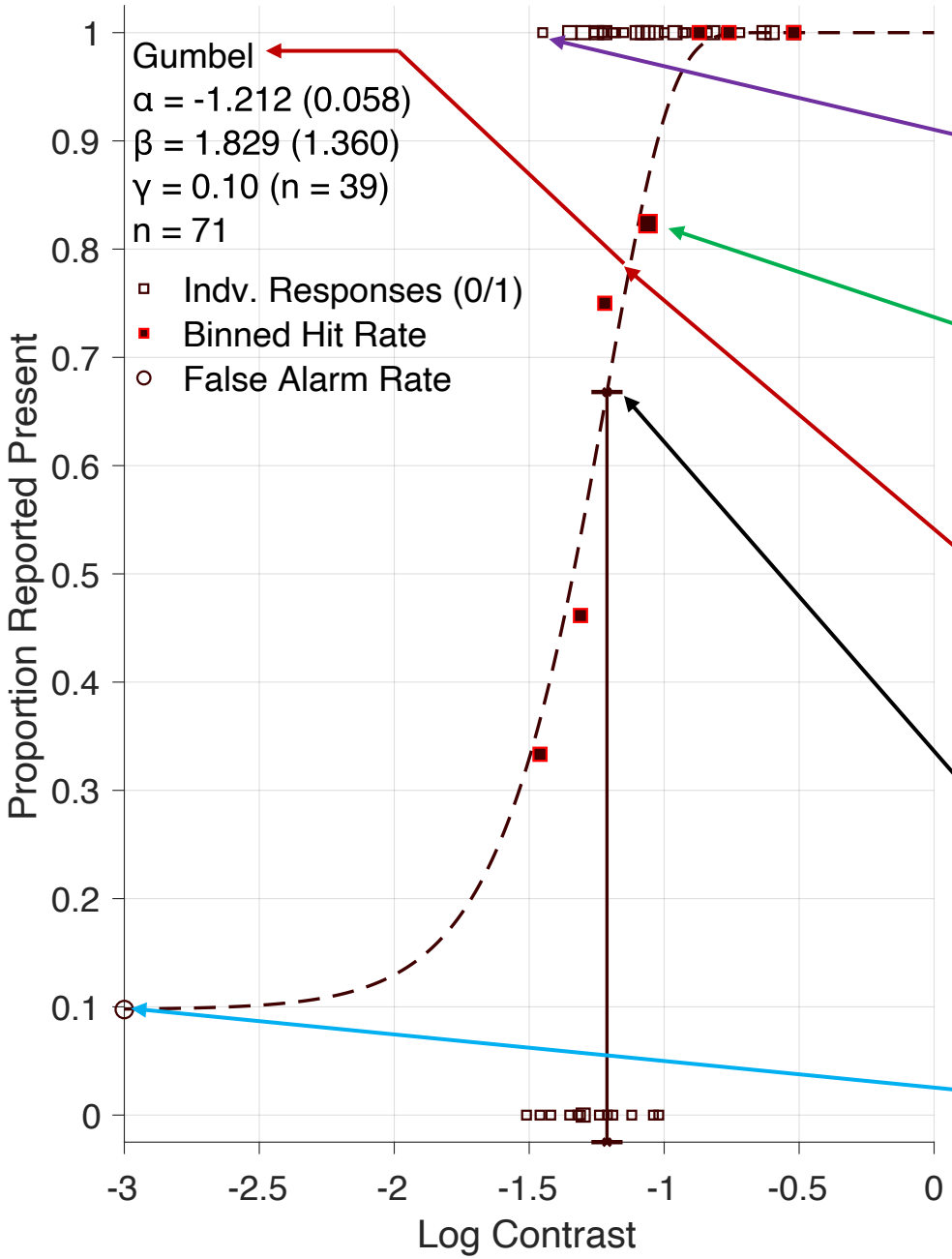
Subject	Task Version	Eye Tested	Rig	# of Conditions	Total Trials
A089	**1.2**	Left	DPI	**24**	1013
A014	**1.2**	Left	DPI	**24**	3799
A013	1.1	Right	DPI	12	2652
A036	1.1	Right	DPI	12	3444
A092	1.1	Right	DPI	12	3683
A0NK	1.1	Right	DPI	12	2819

Eye Movement Behavior

Subject	# of Cond.	*Total Trials*	Valid	*Can Analyze*	*Good Saccade*	*Drift Only*
A089	**24**	*1013*	**867**	*936*	*919*	*876*
A014	**24**	*3799*	**2703**	*3773*	*3406*	*2763*
A013	12	*2652*	2275	*2501*	*2474*	*2296*
A036	12	*3444*	1936	*3281*	*3013*	*1970*
A092	12	*3683*	3009	*3556*	*3481*	*3055*
A0NK	12	*2819*	2266	*2775*	*2711*	*2296*

Valid = Intersecting of “Good Saccade” and “Drift Only” trials.
Can Analyze = trials free of blinks and no tracks, with a saccade present.
Good Saccade = a single saccade, with a RT > 100 ms from saccade cue and a landing error < 100 arcmin from the saccade target.
Drift Only = free of fixational saccades in the post-saccade period.

Response Data with Psychometric Fits – *example from 1 subject of responses from 1 stimulus condition (sf = 2, ecc = 0, time = 50)*



Open squares (or diamonds) indicate **individual responses** of either present (1) or absent (0). Size reflects number of trials.

Filled markers are **average hit rate**, binned across nearby contrast levels. Size reflects number of trials.

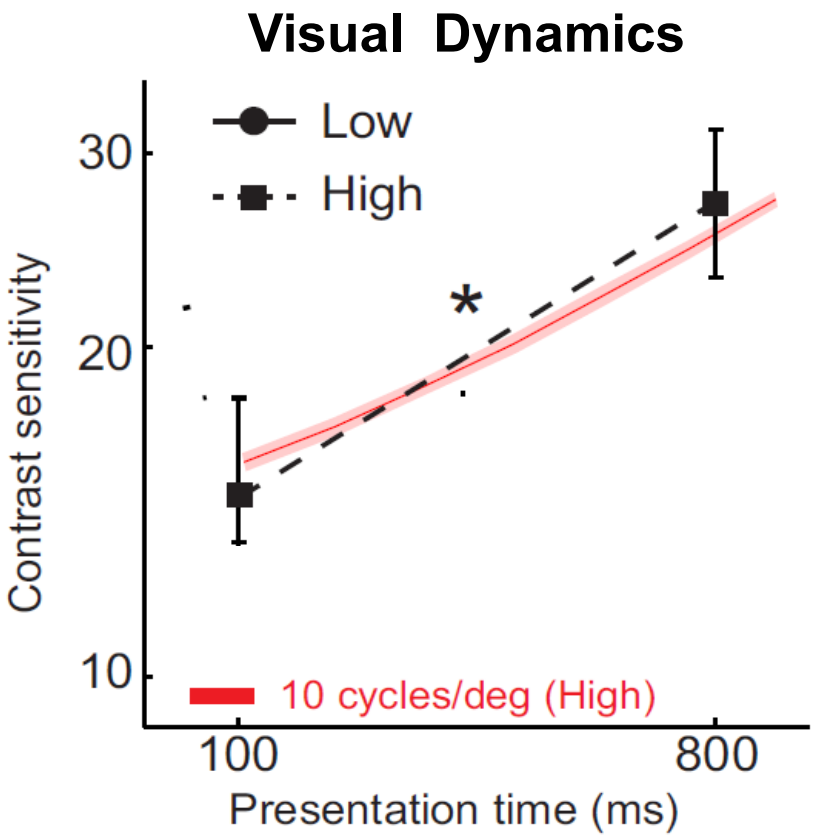
Psychometric function fitted to observed data using a Maximum Likelihood criterion. Threshold (alpha) and slope (beta) are free parameters, gamma (sometimes called "guess rate") is fixed at the false alarm rate, lapse (lambda) is fixed at 0.

Threshold with standard error estimated from 200 bootstraps. SE not shown when bootstrap fails. This value will appear on summary plots.

Open circle on vertical axis indicates the **false alarm rate**, i.e. the proportion of trials where the subject responded present when the stimulus was absent for a given stimulus duration (spatial frequency & eccentricity don't apply when stimulus is absent). Not scaled for n, but n is indicated next to gamma above.

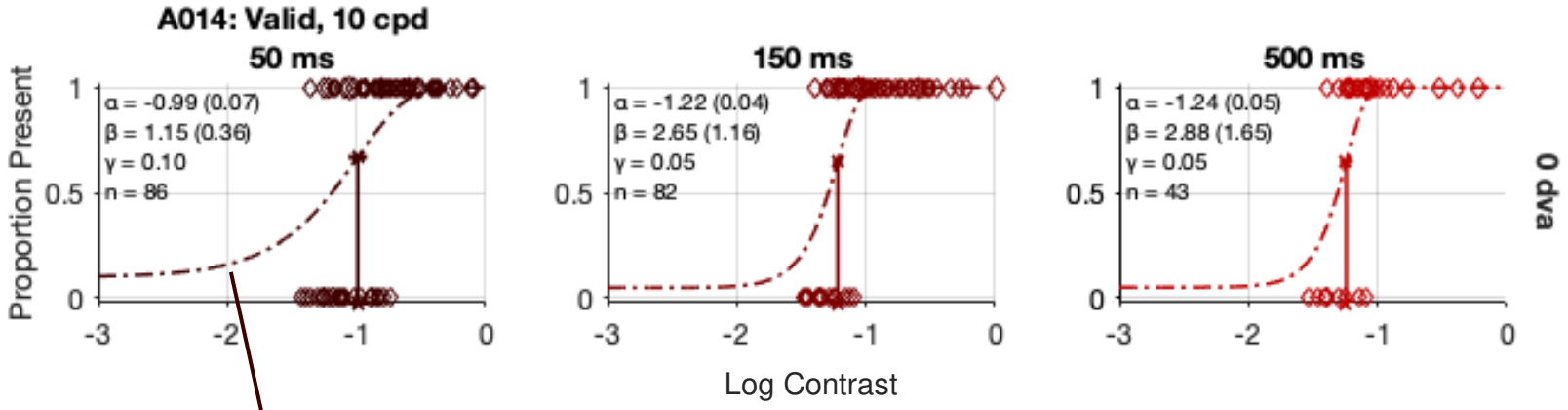
Results: High SF (10 cpd)

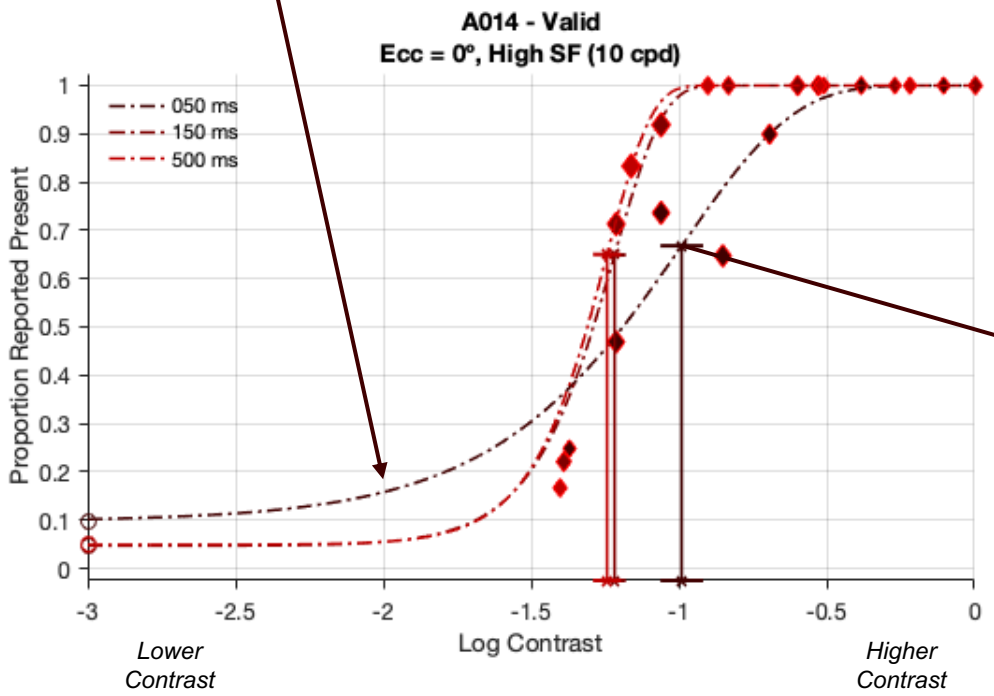
We expect a decrease in threshold (1/sensitivity) with increasing time.

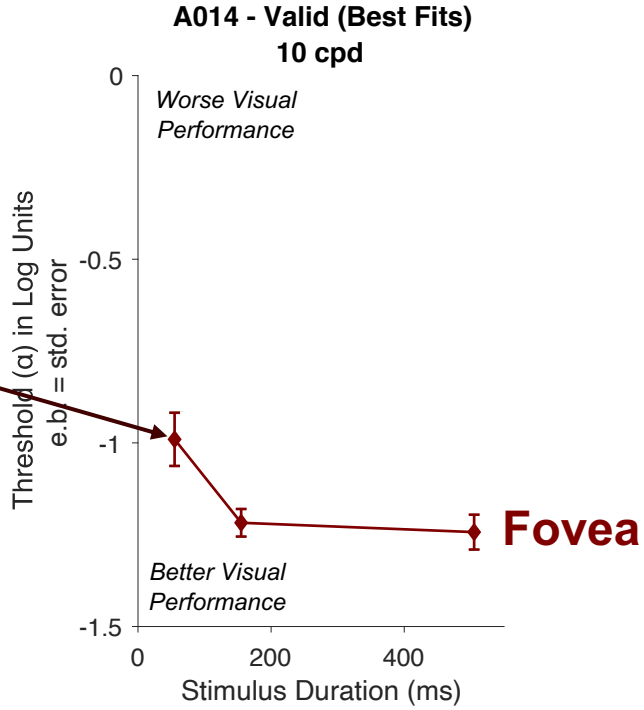


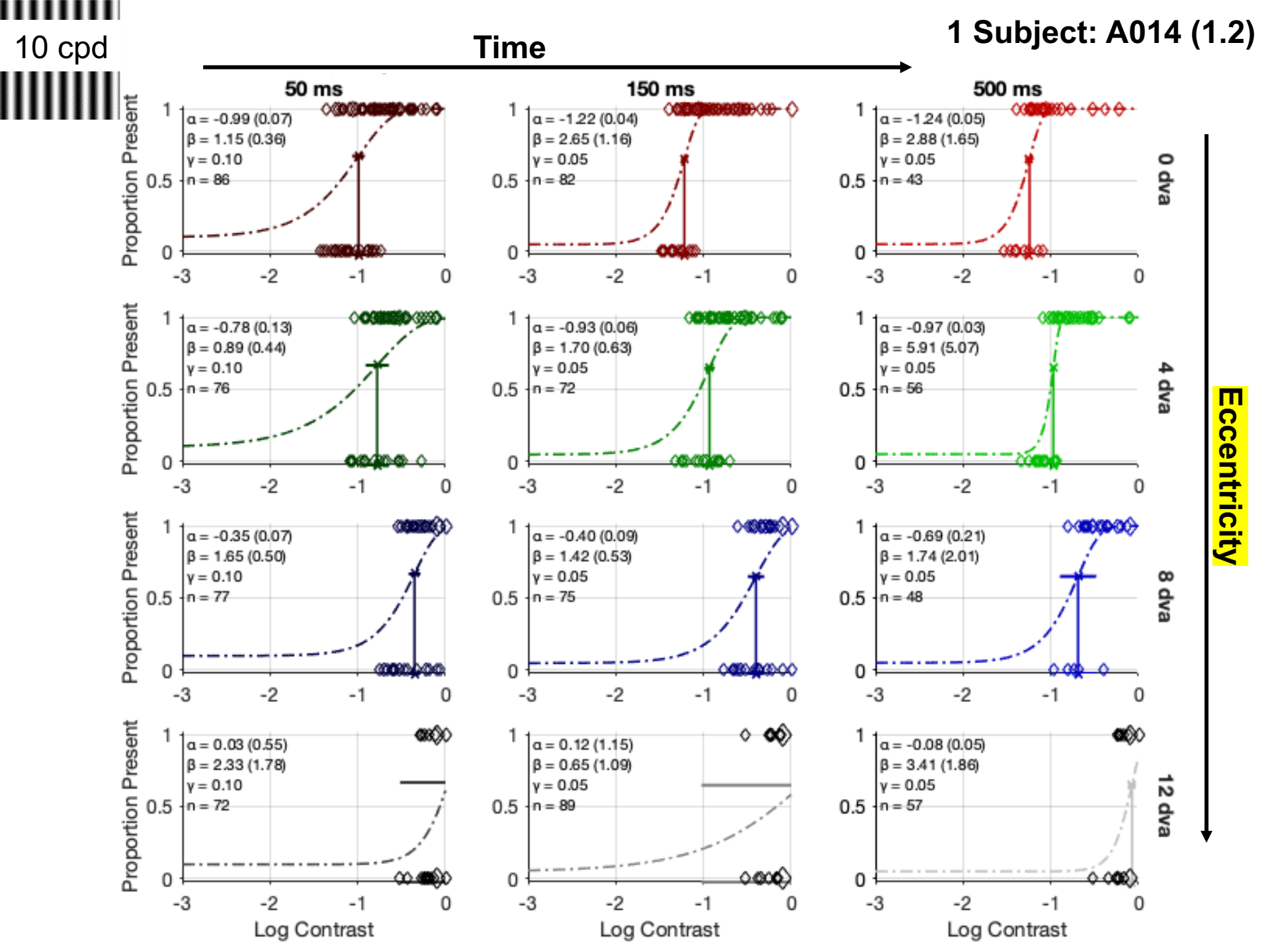
Boi, Poletti, Victor & Rucci, *Current Biology*, 2017

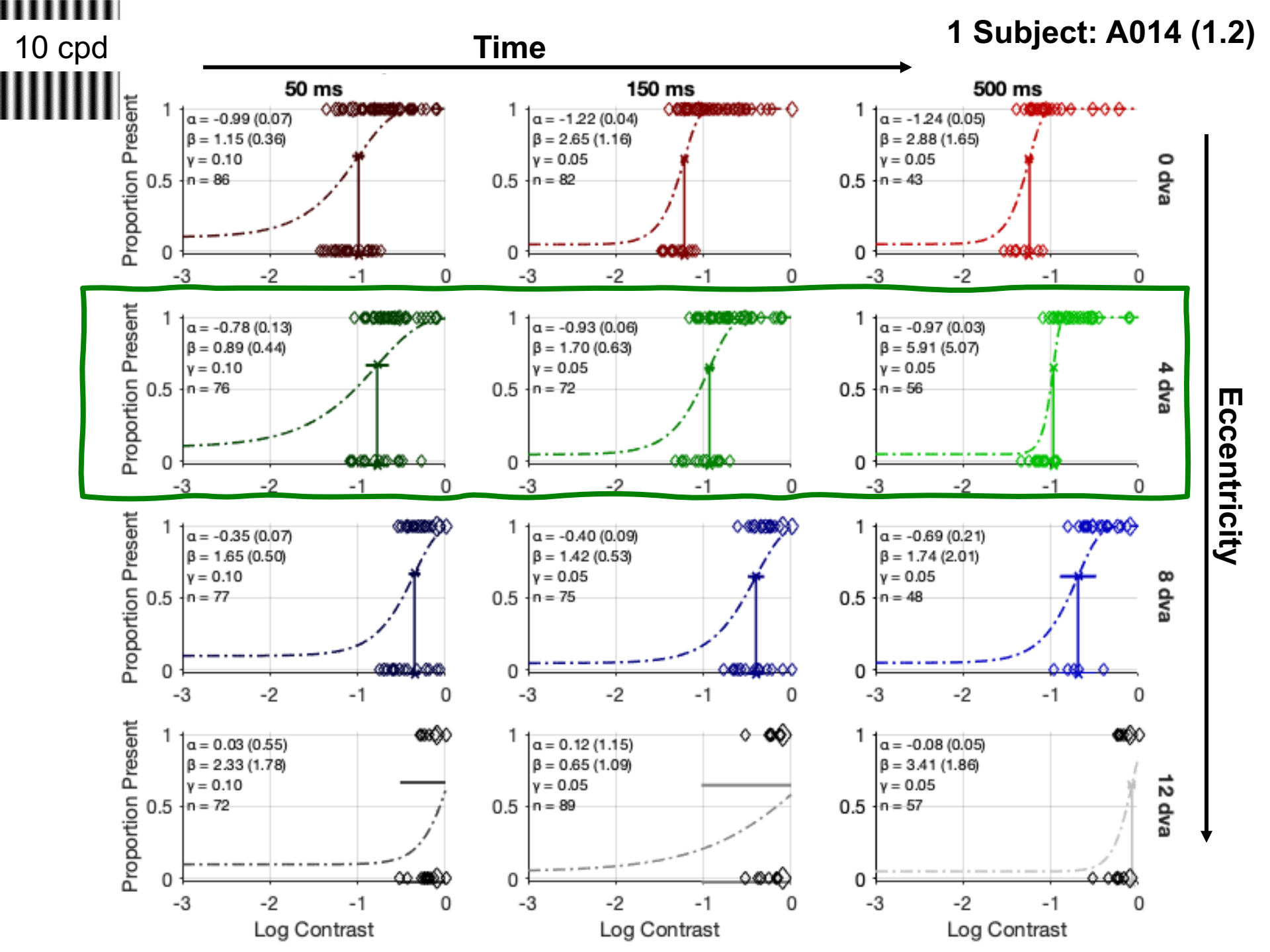
Results: Fovea High SF (10 cpd)



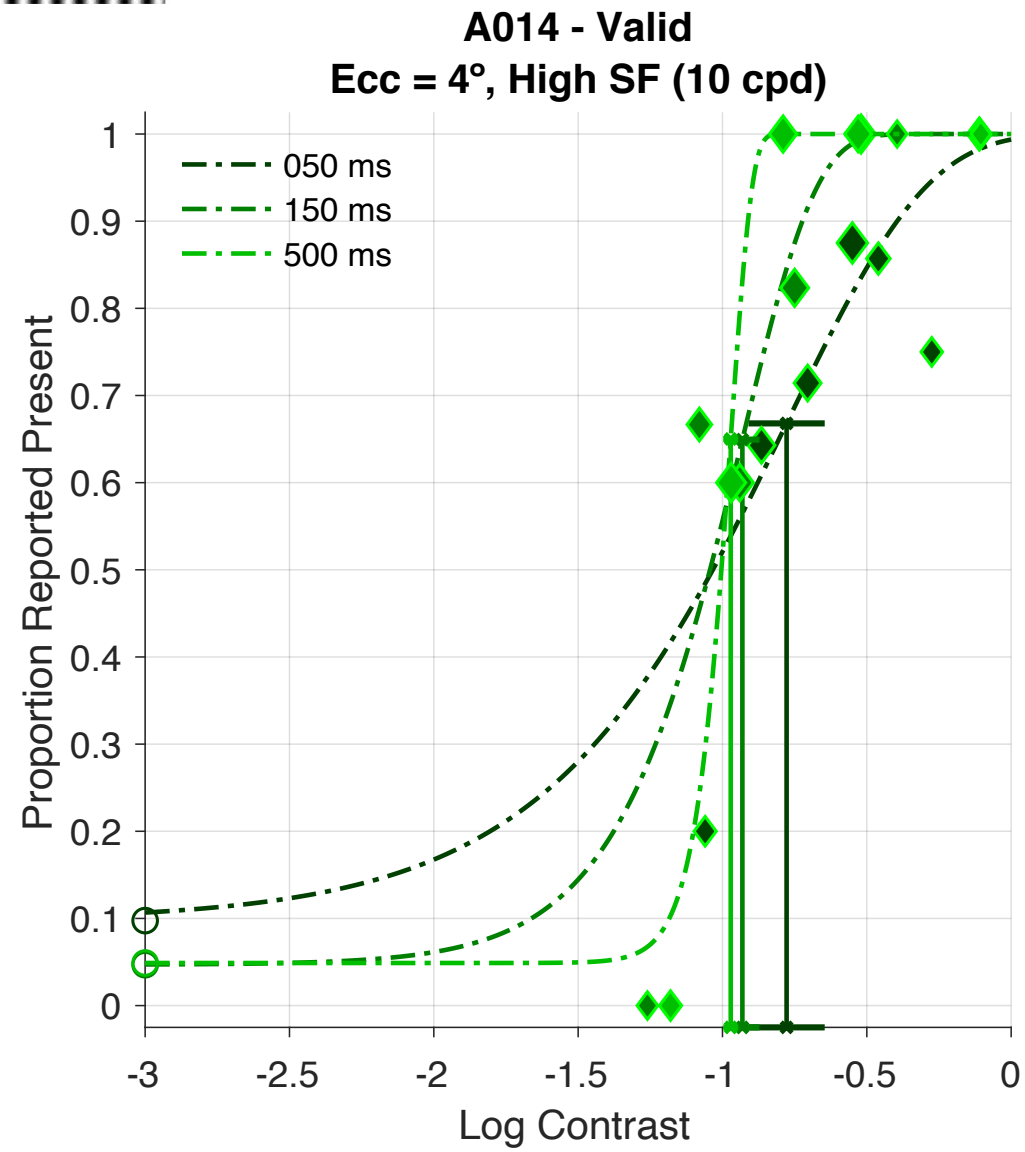


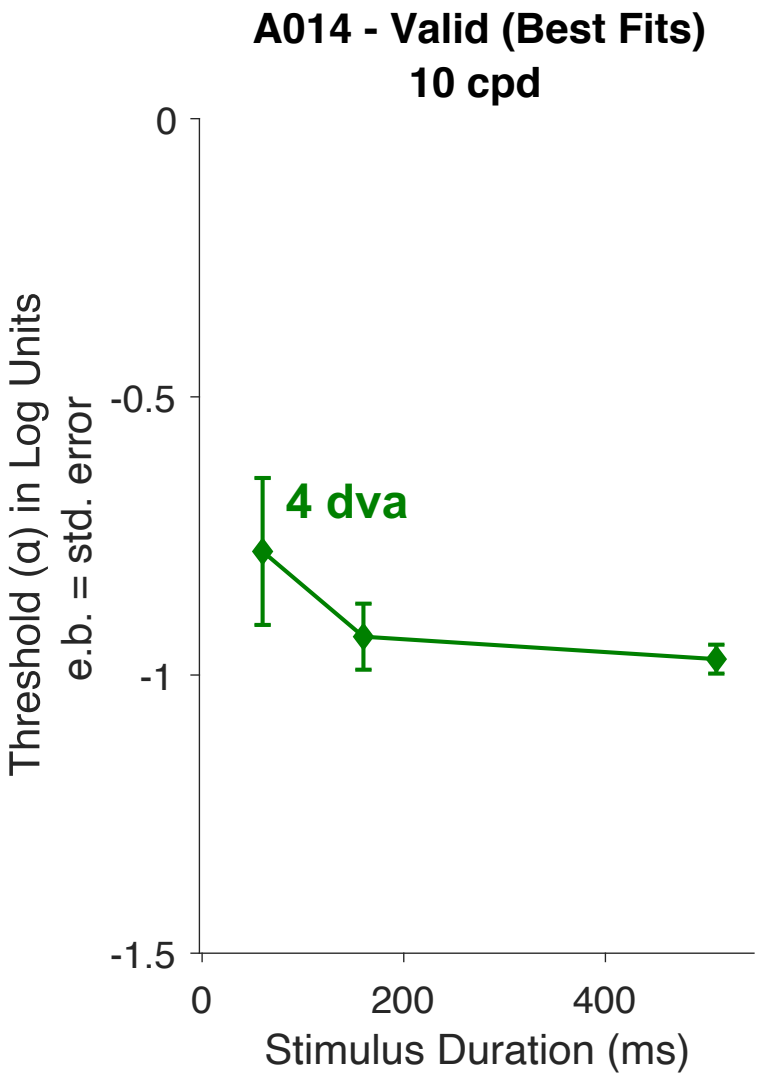


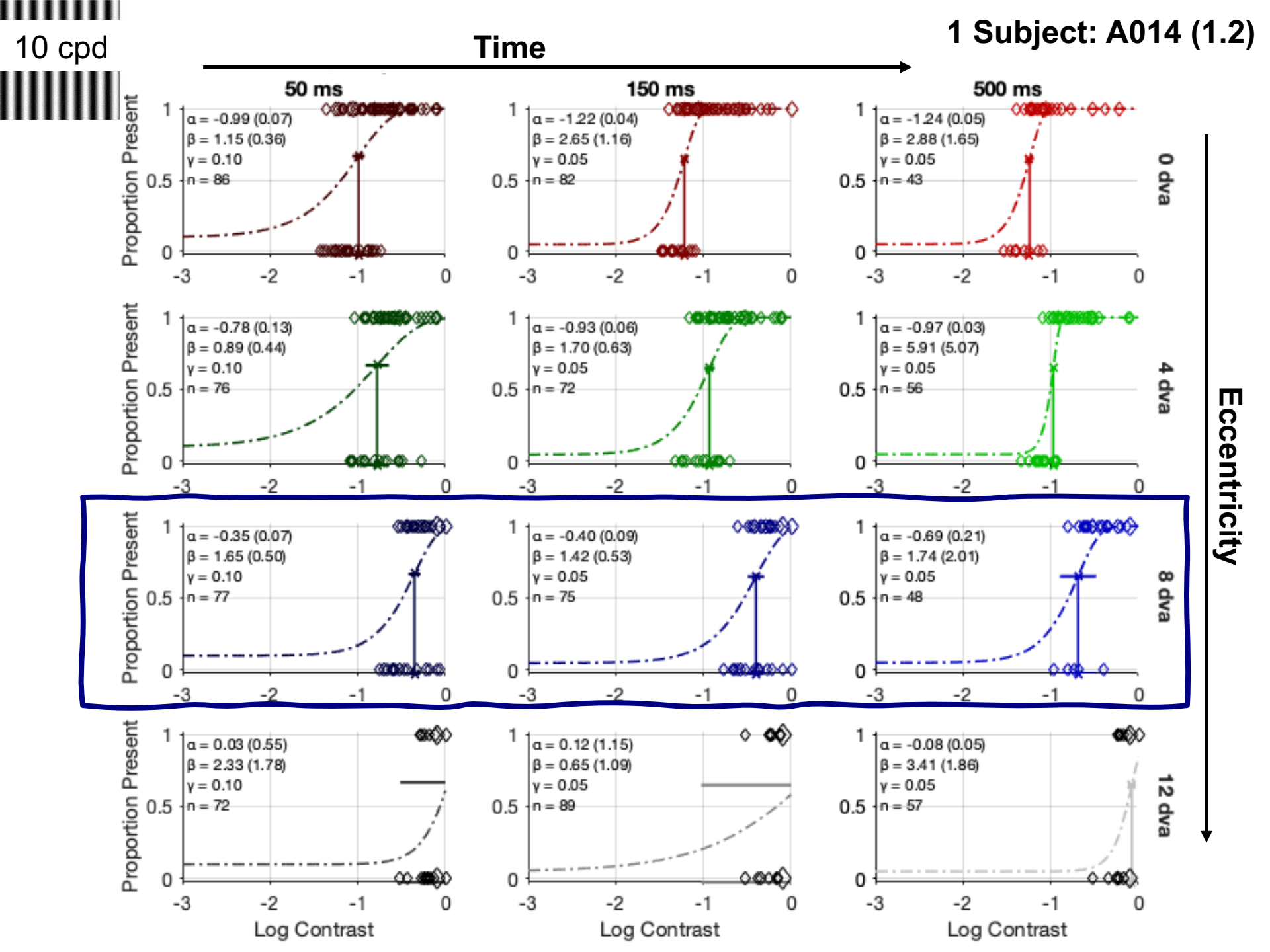

10 cpd
Time
1 Subject: A014 (1.2)
50 ms
150 ms
500 ms
0 dva
4 dva
8 dva
12 dva
Eccentricity
Proportion Present
Log Contrast
α = -0.99 (0.07)
β = 1.15 (0.36)
γ = 0.10
n = 86
α = -1.22 (0.04)
β = 2.65 (1.16)
γ = 0.05
n = 82
α = -1.24 (0.05)
β = 2.88 (1.65)
γ = 0.05
n = 43
α = -0.78 (0.13)
β = 0.89 (0.44)
γ = 0.10
n = 76
α = -0.93 (0.06)
β = 1.70 (0.63)
γ = 0.05
n = 72
α = -0.97 (0.03)
β = 5.91 (5.07)
γ = 0.05
n = 56
α = -0.35 (0.07)
β = 1.65 (0.50)
γ = 0.10
n = 77
α = -0.40 (0.09)
β = 1.42 (0.53)
γ = 0.05
n = 75
α = -0.69 (0.21)
β = 1.74 (2.01)
γ = 0.05
n = 48
α = 0.03 (0.55)
β = 2.33 (1.78)
γ = 0.10
n = 72
α = 0.12 (1.15)
β = 0.65 (1.09)
γ = 0.05
n = 89
α = -0.08 (0.05)
β = 3.41 (1.86)
γ = 0.05
n = 57


10 cpd
Time
1 Subject: A014 (1.2)
50 ms
150 ms
500 ms
Eccentricity
0 dva
4 dva
8 dva
12 dva
Proportion Present
Log Contrast
α = -0.99 (0.07)
β = 1.15 (0.36)
γ = 0.10
n = 86
α = -1.22 (0.04)
β = 2.65 (1.16)
γ = 0.05
n = 82
α = -1.24 (0.05)
β = 2.88 (1.65)
γ = 0.05
n = 43
α = -0.78 (0.13)
β = 0.89 (0.44)
γ = 0.10
n = 76
α = -0.93 (0.06)
β = 1.70 (0.63)
γ = 0.05
n = 72
α = -0.97 (0.03)
β = 5.91 (5.07)
γ = 0.05
n = 56
α = -0.35 (0.07)
β = 1.65 (0.50)
γ = 0.10
n = 77
α = -0.40 (0.09)
β = 1.42 (0.53)
γ = 0.05
n = 75
α = -0.69 (0.21)
β = 1.74 (2.01)
γ = 0.05
n = 48
α = 0.03 (0.55)
β = 2.33 (1.78)
γ = 0.10
n = 72
α = 0.12 (1.15)
β = 0.65 (1.09)
γ = 0.05
n = 89
α = -0.08 (0.05)
β = 3.41 (1.86)
γ = 0.05
n = 57

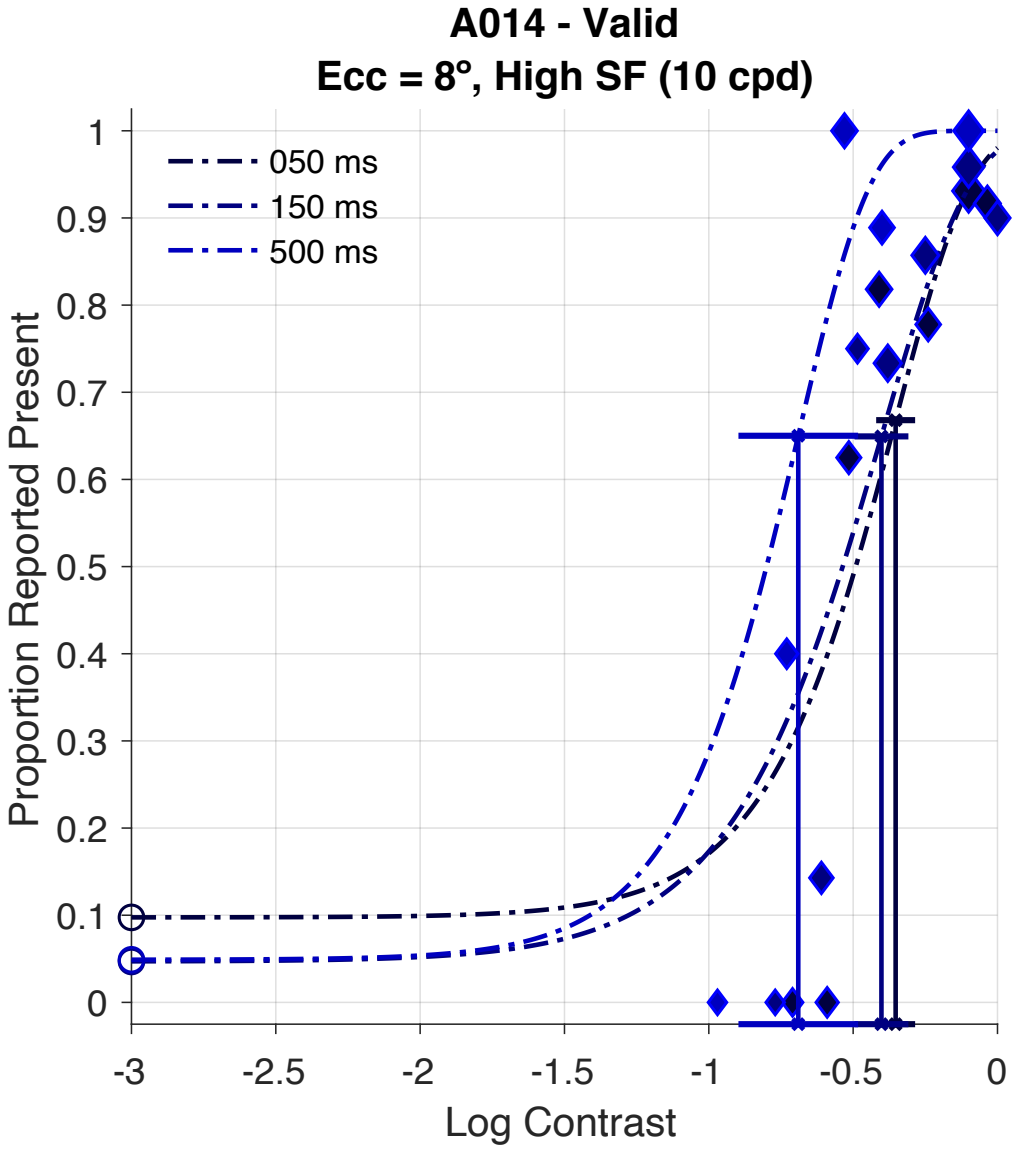
Results: 4° High SF (10 cpd)

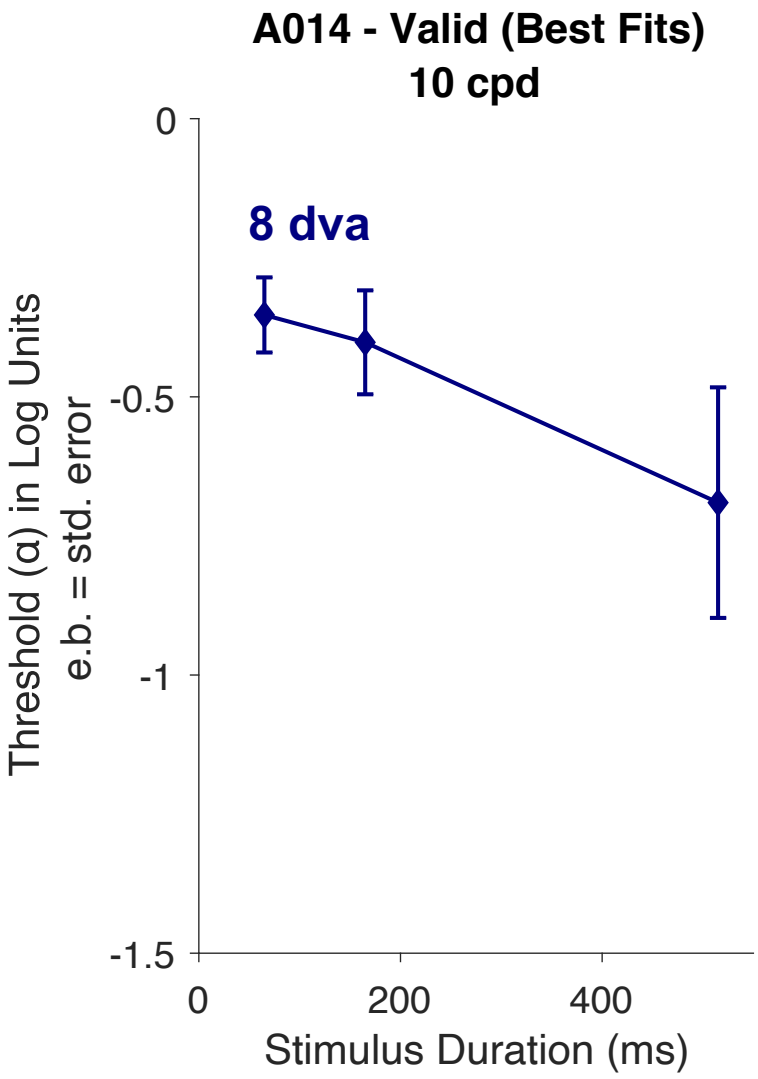




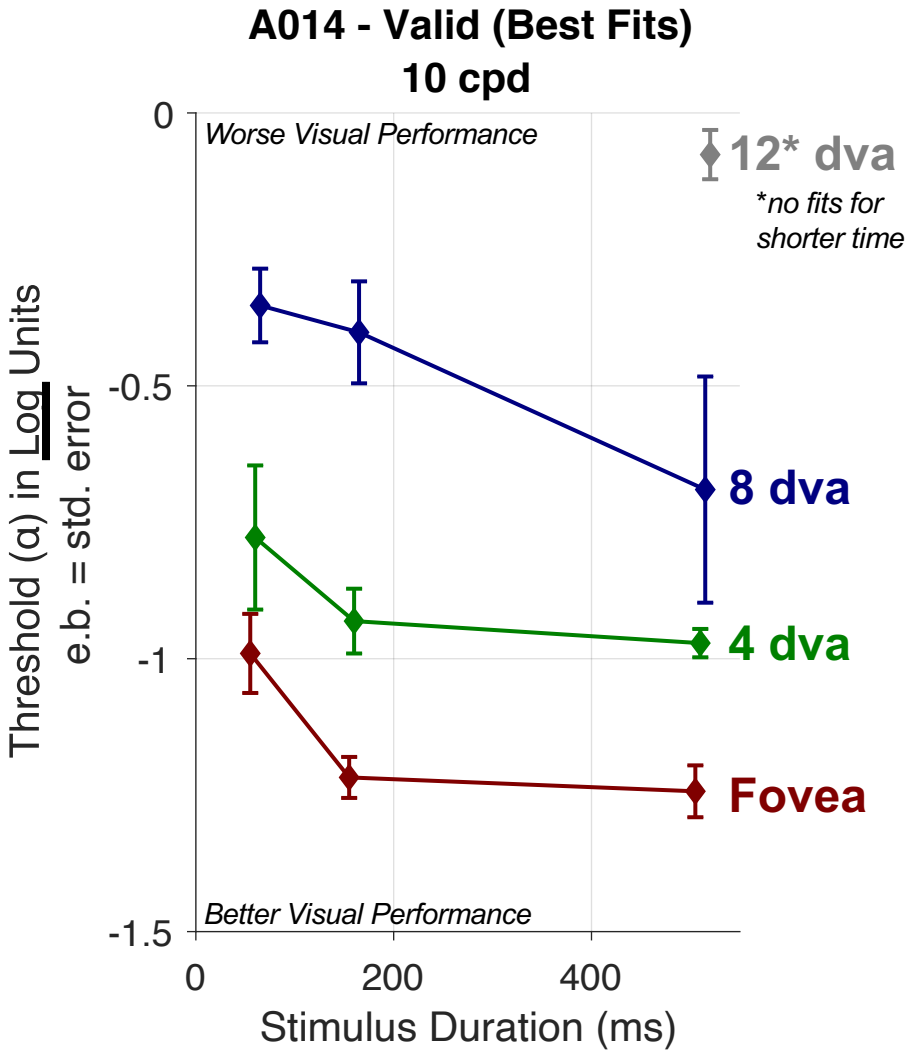

10 cpd
Time
1 Subject: A014 (1.2)
50 ms
150 ms
500 ms
Eccentricity
0 dva
4 dva
8 dva
12 dva
Proportion Present
Log Contrast
α = -0.99 (0.07)
β = 1.15 (0.36)
γ = 0.10
n = 86
α = -1.22 (0.04)
β = 2.65 (1.16)
γ = 0.05
n = 82
α = -1.24 (0.05)
β = 2.88 (1.65)
γ = 0.05
n = 43
α = -0.78 (0.13)
β = 0.89 (0.44)
γ = 0.10
n = 76
α = -0.93 (0.06)
β = 1.70 (0.63)
γ = 0.05
n = 72
α = -0.97 (0.03)
β = 5.91 (5.07)
γ = 0.05
n = 56
α = -0.35 (0.07)
β = 1.65 (0.50)
γ = 0.10
n = 77
α = -0.40 (0.09)
β = 1.42 (0.53)
γ = 0.05
n = 75
α = -0.69 (0.21)
β = 1.74 (2.01)
γ = 0.05
n = 48
α = 0.03 (0.55)
β = 2.33 (1.78)
γ = 0.10
n = 72
α = 0.12 (1.15)
β = 0.65 (1.09)
γ = 0.05
n = 89
α = -0.08 (0.05)
β = 3.41 (1.86)
γ = 0.05
n = 57

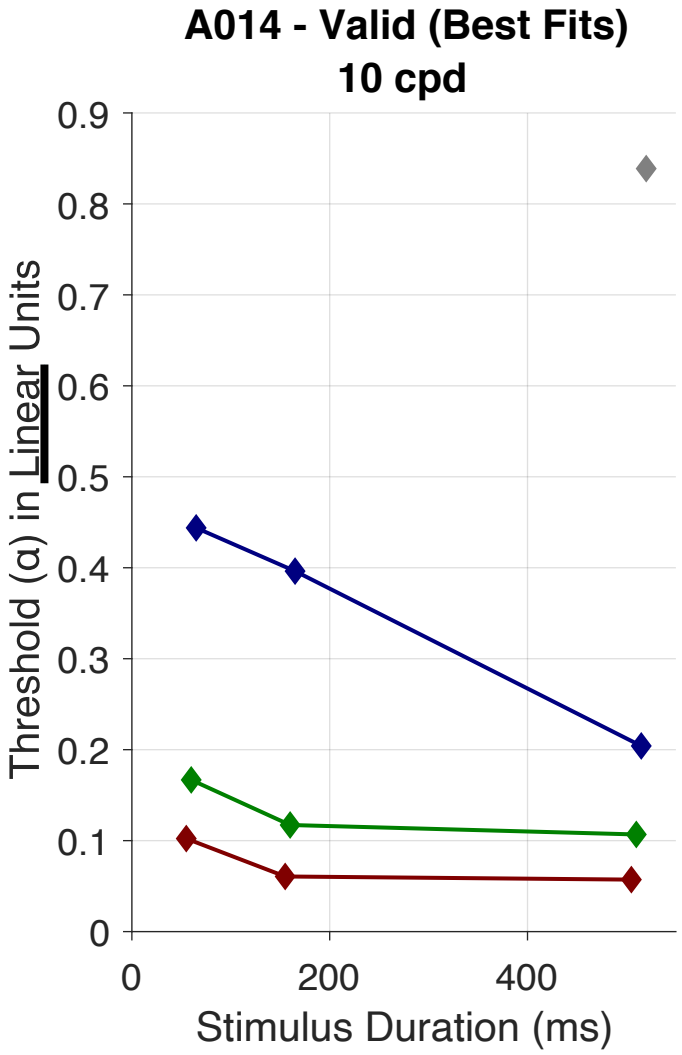
Results: 8° High SF (10 cpd)





Results: High SF (10 cpd)

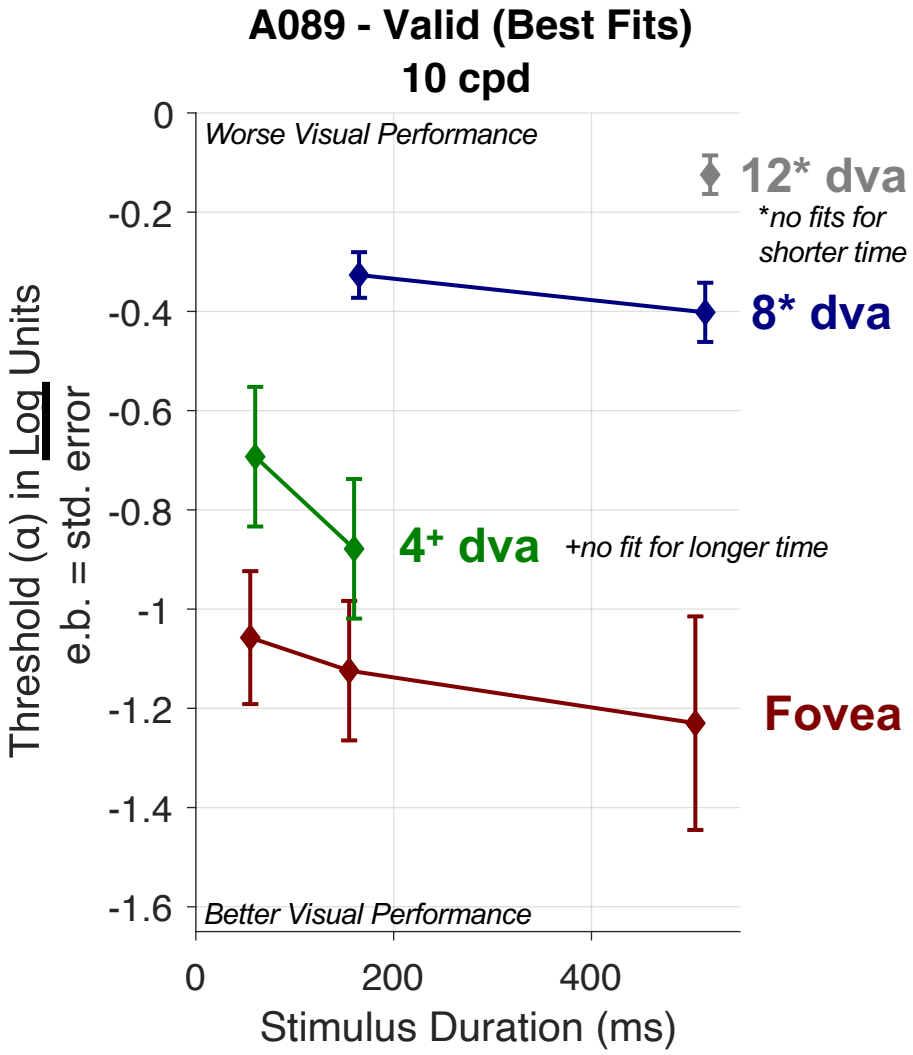


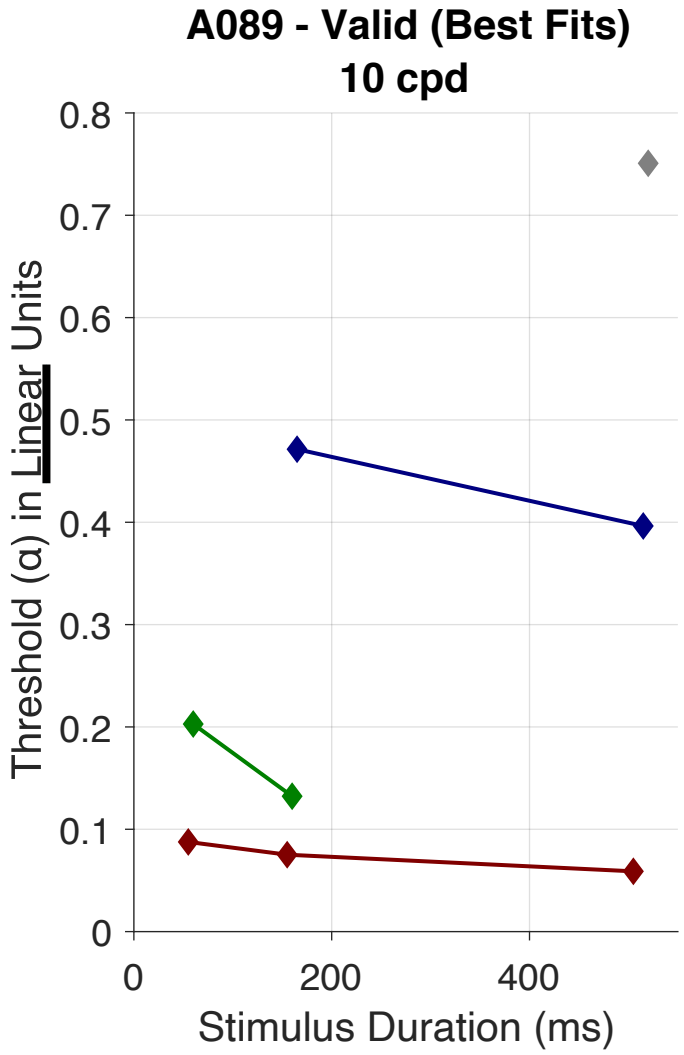


Results: 2nd Subject on Paradigm 1.2

Subject	Task Version	Eye Tested	Rig	# of Conditions	Total Trials
A089	1.2	Left	DPI	24	1013
A014	1.2	Left	DPI	24	3799
A013	1.1	Right	DPI	12	2652
A036	1.1	Right	DPI	12	3444
A092	1.1	Right	DPI	12	3683
A0NK	1.1	Right	DPI	12	2819

Results: High SF (10 cpd)

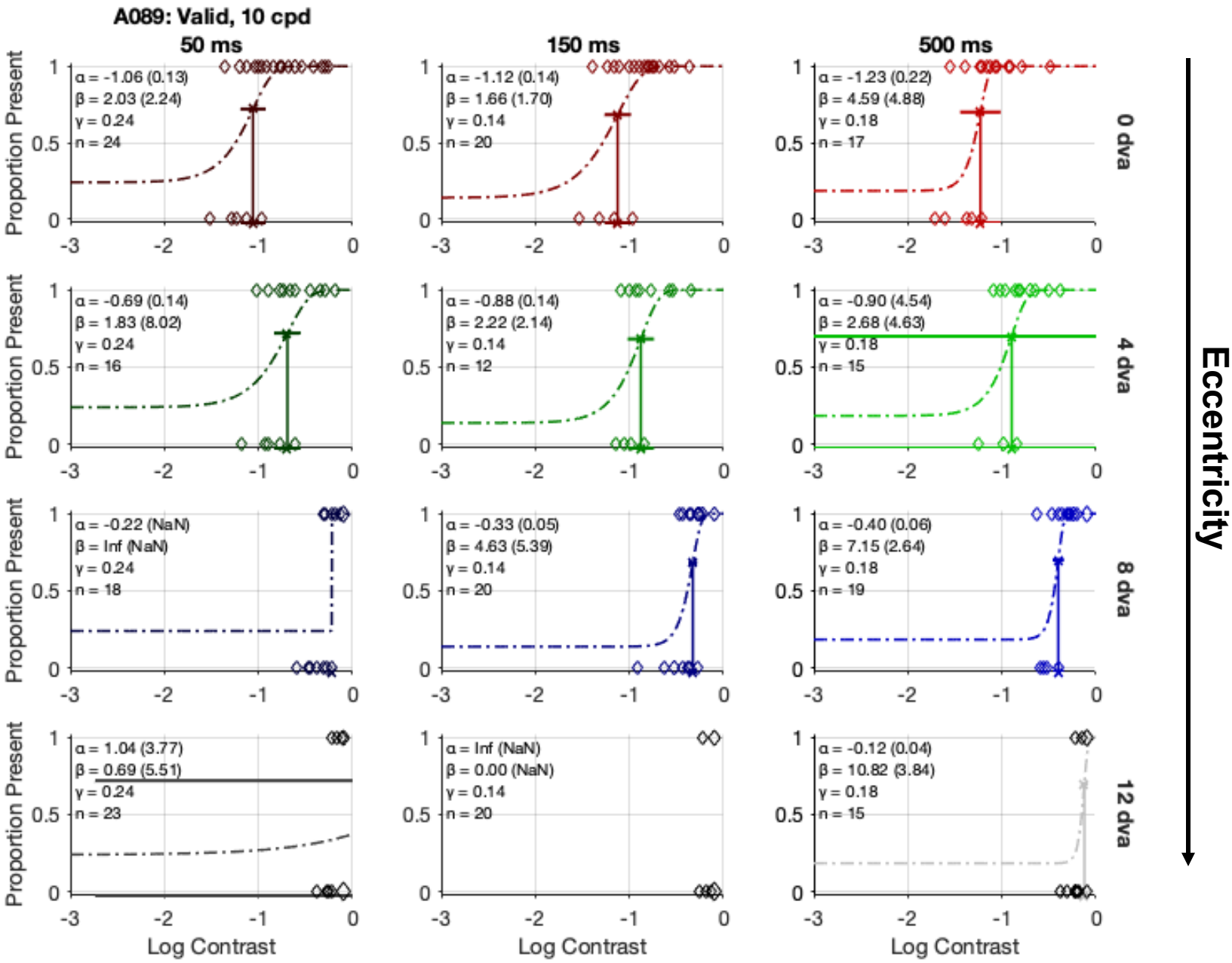




10 cpd

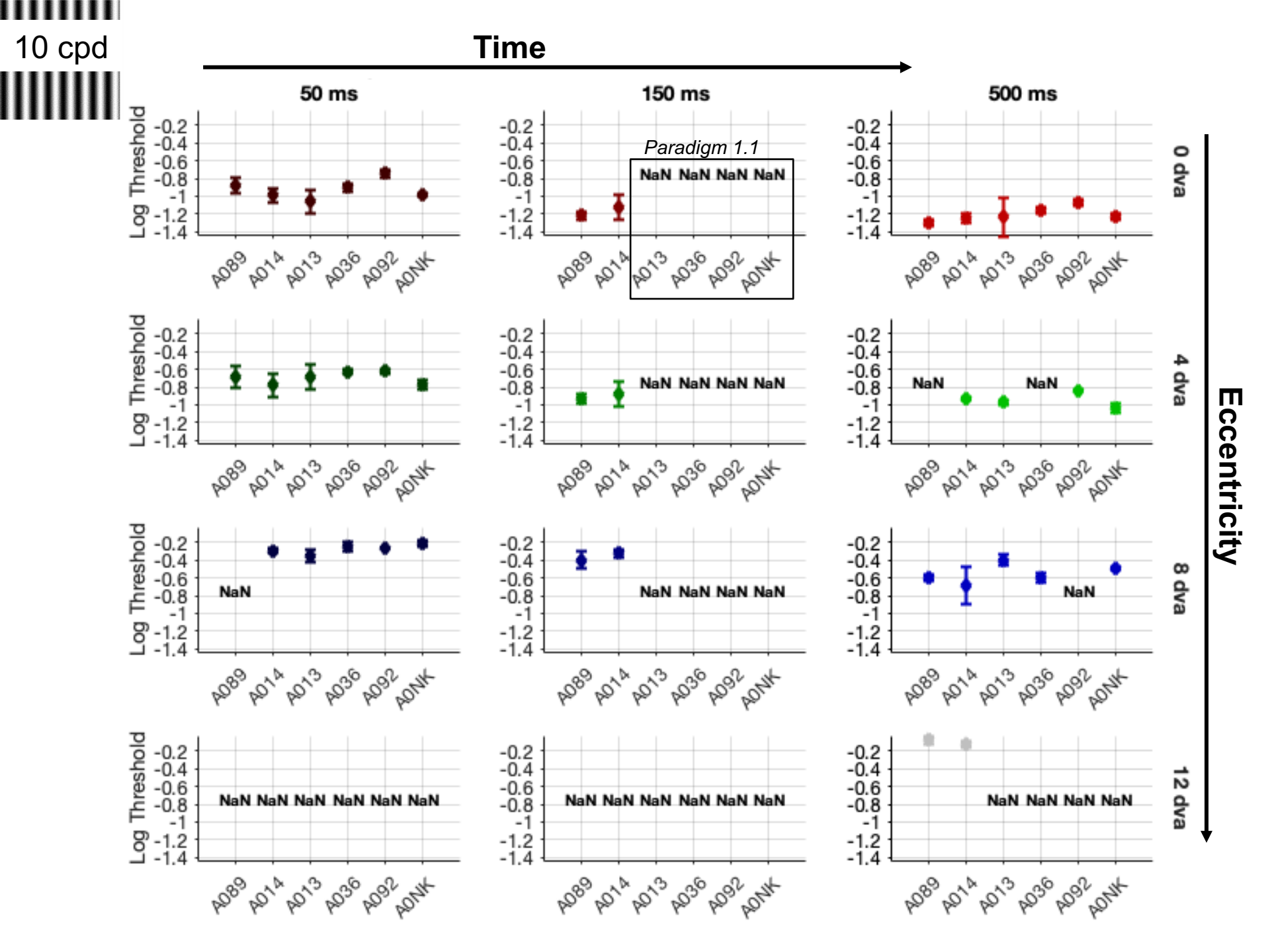
Time

1 Subject: A086 (1.2)



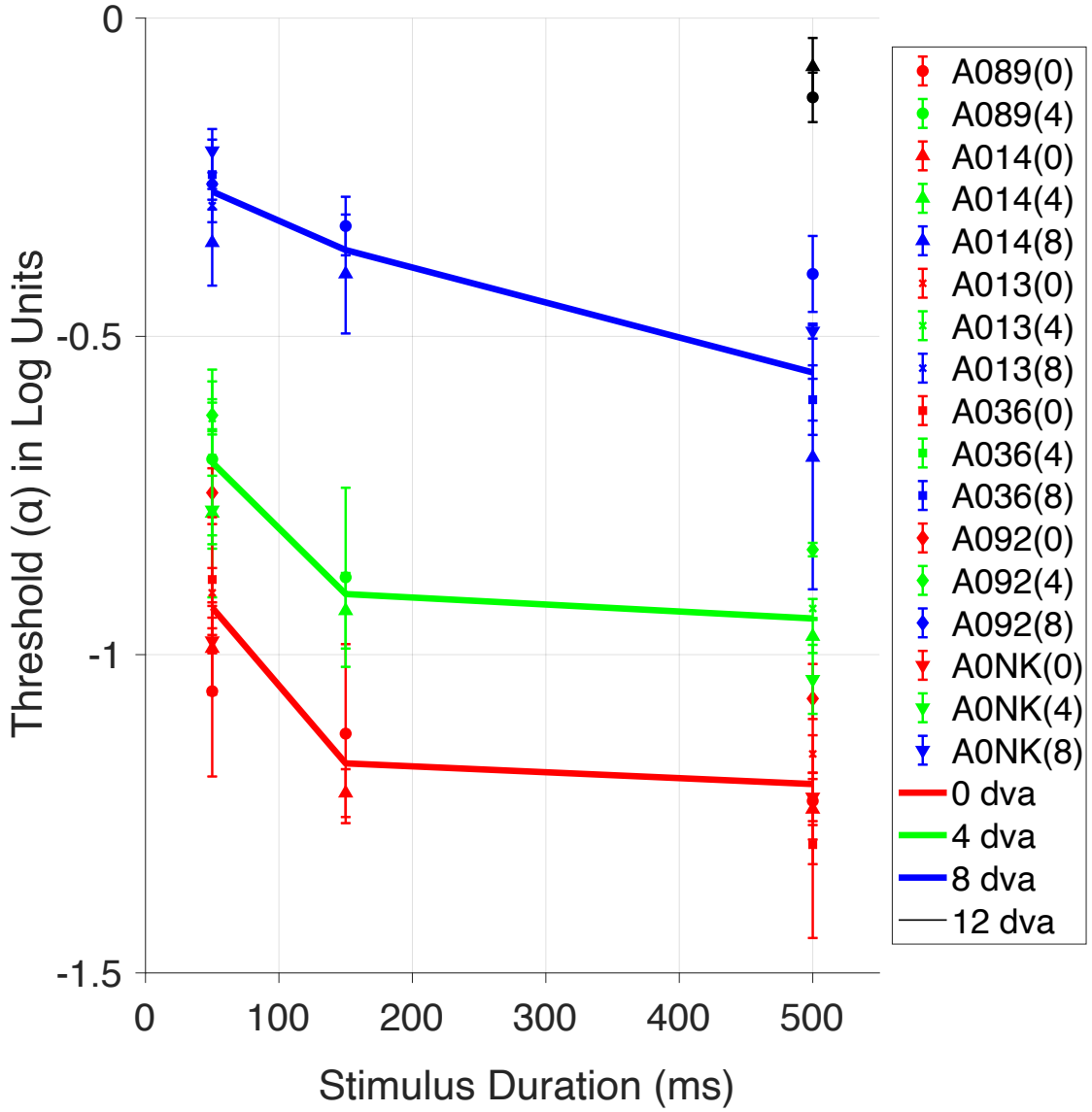
Results: Subjects from Paradigm 1.1 & 1.2

Subject	Task Version	Eye Tested	Rig	# of Conditions	Total Trials
A089	1.2	Left	DPI	24	1013
A014	1.2	Left	DPI	24	3799
A013	1.1	Right	DPI	12	2652
A036	1.1	Right	DPI	12	3444
A092	1.1	Right	DPI	12	3683
A0NK	1.1	Right	DPI	12	2819


10 cpd
Time
50 ms
150 ms
500 ms
Paradigm 1.1
0 dva
4 dva
8 dva
12 dva
Eccentricity
Log Threshold
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
A089
A014
A013
A036
A092
A0NK
NaN NaN NaN NaN
NaN NaN NaN NaN
NaN
NaN
NaN
NaN NaN NaN NaN NaN NaN
NaN NaN NaN NaN NaN NaN
NaN NaN NaN NaN

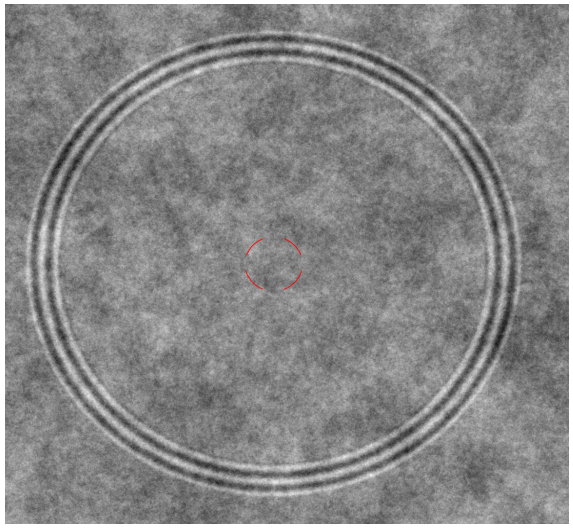
All Subjects

Results: High SF (10 cpd)

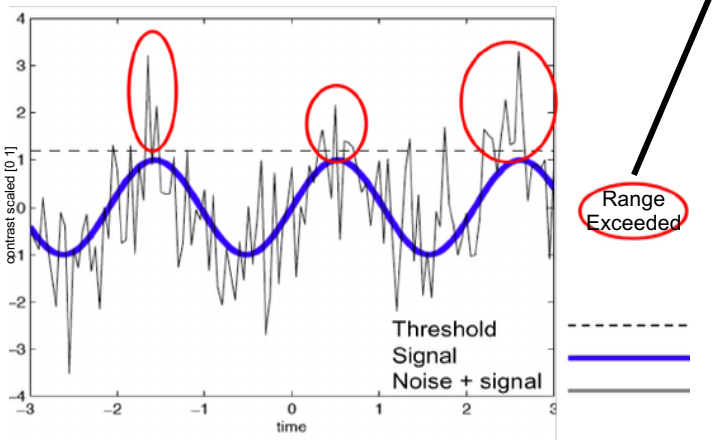


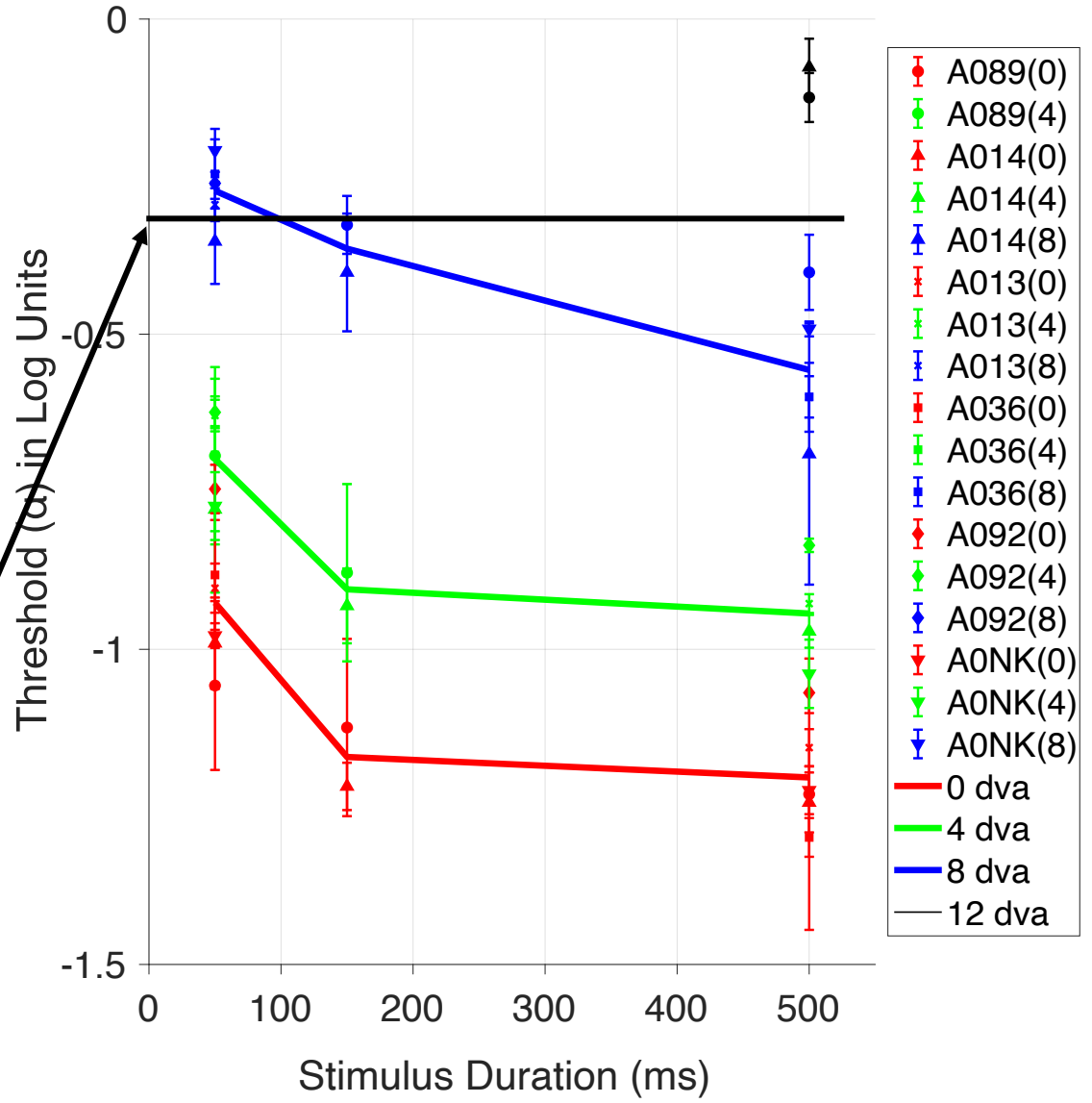
All Subjects

Results: High SF (10 cpd)



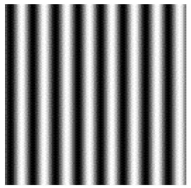
Stimulus = Signal + Noise





All Subjects

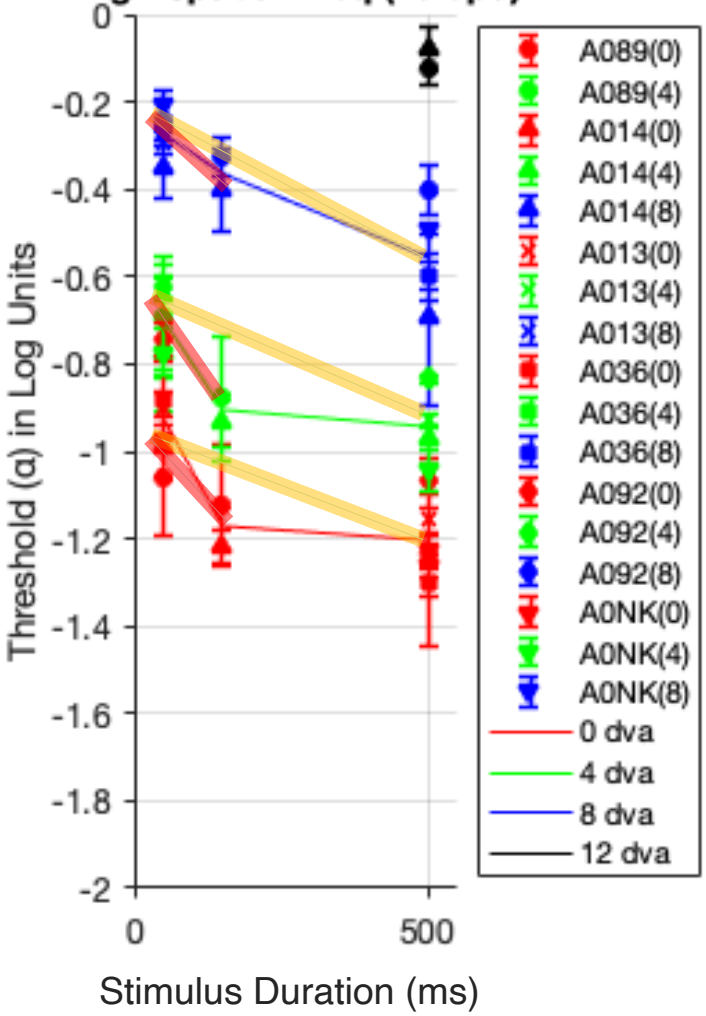
Conclusions: High SF (10 cpd)



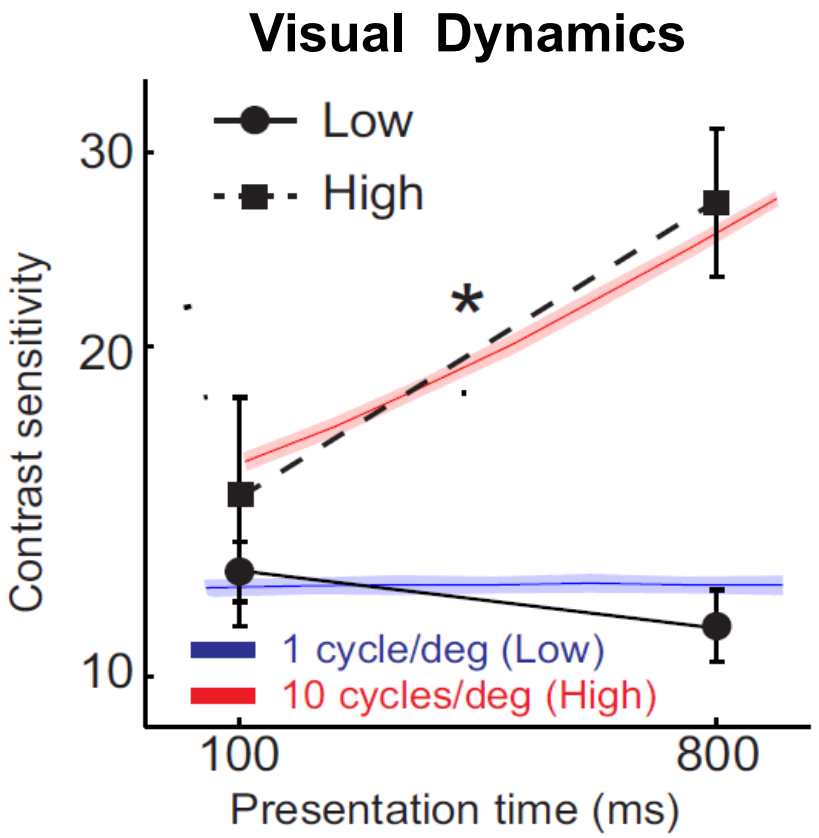
Valid

High Spatial Freq (10 cpd)

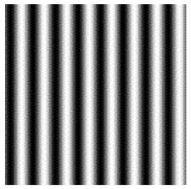
- Decrease in threshold for high spatial frequency with increase in post-saccade fixation time
- Slope of improved sensitivity is steeper at at the fovea (0 dva) than periphery (8 cpd)
  - ? Based mostly on data from 1 subject

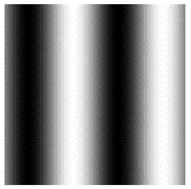


RESULTS: LOW SPATIAL FREQUENCY



Fovea
4 dva
8 dva
12 dva





10 cpd

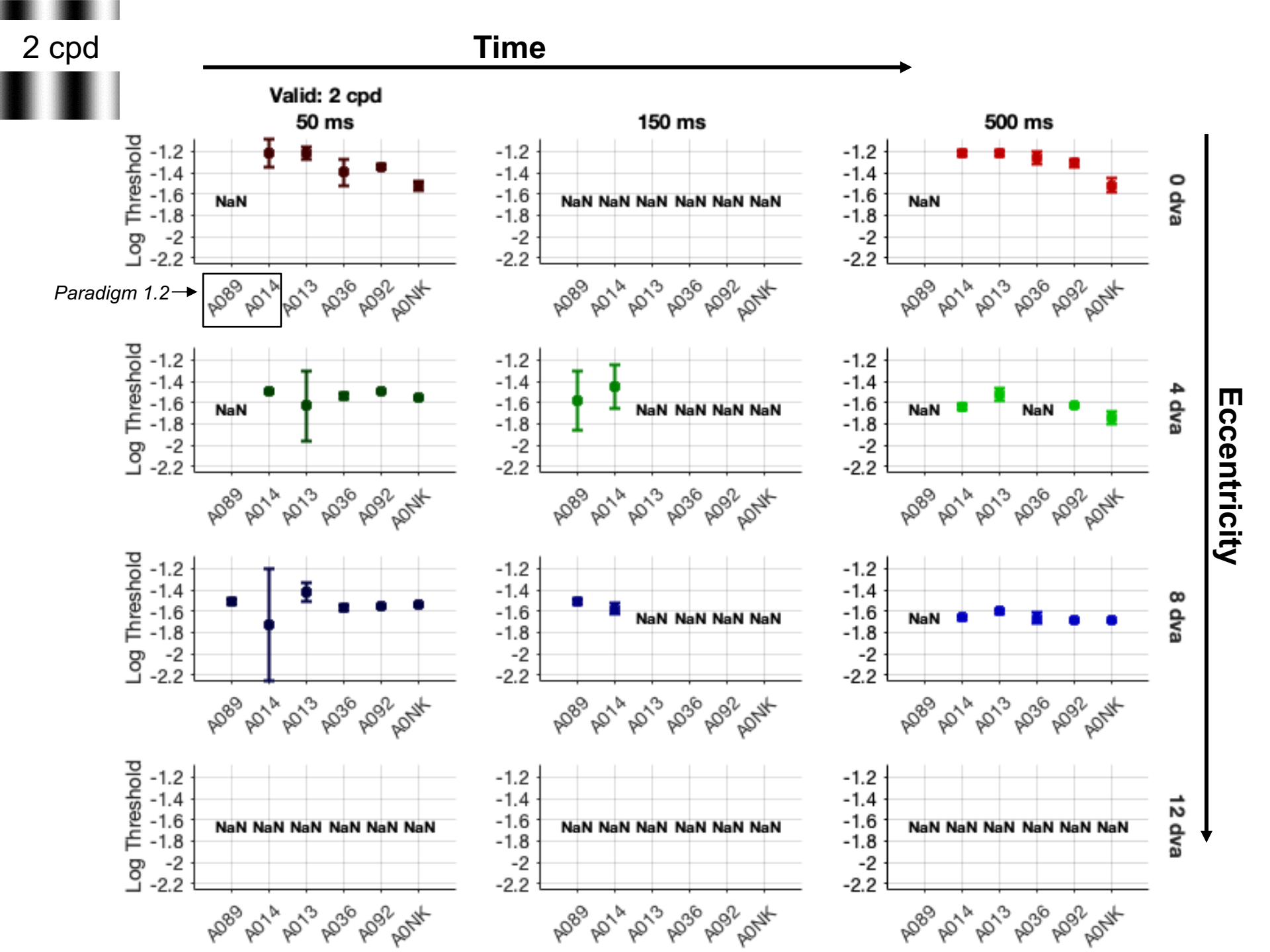
2 cpd

Threshold (α) in Log Units
e.b. = std. error

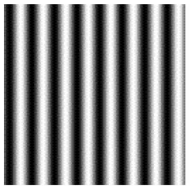
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2

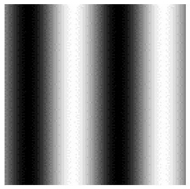
0
200
400

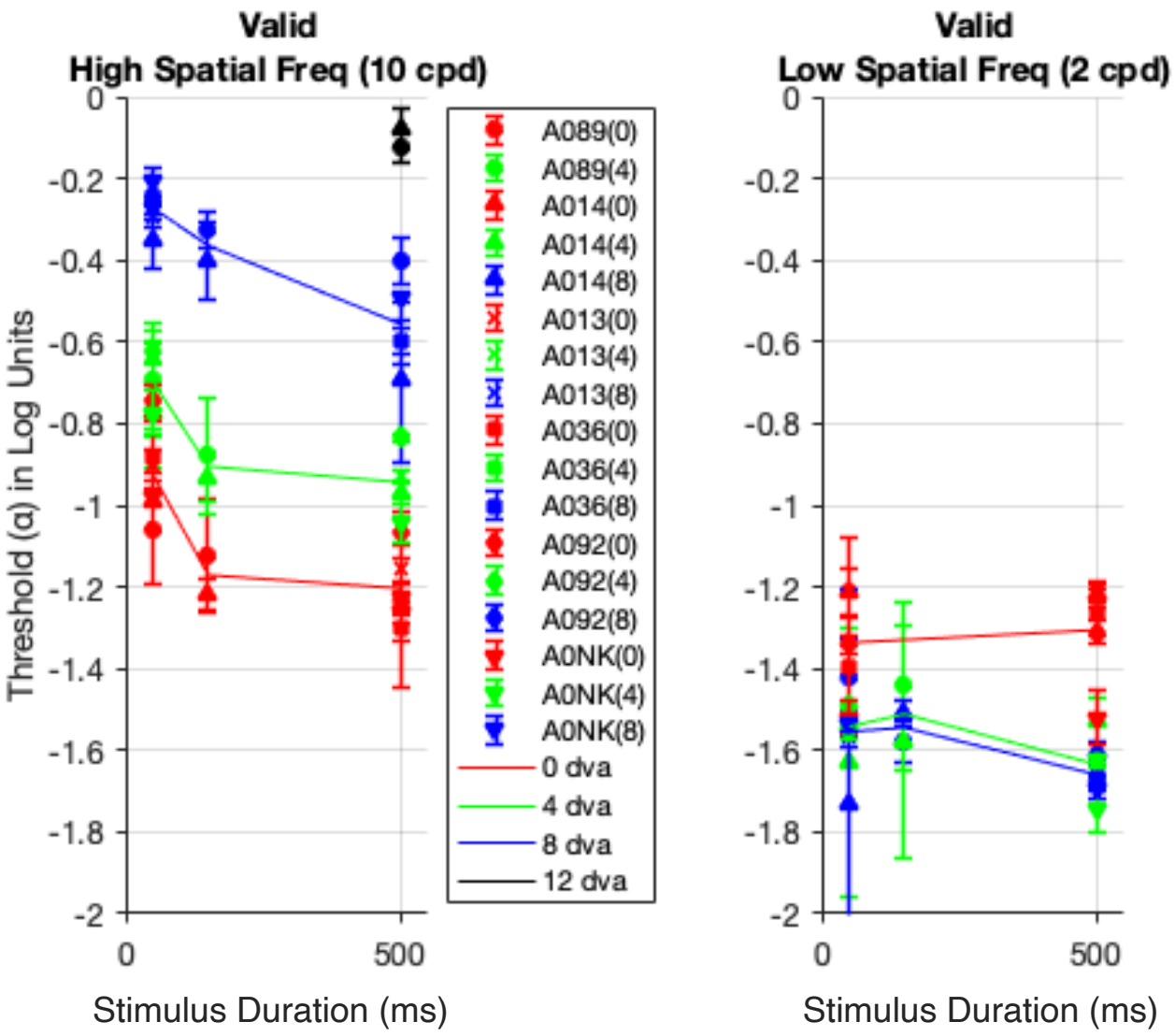
Stimulus Duration (ms)


2 cpd
Time
Valid: 2 cpd
50 ms
150 ms
500 ms
Log Threshold
-1.2
-1.4
-1.6
-1.8
-2
-2.2
NaN
NaN NaN NaN NaN NaN NaN
A089
A014
A013
A036
A092
A0NK
Paradigm 1.2
0 dva
4 dva
8 dva
12 dva
Eccentricity

All Subjects

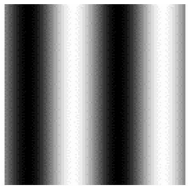


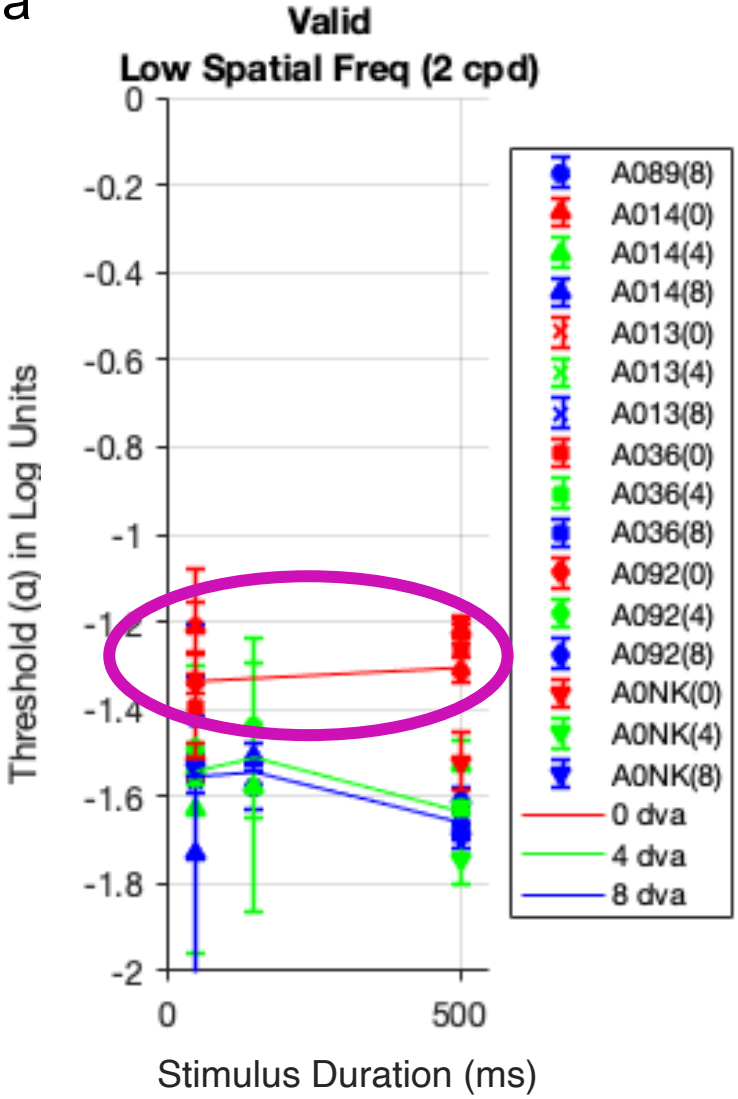




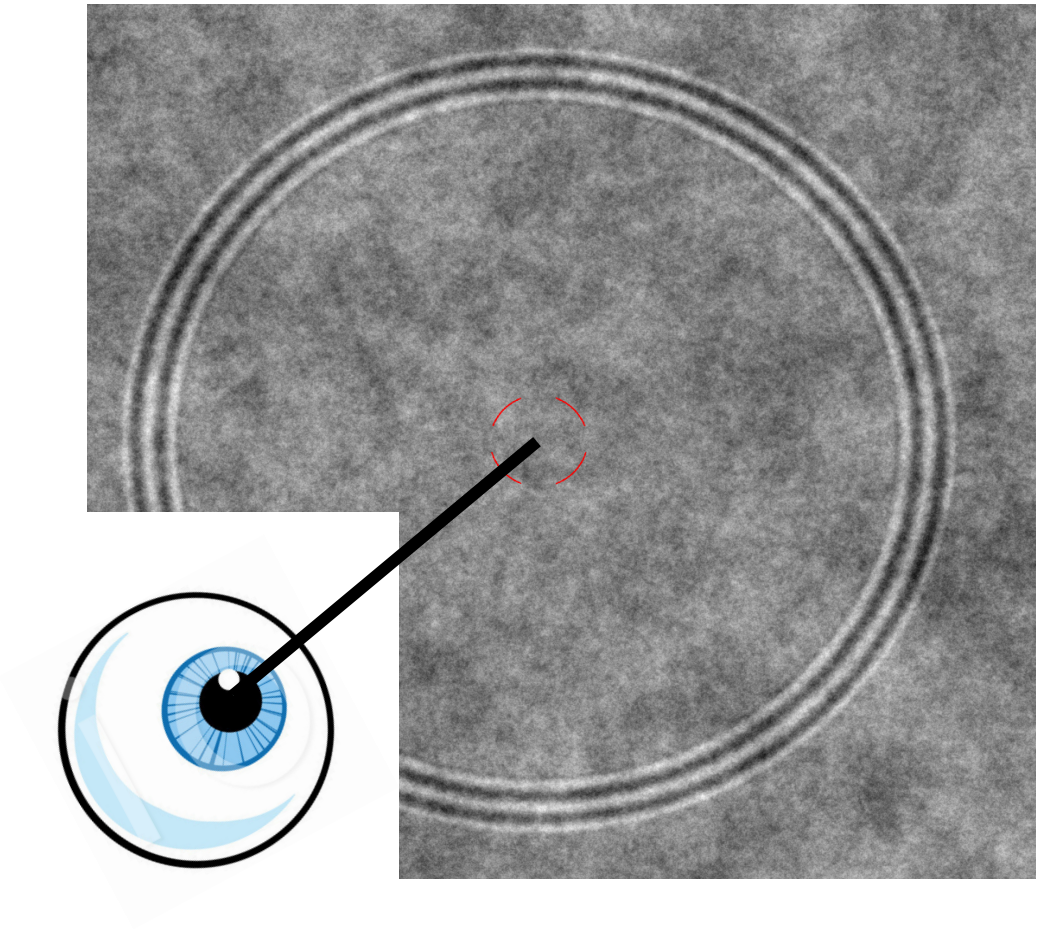
Conclusions: Low SF (2 cpd)

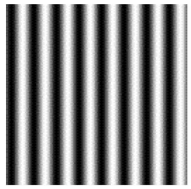
- Threshold is higher (worse) at the fovea



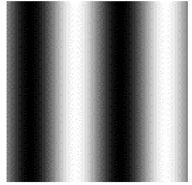


Methods: Method of Adjustment

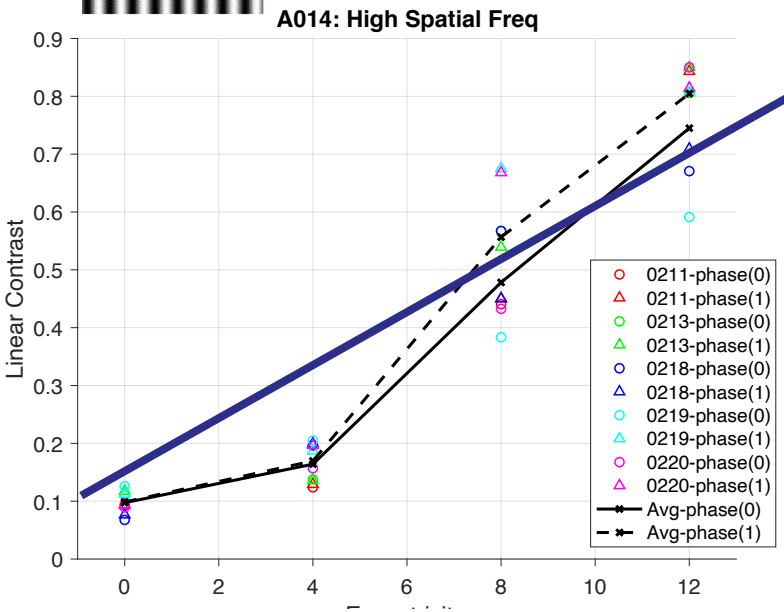


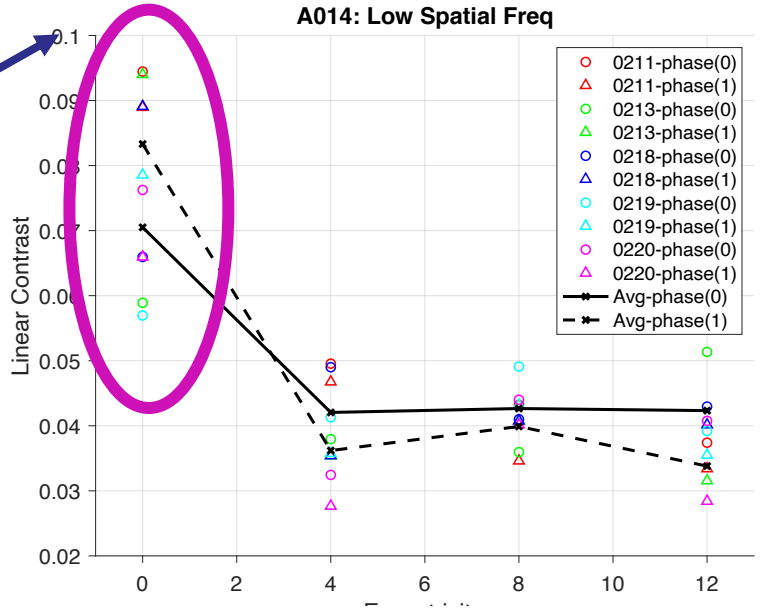


Results: Method of Adjustment

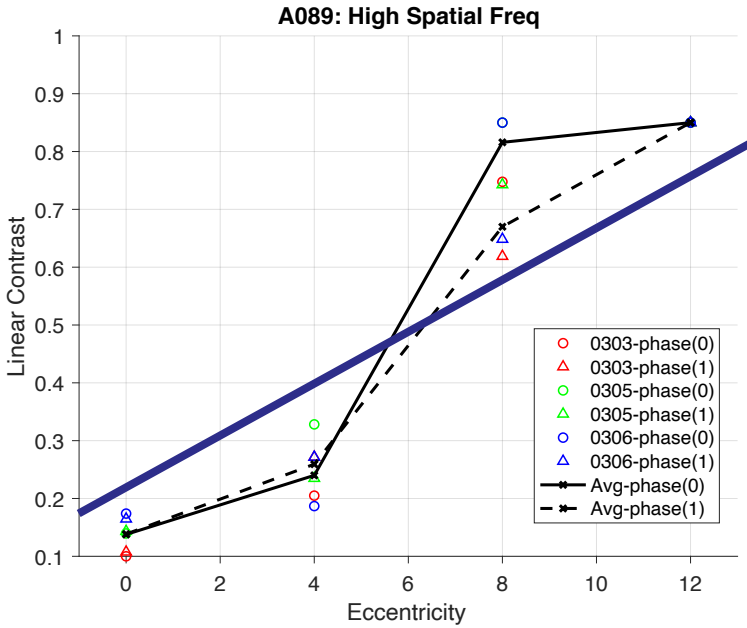


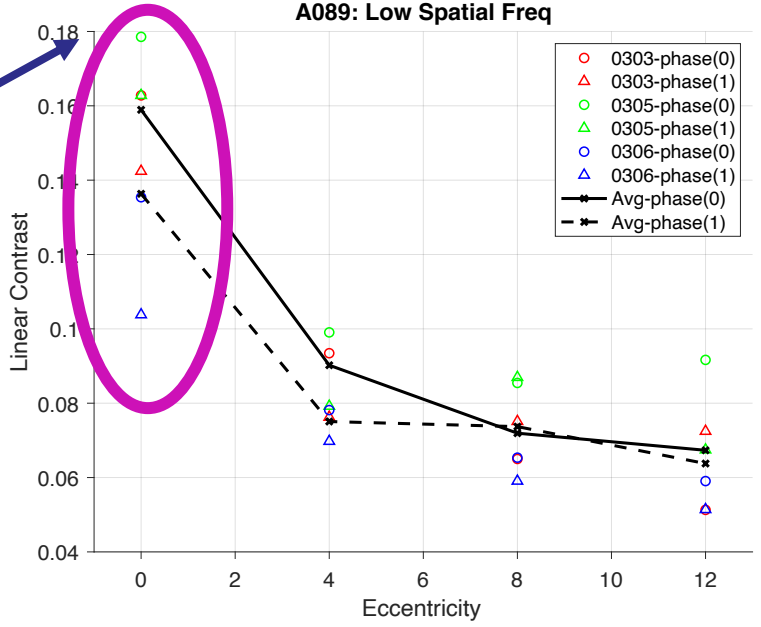
1st Subject



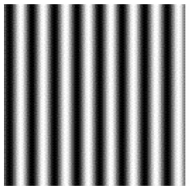


2nd Subject

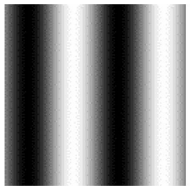




Conclusions



- Decrease in threshold for high spatial frequency with increase in post-saccade fixation time
- [tentative] Slope of improved sensitivity is steeper at at the fovea (0 dva) than periphery (8 cpd)



- Threshold is higher (worse) at the fovea