Eye Chart Experiment: Eye Movements in Visual Acuity Tests

Janis Intoy

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Objectives

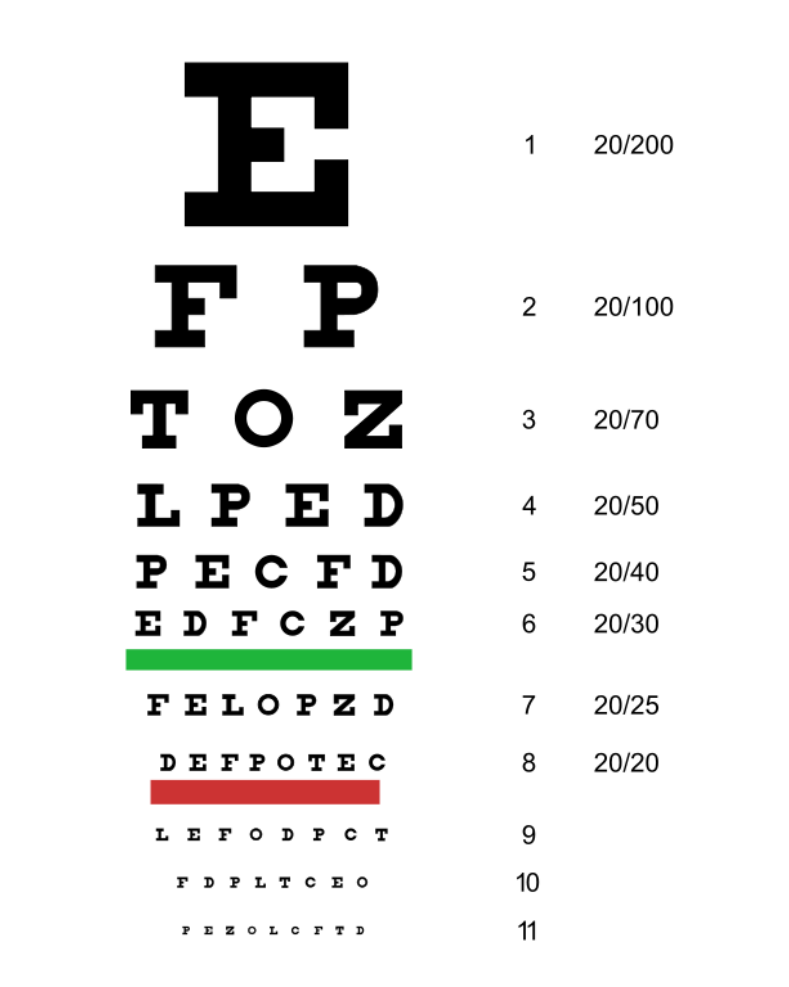
- Determine the role of eye movements in standardized visual acuity tests
- Determine eye movement characteristics associated with high visual acuity
- Examine the homogeneity of contrast sensitivity within the foveola

Motion Effects in Visual Acuity Tasks

- Acuity is unaffected by fixational eye movements in vernier test, single line detection, grating discrimination (Keesey, 1960)
- Microsaccades are exploratory movements in high visual acuity tasks (Ko et al., 2010)
- Acuity is insensitive to retinal-image motion in vernier test and Landolt-C VA test (Westheimer & McKee, 1975; Morgan & Benton, 1989)

Standardized Visual Acuity Tests

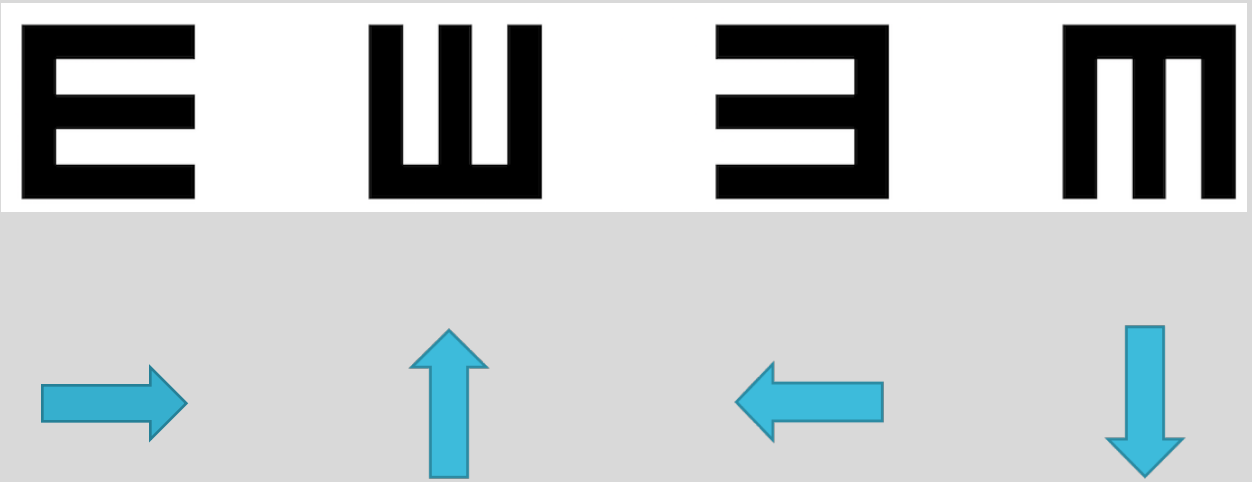
Snellen Chart



LogMAR Chart (Bailey & Lovie, 1976)

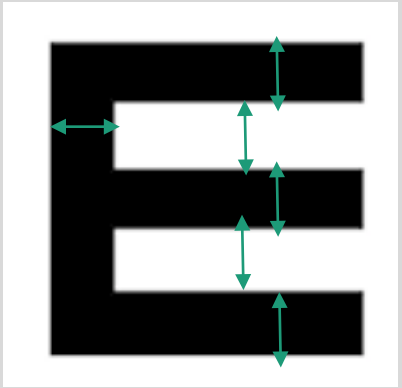
Tumbling-E Task and Stimulus

- Forced-choice discrimination task: identify the orientations of ”E”s in a line from left to right
- Spacing between optotypes is equal to the width of the optotype
- Number of optotypes in line chosen so that the width of the line is less than 1 visual degree (up to 6)



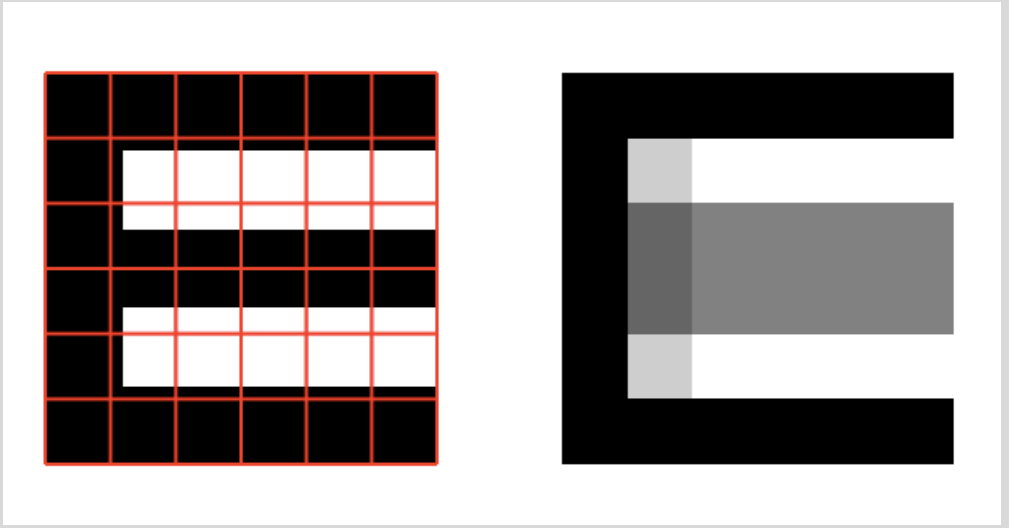
Stimulus Generation

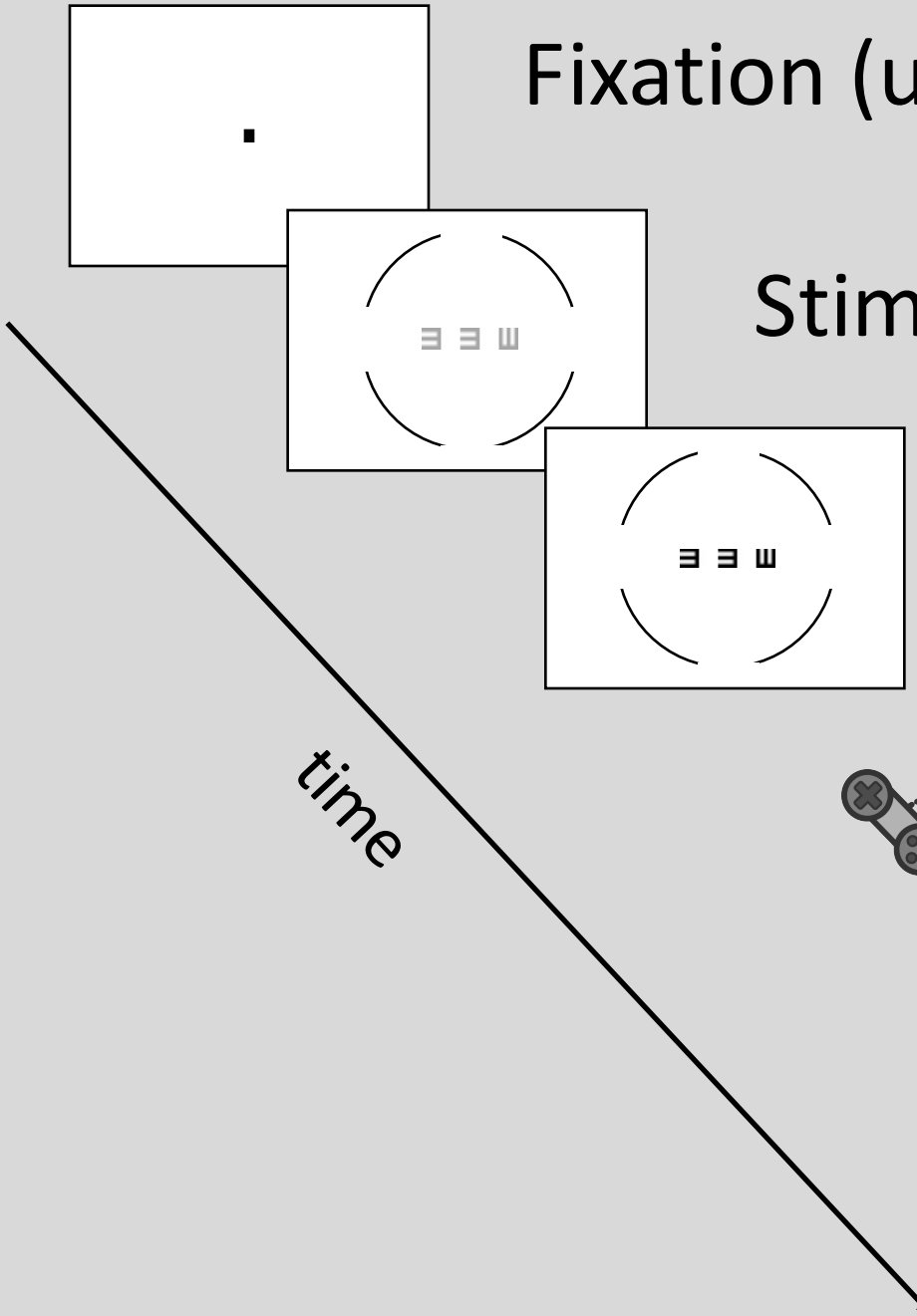
- Optotypes varied in size and contrast (procedure explanation to follow)
- 11 optotype sizes were used ranging from .0253 to .5024 logmar
- “perfect” optoptypes would have pixel dimensions that are multiples of 5 so intermediate-sized optotypes were created using anti-aliasing



α = minimum angle of resolution

Logmar = log10(α)




Fixation (up to 1 sec)
Stimulus ramps in (1 sec)
Response Period (until completion)
time
End of Trial

Experimental Design

- 3 kinds of trial blocks:
  1. “Normal” viewing conditions:
     - Size: Fixed at smallest available optotype
     - Contrast: adjusted until 75% of optotypes are correctly identified using PEST algorithm
  2. “Stabilized-Contrast”: stabilized viewing conditions
     - Size: Fixed at smallest available optotype
     - Contrast: Adjusted until 75% performance is reached using PEST algorithm
  3. “Stabilized-Size”: stabilized viewing conditions
     - Size: Varies randomly (method of constant stimuli)
     - Contrast: Fixed at 75% threshold determined in Block 1

Data Analysis

- Analysis during response period only
- “notrack” trials are discarded (though some notracks < 300ms early in the trial are kept)
- ”blink” trials are allowed as trials could go for 5-15 sec on average
- In Normal blocks, trials with saccades > .5 degree are discarded
- In Stable blocks, trials with saccades > 2 or 1 degree are discarded

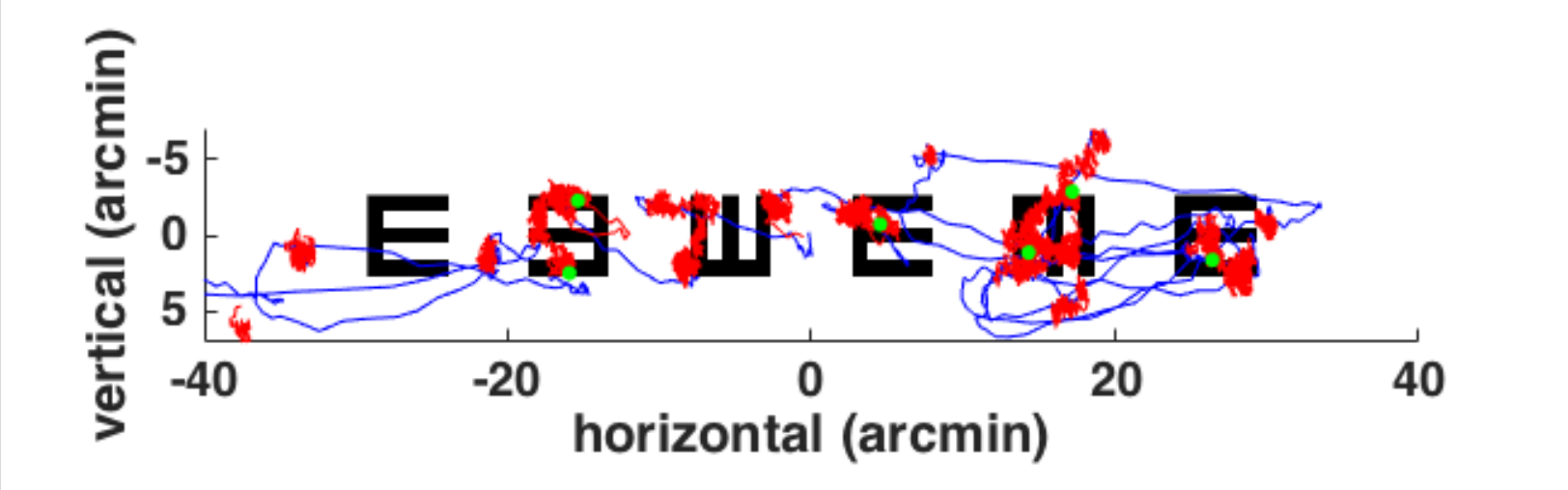
Data Summary (Trials Collected by Block)

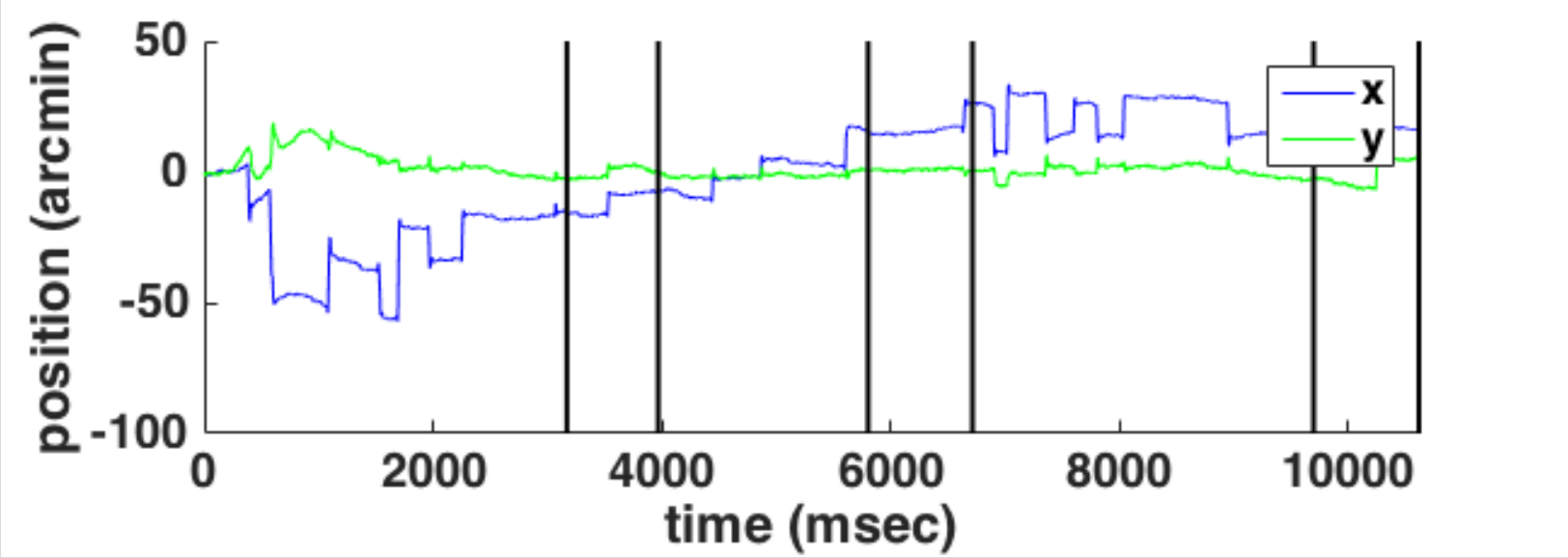
Subject	Normal (6 per)	Stabilized-Contrast (6 per) Discard >2 or >1 deg saccades		Stabilized-Size (# varies) Discard > 2 or >1 deg saccades	
AS	91/129	48/86	35/86		
AB	91/126	20/36	8/36		
CH	93/131	59/73	21/73	122/138	75/138
CS	88/144	44/69	6/69	131/169	92/169
JP?	103/175	27/57	24/57		
SB	112/212	89/99	57/99	159/175	152/175
ML	19/51				

EM Characteristics in Normal Trials

Example Eye Movement Traces (1)

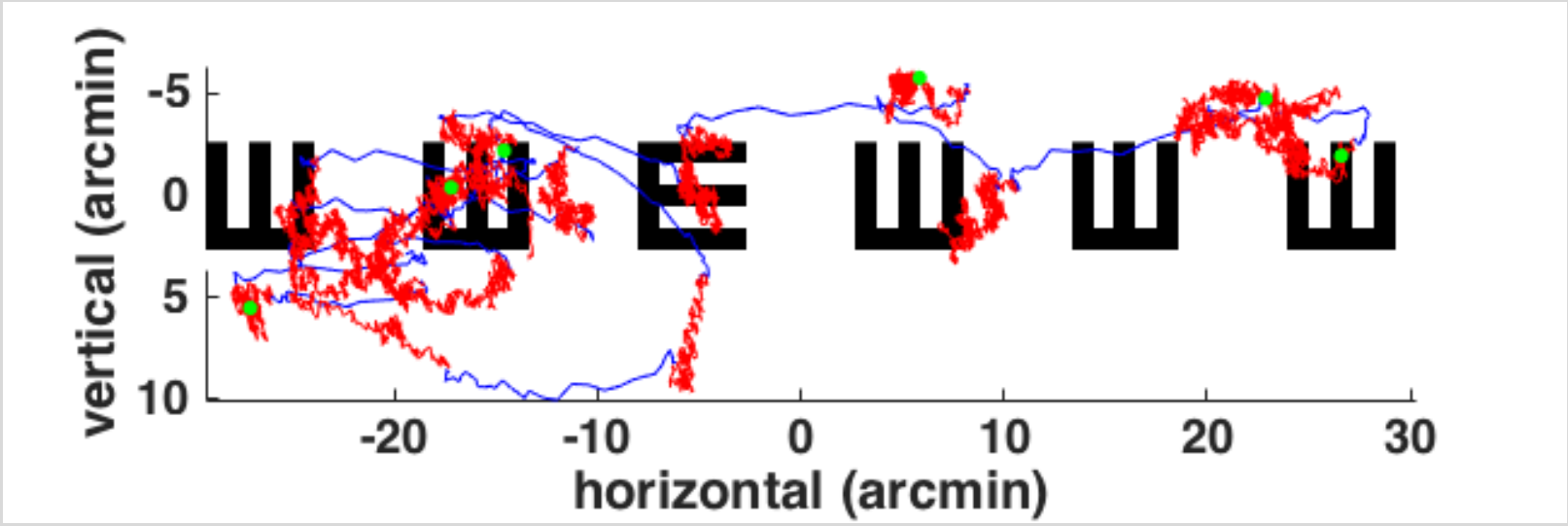
CS

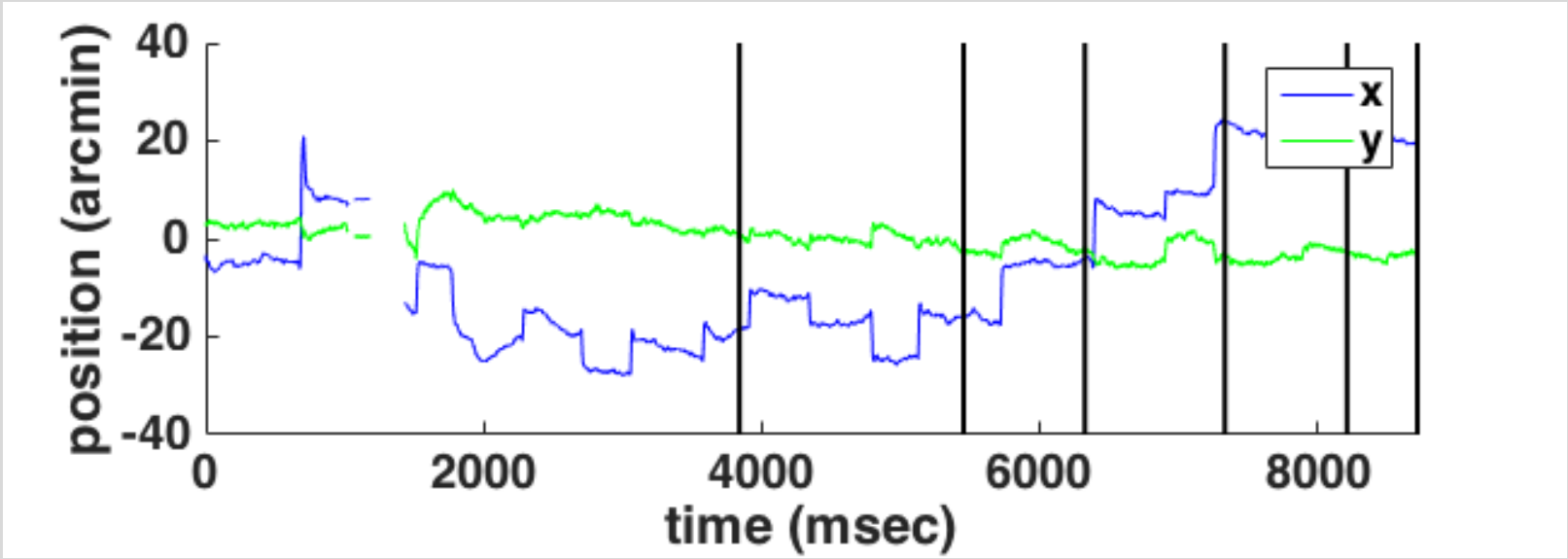




Example Eye Movement Traces (2)

SB

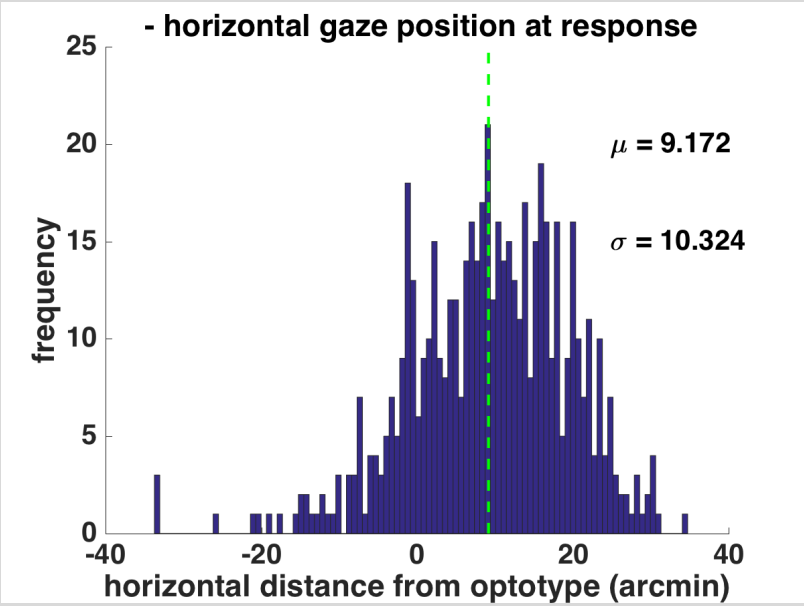




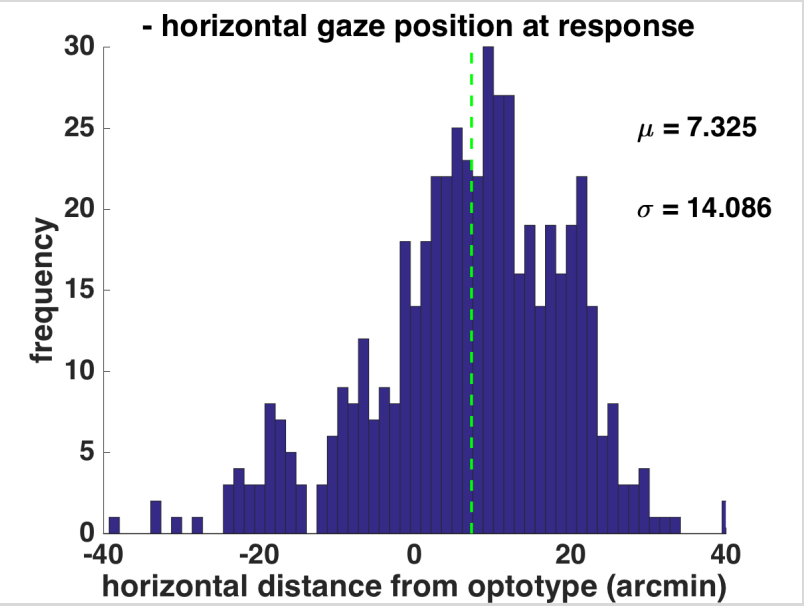
Horizontal Gaze Position at Response

Relative to central position of target optotype

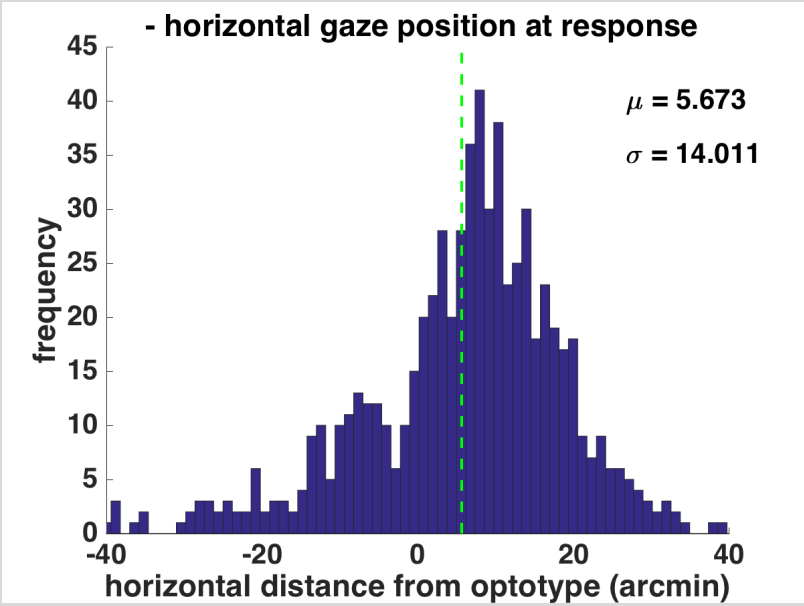
CH



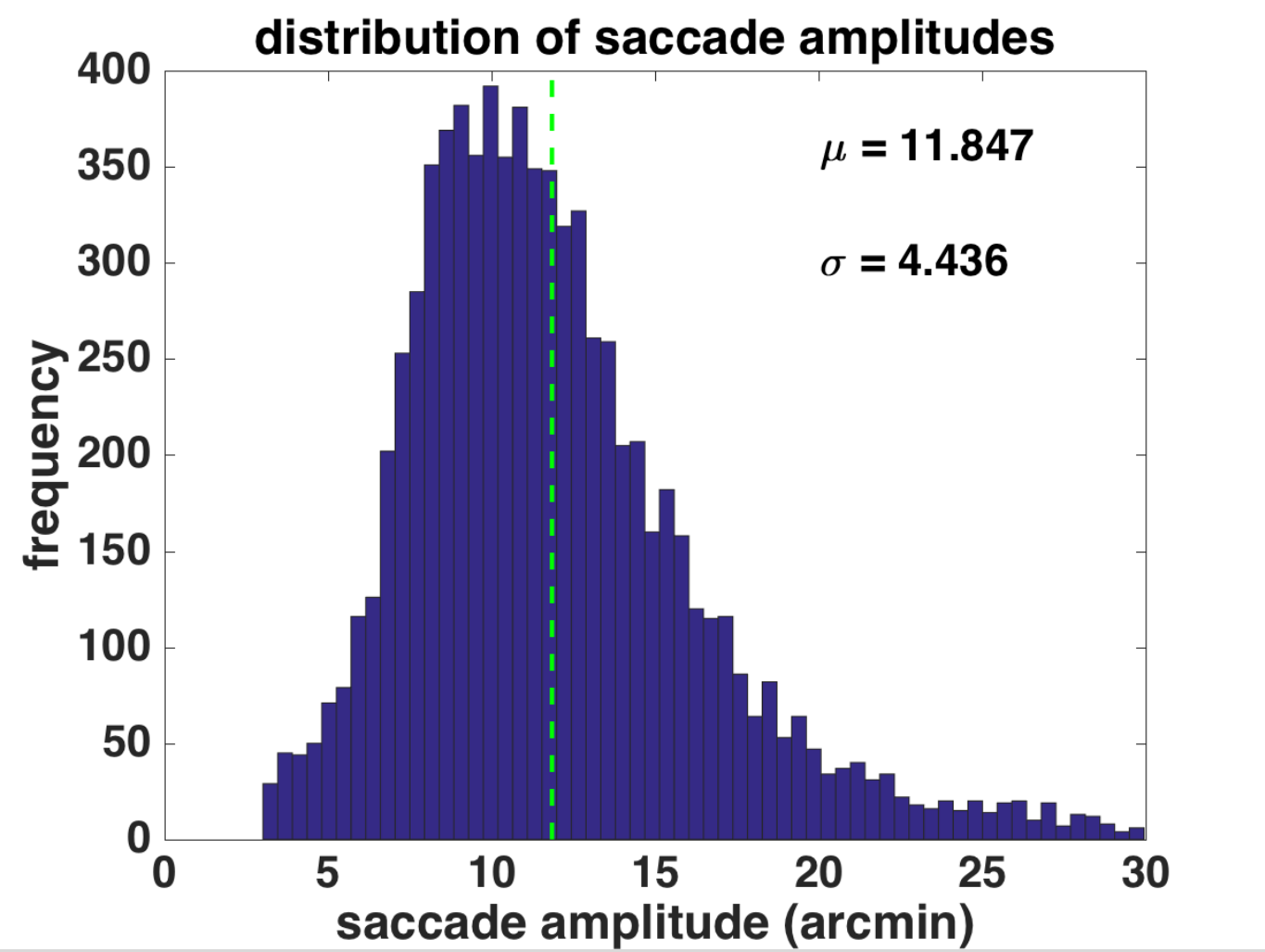
CS



SB



Saccade Size Distribution (Normal)

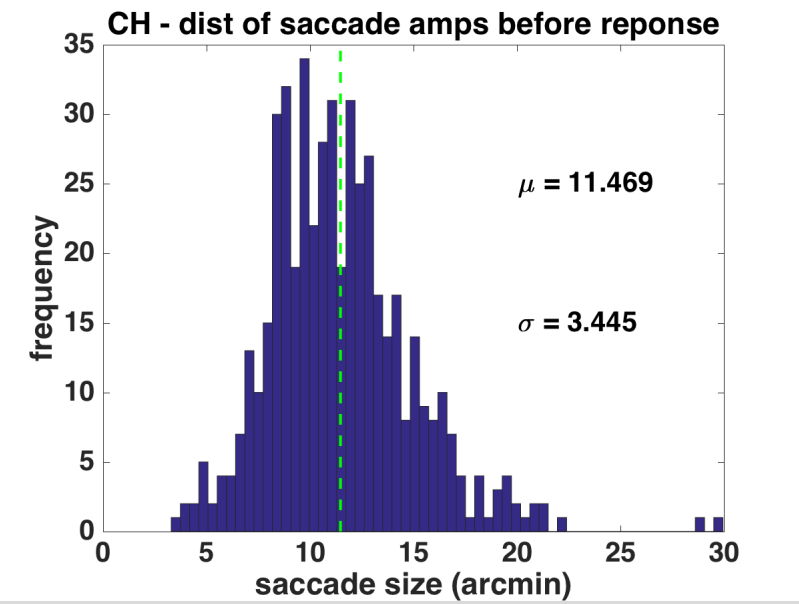


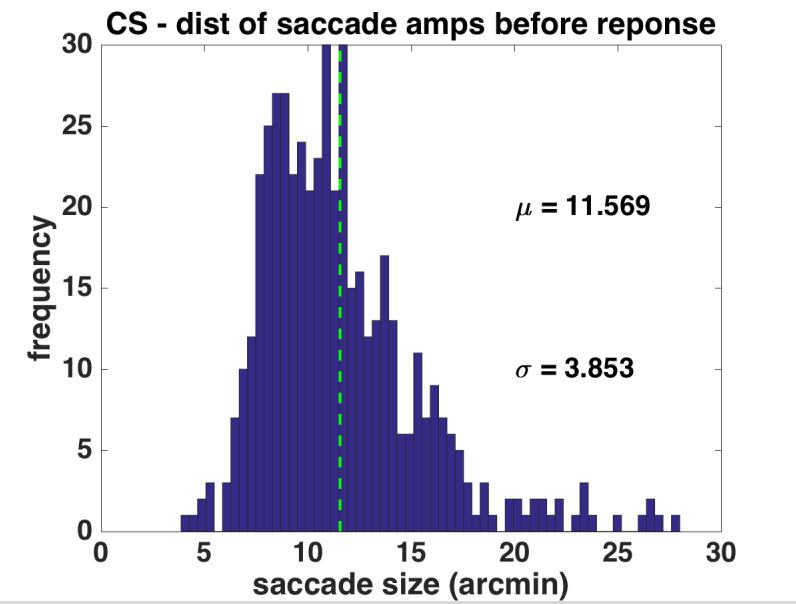
All saccades pooled across all subjects

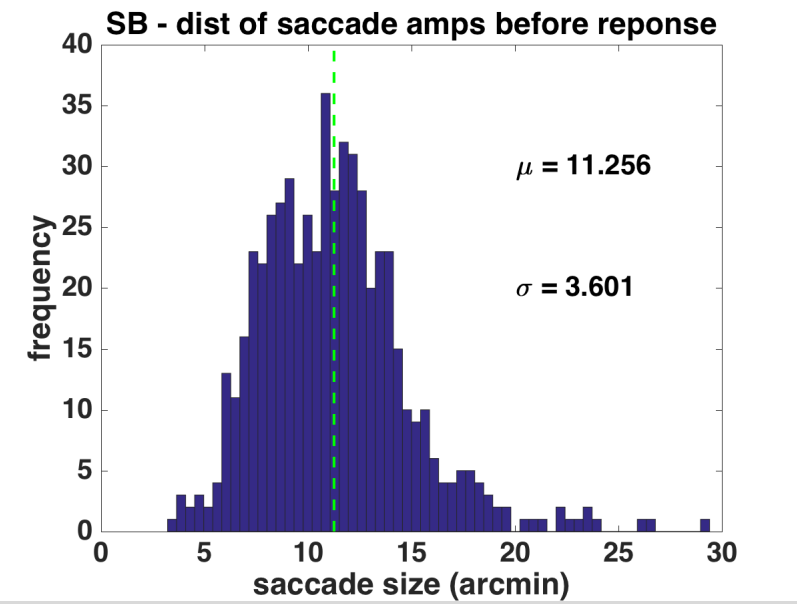
Center-to-center distance between neighboring optotypes = 10.6 arcmin

Saccades Just Before Response

Saccades that start before a response and after the previous response



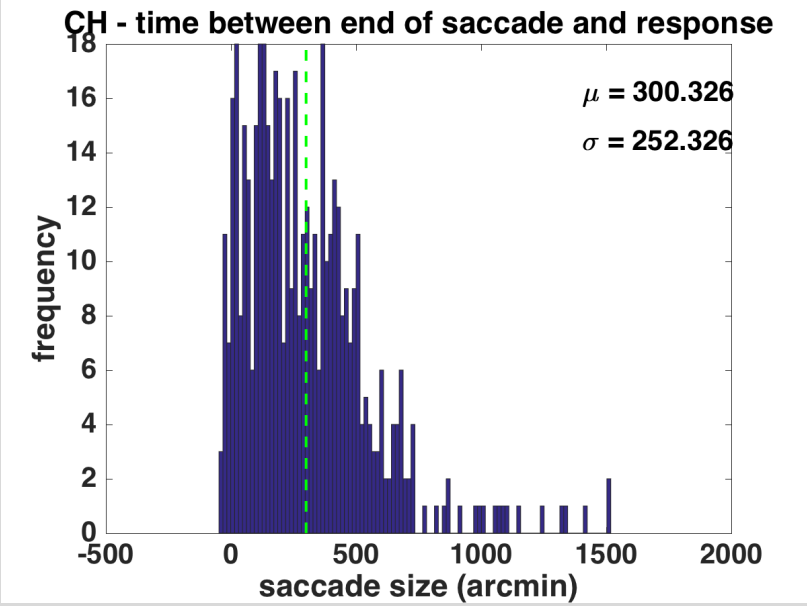


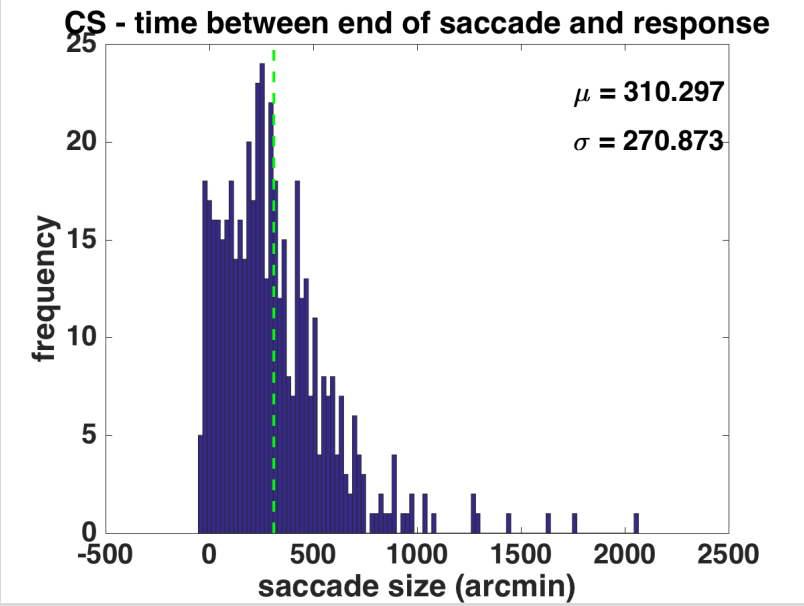


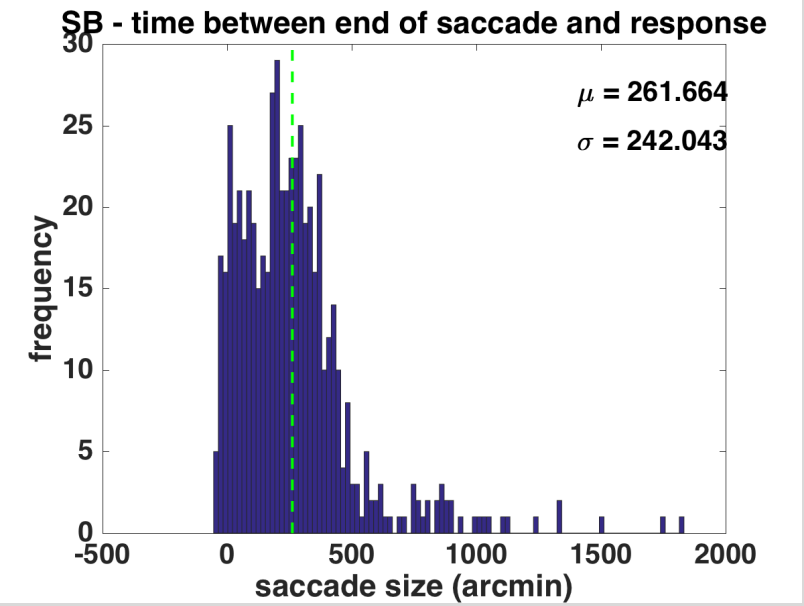
Center-to-center distance between neighboring optotypes = 10.6 arcmin

Time Between Prior Saccade End and Response

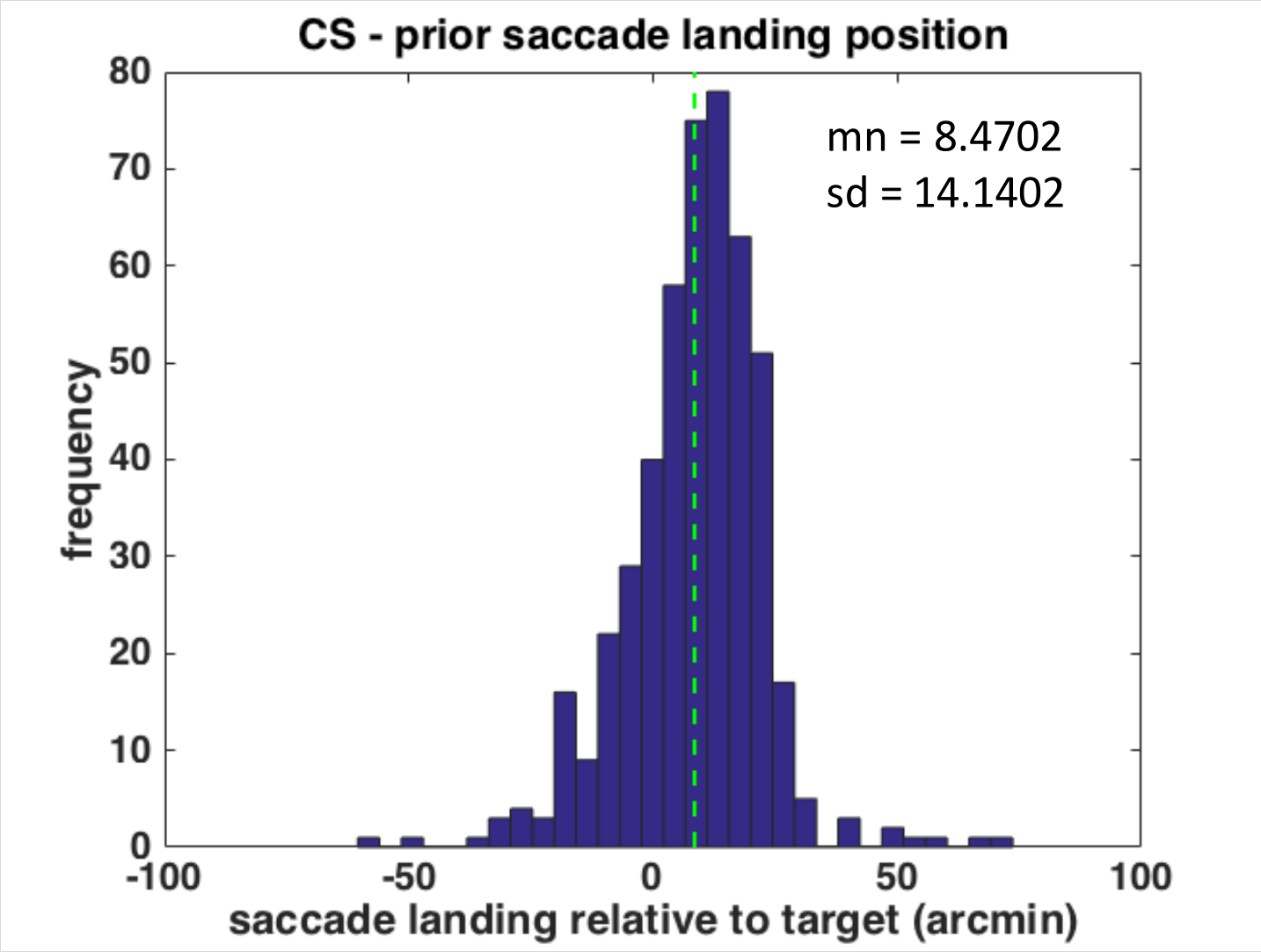
Saccades that start before a response and after the previous response





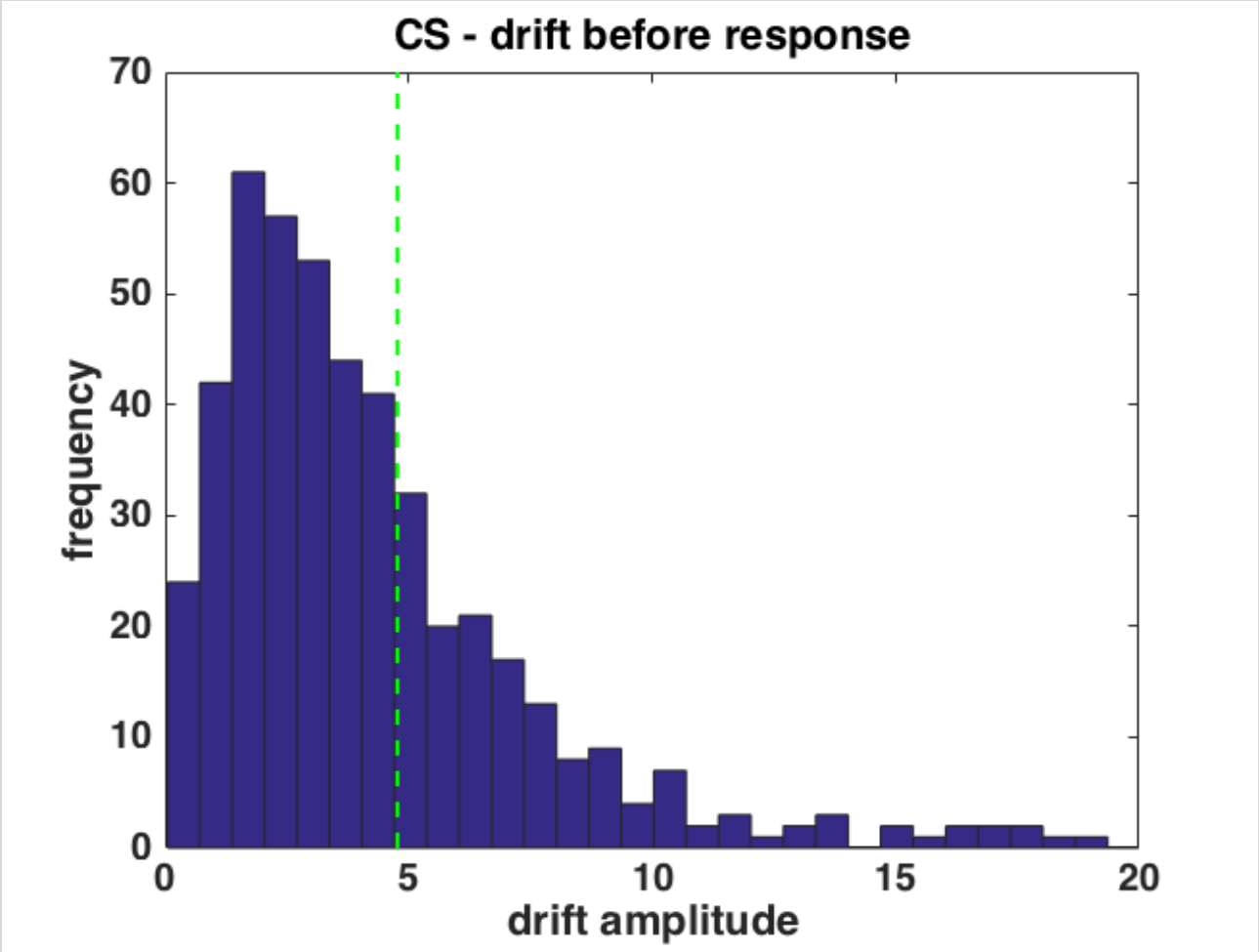


Prior Saccade Landing Position



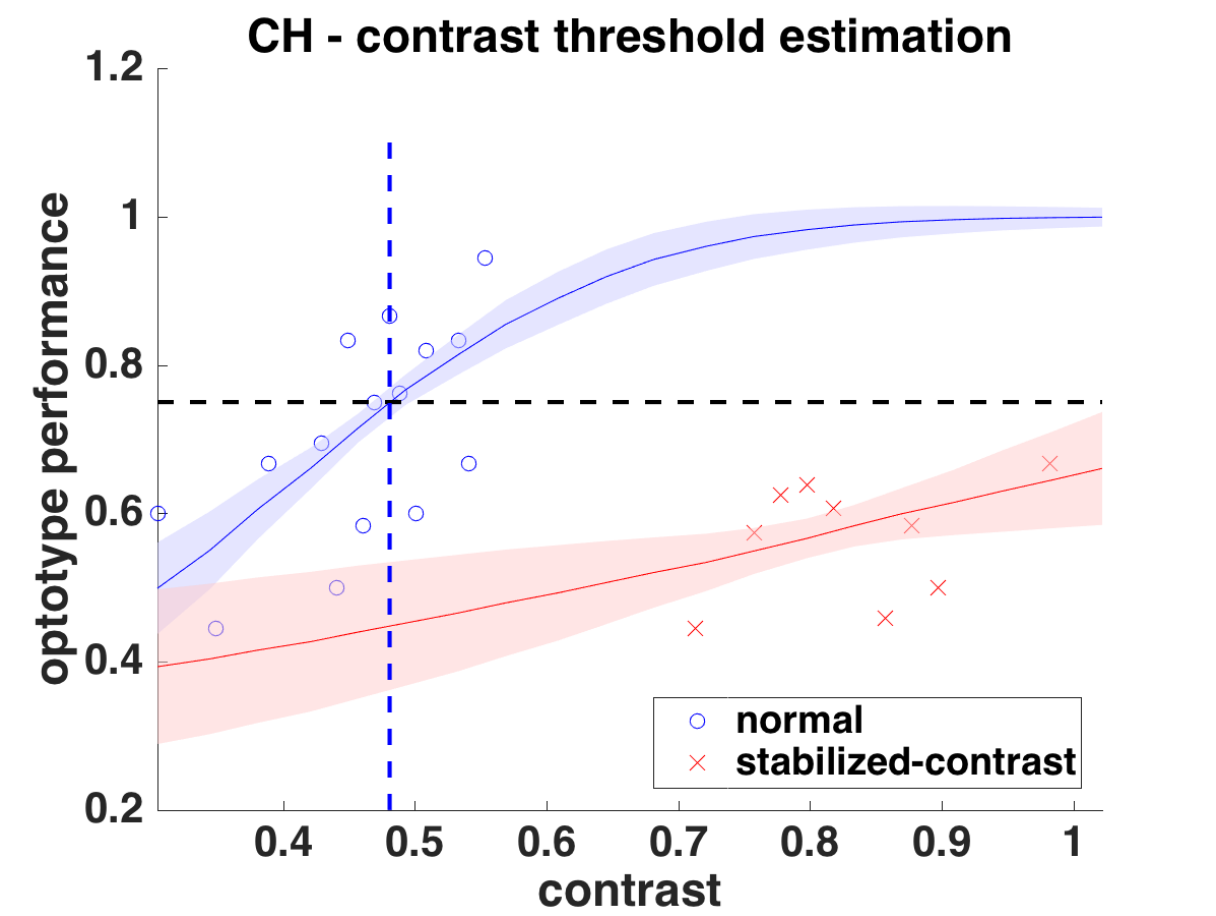
Distance Traveled in Drift Prior to/During Response

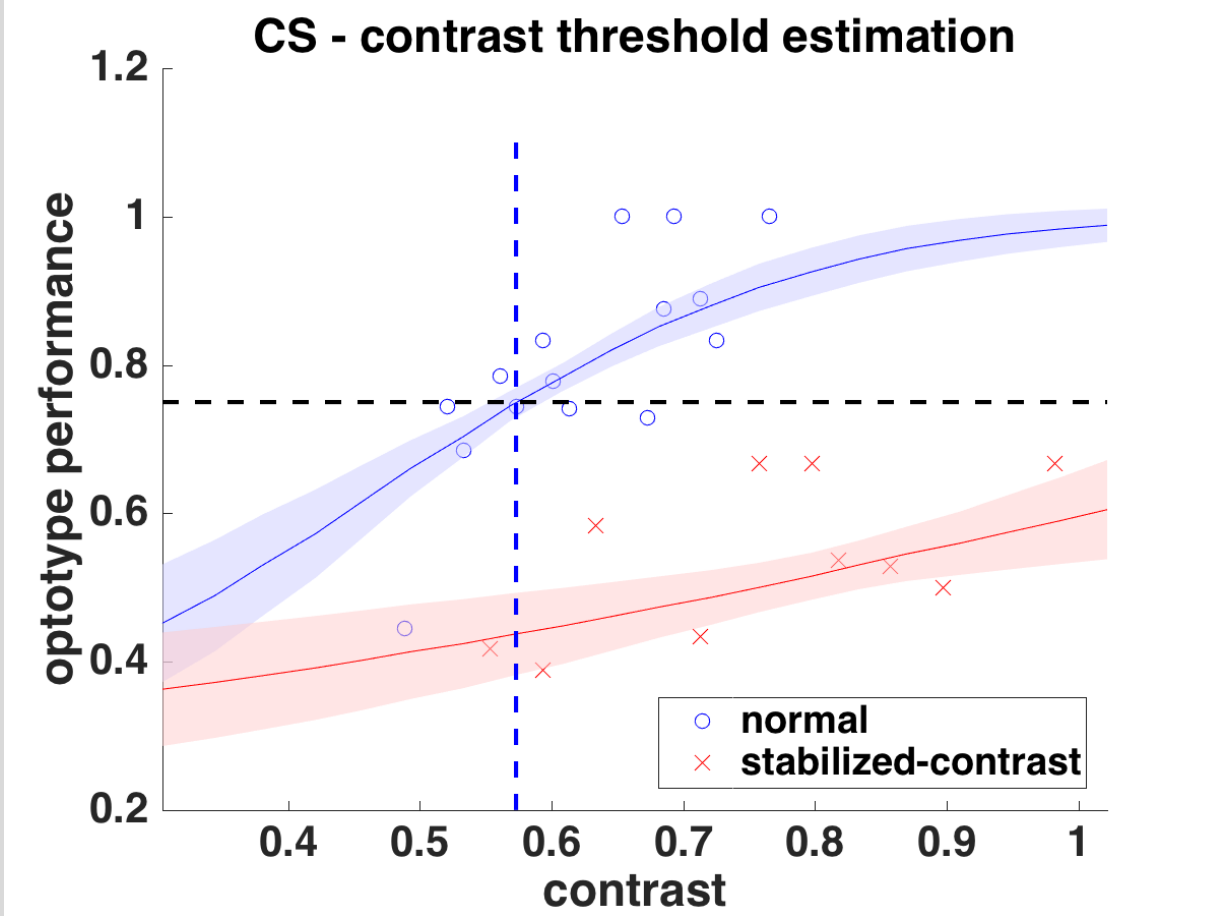
Drifts that start before a response and after the previous response



Normal vs. Stabilized-Contrast

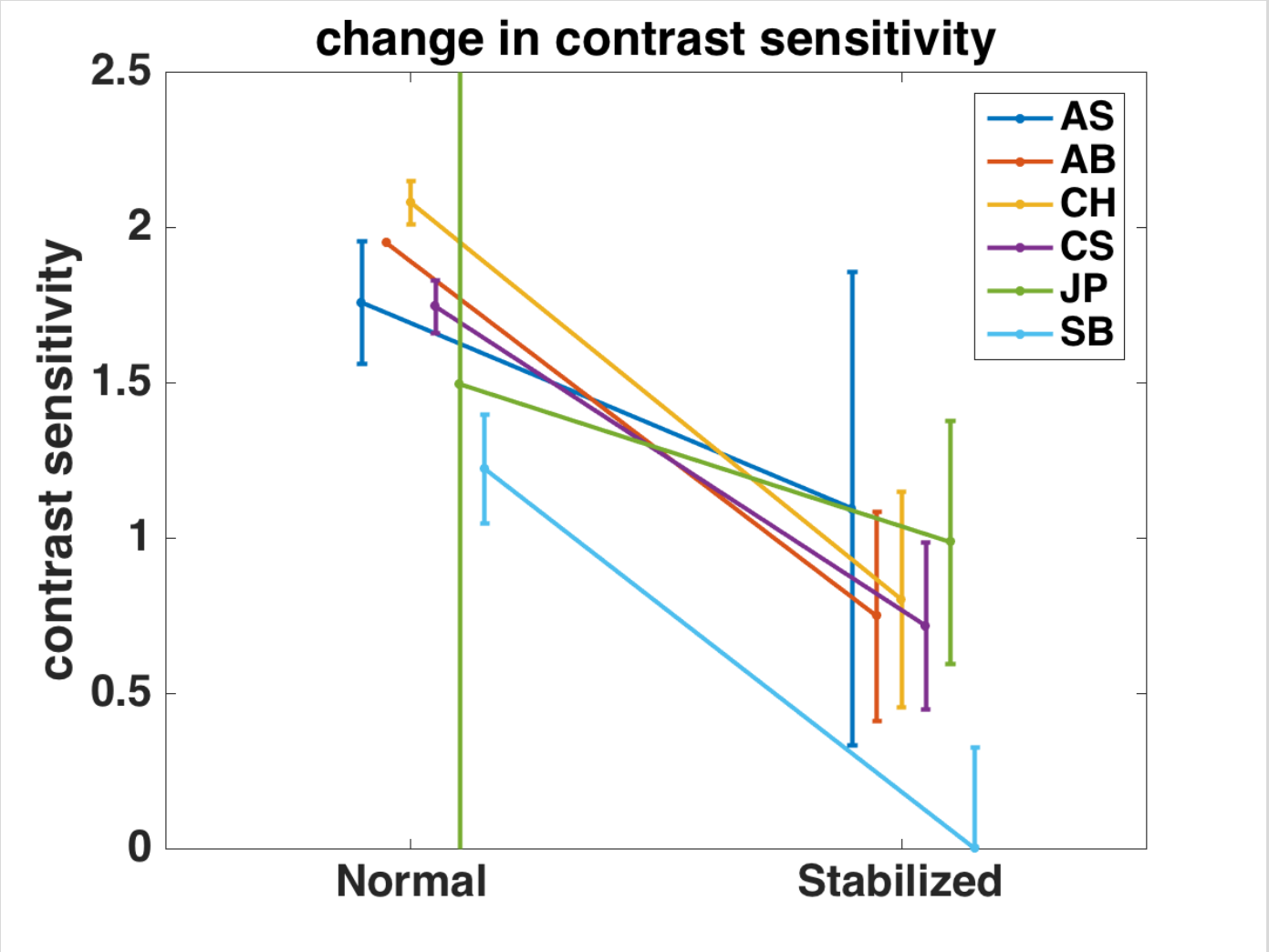
Contrast Threshold Estimation





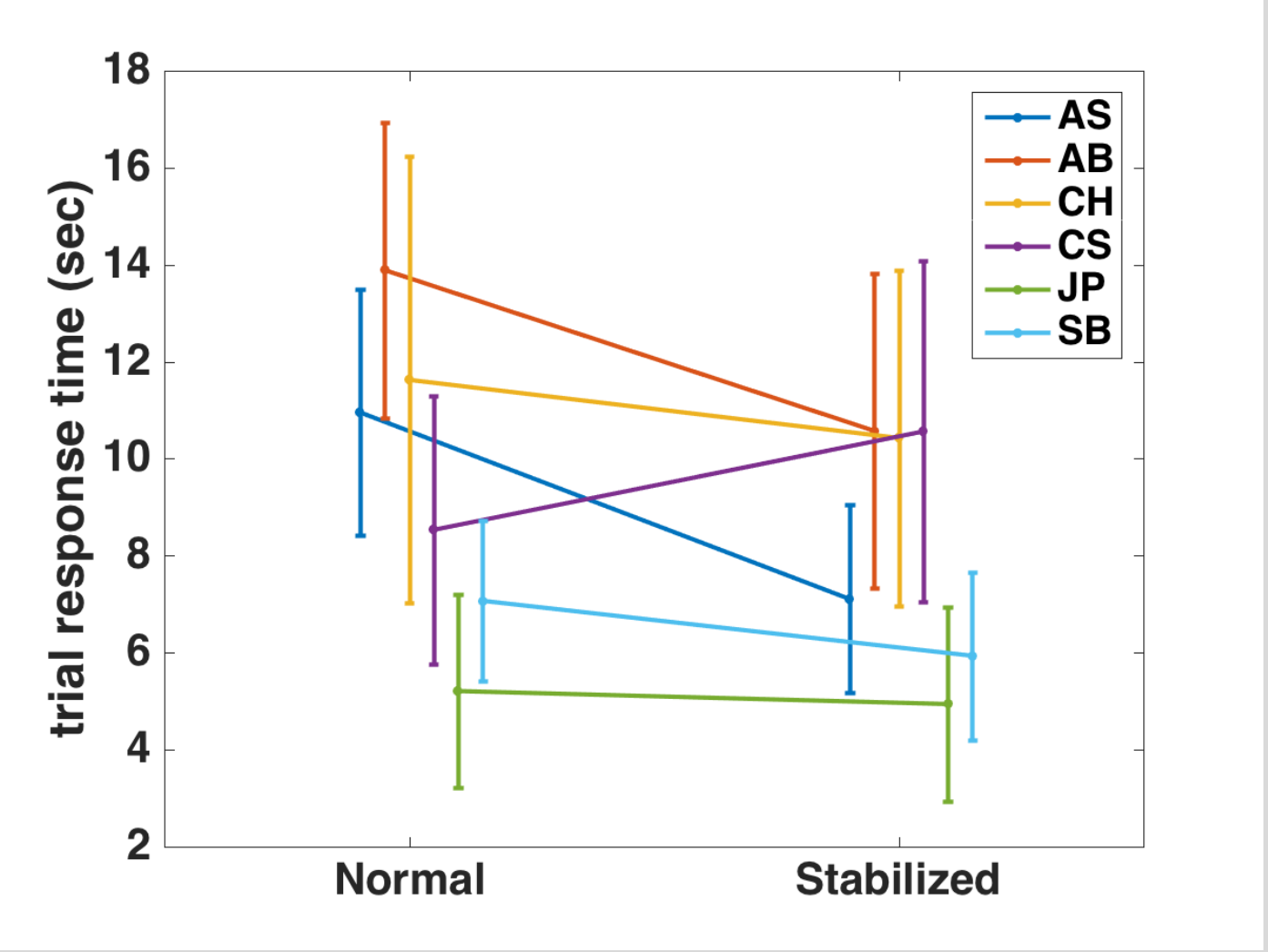
Weber Contrast = $(L_b-L_f) / L_b$

Change in Contrast Sensitivity: Normal vs. Stabilized

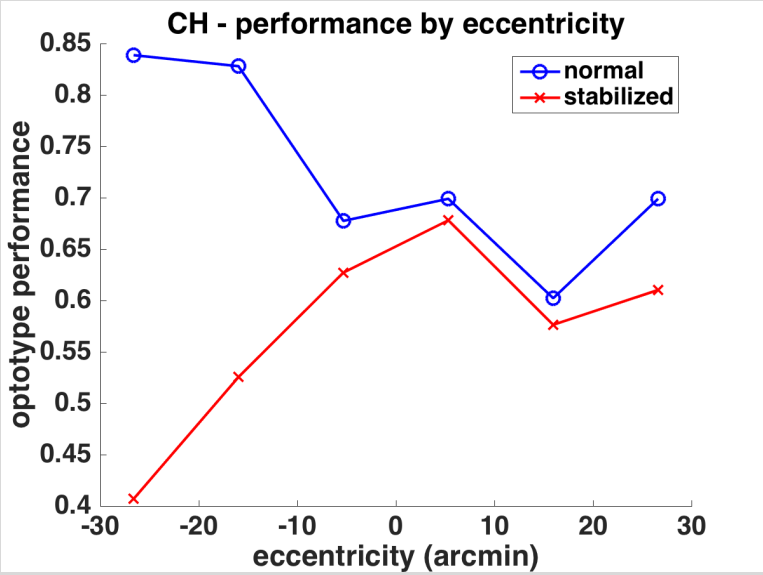


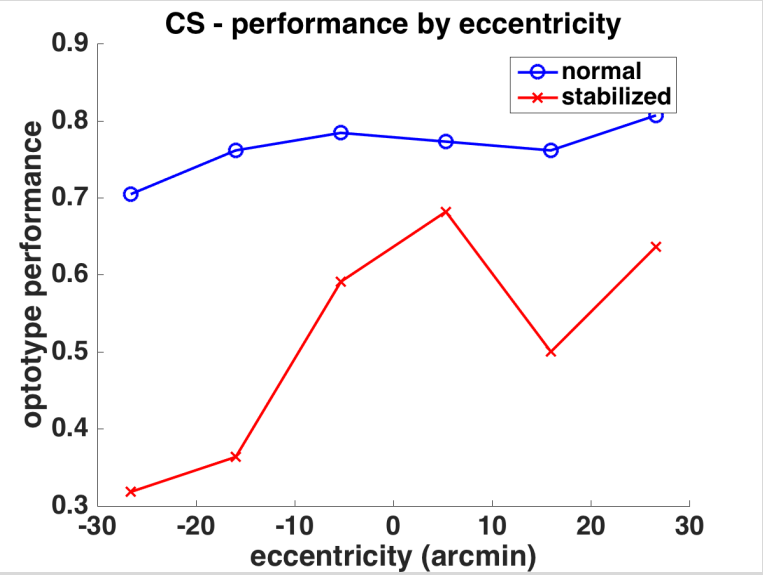
Contrast Sensitivity = Inverse of Weber Contrast = $L_b / (L_b - L_f)$

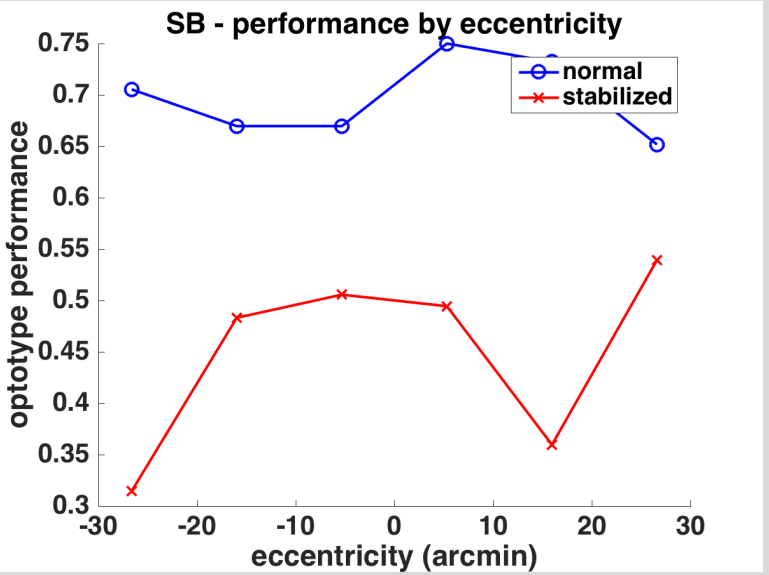
Time of Response Periods

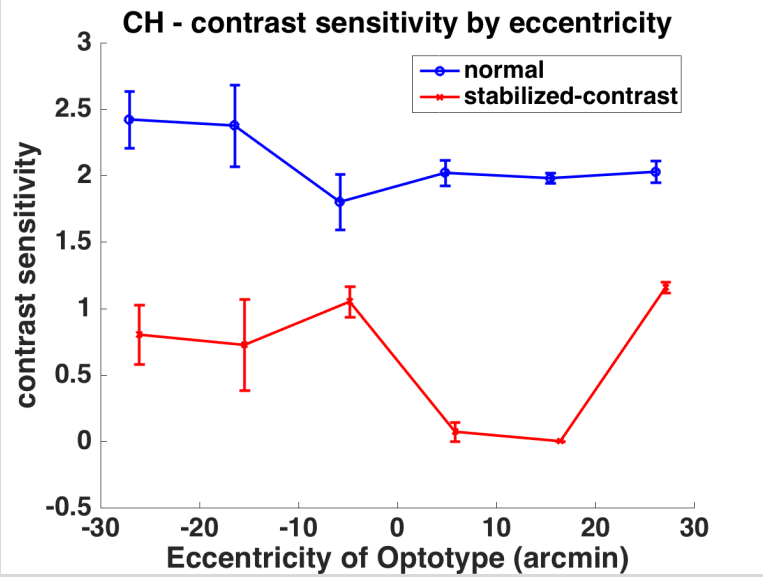


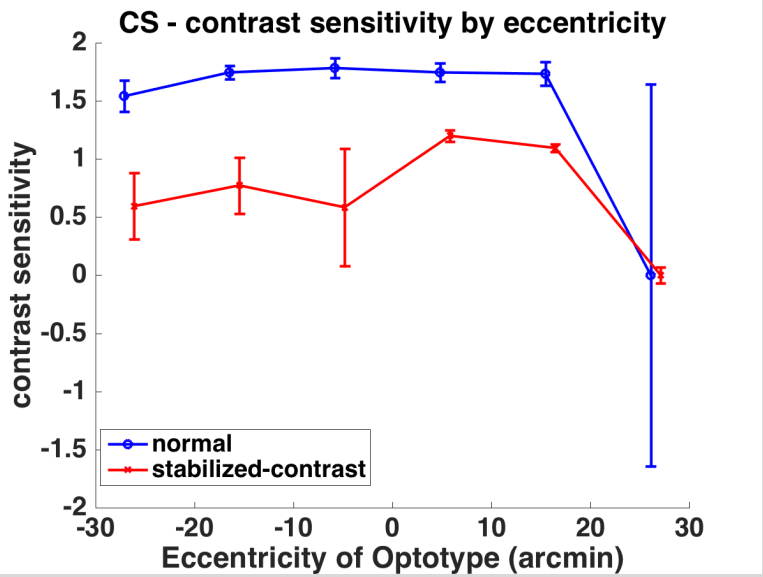
Performance by Eccentricity

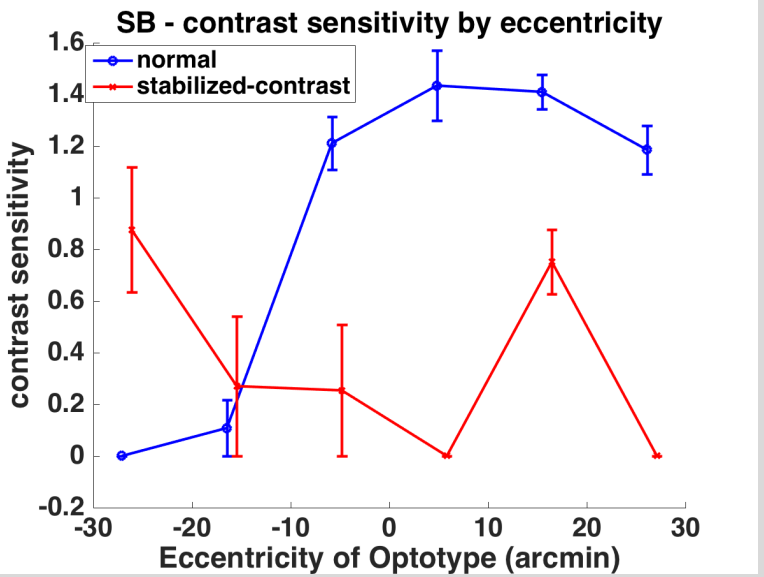








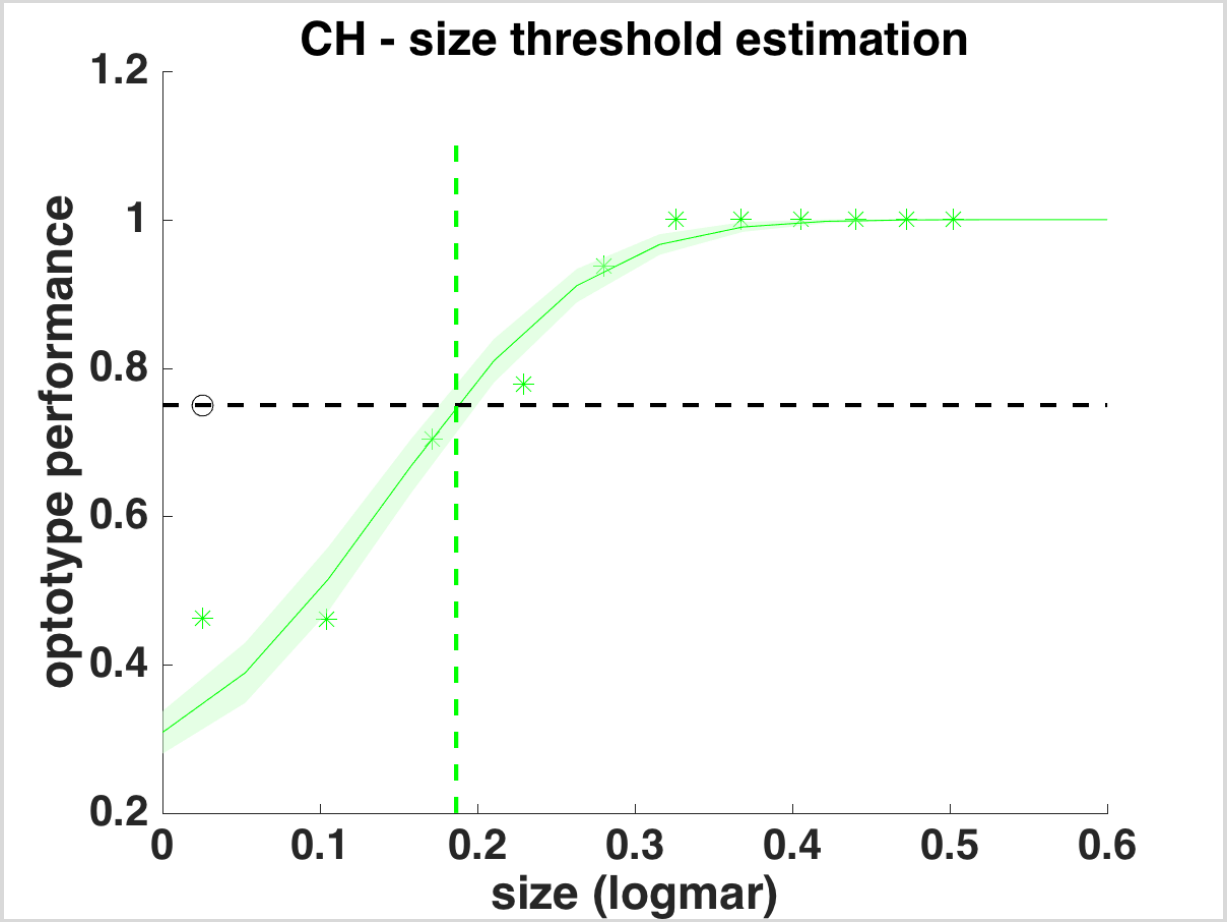


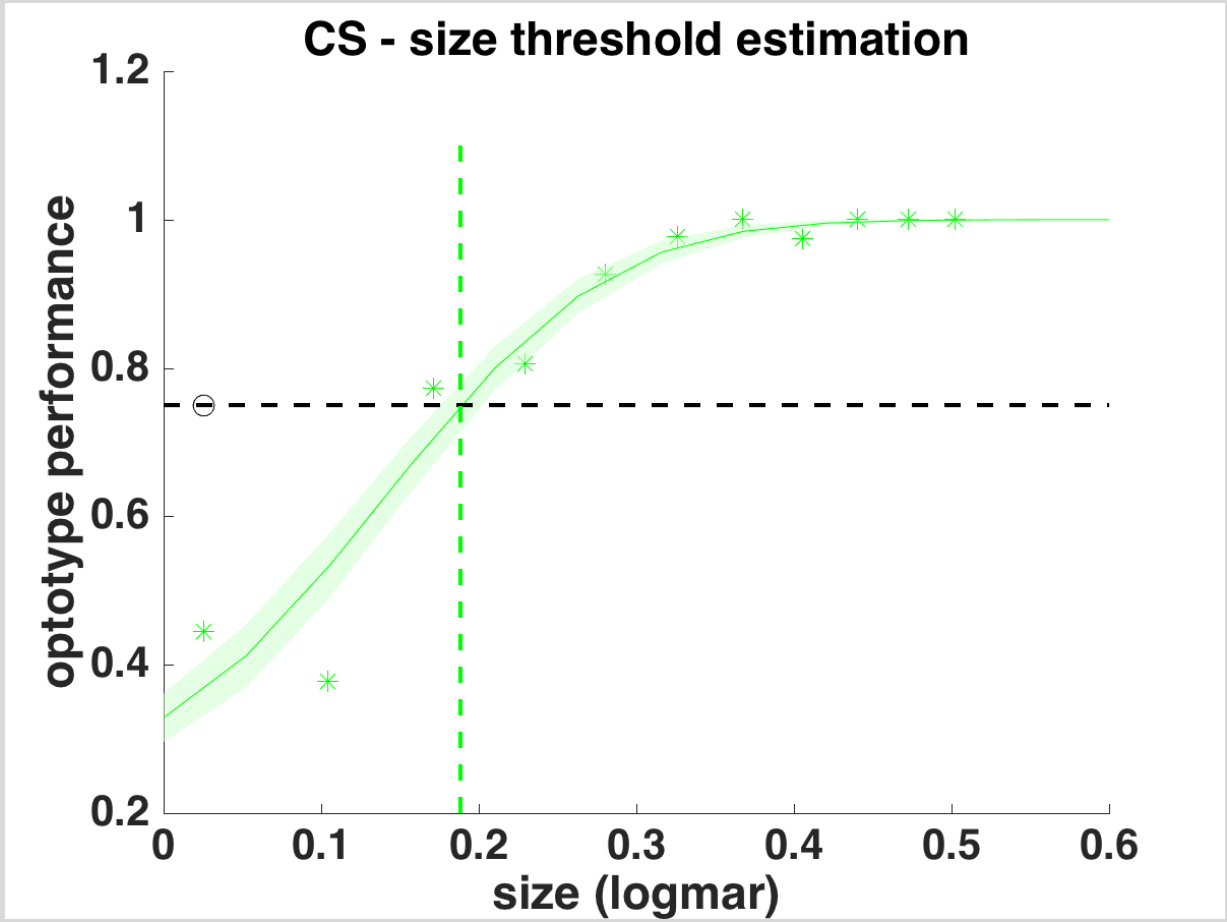


*showing median and median absolute deviations of sensitivities

Normal vs. Stabilized-Size

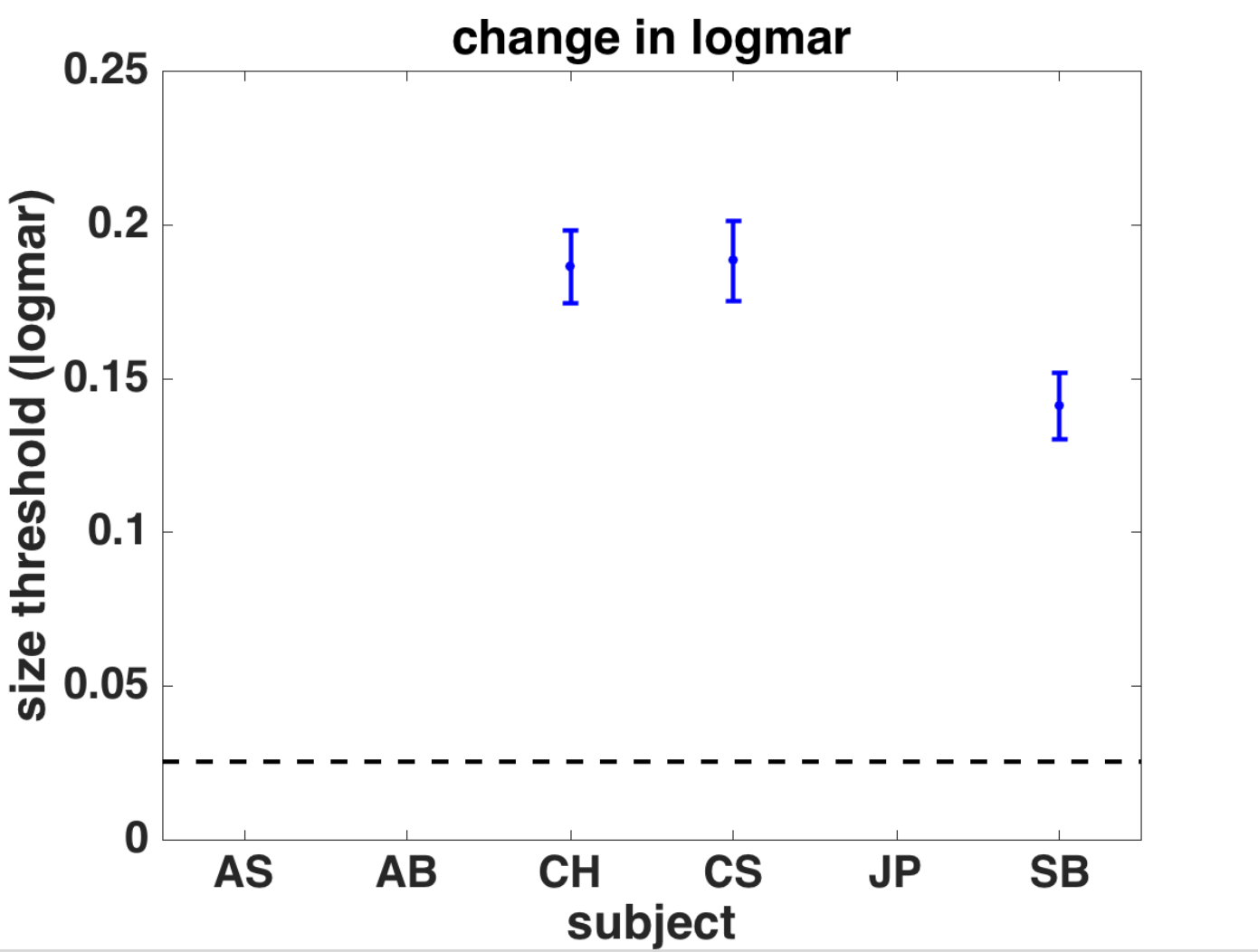
Visual Acuity Threshold Estimation





*as size increases, crowding decreases

Loss of Visual Acuity



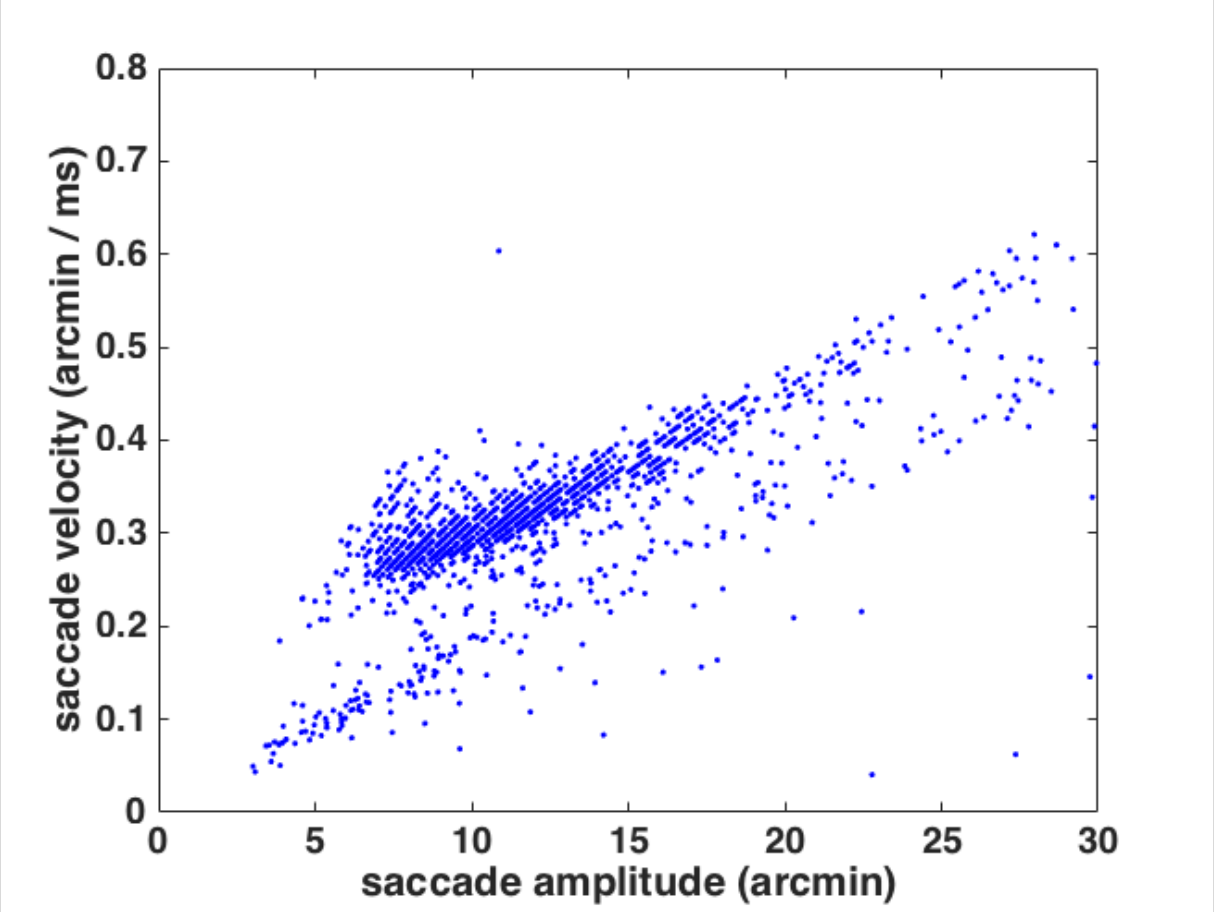
Subject	Δ logmar VA (stabilized – normal)
CH	0.1612 ± 0.0118
CS	0.1631 ± 0.0130
SB	0.1157 ± 0.0107

Discussion

- Microsaccades are used to jump from target to target
- Small drifts are used to explore the target
- Microsaccades and small eye movements are required for good performance at more eccentric targets
- Normal eye movements improve VA by 0.14 logmar
- Future Steps:
  - Calibration offset analysis for better alignment of EM traces and stimuli
  - Analysis of drift locations and saccade take off/landing positions
  - Relationship between EM and performance

Extra Figures

CS – main sequence



SB: relative saccade landing position