

Drift Control of Retinal Power

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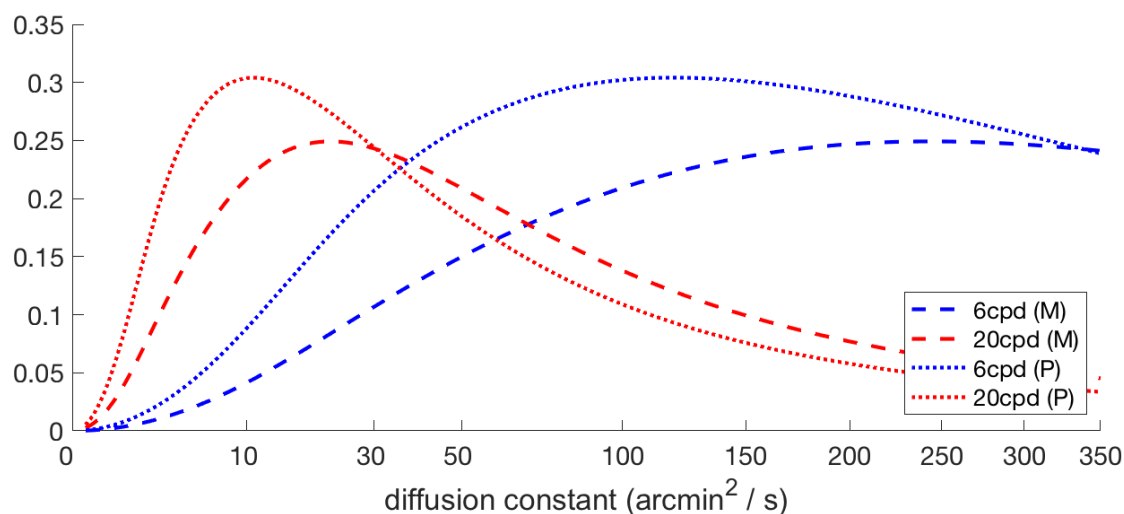
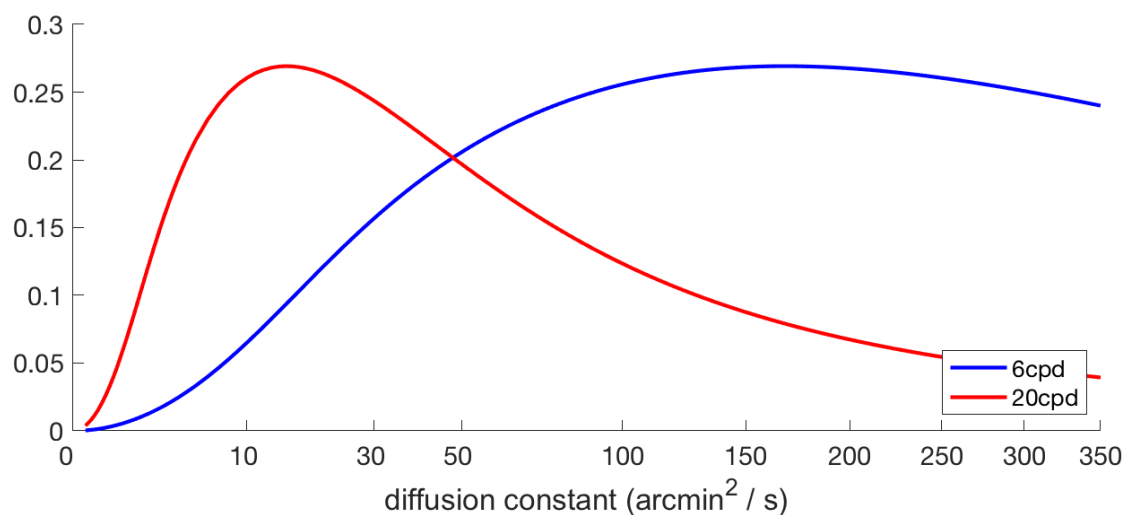
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1 Introduction

Experimental rationale: Please see the experiment proposal on Janis’s wiki page for a full rationale.

The goal of this experiment is to determine whether there are changes in drift behavior based on the power delivered to the retinal input. We hypothesize that drift will be more ‘optimal’ when there is insufficient power on the retina (i.e. low contrast stimuli) compared to when the contrast is high. To test this, we will record eye movements as subjects do a grating discrimination task at a low (6cpd) and high (20cpd) spatial frequency in which the contrast is varied between low and high (65% and 90% performance thresholds respectively). We predict that at low contrasts, the diffusion constant will become larger for 6cpd and smaller for 20cpd than at high contrasts (see proposal for full explanation).



1.1 Experimental Design

The task is a 2AFC grating discrimination task ($\pm 45^\circ$) where the contrast of the grating is ramped up linearly in time over an 800ms period then held constant for a plateau of 500ms (see Fig 1)

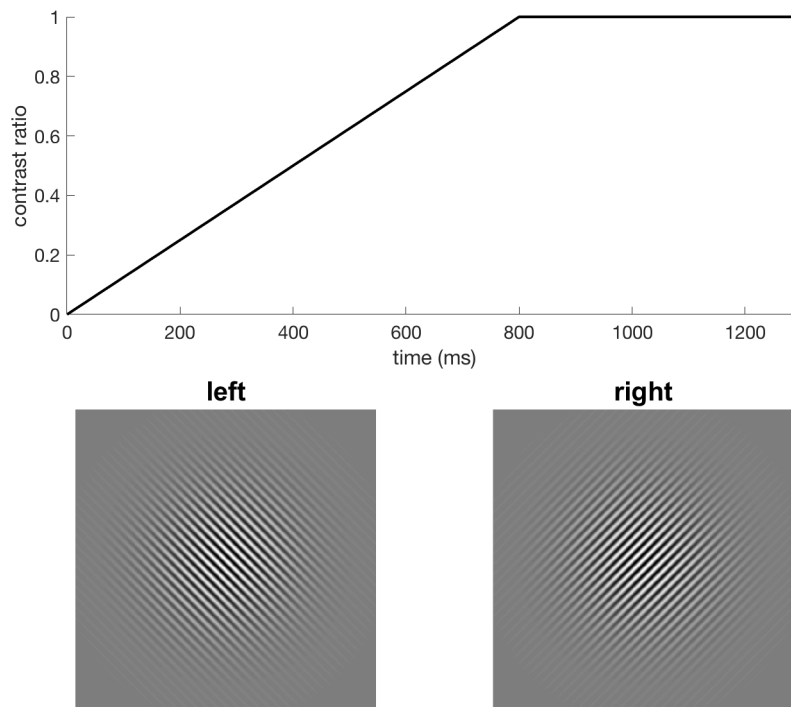


Figure 1: TOP: Stimulus contrast ramp. BOTTOM: left and right tilted gratings with a gaussian envelope (sd of 1.1°). Note that a spatial mask is presented following stimulus presentation, at which point the subject gives their report. Note that arcs were not used for A084, but were otherwise always present.

There are 4 experimental conditions, done in blocks. PEST is used to adjust the contrast in each condition.

		Spatial Frequency	
		6 cpd	20 cpd
Target	65%		
	90%		

1.2 Experimental Settings

This experiment was run on the *varying monitor* at a distance of 1.55m from the subject with a resolution of 1440×900 pixels (~ 0.8 arcmin pixel angle) and a refresh rate of *varying Hz*. The contrast of the brightness of the monitor were both set to 0. RGB gamma settings were 2.1, 2.17, 2.58 respectively (see luminance linearity report on the wiki.) Dithering is used for the contrast, but note that the G:R:B luminances are not precisely the right ratios (4:2:1).

Viewing was done monocularly with the left eye patched.

2 Updates

- Early data was collected on the DPI with the ASUS 278 monitor at 144 Hz with 1440 x 900 pixel resolution (0.8 arcmin / pixel).
- The monitor was switched January 1 (ish) to the ACER 272 with the same spatial resolution, but with a refresh rate of 200hz.
- As of Feb 15, some subjects are being run on the ddpi which has an ASUS 258 monitor running at 200Hz, 1440x900 resolution, same distance, with a pixel angle of 0.71 arcmin / pixel.
- As of September, DPI subjects are running on the ACER monitor. DDPI subjects are on the ASUS 258 monitor.

3 Data Collection

As of May 13, 2020, data collection has begun with 7 naive subjects (two not far enough along to include here)

Subject	Total	drift	MS	S	B/NT
A031	1858	747	145	816	150
6cpd	904	332	74	421	77
20cpd	854	347	67	368	72
Fixation	135	0	17	49	69
A039	1334	915	92	276	51
6cpd	739	516	44	147	32
20cpd	595	399	48	129	19
Fixation	139	11	41	50	37
A084	1070	661	121	168	120
6cpd	584	330	103	78	73
20cpd	486	331	18	90	47
Fixation	148	28	82	11	27
A040	587	222	164	152	49
6cpd	287	111	86	55	35
20cpd	300	111	78	97	14
Fixation	71	0	28	20	23
A047_DDPI	490	323	17	20	130
6cpd	240	164	8	8	60
20cpd	250	159	9	12	70
Fixation	30	0	2	1	27

Table 1: Table of trial counts for each subject split by spatial frequency and fixation. drift = drift only trials. MS = microsaccade occurred. S = saccade occurred. B/NT = blink or no track occurred. Counts are based on the final 1024ms of stimulus presentation.

4 Results

4.1 Results Summary

Subjects reported the orientation of 6 and 20cpd gratings in a 2AFC task. The contrast of these gratings varied according to PEST targeting either 65% or 90% performance. Spatial frequency and target performance varied in blocks of about 80-100 trials each.

Diffusion constants were estimated from trials in each of the four conditions (see Fig ??). Observations:

- Subjects show a trend at the 90% performance level (high contrast) to drift more for the 6cpd than the 20cpd stimulus. At the 65% performance level (low contrast) this is reversed for both subjects. (see Fig ?? - drift only panels)
 - This does NOT fit with our hypothesis that drift is controlled to modulate power on the retina according to our predictions (that behavior would change to compensate for reduced power in the stimulus itself).
 - When the stimulus is highly visible (90% performance level), these results hold with our prediction that a larger drift is beneficial for the 6cpd task and the smaller drift is beneficial for the 20cpd task.
 - Since spatial frequencies were blocked, it seems that drift was not modulated based on the expectation of the current spatial frequency grating, otherwise we would have seen the expected difference in diffusion constants at the 65% performance level as well.
- When all trials are split into three equal groups (low, medium, and high performance) by the contrast level (Fig ?? - drift only panel), we see a trend that the diffusion constant for the 20cpd grating decreases as performance increases in both subjects (consistent with the results above). In contrast, dividing the 6cpd trials into three groups shows a change in behavior when the stimulus is extremely visible (small diffusion constant) and when the stimulus is visible 90% of the time (larger diffusion constant).
- Saccade rates were also analyzed but there don't seem to be any consistent trends between the subjects.

4.2 Psychometric Functions

	Drift				MS				MS+S			
	6cpd		20cpd		6cpd		20cpd		6cpd		20cpd	
A031												
allowed	0.49±0.10	1.18±0.13	12.14±2.25	33.59±3.02	0.61±0.09	1.20±0.11	12.57±2.33	34.08±5.05	0.67±0.09	1.45±0.16	17.02±1.29	50.96±2.66
only	0.49±0.10	1.18±0.13	12.14±2.25	33.59±3.02	0.97±0.22	1.02±0.15	22.41±7.08	37.57±7.65	0.82±0.11	1.80±0.24	25.01±4.18	70.26±14.52
A039												
allowed	0.60±0.06	1.04±0.06	6.28±1.13	15.83±1.22	0.62±0.06	1.03±0.07	5.69±0.79	17.79±2.52	0.71±0.05	1.05±0.06	7.19±1.03	17.08±2.30
only	0.60±0.06	1.04±0.06	6.28±1.13	15.83±1.22	0.77±0.10	0.85±0.05	6.03±0.99	6.15±0.93	0.82±0.14	1.09±0.13	8.80±2.23	14.65±3.81
A084												
allowed	0.58±0.13	1.67±0.21	23.08±3.51	38.98±2.95	0.54±0.17	1.68±0.25	19.99±3.12	43.36±2.37	0.55±0.11	1.96±0.24	23.07±3.52	45.05±4.53
only	0.58±0.13	1.67±0.21	23.08±3.51	38.98±2.95	1.42±0.85	6.31±14.24	34.06±23.13	Inf±NaN	1.26±0.45	2.08±0.33	28.33±9.59	90.98±59.53
A040												
allowed	0.85±0.04	0.87±0.04	9.88±3.04	17.54±3.11	0.76±0.07	1.02±0.07	11.82±1.79	21.61±2.27	0.80±0.06	1.02±0.06	11.79±1.76	24.54±2.44
only	0.85±0.04	0.87±0.04	9.88±3.04	17.54±3.11	0.79±0.28	1.44±0.38	11.20±3.32	25.02±5.12	0.77±0.15	1.14±0.10	13.12±4.79	33.15±6.24
A047_DDPI												
allowed	0.71±0.11	0.96±0.06	9.97±2.51	25.96±4.36	0.68±0.09	0.96±0.06	7.96±1.56	24.92±2.78	0.76±0.05	1.00±0.04	8.28±2.42	29.74±6.43
only	0.71±0.11	0.96±0.06	9.97±2.51	25.96±4.36	0.65±0.83	1.76±1.73	8.35±5.97	9.57±5.82	2.11±2.47	2.59±2.60	17.40±10.25	55.45±75.40

Table 2: Michelson contrast thresholds by subject and eye movement filter. Allowed means that MS or S were mixed in with drift-only trials. Only means that only trials with MS or MS+S were included in analysis.

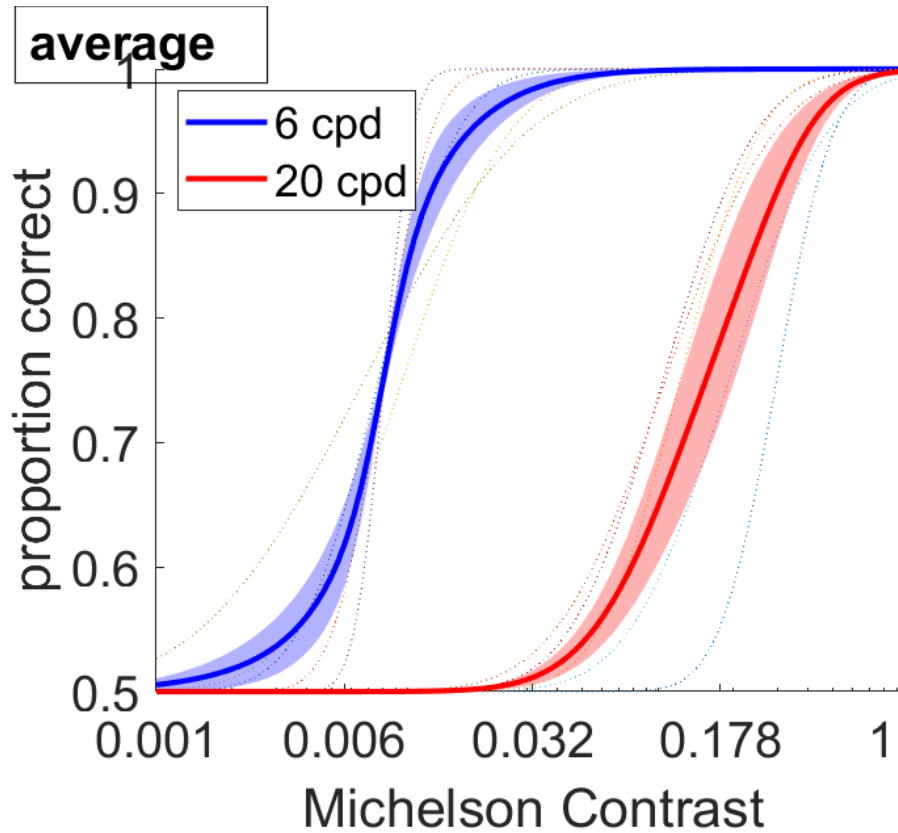


Figure 2: Psychometric functions averaged across observers in drift-only trials. Individuals are shown by thin dotted lines. Shaded regions mark SEM across observers

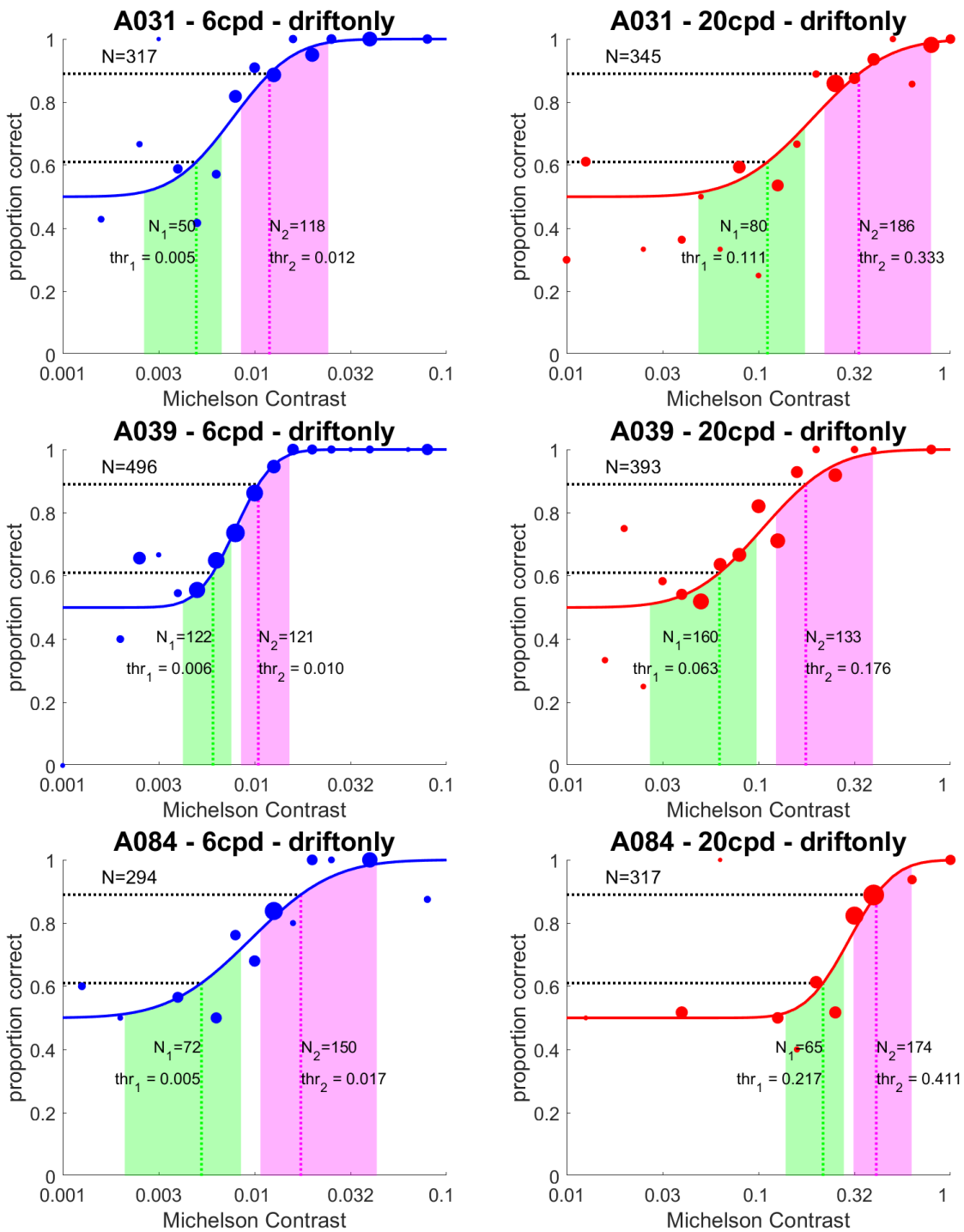


Figure 3: See next page.

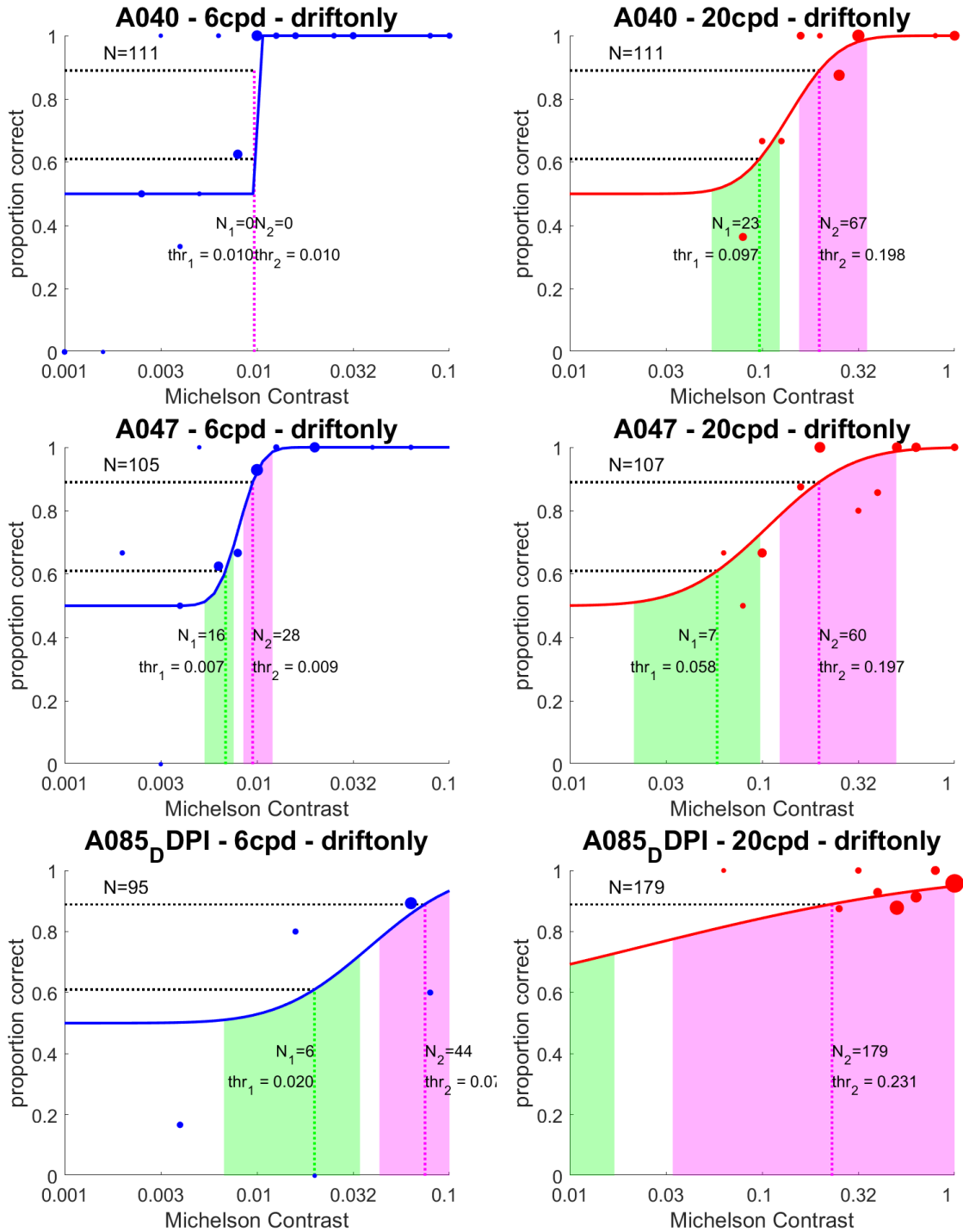


Figure 4: Psychometric fitting for three subjects and 2 spatial frequencies. Data were collected with PEST targeting either 65% or 90% performance. The size of each data point indicates the relative number of trials contributing to that point. Here, drift-only is referring to the analysis period (final 512ms (A031) or 1s (A084) of stimulus presentation). Green and pink vertical lines show contrast thresholds for 62% and 89% visibility respectively in each condition. To analyze eye movements around each threshold, trials were included in a range of contrasts around each thresholds (defined by the contrasts that yielded $\pm 12\text{-}14\%$ performance around threshold).

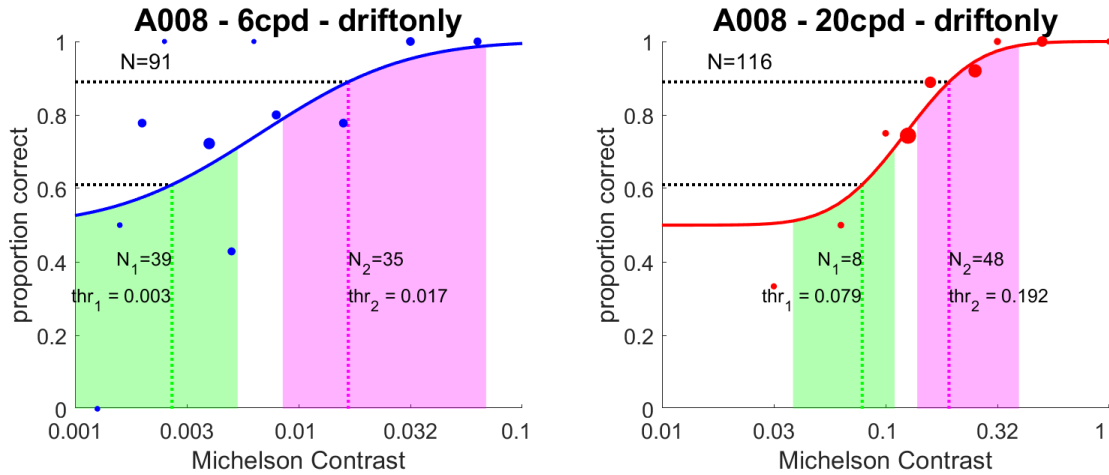


Figure 5: Psychometric fitting for one subjects and 2 spatial frequencies. Data were collected with PEST targeting either 65% or 90% performance. The size of each data point indicates the relative number of trials contributing to that point. Here, drift-only is referring to the analysis period (final 512ms (A031) or 1s (A084) of stimulus presentation). Green and pink vertical lines show contrast thresholds for 62% and 89% visibility respectively in each condition. To analyze eye movements around each threshold, trials were included in a range of contrasts around each thresholds (defined by the contrasts that yielded $\pm 12-14\%$ performance around threshold).

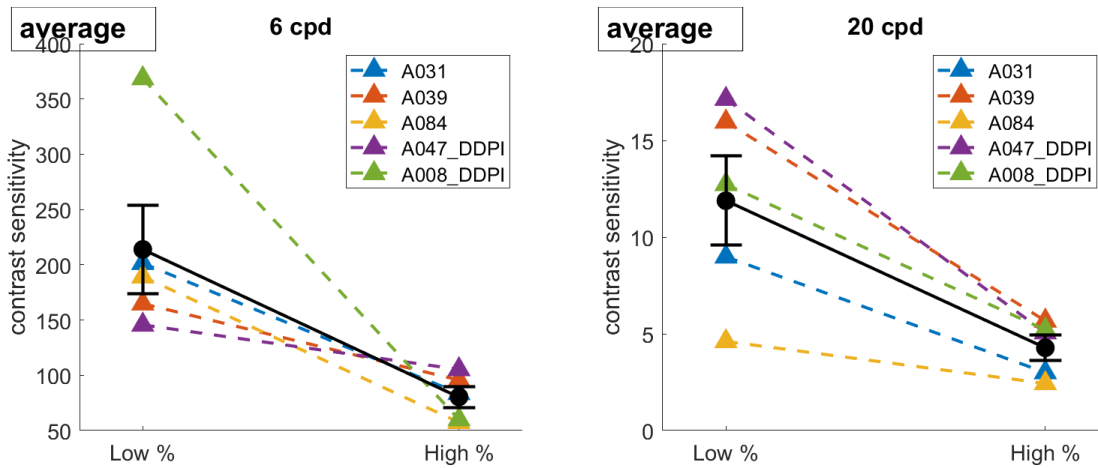


Figure 6: Contrast sensitivity for each subject (drift only trials) for 65% and 90% performance levels.

4.3 Drift Analysis

4.3.1 Drift Diffusion (near Thresholds)

	Drift				MS				MS+S			
	6cpd		20cpd		6cpd		20cpd		6cpd		20cpd	
A031 - All Trials												
Fixation :: 12.27±1.13												
allowed	10.79±1.20	16.27±1.80	12.94±0.95	12.75±0.95	11.82±1.41	16.73±0.93	23.11±8.42	13.25±0.84	12.31±0.54	17.24±1.49	26.34±6.05	13.56±1.10
only	10.79±1.20	16.27±1.80	12.94±0.95	12.75±0.95	0.00±0.00	0.00±0.00	116.79±60.52	19.70±5.38	16.96±3.33	21.43±5.02	40.06±11.28	26.57±3.89
A031 - Correct Trials												
Fixation :: 12.27±1.13												
allowed	10.94±1.99	17.71±2.91	11.29±1.39	12.02±1.06	10.50±1.56	16.11±1.39	33.51±14.47	12.76±0.76	11.59±1.48	15.50±2.31	26.25±6.35	13.23±1.04
only	10.94±1.99	17.71±2.91	11.29±1.39	12.02±1.06	0.00±0.00	0.00±0.00	199.55±107.24	20.44±6.68	18.31±3.48	16.55±7.75	40.85±17.14	22.53±2.73
A031 - Incorrect Trials												
Fixation :: 12.27±1.13												
allowed	10.61±1.47	21.98±2.21	15.34±3.46	17.06±1.97	12.64±1.78	19.75±2.01	15.18±1.99	18.09±4.21	13.54±1.03	28.91±7.31	24.76±1.75	40.36±9.07
only	10.61±1.47	21.98±2.21	15.34±3.46	17.06±1.97	0.00±0.00	0.00±0.00	31.02±18.07	0.00±0.00	12.29±2.95	46.07±16.49	44.55±12.63	77.95±23.64
A039 - All Trials												
Fixation :: 8.57±0.53												
allowed	10.29±0.64	11.05±0.84	7.94±0.84	9.06±1.09	10.86±0.95	10.89±1.10	8.56±0.85	9.03±1.13	10.11±0.83	10.12±1.15	8.82±0.56	9.66±1.25
only	10.29±0.64	11.05±0.84	7.94±0.84	9.06±1.09	6.67±1.72	0.00±0.00	0.00±0.00	0.00±0.00	7.47±1.19	5.96±0.89	12.36±3.09	9.73±2.91
A039 - Correct Trials												
Fixation :: 8.57±0.53												
allowed	11.61±0.80	10.33±0.63	8.22±0.81	9.51±1.32	11.43±0.77	11.44±1.18	9.79±1.50	9.50±1.69	10.22±0.91	10.30±0.92	9.06±0.85	9.09±1.15
only	11.61±0.80	10.33±0.63	8.22±0.81	9.51±1.32	10.33±1.54	0.00±0.00	0.00±0.00	0.00±0.00	9.73±1.28	6.73±1.01	13.53±3.01	10.50±2.26
A039 - Incorrect Trials												
Fixation :: 8.57±0.53												
allowed	9.23±1.54	16.74±2.68	7.24±0.59	8.47±1.58	10.62±1.26	14.40±3.67	7.22±0.43	8.20±0.81	9.81±1.36	14.45±2.97	7.85±0.58	7.86±1.43
only	9.23±1.54	16.74±2.68	7.24±0.59	8.47±1.58	2.03±0.00	0.00±0.00	0.00±0.00	0.00±0.00	5.58±1.38	4.90±0.00	10.33±1.84	2.62±0.00
A084 - All Trials												
Fixation :: 14.69±2.30												
allowed	11.30±1.53	17.98±2.10	21.27±2.31	19.53±2.20	11.88±1.60	18.53±1.80	20.82±2.54	19.89±2.44	11.53±0.96	21.10±3.10	21.27±2.93	21.72±4.49
only	11.30±1.53	17.98±2.10	21.27±2.31	19.53±2.20	11.21±2.73	48.92±11.26	19.67±8.71	106.53±68.30	15.17±2.40	93.00±41.51	27.50±7.31	107.68±29.04
A084 - Correct Trials												
Fixation :: 14.69±2.30												
allowed	10.90±1.09	18.72±1.75	18.42±3.10	18.68±4.23	11.02±1.64	20.22±2.80	18.40±3.30	18.25±4.27	12.27±1.84	20.14±2.58	20.17±4.99	20.77±3.87
only	10.90±1.09	18.72±1.75	18.42±3.10	18.68±4.23	12.98±3.82	41.81±7.07	29.90±0.00	104.50±68.26	15.90±3.90	86.12±33.91	27.85±10.13	129.75±44.18
A084 - Incorrect Trials												
Fixation :: 14.69±2.30												
allowed	13.52±2.14	8.53±4.40	26.48±6.15	26.15±9.19	12.07±2.21	17.88±9.85	24.23±2.35	29.35±9.78	14.34±2.95	12.07±4.84	27.73±3.45	32.23±10.69
only	13.52±2.14	8.53±4.40	26.48±6.15	26.15±9.19	5.09±0.90	78.30±0.00	7.62±1.82	64.50±0.00	16.02±3.23	78.30±0.00	21.33±10.45	94.91±16.60
A040 - All Trials												
Fixation :: 12.92±1.34												
allowed	0.00±0.00	0.00±0.00	13.77±1.87	14.22±0.71	22.40±3.48	13.85±2.34	17.37±2.18	16.54±1.51	24.81±3.49	14.74±2.23	17.90±1.37	16.33±1.46
only	0.00±0.00	0.00±0.00	13.77±1.87	14.22±0.71	18.47±4.06	18.96±0.26	23.62±4.44	25.29±7.06	30.02±3.82	12.74±3.05	22.27±1.73	24.40±6.67
A040 - Correct Trials												
Fixation :: 12.92±1.34												
allowed	0.00±0.00	0.00±0.00	14.94±2.77	15.20±0.77	24.01±3.59	12.96±1.51	16.92±2.31	17.64±1.39	29.43±6.06	14.70±1.88	18.94±1.54	16.47±1.06
only	0.00±0.00	0.00±0.00	14.94±2.77	15.20±0.77	12.83±7.64	18.97±0.38	23.30±5.17	29.24±14.73	34.14±7.30	11.10±1.43	23.44±2.24	25.50±5.45
A040 - Incorrect Trials												
Fixation :: 12.92±1.34												
allowed	0.00±0.00	0.00±0.00	13.61±4.04	9.41±1.07	18.41±3.72	8.82±8.42	16.61±3.09	9.17±1.36	18.23±2.11	11.57±9.09	17.18±2.29	10.98±1.59
only	0.00±0.00	0.00±0.00	13.61±4.04	9.41±1.07	22.76±3.82	0.00±0.00	31.46±15.82	0.00±0.00	21.51±2.63	7.43±7.51	19.80±2.90	4.32±2.28
A047_DDPI - All Trials												
Fixation :: 7.27±5.84												
allowed	8.08±0.76	9.14±1.29	10.36±1.73	11.96±1.25	7.97±0.87	9.33±1.17	11.69±1.34	11.54±0.85	7.73±0.54	9.48±1.92	11.37±1.41	12.08±1.00
only	8.08±0.76	9.14±1.29	10.36±1.73	11.96±1.25	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	8.40±4.00	16.24±3.28
A047_DDPI - Correct Trials												
Fixation :: 7.27±5.84												
allowed	8.43±0.68	10.19±1.25	11.68±1.85	11.19±1.18	8.47±1.34	10.23±1.07	13.07±2.91	12.02±1.31	8.21±0.55	10.11±1.63	10.48±2.09	12.12±1.32
only	8.43±0.68	10.19±1.25	11.68±1.85	11.19±1.18	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	8.33±3.36	16.48±2.10
A047_DDPI - Incorrect Trials												
Fixation :: 7.27±5.84												
allowed	7.65±1.70	5.32±1.67	11.88±2.49	15.09±8.22	7.41±1.79	5.07±1.50	13.12±3.50	12.46±3.98	7.01±1.95	4.96±1.67	10.98±2.14	13.62±7.70
only	7.65±1.70	5.32±1.67	11.88±2.49	15.09±8.22	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	7.59±10.82	6.91±0.00

Table 3: Diffusion constants for drift in different conditions (spatial frequency by visibility level by correct or incorrect.)

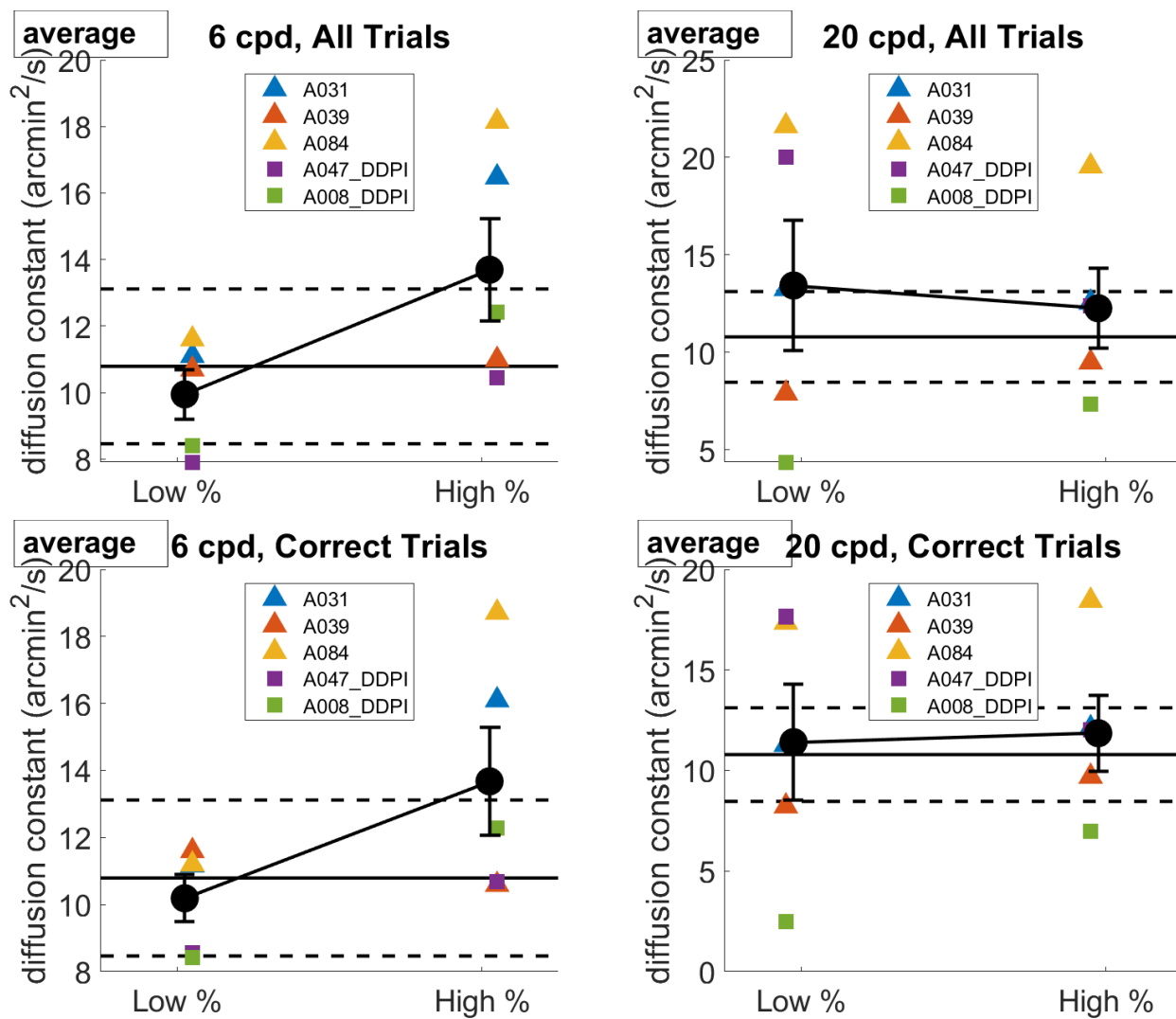


Figure 7: Diffusion constants estimated across observers for All trials (top) and correct trials (drift-only). Circles and error bars show mean and SEM across observers (triangles) at low and high visibility (65% and 90% thresholds).

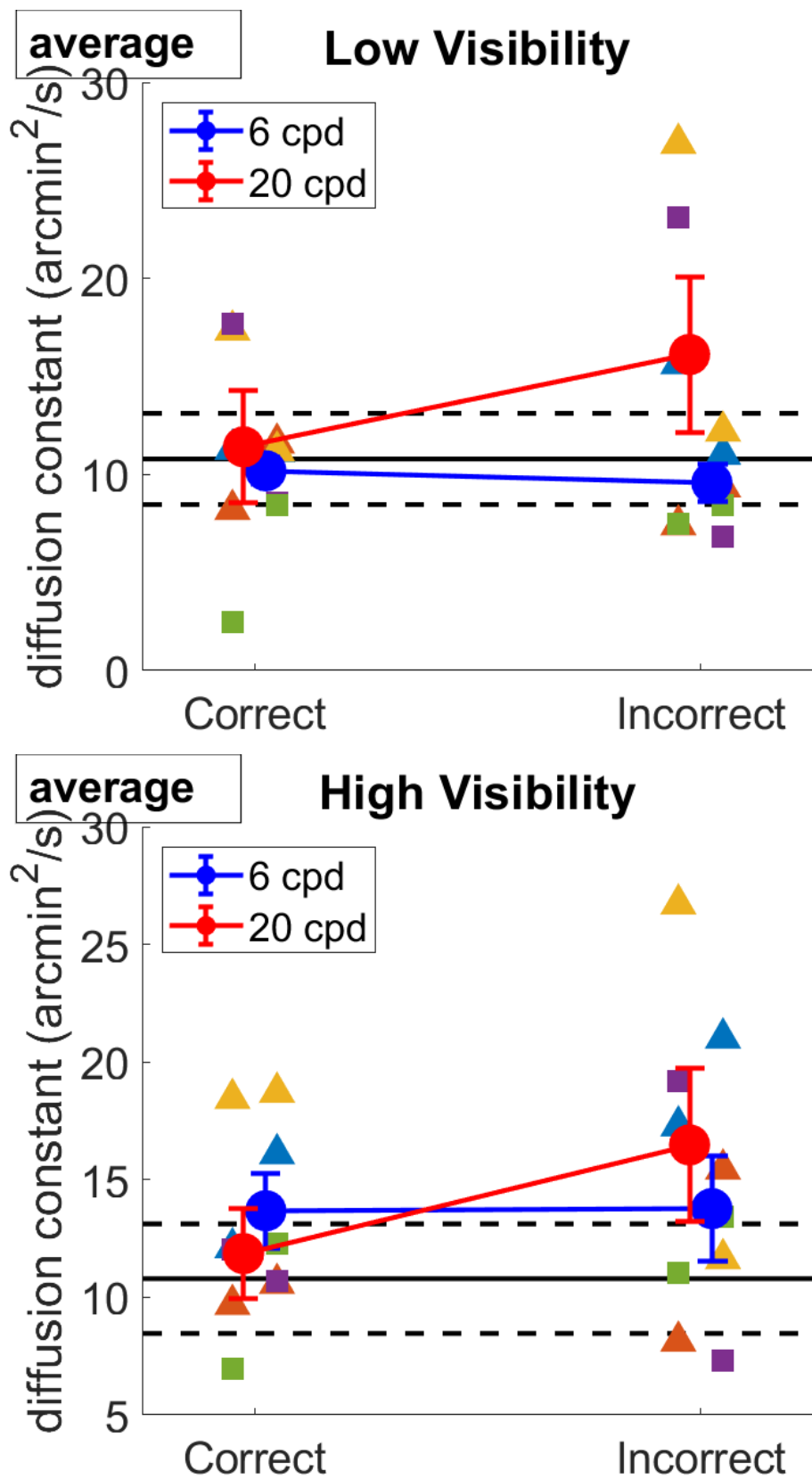


Figure 8: Diffusion constants compared between correct and incorrect trials for low visibility trials (65% threshold) and high visibility trials (90% threshold)

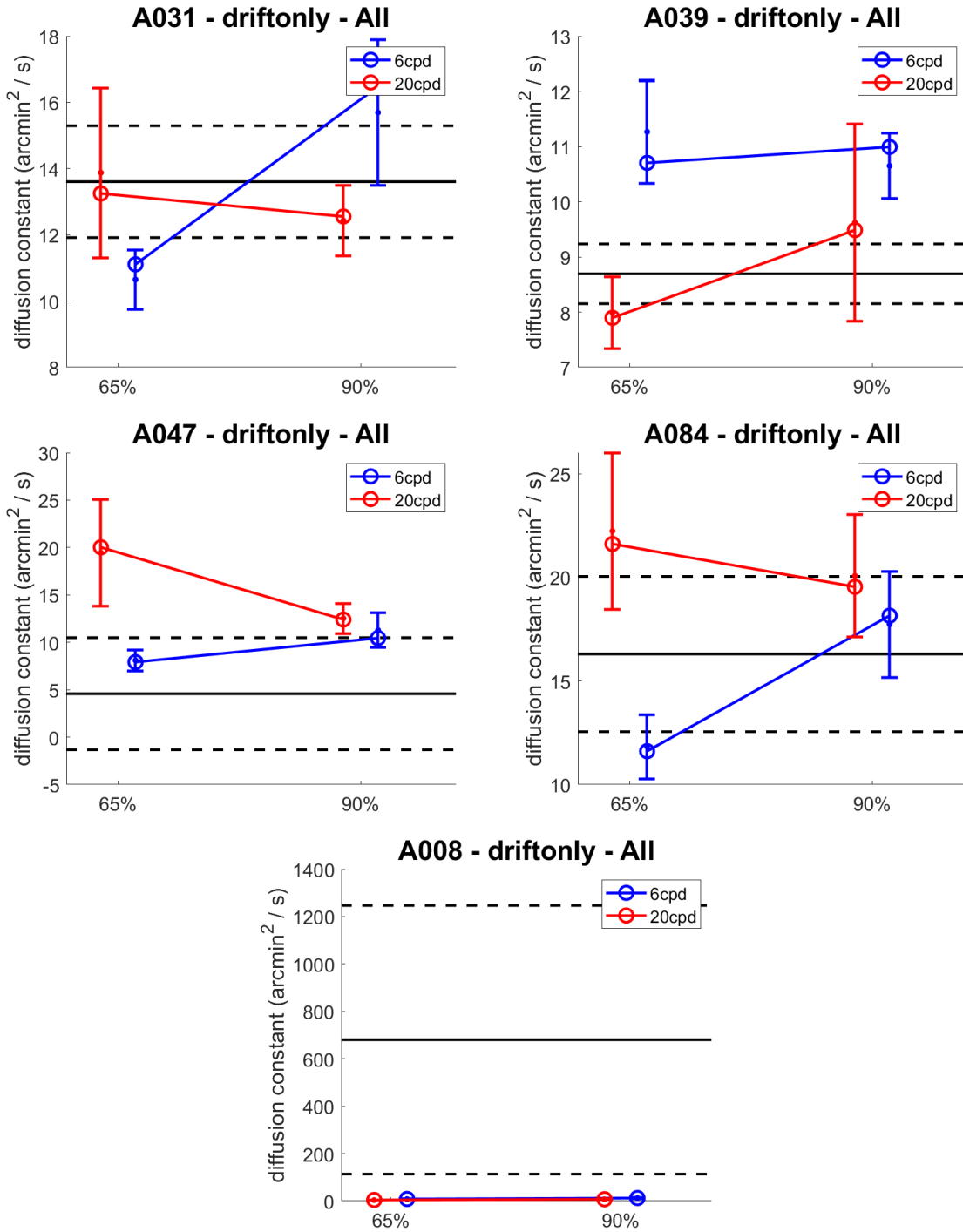
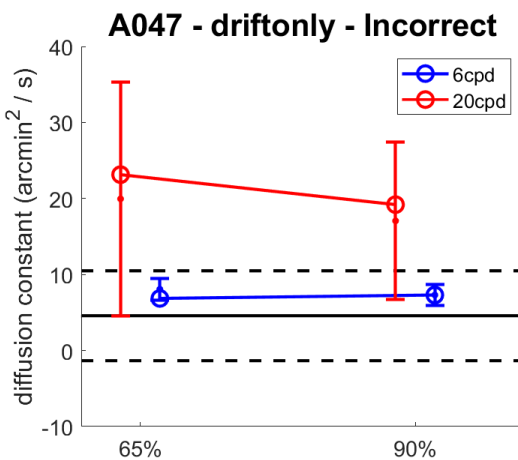
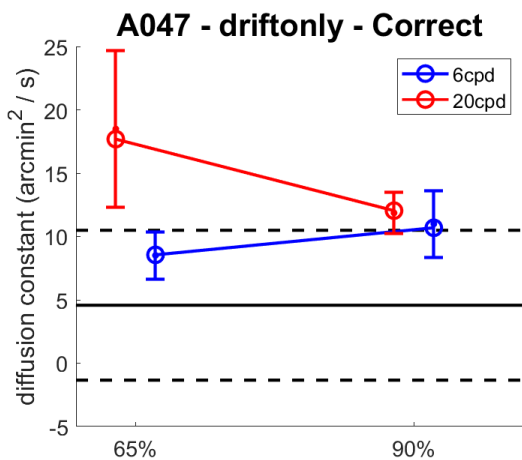
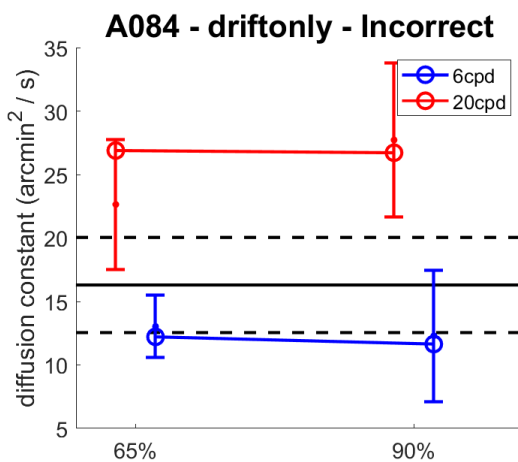
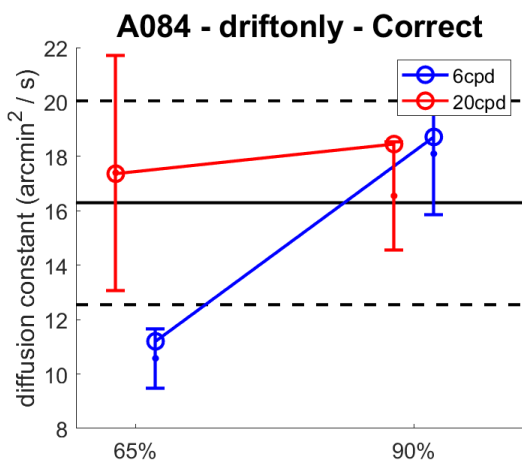
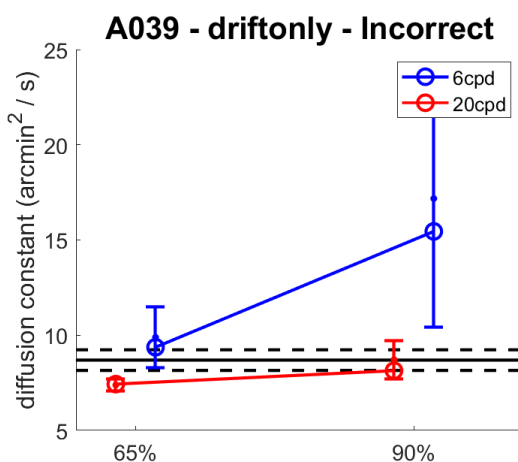
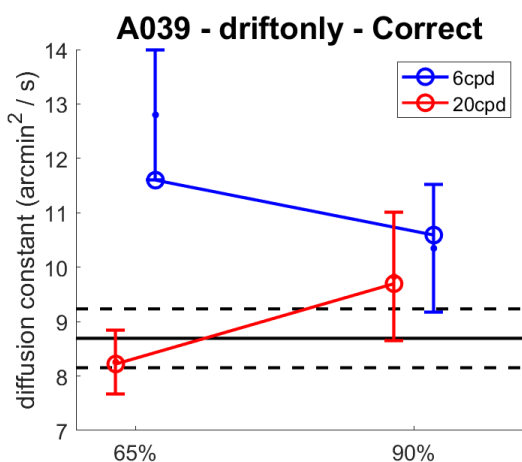
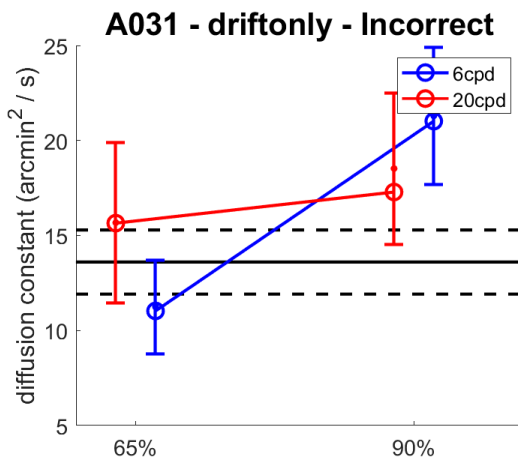
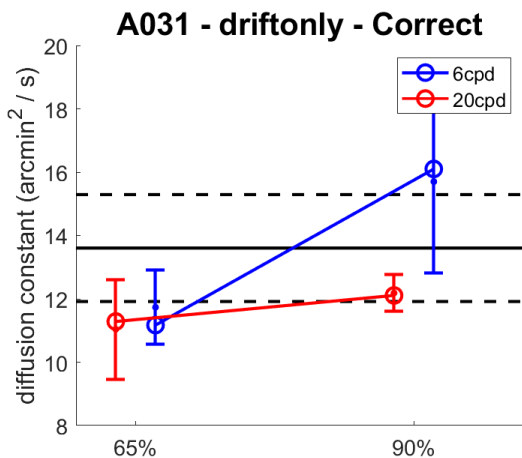


Figure 9: Diffusion constants in different subjects at different visibility levels. Open circles are the diffusion constant estimated from all data and error bars are SEM estimated from 100 bootstrap iterations. Drift only = drift only trials. Black lines are the mean \pm SEM in Fixation.



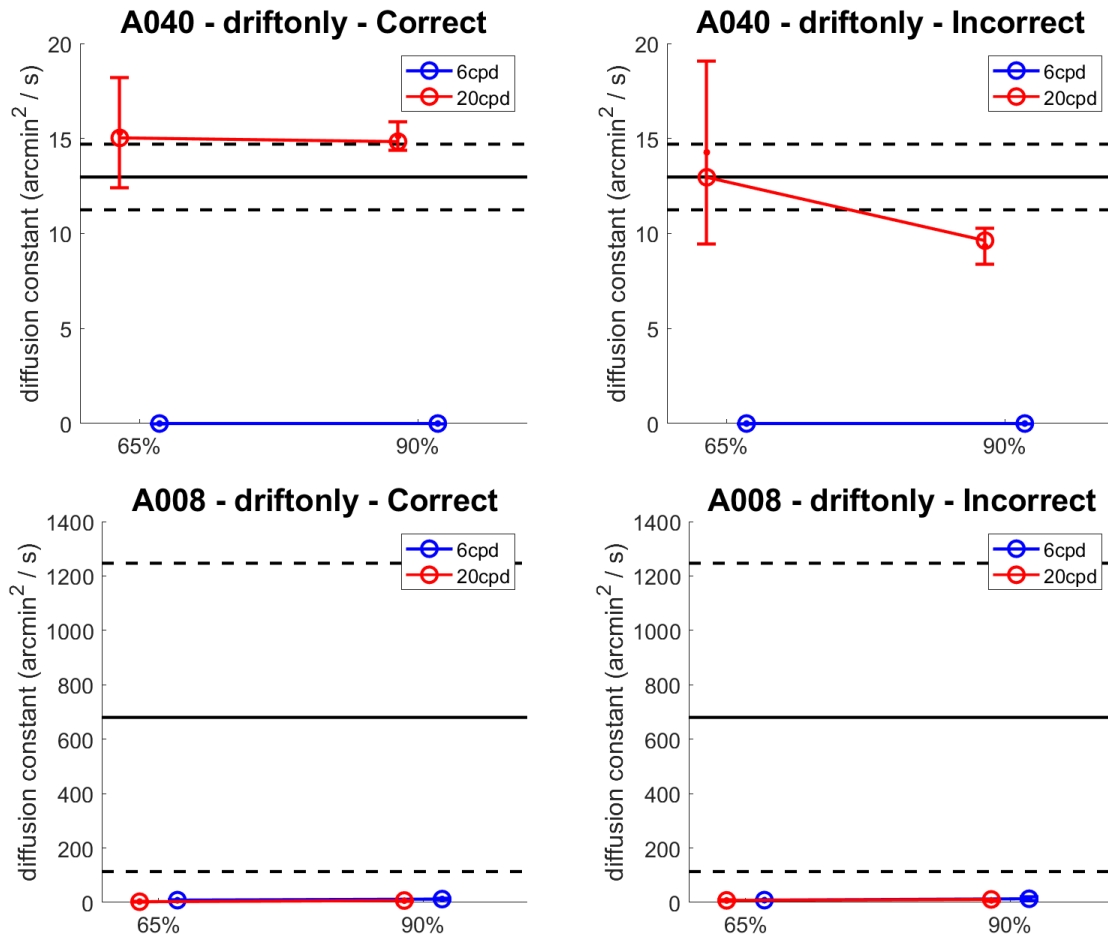


Figure 10: Diffusion constants in different subjects at different visibility levels in correct (left) and incorrect trials). Open circles are the diffusion constant estimated from all data and error bars are SEM estimated from 100 bootstrap iterations. Drift only = drift only trials. Black lines are the mean \pm SEM in Fixation.

4.4 Temporal power provided by drifts

4.4.1 Correct & Incorrect trials included

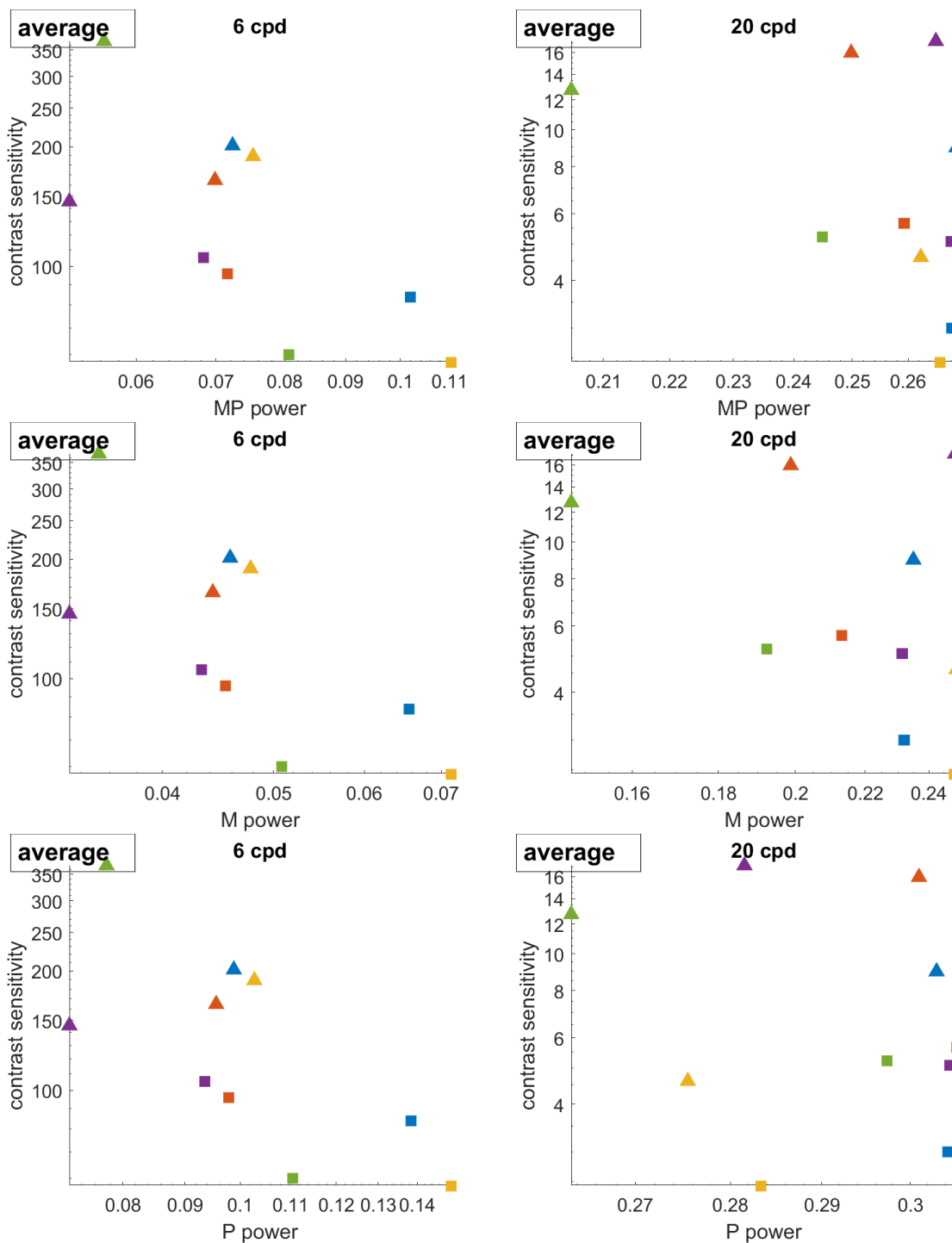


Figure 11: Contrast sensitivity versus temporal power across individuals in drift only trials. Power is computed for M+P cells (top row), M cells only (middle row) and P cells only (bottom row). Triangles are 90% performance, squares are 65% performance thresholds and power.

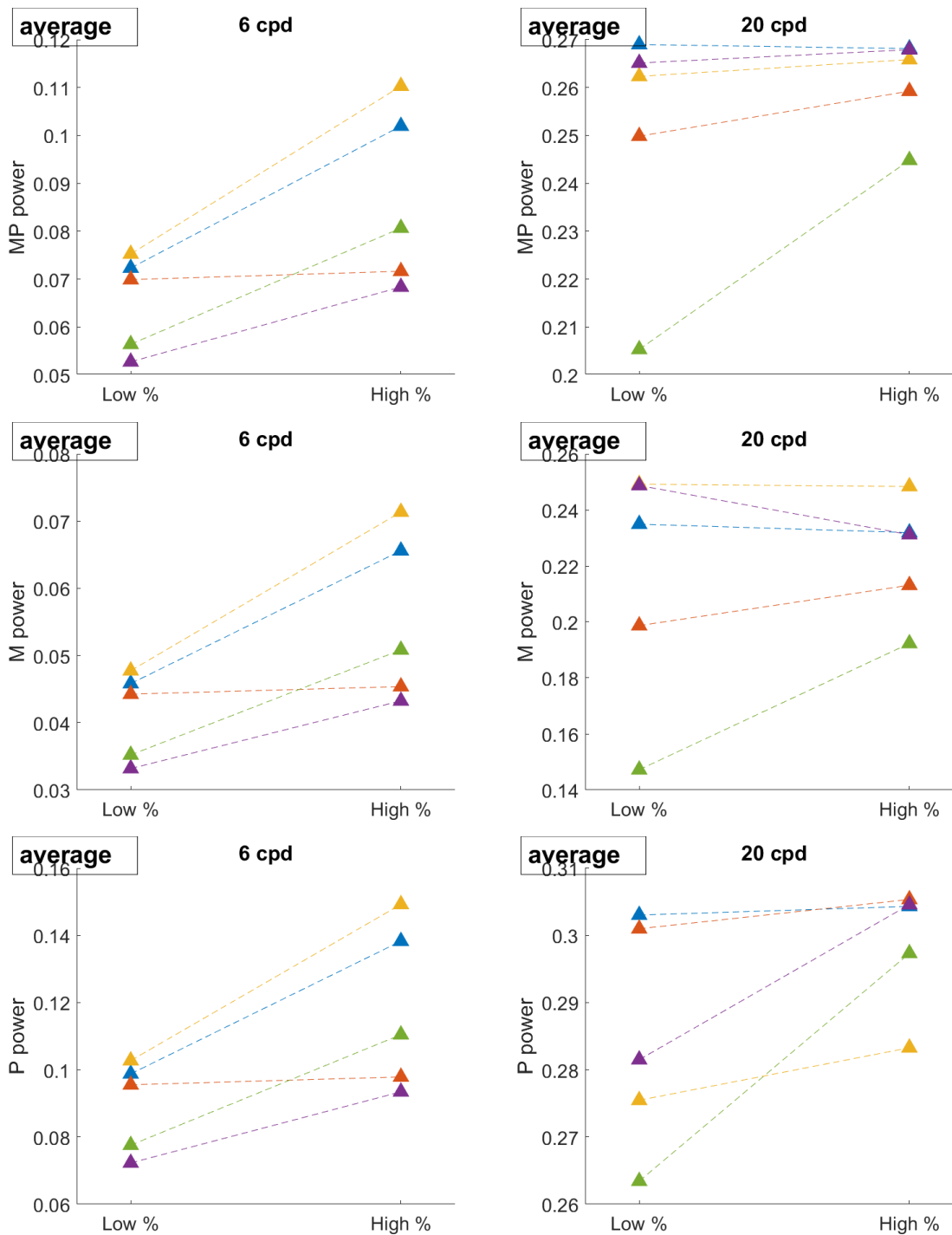
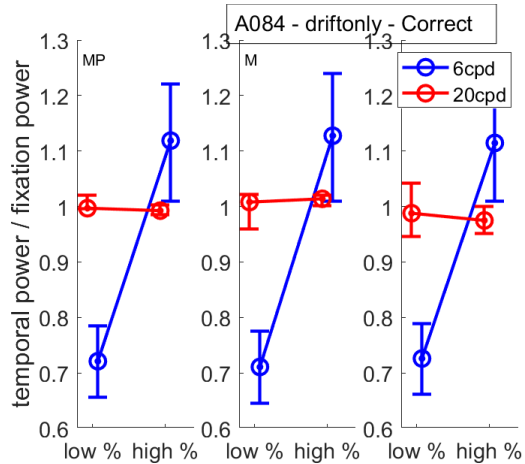
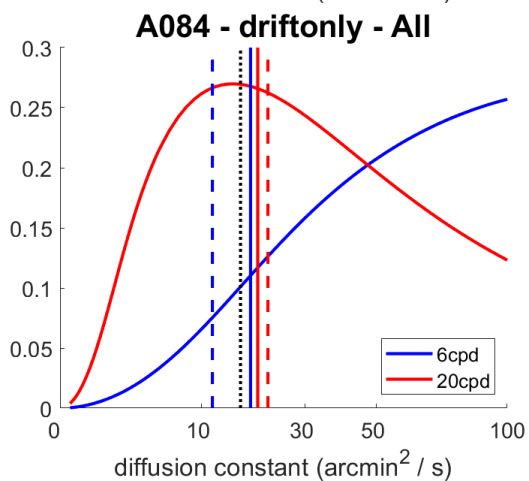
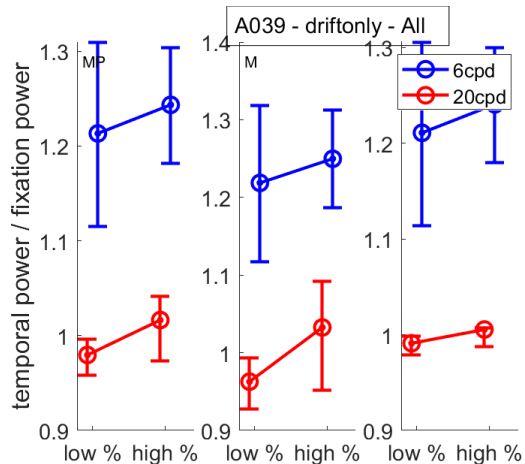
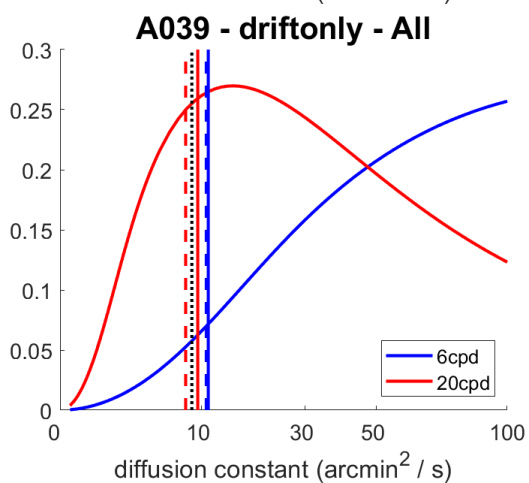
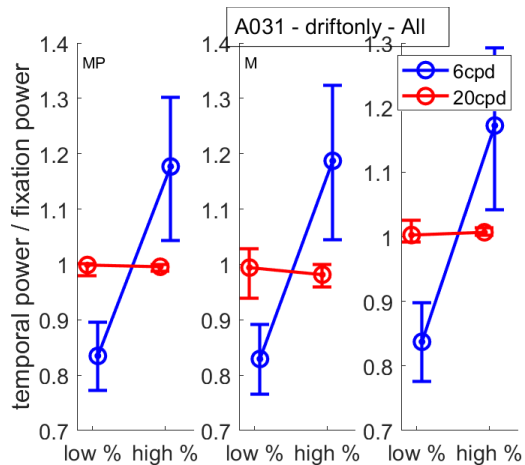
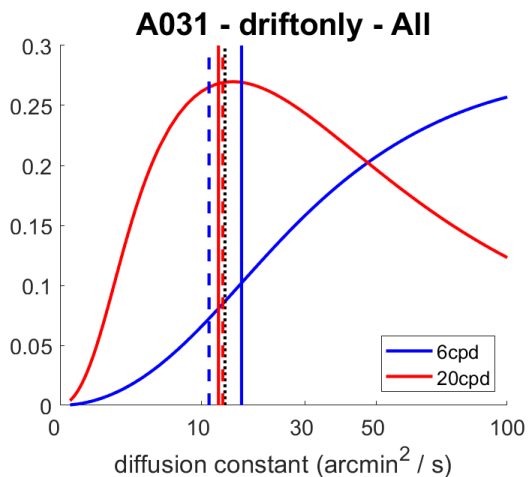


Figure 12: Temporal power for high and low visibility across subjects in drift-only trials. Power is computed for M+P cells (top row), M cells only (middle row) and P cells only (bottom row).



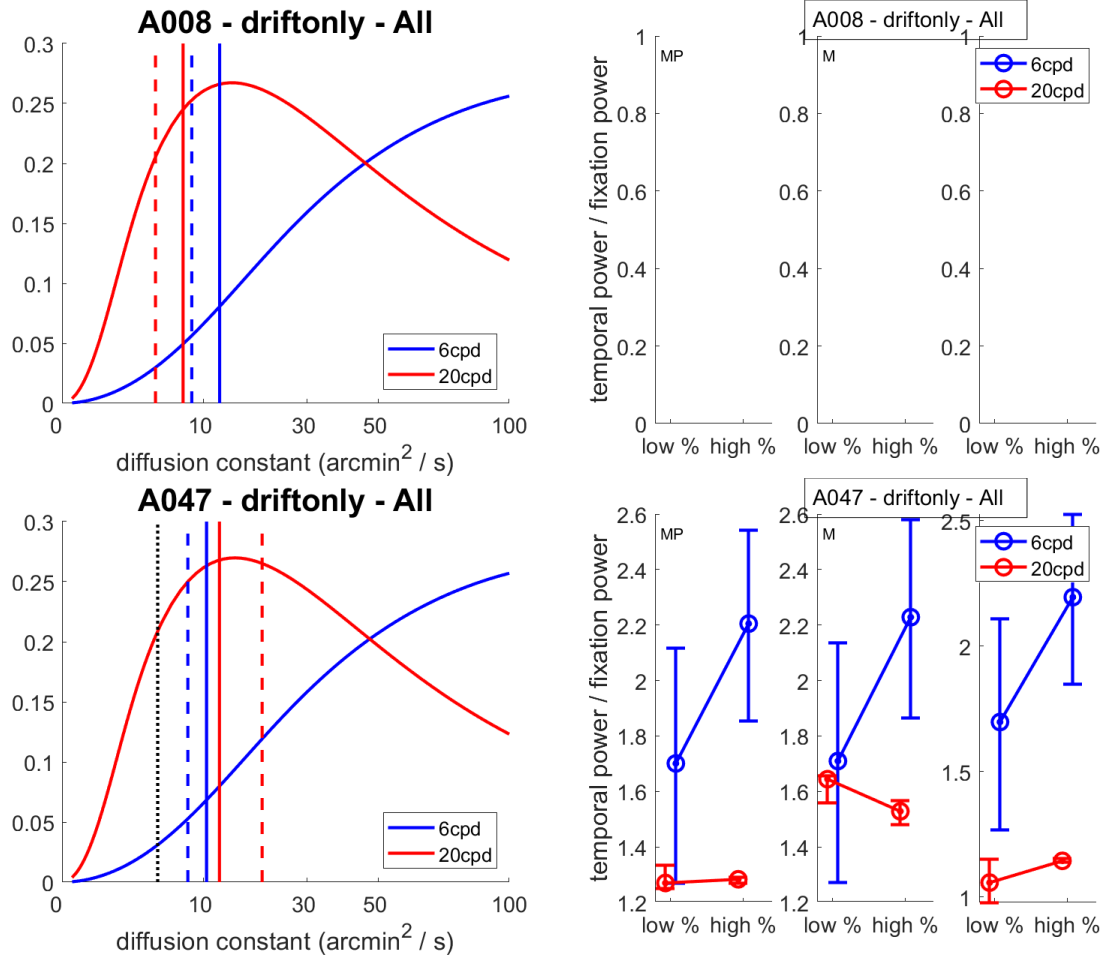
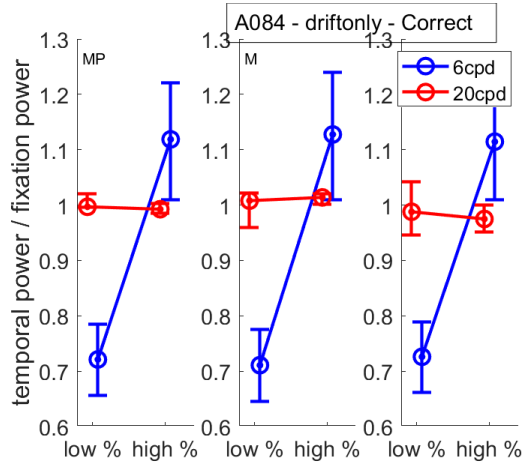
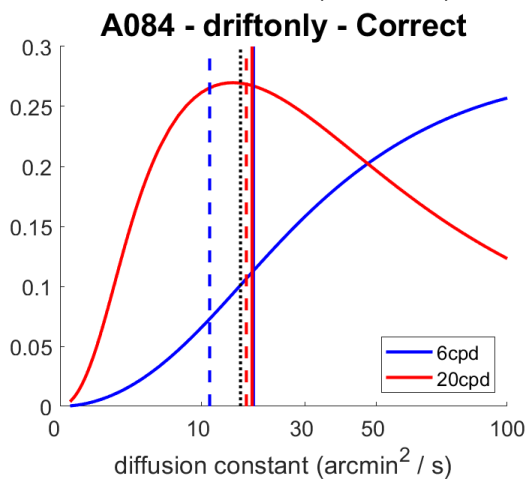
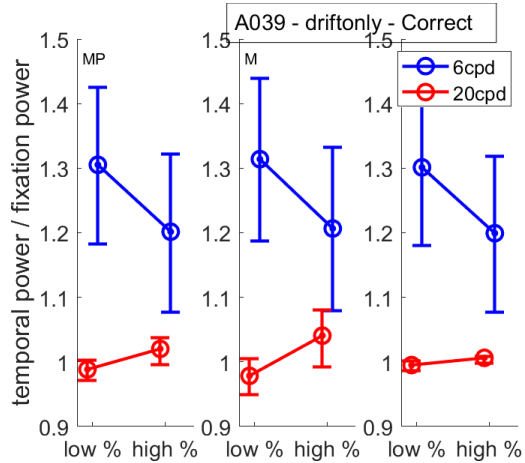
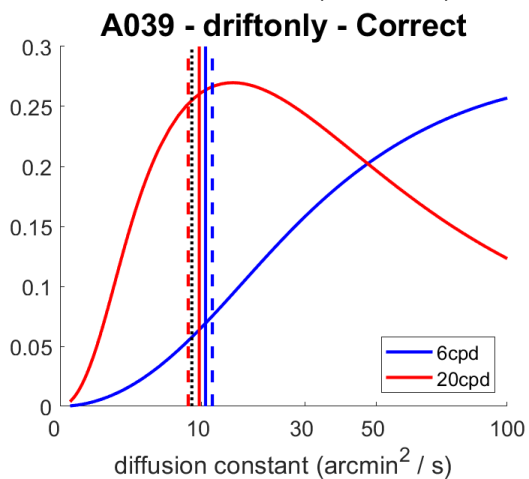
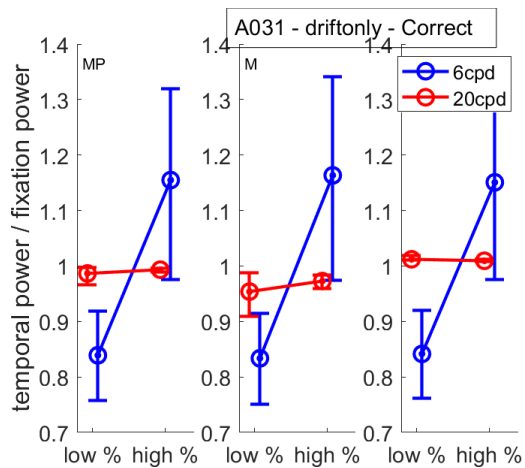
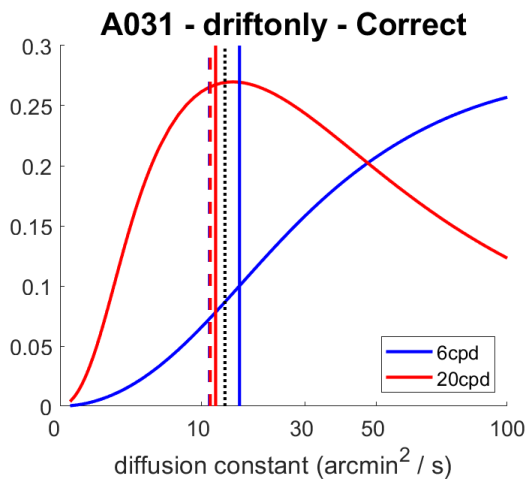


Figure 13: LEFT: Diffusion constants in estimated for each condition overlaid on the estimated temporal power on the retina (average of M and P cells). Blacked dotted line marks fixation diffusion constant. Dashed lines are 65% performance and solid lines are 90% performance. RIGHT: Power from each drift normalized by drift during fixation for the average of M and P cells, M-cells only, and P-cells only..

4.4.2 Correct Trials Only



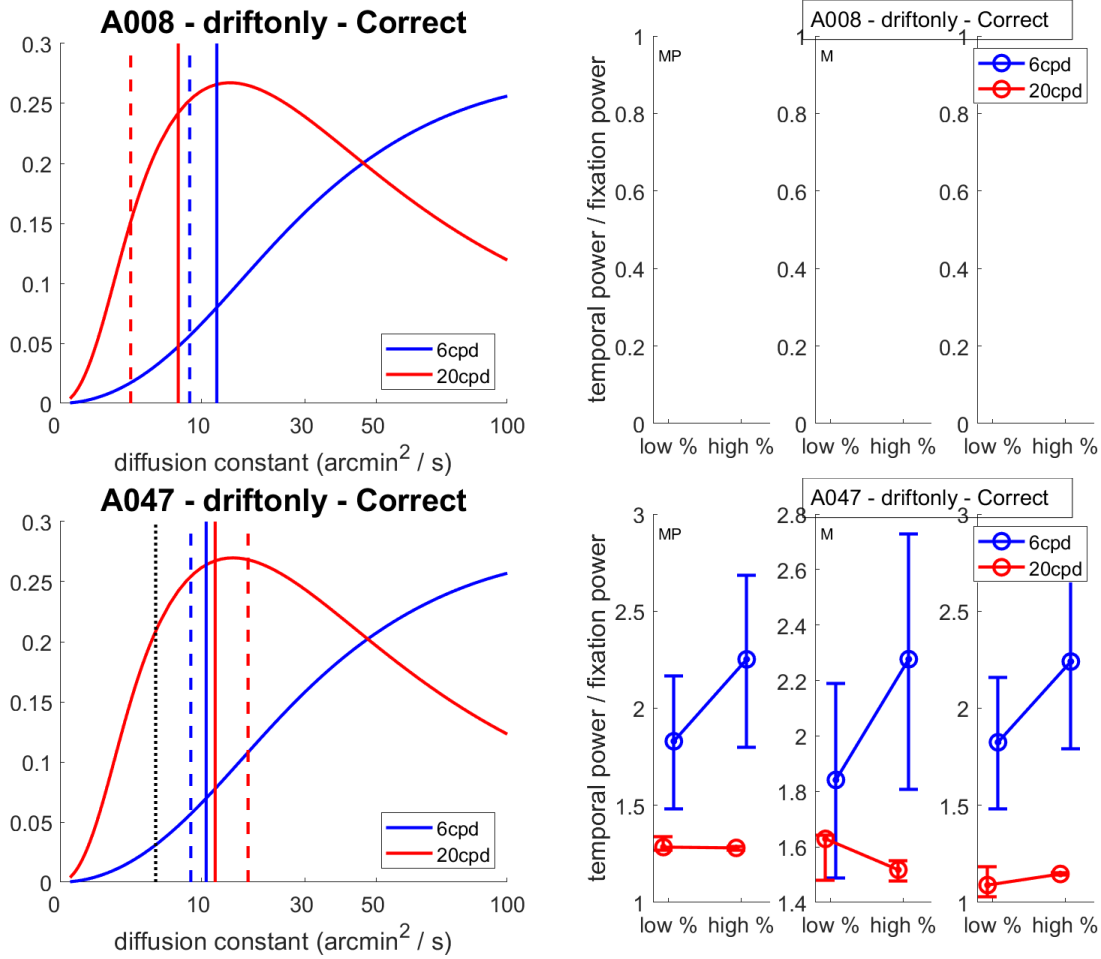


Figure 14: LEFT: Diffusion constants (correct trials only) in estimated for each condition overlaid on the estimated temporal power on the retina (average of M and P cells). Blacked dotted line marks fixation diffusion constant. Dashed lines are 65% performance and solid lines are 90% performance. RIGHT: Power from each drift normalized by drift during fixation for the average of M and P cells, M-cells only, and P-cells only..