# Radial Bias Pilot 1

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# 1 Experiment Description of Pilot 1

To measure radial direction bias with 1D drifting gratings at 8 polar angle locations at 7 deg eccentricity. A total of 3 motion conditions will be tested, 2 radial (inwards and outwards) and 1 tangential (combined), to measure the performance differences between (1) centrifugal and centripetal motion directions, and (2) radial and tangential motion directions.

## 1.1 Parameters

Eccentricity from central fixation: 7 degrees
Locations tested (polar angle relative to fixation): 0-315 degrees in 45 degree increments
Stimulus: sine wave gratings w/ 0.4 deg sigma gaussian mask
Stimulus spatial frequency: 1 c/deg
Stimulus drift speed: 8 deg/s
Stimulus contrast: 50% contrast per grating + gaussian mask
Stimulus aperature diameter: 2.5 deg
Black circular aperature was put onto screen to avoid perceptual artifacts from screen edges
Aborts trials that have breaks in fixation during stimulus presentation (stimulus_start - 300 ms TO stimulus_end)
Number of subjects: 3

## 1.2 Subject Instructions

For each of the following trials, a fixation dot will appear on the screen. A drifting pattern will appear at some distance from the center. Your task is to determine whether the pattern is drifting clockwise or counterclockwise relative to the reference.
Please remain fixated on the dot throughout the trials.
Press the RIGHT ARROW for clockwise direction.
Press the LEFT ARROW for counterclockwise direction.

## 1.3 Experimental Design

The pilot uses a 2AFC paradigm, within a block each trial includes a drifting grating presented at 1 of 4 possible positions, while the subject maintains fixation at the central dot. A method of constant stimuli is used which is set based on the performance of the training session (see Methods). The angular values added to the internal reference frame is chosen at random from the following constants [-8, -4, -2, -1, -0.5, 0.5, 1, 2, 4, 8] – logarithmic spacing from 0.5 to 8. The observer must determine whether the direction of motion if clockwise or counterclockwise relative to the internal

reference. The sequence of each trial for the 4 motion standards (specific to diagonal locations) at one location is depicted below:

Figure 1: Blue arrow represents the internal reference, the orange arrow represents an example of the direction at which the stimulus is presented (can be clockwise or counterclockwise to the blue arrow.

## 1.4 Block sequence

Four blocks were run, and each block corresponded to 1 of the 4 conditions being tested (tangential lower left motion, tangential upper right motion, radial upper left motion, radial lower right motion). The internal reference frames for each block is shown below:

Prior to the actual experiment, the "standard" motion direction corresponding to that specific block will be showed to the observer to use as an internal reference. Then a training session is conducted to determine how much tilt is required to meet 75% accuracy with staircase procedure (MLPest), and to allow subject to practice task with feedback. The estimated angular value to add/subtract to the standard to achieve 75% performance of the clockwise/counterclockwise will be used to determine constants. For this pilot, constants [-8, -4, -2, -1, -0.5, 0.5, 1, 2, 4, 8] were

chosen for all 8 blocks. Note positive and negative values for clockwise v. counterclockwise tilt. Each block contained 4 locations x 5 tilt values x 2 (clock v cc) x 20 repetitions = 800 trials. There are 8 blocks * 800 trials = 6400 total trials (3200 tang, 1600 radial-in, 1600 radial-out). Each full-block takes 45 min; all 8 blocks took 360 min.
Example sequence of blocks for RE

1. diag-UL [angles: +- 0.5, 1, 2, 4, 8] (45 min)
2. card-HR [angles: +- 0.5, 1, 2, 4, 8] (45 min)
3. diag-LR [angles: +- 0.5, 1, 2, 4, 8] (45 min)
4. card-VL [angles: +- 0.5, 1, 2, 4, 8] (45 min)
5. diag-UR [angles: +- 0.5, 1, 2, 4, 8] (45 min)
6. card-HL [angles: +- 0.5, 1, 2, 4, 8] (45 min)
7. diag-LL [angles: +- 0.5, 1, 2, 4, 8] (45 min)
8. card-VU [angles: +- 0.5, 1, 2, 4, 8] (45 min)

# 2 Subject Data

## 2.1 Psychometric Fits

Figure 2: LEFT: 200 trials per point. RIGHT: Each point is 400 trials.

Figure 3: LEFT: 200 trials per point. RIGHT: Each point is 400 trials.

Figure 4: LEFT: 200 trials per point. RIGHT: Points are either 200 or 400 trials.

## 2.2 Sensitivity Polar Plots

Figure 5: LEFT: 200 trials per point. RIGHT: Each point is 400 trials. 95% CI plotted from 1,000 bootstraps.

## 2.3 Sensitivity Cartesian Bar Plots

Figure 6: LEFT: 200 trials per point. RIGHT: Each point is 400 trials. Green asterisk indicates 68% CI do not overlap. Black asterisk indicates 95% CI do not overlap.

## 2.4 Sensitivity Cartesian Line Plots

Figure 7: LEFT: 200 trials per point. RIGHT: Each point is 400 trials. Green CIs are 68% confidence. Black CIs are 95% confidence.

## 2.5 Bias Polar Plots

Figure 8: LEFT: 200 trials per point. RIGHT: Points are either 200 or 400 trials. 95% CI plotted from 1,000 bootstraps.

## 2.6 Bias Cartesian Bar Plots

Figure 9: LEFT: 200 trials per point. RIGHT: Each point is 400 trials. Green asterisk indicates 68% CI do not overlap. Black asterisk indicates 95% CI do not overlap.

## 2.7 Bias Cartesian Line Plots

Figure 10: LEFT: 200 trials per point. RIGHT: Each point is 400 trials. Green CIs are 68% confidence. Black CIs are 95% confidence.

# 3 Group Data

## 3.1 Sensitivity Polar Plots

Figure 11: LEFT: 600 trials per point. RIGHT: Each point is 1200 trials. Error bars represent SEM across subjects.

## 3.2 Sensitivity Cartesian Line Plots

## 3.3 Bias Polar Plots

## 3.4 Bias Cartesian Line Plots

# 4 Supplementary Images: PFs per location

## 4.1 RE PFs Per Location

RE loc180
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

RE loc180
radial
tangential
clockwise response
added tilt (deg)

RE loc225
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

RE loc225
radial
tangential
clockwise response
added tilt (deg)

RE loc270
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

RE loc270
radial
tangential
clockwise response
added tilt (deg)

RE loc315
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

RE loc315
radial
tangential
clockwise response
added tilt (deg)

## 4.2 FH PFs Per Location

FH loc180
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

FH loc180
radial
tangential
clockwise response
added tilt (deg)

FH loc225
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

FH loc225
radial
tangential
clockwise response
added tilt (deg)

FH loc270
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

FH loc270
radial
tangential
clockwise response
added tilt (deg)

FH loc315
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

FH loc315
radial
tangential
clockwise response
added tilt (deg)

## 4.3 BB PFs Per Location

BB loc180
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

BB loc180
radial
tangential
clockwise response
added tilt (deg)

BB loc225
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

BB loc225
radial
tangential
clockwise response
added tilt (deg)

BB loc270
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

BB loc270
radial
tangential
clockwise response
added tilt (deg)

BB loc315
outward
inward
tangleft
tangright
clockwise response
added tilt (deg)

BB loc315
radial
tangential
clockwise response
added tilt (deg)

# 5 Current Goals

1. Several papers demontrate that sensitivity to radial orientations is greater than tangential orientations; similarly, radial direction bias is reported for moving dot stimuli. But orientation and motion direction is always orthogonal with 1D drifting gratings. Is sensitivity greater for radial motion or radial orientations w/ 1D drifting gratings? If the radial sensitivity is greater in respect to motion direction, then the radial orientation effect is weaker than the radial motion effects (or visa versa).
   - Interesting because the reported effects seem at odds, physiologically. Component neurons generally respond to motion that is orthogonal to their preferred orientation.
   - So far, data points to radial bias in respect to motion domain (conflict w/ Hong).
2. Is sensitivity generally greater in cardinal locations compared to non-cardinal locations?
   - Note: if sensitivity is higher in cardinal locations, this could be due to the location or due to the feature of the stimulus (cardinality in orientation/motion).
3. Is the difference in radial and tangential sensitivity more pronounced in non-cardinal locations compared to cardinal locations?
   - Note: Cardinal bias might enhance sensitivity disproportionately for orientation, which minimizes radial bias differences on the cardinal axes.

# 6 Incorporating fMRI

## 6.1 Goals

1. Localize MT+ using moving vs. static stimuli
2. Map retinotopy of MT, MST, (and V1) using methods similar to Huk et al., 2002 and Amano et al., 2009
   - Create polar angle maps and calculate cortical surface area dedicated to upper 45 deg wedge., lower 45 deg. wedge
   - Extend analysis to upper vs. lower visual field since found in macaque but not yet reported for human
3. Calculate difference in BOLD magnitude for upper vs. lower vertical meridian
4. Inverted encoding model (can we predict what stimulus was shown – radial vs. tangential)
   - Use stimulus to map channel responses for each motion direction, and use as weights to reconstruct signal
   - First create encoding model by using basis functions for each motion direction
   - Then, for each ROI voxel, for each trial, calculate channel weights for each basis function ("forward model")
   - Fit to testing data on different trials/runs to reconstruct population-level stimulus representation
   - We would expect better decoding for radial motion directions in lower vertical meridian

# 7 Extending to Plaid Stimuli

1. How does this extend to plaid stimuli? Does the bias apply to the component motion direction or the perceived motion direction?

# 8 Supplemental Questions

1. Is there an HVA or VMA present for any/all of the conditions? (SF in design matters in this case)
2. Is there a difference in sensitivity to radial-inward vs. radial-outwards motion?
   - So far, there doesn't seem to be a difference at 7 deg eccentricity.
3. Maybe abandon question about how these biases change w/ eccentricity.

# 9 Updates

- Design Related
  - Fixed beep volume (lower pitch sounded lower in volume)
  - Keeping fixation dot throughout trials (better eye tracking data this way)
  - Fixed the short delay between stimulus and response period
- Analysis Related
  - Computed averages across subjects (for the above plots), with SEM error bars
  - PFs match the bias/slope values in the histograms/barplots
  - Fixed error bars (all data is bootstrapped), and bias plots axes (intervals even for all subjects), and labeled bias direction
  - Added cartesian plots with CIs and stats
  - Replaced Palamedes functions with FitCumNormYN throughout scripts, but Palamedes function PF still used for plotting the fit.
  - Plotted psychometric functions per subject : per condition, per location
  - Added/Changed all bar plots to line plots (includes a jitter on the x-axis, and excludes asterisks for significance)
- Other improvements
  - Showing legend for each location somehow in barplots
  - Made sure all y-axes are labeled
  - For PF curves, plotted dots of different sizes so we can see (largest in back))
- For discussion
  - Go over mock VSS abstract
  - Go over individual PFs?
  - Should continue with data collection with current paradigm?
  - fMRI design
  - Plaid design
  - Eye-tracking to ensure to breaks in fixation (how many ms prior to stimulus? Currently it is 300 ms to maximize trials.)
  - Eye tracker in RM 956
    * Afp server not compatible with PC? – where to backup data?
    * CRT monitor calibration.

# 10 To Do

- Feedback for Analysis
  - Can try adding 6 random data points each of the 4 conditions at each tilt value to see if plots significantly change
  - Plot TangRight Sensitivity against TangLeft Senstivity; then on top RadialIn vs RadialOut in a different color
  - Add CIs to bar plots per condition of sensitivity/bias across all locations
  - *Update PF functions for cardinal/oblique separately
  - *Plot polar plots based on each MOTION VECTOR per condition (per subject)
  - Create bar plots of sensitivity/bias within (first/second half) per block and across blocks
  - Check in with Nina about the Eyelink File
  - LATER: fit linear mixed effects model to include condition (radial/tang) and location as covariates – should see effects for both. Can also do conditions (radialin, radialout, tangright, tangleft).
- Feedback for Experiment Design
  - *Equally distribute difficulty levels and clock/counterclockwise within each block
  - *Explore 2-up 1-down converging staircases as method to compute slope and bias for my purposes (try this on myself)
  - *Print thank you message before saving eyelink data (last trial)
  - *Save data outside of Experiment directory so that it does not upload to github
  - *Fix physical aperture for monitor so it's more optimal for people of different heights
  - *Ensure speed is the same across locations (Billy & Jon both mention some seem faster)
  - *Billy also reported that LL radial motion seemed more clockwise – double check that CRT monitor does not cause issues with stretching
- Feedback for Presentation/Other
  - Type up instructions for experiment
  - Latex image directory needs to be outside of directory loaded to github
  - Latex file – any way to generate in parent folder?
  - Can let subjects rotate keyboard when right/left if more intuitive for subject
  - Table for now: If we want to capture polar angle differences, might need to increase SF? (confirmed in other exp around 6 cpd, 6 deg ecc)
  - Double check sigma of gaussian for reporting purposes (and at what eccentricity contrast drops below 1 perc)

# 11 Software to Cite

- PsychToolbox Extensions (Brainard, 1997; Pelli, 1997; Kleiner et al, 2007)
- Prins, N & Kingdom, F. A. A. (2018) Applying the Model-Comparison Approach to Test Specific Research Hypotheses in Psychophysical Research Using the Palamedes Toolbox. Frontiers in Psychology, 9:1250. doi: 10.3389/fpsyg.2018.01250
- Plummer, M. (2003, March). JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling. In Proceedings of the 3rd international workshop on distributed statistical computing (Vol. 124, No. 125.10, pp. 1-10). (http://mcmc-jags.sourceforge.net/)

# 12 Data that still needs updating

## 12.1 RE Psychometric Fits (Cardinal/Oblique)

Figure 12: RE new data (speed 8 deg/s) across 8 blocks that each contain 1 reference vector. Top row: All trials (combining cardinal and oblique blocks). Each point = (20 x 8 locations); Second row: subset of data in first row, including only the oblique motion directions (diagonal locations). Each point = (20 x 4 locations); Last row: subset of data in first row, including only the cardinal motion directions (cardinal locations). Each point = (20 x 4 locations). Positive bias = more counterclockwise responses. All means/confidence intervals were computed from samples of posterior distribution using Markov chain Monte Carlo method (from PAL_PFHB_fitModel.m) - 5000 samples, 3 chains.

**RE SENSITIVIY/SLOPE**
Radial out beta = [cardinal & diagonal directions = 0.58, cardinal = 0.72, diagonal = 0.48]
Radial in beta = [cardinal & diagonal directions = 0.58, cardinal = 0.73, diagonal = 0.48]
Tangential beta = [cardinal & diagonal directions = 0.48, cardinal = 0.63, diagonal = 0.40]
**RE BIAS**
Radial out alpha = [cardinal & diagonal directions = -0.66, cardinal = -0.52, diagonal = -0.82]
Radial in alpha = [cardinal & diagonal directions = -0.31, cardinal = -0.43, diagonal = -0.16]
Tangential alpha = [cardinal & diagonal directions = -0.25, cardinal = -0.48, diagonal = 0.02]

## 12.2 RE Polar Plots Percent Correct (W/ eyetracking vs. No eyetracking)

Figure 13: Polar plots by performance (range 50-100%). Each point is 400 trials (collapsed across blocks). LEFT: new data w/eyetracking. RIGHT: old data.

## 12.3 Quality Control & Misc.

Figure 14: To check that performance does not vary too much between blocks. Cardinal blocks are interweaved with diagonal blocks, and consistently show better performance. LEFT: data with eyetracking. RIGHT: data without eye tracking.

## 12.4 FH Psychometric Fits (Cardinal/Oblique)

Figure 15: Same arrangement as previous page, but for subject FH (only includes half of full dataset: UR, VL, LL, HR).

**FH SENSITIVIY/SLOPE**
Radial out beta = [cardinal & diagonal directions = 0.29, cardinal = 0.62, diagonal = 0.20]
Radial in beta = [cardinal & diagonal directions = 0.28, cardinal = 0.70, diagonal = 0.22]
Tangential beta = [cardinal & diagonal directions = 0.27, cardinal = 0.41, diagonal = 0.20]
**FH BIAS**
Radial out alpha = [cardinal & diagonal directions = -0.61, cardinal = -0.59, diagonal = -0.49]
Radial in alpha = [cardinal & diagonal directions = -0.27, cardinal = -1.39, diagonal = 1.66]
Tangential alpha = [cardinal & diagonal directions = -0.48, cardinal = -0.78, diagonal = -0.03]

## 12.5 BB Psychometric Fits (Cardinal/Oblique)

Figure 16: Same arrangement as previous page, but for subject BB (only includes partial dataset: VU, LR). Not error range is too large (uninterpretable)

**BB SENSITIVIY/SLOPE**
Radial out beta = [cardinal & diagonal directions = 0.44, cardinal = 0.47, diagonal = 0.43]
Radial in beta = [cardinal & diagonal directions = 0.55, cardinal = 0.74, diagonal = 0.46]
Tangential beta = [cardinal & diagonal directions = 0.45, cardinal = 0.78, diagonal = 0.33]
**FH BIAS**
Radial out alpha = [cardinal & diagonal directions = 0.37, cardinal = -0.21, diagonal = 0.95]
Radial in alpha = [cardinal & diagonal directions = -1.60, cardinal = -1.14, diagonal = -2.1]
Tangential alpha = [cardinal & diagonal directions = 0.09, cardinal = 0.04, diagonal = 0.14]