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Quantifying the Correlation Between Eye-Movement and Perceptual Responses to Moving Plaids

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Introduction

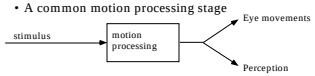
- The question: Do smooth eye movements and motion perception share a common neural process?
- The approach: Simultaneously measure psychophysics and eye movements
- Previous results: Perceptual and eye movement biases in the direction of motion are similar on average
- New Result: Trial-by trial correlation in eye movements and perceptual judgements

1. Background

A. Models

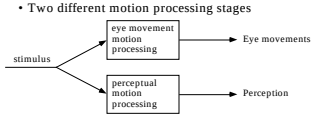
Correlated Model

- A common motion processing stage



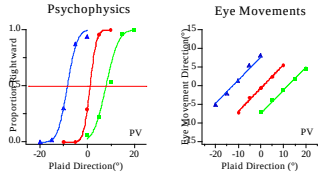
Uncorrelated Model

- Two different motion processing stages



B. Previous Result

- Stimulus: plaids windowed by asymmetric gaussians (±40°, 0°)
- Eye movement task: track the moving plaid
- Perceptual task: judge if the motion is right / left of straight down
- Result: equal biases in both eye movements and perceptiion



C. Discussion: One process or two?

- Equal average biases imply similar processes, but not necessarily the same neural structure
- Trial-by-trial comparisons of eye movements and percepts can distinguish between one common and two seperate processes
  - A common neural structure implies that the eye movement and the percept will covary on each trial
  - Two functionally similar, but separate, neural structures imply that the eye movement and the percept will vary independently on each trial

2. Theory: Correlation Analysis

A. Goals

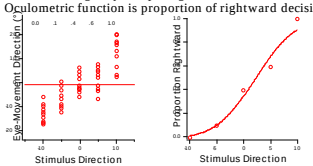
- Compute the predictabilty of perceptual decisions from eye movements
- Quantitatively measure the trial-by trial variability between eye movements and psychophysics

B. Analysis Procedure

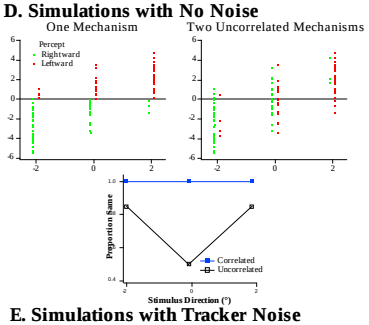
- Predict decisions from eye movements using an oculometric decision rule
- Compare predicted and actual perceptual decisions, and compute the proportion that are the same
- Compute the predictions of an uncorrelated model

C. Oculometric Decision Rule

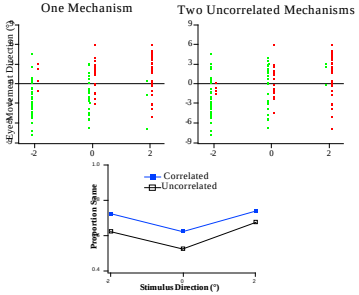
- Trial-by-trial decision based on eye-movement direction
- Choose left / right by comparing direction to a threshold
- Oculometric function is proportion of rightward decisions



D. Simulations with No Noise



E. Simulations with Tracker Noise



3. Experiment

A. Methods

- We simultaneously measured psychophysics and eye movements
- Observers were asked to track the moving plaid and determine if the motion was leftward or rightward of straight down

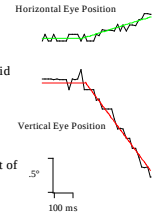
B. Stimuli

- Symmetric, 90°, drifting plaids
- Direction of motion -2°, 0°, or +2° relative to straight down

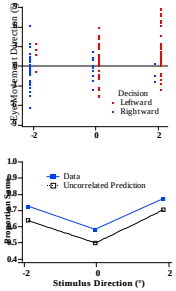
- Components were sine wave gratings
  - contrast 25%
  - temporal frequency 4 Hz
  - spatial frequency 0.6 cycles / degree
  - duration 600 ms
- A fixation cross appeared 500 msec before stimulus onset and was extinguished as the plaid appeared

C. Oculomotor Data Collection

- Infra-red video-based ISCAN model RK426 eye tracker (60 Hz)
- Calibration (prior to each run)
  - Observers sequentially fixate 9 points arranged in a 3x3 grid
- Calculation of tracking direction
  - analyze first 300 ms of saccade free tracking (~ open loop)
  - fit horizontal and verical traces separately
  - calculate direction as arctangent of the ratio of the slopes
  - calculate tracker direction noise

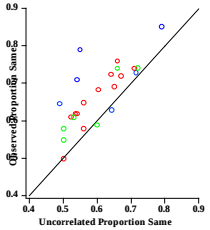


D. Data



- Data are more correlated than the predictions of the uncorrelated model

E. Summary



- Performance was more correlated than the predictions of the uncorrelated model for 21 of the 24 measurements

4. Alternate Analysis: SOC

(Newsome, Britten, Salzman, & Movshon, 1990)

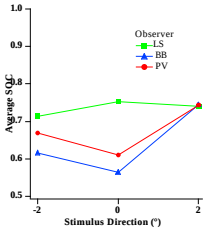
- Answers the 2AFC question: Given two eye movements, one corresponding to a rightward and the other corresponding to a leftward decision, what proportion of the time can the eye movements be correctly matched to the decisions?

A. Procedure

- Bins eye movements by psychophysical decision
- Quantifies the difference in the two distributions

$$P_{SOC} = \int_{-\infty}^{+\infty} dx \; P(x|R) \int_{-\infty}^{x} dy \; P(y|L)$$

B. Results



- SOC analysis also shows that eye movements and motion percepts are correlated

Conclusions

- The direction of smooth eye movements and the perceived direction of motion covary on a trial-by-trial basis
- Eye movement and perceptual processing share a common neural motion-processing stage, perhaps area MT

5. Work in Progress

A. Goals

- Overcome eye-tracker noise by increasing the psychophysical uncertainty
- Confirm results for a different stimulus

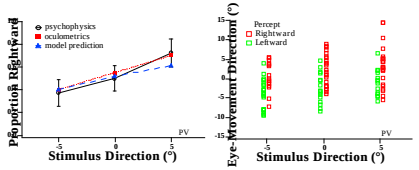
B. Stimuli

- Dynamic random dots (3 frame lifetime @ 67 Hz)
- Speed 31 deg / s
- Field of view 30° x 30°
- Density 0.24 dots / deg²
- Gaussian distribution of directions (μ = -5, 0, 5°, σ = 45°)
- Duration 500 ms

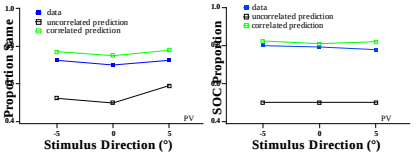
C. Tasks

- Eye movement : Track stimulus
- Perceptual: Judge motion right / left of straight down

D. Data



E. Results



F. Model