Predictive context biases perceptual selection during binocular rivalry

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Background

Do we see what we expect to see?

- Prior information can influence sensory processing and decision making [1,2]
- Based on prior information, the brain is thought to generate predictions of forthcoming sensory information [3,4]

Question: Does predictive information influence perceptual selection?

- Here, we test for effects of predictive signals on perceptual selection using binocular rivalry
- Since binocular rivalry between orthogonal orientations is thought to be resolved at early stages of visual processing, this approach probes predictive signals at low levels of the visual system

Predictive context: Sensory events that contain information about what future sensory events are likely to occur

Bayesian formulation: 2 competing percepts

$P(H_1|S) \propto P(S|H_1)P(H_1)$

$P(H_2|S) \propto P(S|H_2)P(H_2)$

H = Perceptual hypothesis
S = Stimulus

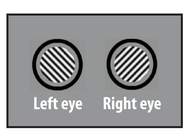
Posterior *Likelihood* *Prior*

- An optimal way of combining prior information (here, predictions) with current information (here, sensory evidence)
- In this framework, the percept is the hypothesis with the highest posterior probability [5]

Methods

Binocular rivalry

- Conflicting images presented to the two eyes result in a perceptual alternation between the two images
- To assess prediction effects, we measure the *initial percept* -- what do subjects see first, following predictive context?



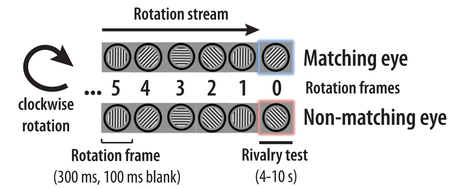
Continuously report percept by holding down keys:
left tilt or **right tilt**
(No key press for ambiguous percepts)

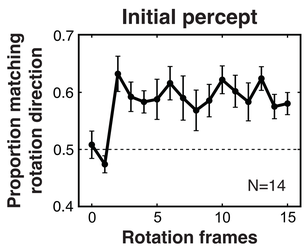
Experimental setup
Stimulus displays were generated on a Macintosh PowerPC computer using Matlab and Psychophysics Toolbox and were displayed on two halves of a NEC MultiSync FE992 CRT monitor with 60 Hz refresh rate at a viewing distance of 100 cm. Subjects viewed all stimuli through a mirror stereoscope.

Stimuli
Rivalry stimuli were circular patches of sinusoidal gratings, 1.8 degrees in diameter, with 3 cycles per degree, presented at 10% contrast (except where noted) on a medium gray background. Each grating was surrounded by a dark annulus of 2.6 degrees in diameter, 0.2 degrees thickness, which served as a vergence cue. Left and right gratings were orthogonally oriented with +/-45 degree tilts.

Rotation stream stimuli consisted of identical sinusoidal gratings presented to both eyes, which rotated clockwise or counter-clockwise in 45 degree increments, with each "rotation frame" lasting 300 ms with a 100 ms blank annulus separating each frame.

Exp. 1: Rotation rivalry



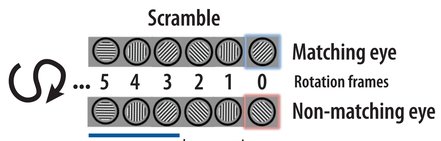


Methods
4-s, 5-s, or 10-s rivalry duration (different subjects)
0-15 rotation frames
Clockwise or counter-clockwise rotation
24 or 32 trials per condition (different subjects)
All conditions randomly intermixed

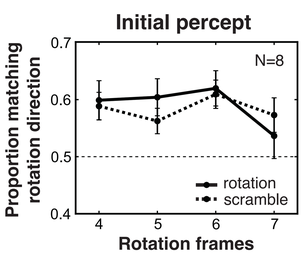
- A consistent rotation matching effect, similar for different stream lengths

Exp. 2: Recent or distant past?

- In Experiment 1, the rotation matching effect was seen with as few as two rotation frames.
- Does the presence of a consistent rotation direction prior to two rotation frames enhance the rotation matching effect?



No consistent rotation in early part of scrambled stream The last two stream items were always consistent with a particular rotation direction (here, clockwise) for both rotation and scramble trials.

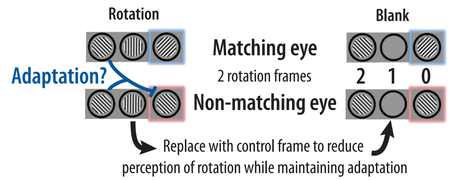


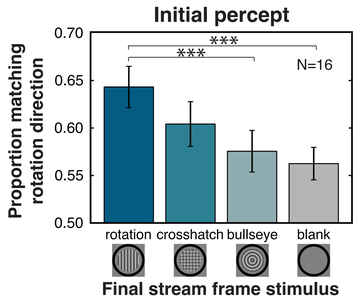
Methods
5-s rivalry duration
Rotation and scrambled streams
4-7 frames in the stream
Clockwise or counter-clockwise rotation
24 trials per condition
All conditions randomly intermixed

- Scrambling the stream prior to two rotation frames does *not* diminish the rotation matching effect. Therefore this effect depends only on recent stimulus history.

Exp. 3: Adaptation control

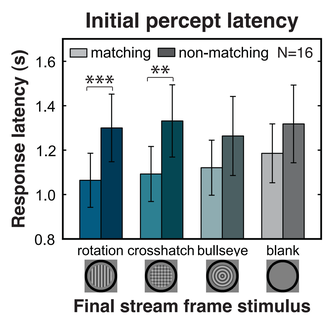
- Could the rotation matching effect be explained by adaptation to the second-to-last rotation frame? Such adaptation could bias perceptual selection against the non-matching stimulus.





Methods
10-s rivalry duration
4 stream conditions
Always 2 frames in the stream
48 trials per condition
All conditions randomly intermixed

- All conditions result in above-chance rotation matching, suggesting that adaptation contributes to the effect
- Importantly, the matching effect in the rotation condition is greater than that in the bullseye or blank conditions, arguing for the presence of a prediction effect

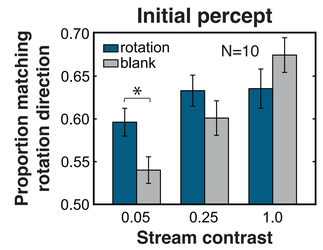


Matching faster than non-matching

- The first response to the rivalry stimulus is also significantly *faster* for percepts matching the rotation direction compared to non-matching percepts, only in the rotation and crosshatch conditions
- Prediction speeds perceptual report. This may reflect a shorter time required to establish a predicted compared to a non-predicted percept.

Exp. 4: Effect of contrast

- Does stimulus strength during a period of predictive context increase the strength of the associated prior? If so, then higher stream contrast should result in greater prediction effects.



Methods
5-s rivalry duration
5%, 25%, and 100% stream contrasts
Rotation and blank stream conditions
Always 2 frames in the stream
32 trials per condition
All conditions randomly intermixed

- Stream contrast does not affect the strength of the predictive prior: Adaptation effects depend strongly on stream contrast, but *any* suprathreshold stimulus seems to produce prediction effects
- Prediction effects are revealed at low stream contrasts; adaptation dominates at high stream contrasts (contrast x stream type interaction, $p<0.001$)
- We also replicated the latency effect shown in Experiment 3, specifically for the lowest stream contrast (data not shown). This is a further dissociation of prediction and adaptation.

Conclusions

1. Predictive context can influence perceptual selection during binocular rivalry, with above-chance selection of predicted stimuli.
2. This effect depends on only very recent stimulus history.
3. With the rotation rivalry stimulus, the motion direction matching effect is partially but not entirely due to adaptation. Low stream contrasts allow the prediction effect to be measured in the presence of minimal adaptation.
4. Predictive context also speeds perceptual selection as measured by the response latency for the initial percept.
5. These results suggest that predictive signals exist at neural sites that contribute to perceptual selection during binocular rivalry.

Future directions

- We would like to quantitatively test a Bayesian model of perceptual selection by manipulating prior (predictive) context and sensory evidence for each possible percept

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