Brenner Color Illusion

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1 Experiment Description

This experiment investigates the effect of retinal stabilization on the perception of colors. A previous experiment showed that when a central disk is stabilized on the retina but a surrounding ring stays stationary on the screen, the central disk intermittently disappears and takes on the color of the surrounding ring (Krauskopf, 1963). This study suggests that filling in occurs when the border between two colors fades as a result of retinal stabilization.

Here we test whether the color perception can be induced by stabilizing select borders with a multi-colored surround, as in Figure 1. When presented with the stimulus, the subjects had to report whether the central patch, the color of which varied from trial to trial, appeared more red or more green.

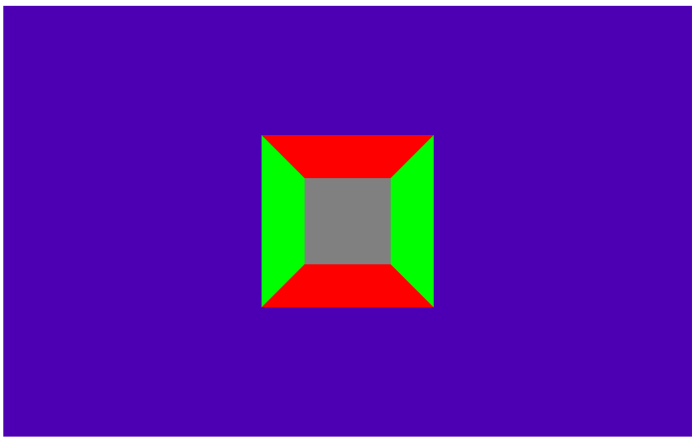

Figure 1: Example of stimulus. Central gray square was presented with green flankers in one direction and red on the other. The background was a purple/bluish color. Colors here do not match how the stimulus actually appear on the screen.

The stimulus was stabilized on the retina either horizontally or vertically. These conditions were labelled by the color of the flanker of the direction that was stabilized - red-direction stabilized or green-direction stabilized as shown in Figure 2. By stabilizing the horizontal flankers of the stimulus, the vertical flankers will allow for small jitters of the retina to cross from the inner square to the contrasting flankers.

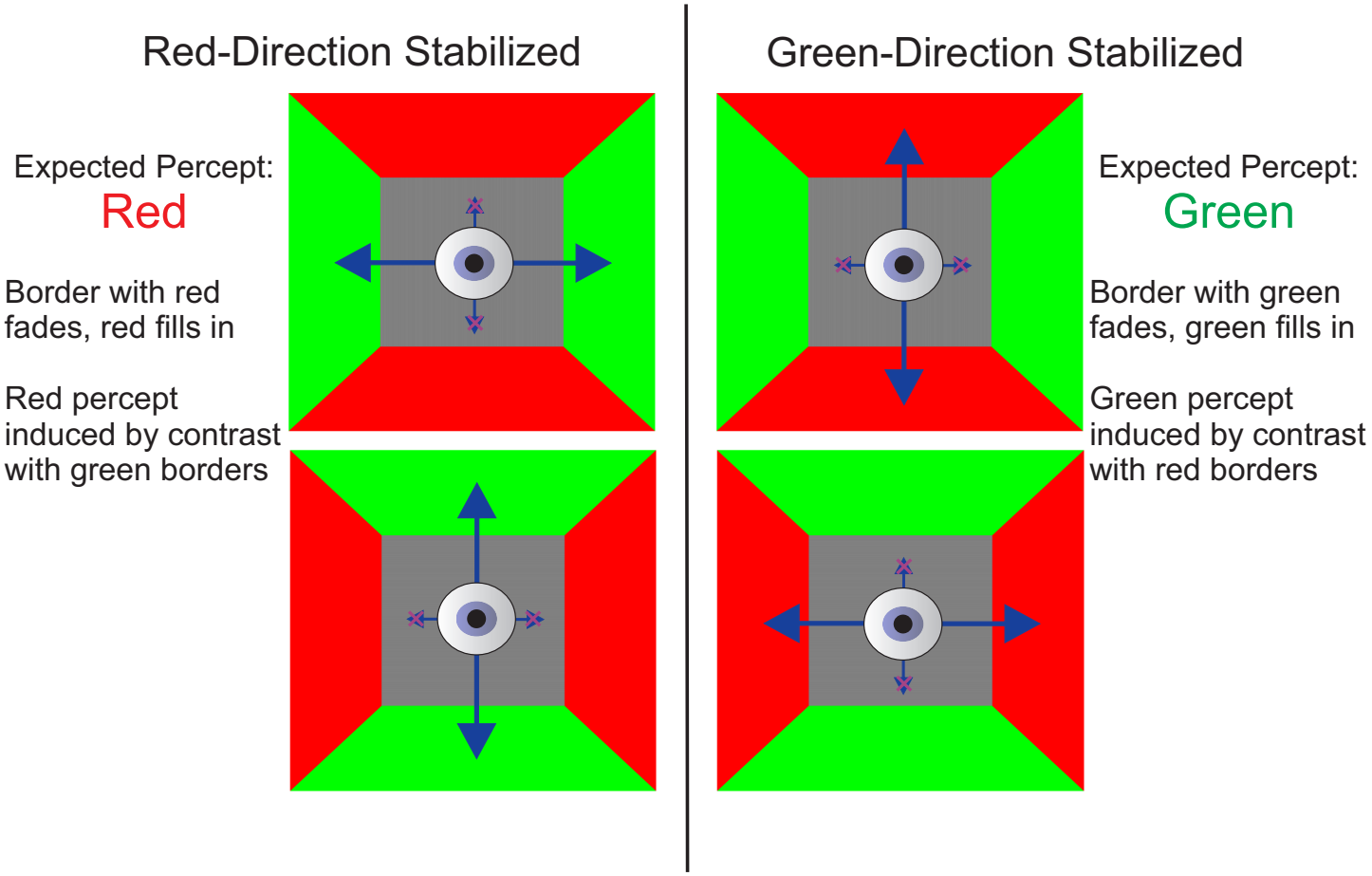

Figure 2: LEFT: red-direction stabilized condition. Gaze was allowed to pass over the borders of the central patch with the green flankers, but could not approach the borders with the red flankers. RIGHT: green-direction stabilized condition. Gaze was allowed to pass over the borders of the central patch with the red flankers, but could not approach the borders with the green flankers.

1.1 Experiment Flow

A fixation of 500 ms was presented at the center of the screen, with the same background color shown in Figure 1). The ramp gradually introduced the stimulus which then appeared on screen. This 1 s ramp increased the contrast of the stimulus linearly until fully presented. The stimulus was then displayed for 1 s, after which the subject indicated whether the central patch was more red or more green. The color of the central patch changed randomly from trial to trial from a discrete set of 9 different near-gray colors that tended either towards more red or more green.

Depending on the data collected, experimenters can later limit the stimulus presentation to the inner 4 of the 9 discrete colors. There was a recalibration procedure that took place every 10 trials, prior to the fixation period.

1.2 Hypothesis

Color induction is primarily caused by temporal modulations in the position of the image on the retina, demonstrated by: (1) the lack of temporally varying stimulation of receptors cause local retinal adaptation results in the boundary of the stabilized image to fade and the outer color to "fill in" (2) the presence of temporally varying stimulation of receptors produced by small eye movements that jitter the retina across the edge enhance contrast.

In red-direction stabilized cases, stabilization of the red flankers would cause the boundary between the center and red flankers to fade resulting in the red color to "fill in" the central path while, in the same trial, jittering across the edge of a contrasting color would produce a red percept. Therefore, red-direction stabilization cases would produce more red responses and more green-direction stabilization cases would produce more green responses.

1.3 Control Task

The current control task is similar except that the flankers are all one color. Stabilization occurs on only the horizontal or vertical axis as before. In this case, the expected effects of filling in and color contrast oppose each other. Based on responses we can then determine which of these mechanisms is stronger in influencing color perception. The control task is also informative of any potential bias of the subject. The amount of control tasks has been reduced but is still present.

2 Data Collection and Analysis

Data is located in `//casfsb/APLAB/JanisData/TheBrennerExperiment`.

Experiment and analysis code: `https://gitlab.com/jintoy/BrennerExperiment`

2.1 Trial Filtering

Data has been collected for a total of 3 subjects (2 from the lab).

Trials with no-tracks, blinks, saccades, or microsaccades ($< 30'$) in the stimulus presentation period (the first 2 seconds of the trial) should be removed from analysis.

Subject	Total Trials	# w/ No Track / Blink	# w/ Saccades	# w/ Microsaccades	Valid Trials
Rania	915	206	372	270	67
Janis	367	12	12	243	100
Adriana	1079	10	58	438	573

Results are included below for 1) All Trials and 2) Microsaccades allowed (Valid Trials + Trials with Microsaccades), and 3) Valid Trials. 95% confidence intervals on the red-level thresholds (the red-level when the proportion of red responses was 0.5) were computed for both red- and green-direction stabilized though in each case presented below they overlapped.

p-values for the hypothesis that the green-direction stabilized threshold were greater than the red-direction stabilized condition was computed as $1 - r$ where r was the proportion of bootstrap iterations when this hypothesis held. These p-values are reported in the table below.

Subject	All Trials	Valid + Microsaccade Trials	Valid Trials
Rania	0.35	0.56	0.52
Janis	0.02^*	0.02^*	0.02
Adriana	0.2	0.09	0.04

2.2 Results (All Trials Included)

Currently, all trials are included in analysis. Top graphs below show proportion red responses versus the red level of the central patch. Bottom graphs show psychometric functions fit to the raw data with shaded regions representing SEM over 100 bootstrap iterations.

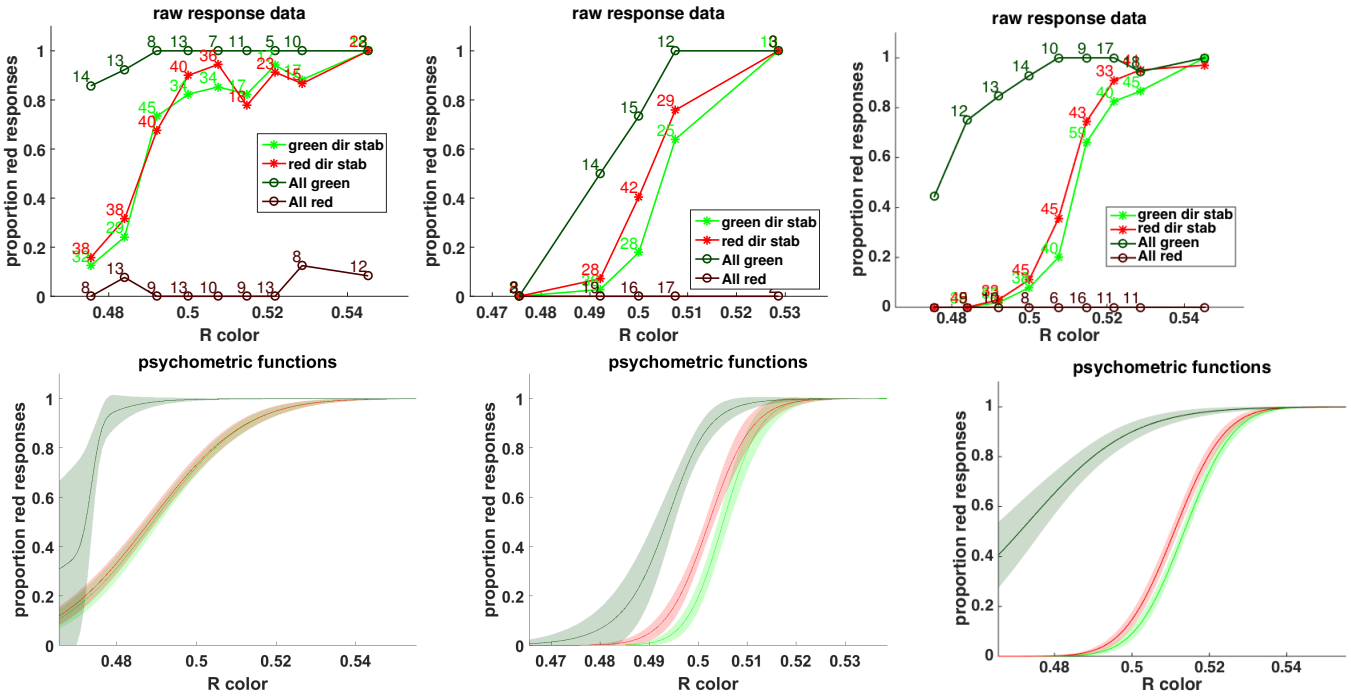

Figure 3: Left: Rania. Center: Janis. Right: Adriana. Numbers above each data point indicate numbers of trials collected in that condition at that red-level. (For Janis, red levels of central patch were limited to the region of highest sensitivity for collecting data more quickly)

2.3 Results (Eliminate Blinks/No-Tracks and Saccades; Microsaccades allowed)

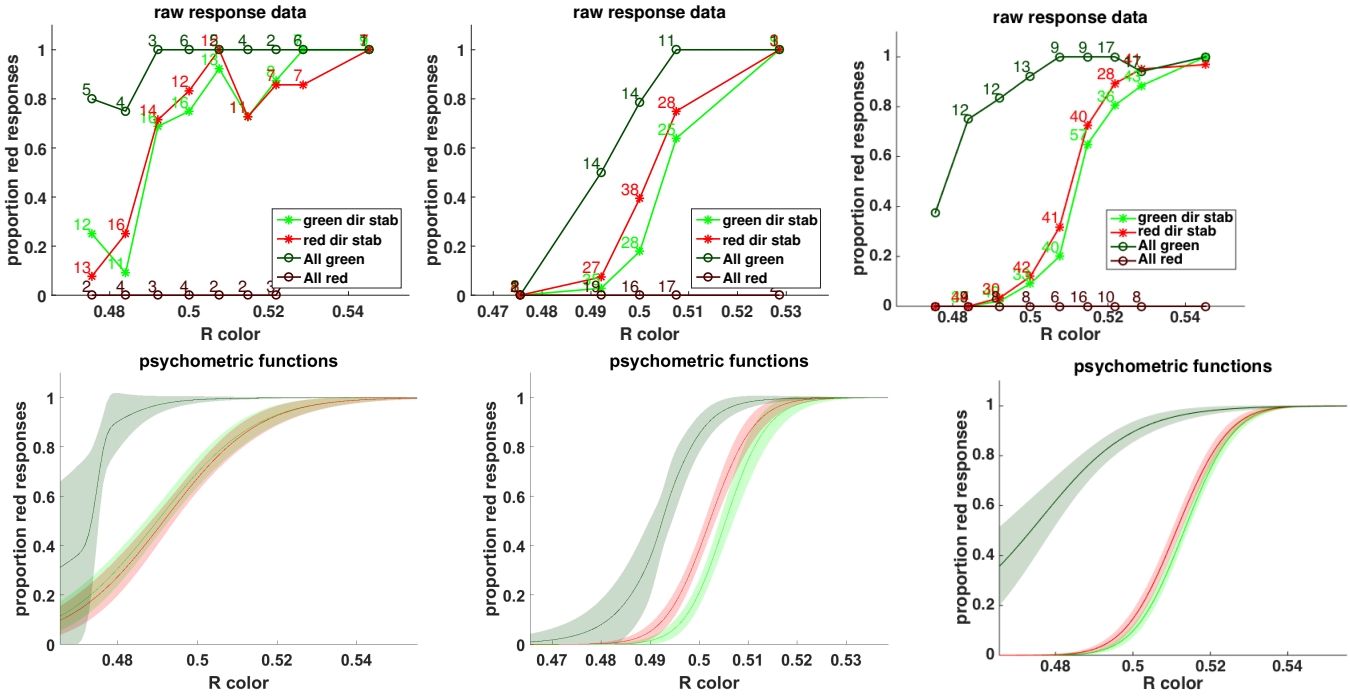

Figure 4: Left: Rania. Center: Janis. Right: Adriana. Numbers above each data point indicate numbers of trials collected in that condition at that red-level. (For Janis, red levels of central patch were limited to the region of highest sensitivity for collecting data more quickly)

2.4 Results (Valid Trials)

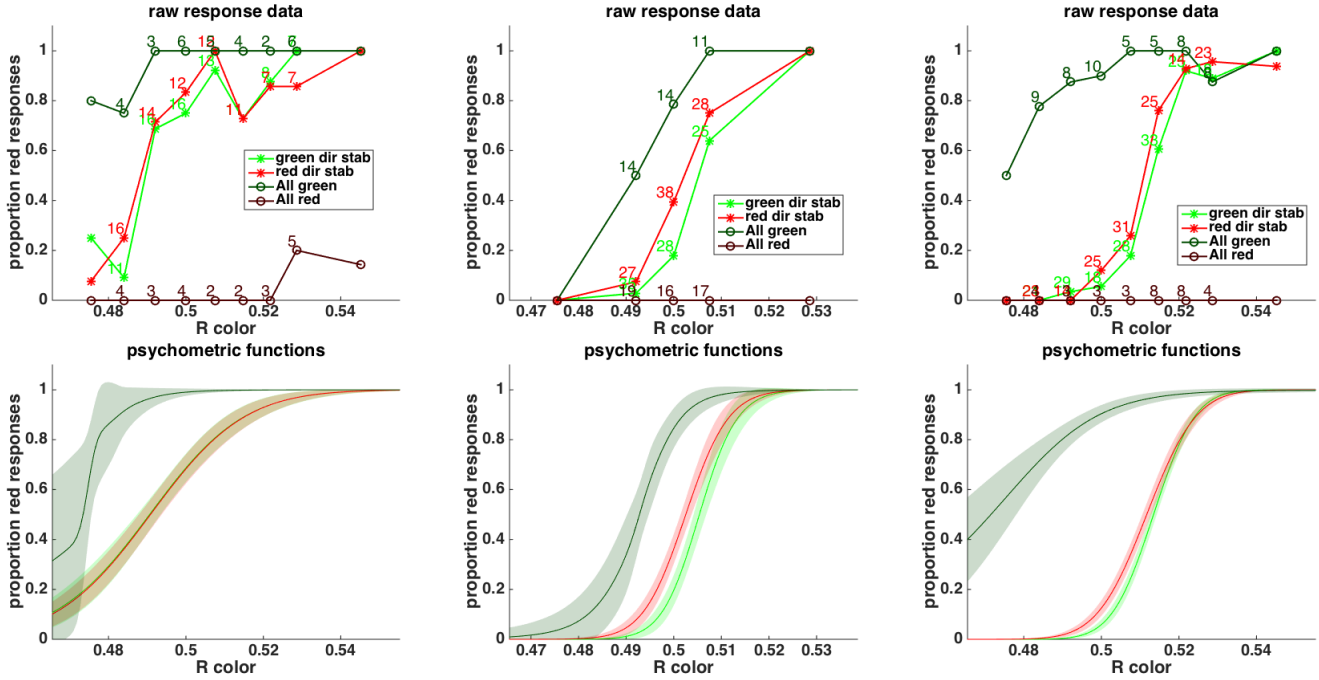

Figure 5: Left: Rania. Center: Janis. Right: Adriana. Numbers above each data point indicate numbers of trials collected in that condition at that red-level. (For Rania, valid data amount under the set threshold)

3 Next Steps

3.1 Questions for Eli

- Is there a way to get a continuous scale of colors for the central patch for adaptive procedures? Eli described a procedure in which he converted between the monitor gun space, CIE color space, and cone color space to select colors but is this something we can automate?

3.2 Updates

- Added demo for first session
- Altered the recalibration procedure to every 10 trials
- Limited control trials
- Added fixation period prior to stimulus (0.5 sec)
- Added ramp to stimulus presentation (1 sec)
- Added beep after response
- Updated code to not include fixation in trial data

3.3 Possible other experiments

- Do a longer experiment with continuous response on the color of the central patch. This would give us the temporal dynamics of the color induction.
- Replicate Krauskopf experiment. (Code exists, no data collected)