Sensitivity Across the Retina

Janis Intoy

Updated: October 13, 2018

Contents

Next Steps (Oct 13, 2018)

- Implement contrast ramp following saccades, blinks and no-tracks
- Test maximum contrast values in different conditions
- How to avoid detection of aliased grating?
- For foveal display, add option to use oriented grating instead of radial wave.

1 Introduction

The goal of this experiment is to characterize spatiotemporal sensitivity at various eccentricities across the retina. This has not been done thoroughly, particularly at points nearer to the fovea, and can be done more accurately with retinal stabilization.

These results would of course be interesting on their own, but will also enable us to make more accurate positions about visual function at different points in the retina.

2 Design

2.1 Stimulus

Here we will measure contrast sensitivity at different eccentricities and spatial and temporal frequencies by the method of adjustment. A sinusoidal grating (options in Figure 1) with a sinusoidal temporal modulation will be presented in an annulus at some eccentricity under retinal stabilization.

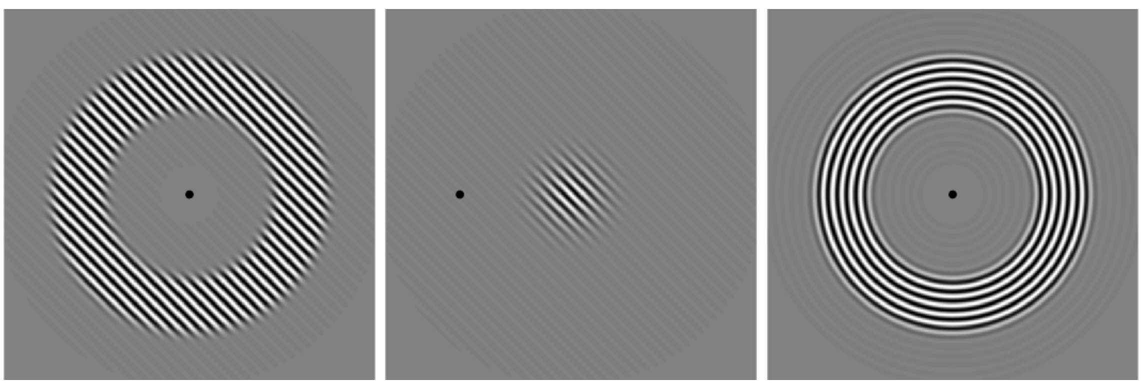

Figure 1: LEFT: Oriented grating in an annulus. (Con: long stripes along parts of ring) MIDDLE: Oriented grating with gaussian envelope eccentric from fixation. RIGHT: radial sine wave in annulus (current preferred option)

Conditions: [0, 2, 4, 6, 8, 10 deg] $\times$ [1, 4, 10, 16, 20 cpd] $\times$ [1, 5, 10, 16, 25 Hz][1,2]
Total Conditions = $6 \times 5 \times 5 = 150$

2.2 Task

The subject will be asked to adjust the contrast until it is just barely visible using buttons on the joypad (detection task). We would also want several measurements per condition ($\sim$ 4) and take an average to get contrast sensitivity. (600 trials total) Two possibilities:

[1] JI: These may be adjusted based on the refresh rate of the monitor.
[2] JI: Need to be careful that we don't go beyond the Nyquist limits of cones/RGC. Since this is a detection task we may capture aliasing effects.

1. Initial contrast high: Subject is instructed to decrease contrast until the waves just disappear, then increase contrast slightly until they reappear.

2. Initial contrast low: Subject is instructed to increase contrast until the waves appear, then decrease contrast until they disappear gain.

I'm not sure how long each of these trials would need to be - I imagine subjects will get faster at this with practice though.

2.3 Potential Challenges

- The stimulus presentation will be continuous, so it may not be feasible to measure sensitivity with drift only. To minimize the effects of visual transients resulting from blinks and saccades, I can turn off and ramp the stimulus back in after these events.

- The detection task relies heavily on the subjects' judgment, as opposed to a discrimination task where there are correct and incorrect responses.

2.4 Implementation

There are two technical challenges with this experimental design:

1. **Temporal modulation of stimulus contrast and real-time user adjustment of contrast.**

   - Current implementations of changing the contrast of on-binary stimuli in EyeRIS are not computationally efficient (i.e. SmartGray developed for dithering by Boi. But also Ruei mentioned that the CShader class would be useful for this). Specifically, pre-generating a series of large images to play as a movie is slow because changing the contrast is done in series with pixel-by-pixel multiplication.
   - Solution: To vary the contrast of the stimulus, the grating is masked by a solid plane with uniform luminance and transparency. Since the mask is uniform, it is a 1×1 pixel image that is later resized so the alpha channel can be adjusted in real time. My impression is that the blending of the grating and mask is linear:

     $$\text{(stimulus pixel gray)} = \text{(full-contrast pixel gray)} \times (1 - \alpha) + 127 \times \alpha$$

   - I'll check that the resulting luminances are still linear with this method.
   - This method does not reverse the polarity of the grating (i.e. the temporal modulation would be a full-rectified). To have a sinusoidal temporal modulation we can have two full-contrast stimuli of reverse polarity that alternate in sync with the modulating transparency.

2. **Efficient controls for user to adjust contrast.**

   - The ideal control for this experiment would be an analog joystick in which pressing harder changes the contrast faster, and pressing softly changes the contrast more slowly.

- Current solution: Up and down arrows on either side of joypad adjust contrast by big or small steps.

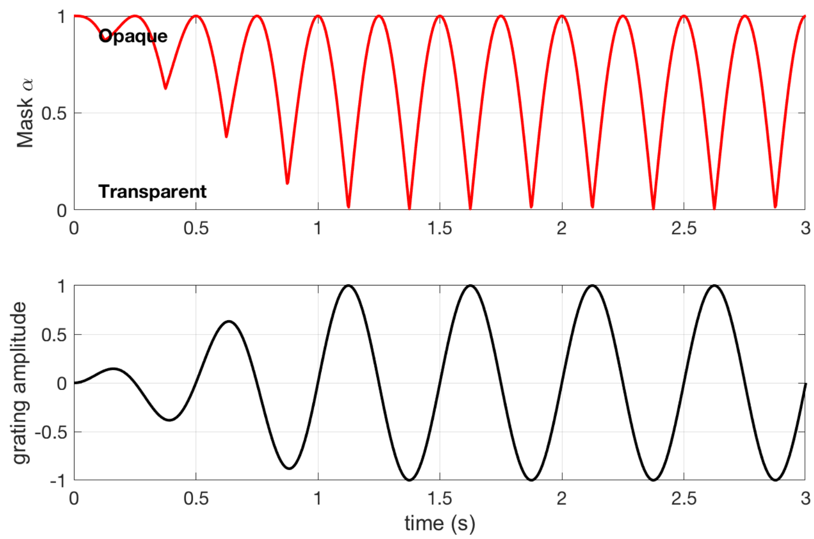

Figure 2: The transparency of a uniform mask is modulated in time (TOP) so that the contrast of the underlying image seems to vary in time (BOTTOM). The stimulus contrast will be ramped in upon trial onset, following blinks and saccades, and when gaze leaves a certain radius around fixation.

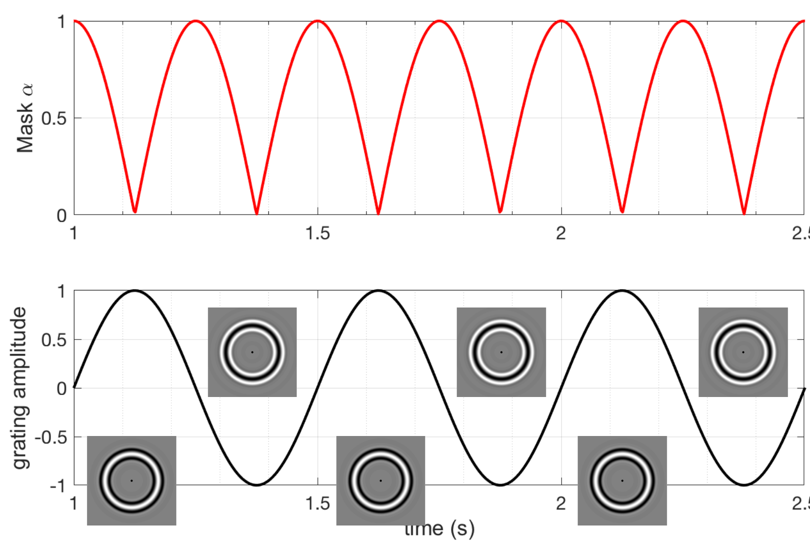

Figure 3: Varying transparancy of the mask does not affect the polarity of the grating, so the underlying stimulus is switched between polarities when the mask is fully opaque. (i.e. two images of reverse polarity are presented as a square wave with the desired temporal frequency.)

3 Literature Review

Need more work here:

- Overlap with Janis's Drift Gain Lit review: https://docs.google.com/spreadsheets/d/138vTYngWrrW0QjATXNuCtDKuO93XcuS-NkM9Exk6S64/edit#gid=0
- Janis's Drift gain overview: https://wiki.bcs.rochester.edu/ApLab/LabMeeting?action=AttachFile&do=get&target=LabMeeting_2018-07-24_Part1.pdf
- Kelly 1979 compared standing vs traveling waves - sensitivity is higher to traveling waves, possibly because each point in the grating is being modulated in time with full amplitude in a travelling wave whereas in a standing wave only the peaks are being modulated at full amplitude. In other words, traveling waves stimulate different parts of the retina with the same contrast, whereas standing waves provide full contrast to only some parts of the retina.
- Azzopardi et al 1999: P-to-M cell ration varies across the retina (M-cells become increasingly prominent away from the fovea)
- M-cell divergence from retina to LGN (???)
- Do M- and P-cell properties change with eccentricities???
- Speed of information processing varies with eccentricity - faster in periphery ... I think this compared 4-deg and 9-deg eccentricity? (Carrasco et al 2003)
- Foveal sensitivity is more lowpass and peripheral sensitivity is more bandpass (Snowden & Hess 1992; Allen & Hess 1992)
- Sensitivity shape is similar at all retinal locations, just poorer in periphery (Virsu et al 1982, Rovamu et al 1978)
- Others who have studied temporal sensitivity across the visual field choose larger eccentricities - fovea, 10deg, 30deg, 60deg (Pointer & Hess 1989)

4 Resources

- Latex report is available on gitlab (ask Janis for access).
- Current experiment code (in progress) is available https://gitlab.com/jintoy/ContrastSensitivi
Ecc_ExpCode