9.35 Spring 2023
Problem Set 3

The goals of this problem set are to:
a) think about auditory "streaming", and learn about its relation to "schemas"
b) gain experience generating filters and applying them to images
c) experience another aftereffect and think through how to explain them in terms of neural tuning
d) think about spatial frequency tuning and the contrast sensitivity function

If working with Python, make sure to add the following imports.

import matplotlib.pyplot as plt
import numpy as np

Please show your work for all problems.

1. Please read the paper by Billig and colleagues. Also download the audio file "Billig verbal transformation demo".

a) Listen to the audio file using a sound player that will allow you to loop continuously. How many repetitions of the word "stem" does it take for you to hear "dem" instead of "stem"? How many additional repetitions does it take for the percept to flip back?

b) Why are the gap detection results of Figure 3C relevant to the central hypothesis being tested in the paper?

c) In Figure 4B, reporting gap detection in the penultimate syllable of a sequence, why is there an effect of the lexicality of the precursor syllables, but not of the penultimate syllable?

2. Use a camera to take an image of a real-world scene. Read the image into Matlab or Python, and apply a mask (it could be a square aperture to make your life easier) to demonstrate some examples of local image ambiguity (e.g. cases where border ownership is locally unclear, or where an edge is not apparent given only local information, or where the cause of an edge in terms of reflectance, shape, occlusion etc. is not obvious). Hint: it might be useful to write a program to display the image with the mask at a sequence of adjacent positions, so that you can "scan" over the image. How might your visual system resolve the local ambiguity?

3. Write a Matlab/Python function to generate a Gabor filter (the product of a sinusoid and a Gaussian) parameterized by:

theta – the orientation
lambda – the spatial frequency
phi – the phase
sigma – the receptive field size

Hint: use meshgrid (or numpy.meshgrid) to define matrices of x and y coordinates (for simplicity, use units of pixels, and have the filter span 100 pixels), and apply a rotation:

$x_r = x \, cos(\theta) + y \, sin(\theta)$

$y_r = -x \, sin(\theta) + y \, cos(\theta)$

$\theta = $ orientation

$\lambda = $ wavelength

$\phi = $ phase

$\sigma = $ Gaussian width

Then you can generate the Gabor as:

$$G = \exp\left(-\frac{(x_r^2 + y_r^2)}{2\sigma^2}\right) \sin\left(x_r \frac{2\pi}{\lambda} + \phi\right)$$

Use your function to generate Gabor filters of a few different orientations, phases, and wavelengths. Use the imagesc function to display the filters.

4. Take a picture or find one using google. For best results choose something with both horizontal and vertical edges. Use imread (or cv2.imread for Python) to read it into Matlab. If it is an RGB image, choose one of the color channels to work with (we will be ignoring color for the purposes of this exercise).

Generate a horizontal Gabor filter with a phase of zero, and another with a phase of 90 degrees. Pick something reasonable for the lambda and sigma. Convolve each of the filters with your image using conv2 (use the 'same' option to end up with a filtered image of the same size). Display the filtered images using imagesc. Are the Gabor filters acting as edge detectors?

Now take the two filtered images, pointwise square them, and add them together. This is the energy model of a complex cell. Display the result using imagesc (or plt.imshow). Does it behave like an edge detector?

Do the same thing for vertical filters.

5. Look at the two gratings on the right side of the figure. Marvel at their similarity.

Now for about 60 seconds scan your gaze back and forth along the red horizontal bar between the two gratings on the left. Then fixate on the red square between the gratings on the right.
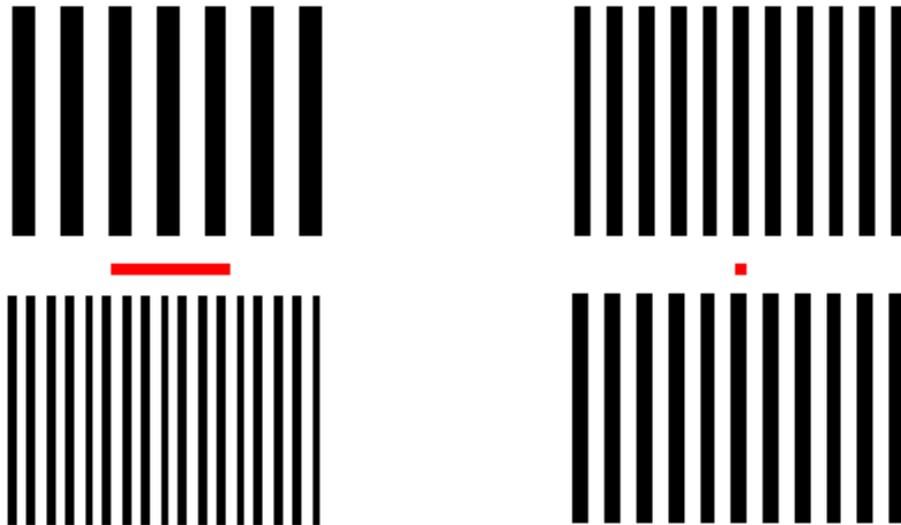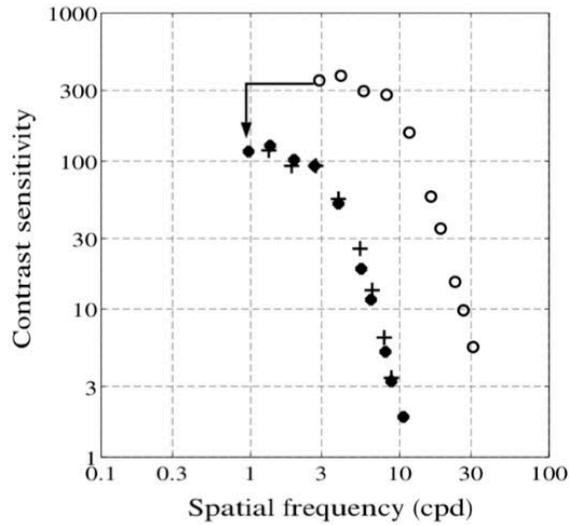

Adapted from Blakemore & Sutton, 1969

a) What differences do you see between the two gratings on the right compared to when you looked at them to begin with? There should be a difference – if you don't see one, try looking at the gratings on the left again, for a longer period.

b) Now repeat the experiment, except stare at the page with your right eye (with your left eye covered) during the adaptation period, and then look at the test gratings with your left eye (with your right eye covered). Is the effect any different?

c) Explain this effect in terms of the neural activity evoked by the gratings before and after adaptation. Take into account the frequency content of a square wave.

d) What would have happened if you hadn't scanned the red bar, and had instead been fixating a single point?

6. Consider the following graph. The open circles plot contrast detection thresholds (plotted as sensitivity – their reciprocal) for sine wave gratings (i.e., the contrast sensitivity function). The crosses plot the contrast at which a square wave can be discriminated from its fundamental frequency. The solid circles replot the contrast sensitivity function shifted over by a factor of three in each dimension. Why do the solid circles and crosses align?