SUGGESTION FOR EXPLORATION

Implement your favorite Photoshop routine in MATLAB.

Let's get back to psychophysics. Fechner formalized three fundamental methods to elicit the relationship between mental and physical qualities and introduced them to a wider audience. These methods are still in use today. You should recognize the *method of limits* from visits to the ophthalmologist investigating your vision or the otologist investigating your hearing. Basically, the observer is presented with a series of stimuli in increasing (or decreasing) intensity and asked to judge whether or not the stimulus is present. This method is extremely efficient because only a few stimuli are necessary to establish fairly reliable thresholds. Unfortunately, the method suffers from hysteresis; the threshold is path dependent, as participants exhibit a certain inertia (e.g., stating that the stimulus is still present even if they can't detect it, if coming from the direction of a stimulus being present). This problem can be overcome by counterbalancing (starting from different states). However, a better correction is the *method of constant stimuli*. In this method, the experimenter presents stimuli to be judged by the observer in random order, from a predetermined set of values. The advantage of this method is that it yields very reliable and mostly unbiased threshold measurements. The drawback is that one needs to sample a relatively large range of stimuli (as one doesn't a priori know where the threshold will lie) and a large number of repetitions per conditions to reduce error. Hence, this method is usually not used where time is at a premium (such as in a doctor's office), but rather in research, where the time of undergrad or grad student observers is routinely sacrificed for increases in accuracy.

Finally, the *method of adjustment* lets the research participant manipulate a test stimulus that is supposed to match a given control. This method is particularly popular in color psychophysics. It is relatively efficient, but suffers from its own set of biases.

8.4 PROJECT

In this project, you will use the method of constant stimuli to determine the absolute threshold of vision, a classic experiment in visual psychophysics (Hecht, Shlaer, and Pirenne, 1942). Obviously, you will be able to do only a crude mock-up of this experiment in the scope of this chapter. The actual experiment was extremely well controlled and took a long time to carry out (not to mention specialized equipment).

Since you are unconcerned with publishing the results (these are extremely well established), you can pull off a "naïve" version in order to highlight certain features and principles of the psychophysical method. If you want to increase experimental control, perform the experiment in a dark room and wait 15 minutes (or better 30 minutes) before data collection. Also, try to keep a fixed distance from the monitor (e.g., 50 cm) throughout the data collection phase of the experiment.

However, before you can collect data, you need to write a stimulus control program utilizing the skills from the previous two chapters and the image manipulation skills introduced in this chapter. Here is a simple program that will do what is needed (make this an M-file). Note the somewhat obsolete use of the modulus function to order the stimuli. We could also do this with **randi** in the latest versions of MATLAB. On the other hand, the use of the modulus function allows you to have exactly the same number of trials per condition (as opposed to them having random frequencies).

```
clear all; %Emptying workspace
close all; %Closing all figures

temp = uint8(zeros(400,400,3)); %Create a dark stimulus matrix
temp1 = cell(10,1); %Create a cell that can hold 10 matrices

for ii = 1:10 %Filling temp1
  temp(200,200,:) = 255; %Inserting a fixation point
  temp(200,240,:) = (ii-1)*10; %Inserting a test point 40 pixels right
                                   %of it. Brightness range 0 to 90.
  temp1{ii} = temp; %Putting the respective modified matrix in cell
end %Done doing that

h = figure %Creating a figure with a handle h

stimulusorder = randperm(200); %Creating a random order from 1 to 200.
                                   %For the 200 trials. Allows to have
                                   %a precisely equal number per condition.

stimulusorder = mod(stimulusorder,10); %Using the modulus function to
                                   %create a range from 0 to 9. 20 each.

stimulusorder = stimulusorder + 1; %Now, the range is from 1 to 10, as
                                   %desired.

score = zeros(10,1); %Keeping score. How many stimuli were reported seen

for ii = 1:200 %200 trials, 20 per condition
image(temp1{stimulusorder(1,ii)}) %Image the respective matrix. As
                   %designated by stimulusorder
ii %Give observer feedback about which trial we are in. No other feedback.
pause; %Get the keypress
temp2 = get(h,'CurrentCharacter'); %Get the keypress. "." for present,
                   %"," for absent.
temp3 = strcmp('.', temp2); %Compare strings. If . (present), temp3 = 1,
                 %otherwise 0.
score(stimulusorder(1,ii)) = score(stimulusorder(1,ii)) + temp3; %Add up.
                                 % In the respective score sheet.
end %End the presentation of trials, after 200 have lapsed.
```

Note that these are relatively crude steps. In a real experiment, you might want to probe every luminance value and collect more samples per condition (50 or 100 instead of 20).

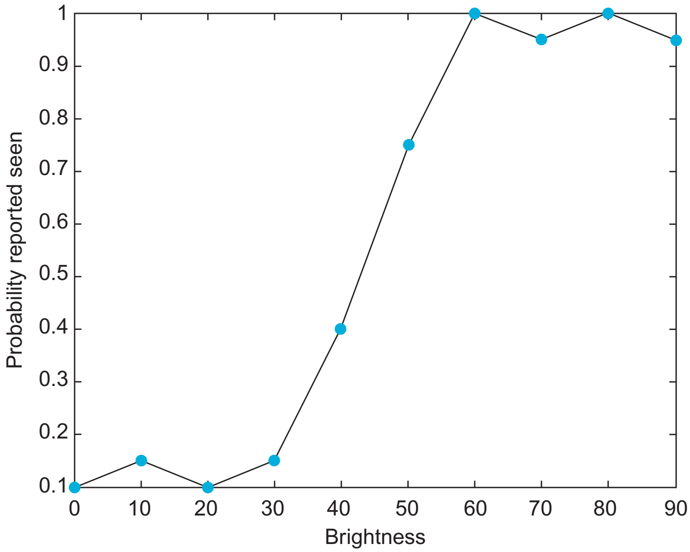

FIGURE 8.8 The psychometric curve reveals below-threshold regions, saturation regions, and a linear range.

Also, a time limit of exposure and decision time is usually used. But for now, this will do. When running this program yourself, make sure to focus on the central fixation dot. Don't get frustrated or bored. Psychophysical experiments are extremely intricate affairs, usually operating at the limits of the human sensory apparatus. Hence, they are rarely pleasant. So try to focus the firepower of your cortex on the task at hand. Also note that you will make plenty of errors. Don't get frustrated. That is the point of psychophysics. In a way, psychophysics amounts to a very sophisticated form of producing and analyzing errors. If you don't make any errors, there is no variance, and without variance, most of the psychophysical analysis methods fail—hence the large number of trials. Given enough trials, you can count on the statistical notion that truly random errors will average out, while retaining and strengthening the systematic trends in the data, revealing the properties of the system that produced it. As a matter of fact, you might want to throw in a couple of practice runs before deciding to analyze your data for real. Given that you are likely to be what is technically called an untrained observer there will be various dynamics going on during the experiment. At first, practice effects will enhance the quality of your judgments; then fatigue will diminish it. Also note that you are technically not a "naïve" observer, as you are aware of the purpose of the experiment. Don't let this discourage you for now. Doing so, we obtained the curve shown in Figure 8.8. This figure shows a fairly decent psychometric curve. It is obvious that we did not see the dot on the left tail of the curve (the observed variation represents errors in judgment). Similarly, it is obvious that we did always see the dot on the right of the curve, yet there is some variation in the reported instances seen. In other words, the points on the left are below threshold, whereas the points on the right are already saturated. In a real experiment, we would resample the range between the brightness values 20 and 70 much more densely, as it is clear that the date points outside this range add no information. However, this neatly illustrates one problem of the method of constant stimuli. We didn't know where the threshold would

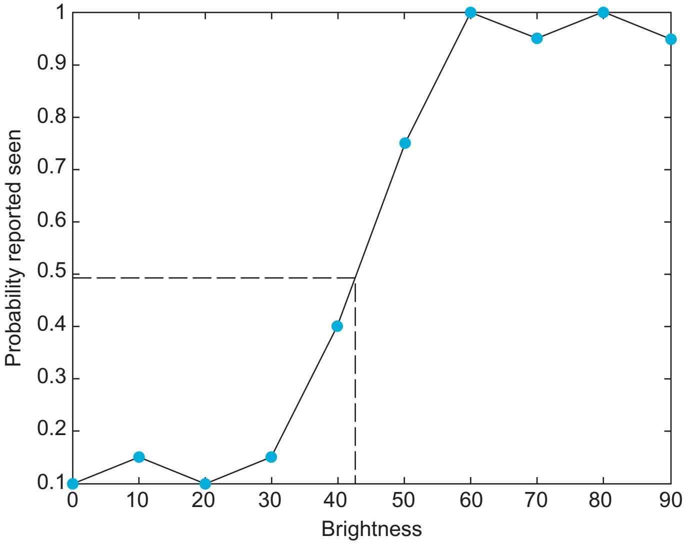

FIGURE 8.9 The psychometric curve allows you to establish the absolute detection threshold.

lie. Hence, we had to sample a broad range—undersampling the crucial range and oversampling regions of no interest. Even limiting the range from 0 to 90 was an educated guess. Strictly speaking, and without any previous knowledge, we would have had to sample the entire range of 0 to 255. Modern "staircase" procedures attempt to solve this problem, but are beyond the scope of this chapter. Psychophysicists like to boil down this entire dataset into one number: the *absolute threshold*. In this case, you can derive this value by interpolation. It is the x-value that corresponds to the intersection between the curve and the y-value of probability reported seen of 0.5, as shown in Figure 8.9. In other words, this analysis indicates an absolute threshold of a brightness value of 43. If you want to get a precise threshold, you would have to resample the range between 30 and 60 (or even between 40 and 50) very densely. Also note that this value of 43 is not inherently meaningful. Without having the monitor calibrated with a photometer, we don't know to how much physical light energy this corresponds to. Hence, we can't relate it to the minimum number of light quanta that can be detected. However, this threshold is meaningful in the context of a behavioral task: a shifted threshold under different conditions can give rise to conjectures about the structure and function of the physiological system producing these thresholds, as you will see when doing the exercises. Moreover, the absolute threshold is a stochastic concept. It is not true that lights below it are never seen. Of course, psychophysicists have very elaborate ways to analyze data like these. Most straightforwardly, they like to fit sigmoidal logistic curves to such data. We will go into the intricacies of psychophysical data analysis in the next chapters. Finally, we chose luminance values that worked on our monitor, yielding a decent psychometric curve, allowing us to determine the threshold. You might have to use a different range when working within your setup. For more background on psychophysical methods, read the classic *Elements of Psychophysics* by Fechner (1860) or, for a modern treatment of the use of these methods in visual neuroscience, *The Psychophysical Measurement of Visual Function* by Norton, Corliss, and Bailey (2002). In this project, you should specifically address the following issues: Compare thresholds in the periphery and center. You just did a parafoveal stimulus presentation (if you were honest and fixated the fixation point) or even a foveal presentation (if you looked at the stimulus directly). How does the threshold change in the periphery (putting the stimulus several hundred pixels away from the fixation point)?

Determine the thresholds for brightness values of the red, green, and blue guns individually. Which gun has the lowest threshold (is perceived as brightest)? Which gun has the highest threshold (is perceived as dimmest)? Can you account for the white threshold (as we did above) by adding the individual thresholds?

You just determined absolute thresholds. Another important concept in psychophysics is the relative threshold. To determine the relative threshold, put another test dot to the left of the fixation point. The task is now to indicate if the brightness of the right dot is higher (.) or lower (,). Does the relative threshold depend on the absolute brightness values of the dots? If so, can you characterize the relationship between relative threshold (difference in stimulus brightness values that gives a probability of 0.5) and absolute value of the stimuli?

When determining the relative threshold, can you reason why it makes sense to ask which of the two is brighter, instead of asking if they are the same or different (which might be more intuitive)?

MATLAB FUNCTIONS, COMMANDS, AND OPERATORS COVERED IN THIS CHAPTER

uint8
double
convn
circshift
image
bench
imread
imwrite
memory
movie
getframe
movie2avi
randperm
mod
spy