1 Laboratory #4: Human Visual System

1.1 Objective:

To explore various aspects of the human visual system: specifically, location of the blind spot, lens accommodation, and dark adaptation.

1.2 Materials:

1. Your eyes
2. Your finger
3. Ruler
4. Pen
5. grayscale image (included on last page)

1.3 Background:

The human eye is a roughly spherical, light-tight enclosure consisting of a hard, white outer wall called the *sclera*, a clear *cornea* that provided most of the optical power of the eye, the *lens* which can adjust its optical power to let you focus on objects at different distance, and a light sensitive layer at the rear of the eyeball called the *retina* where the image is formed. The retina includes two classes of receptors to detect light: *rods* and *cones.* The colored part of the eye is called the *iris*, which acts as a diaphragm to control the amount of light that enters the eye. The dark circular opening in the center of the iris is called the *pupil.*

At the rear of the eyeball, along the retina but off axis from the center of the eye, is a bundle of nerve cells that carry the signals from the rods and cones to the brain for more processing and perception. The bundle of nerves is called the *optic nerve* and conveys the signals from the retina to the brain where they are processed for perception. Because of the layout of the eye, there are no light-sensitive cells at the location where the optic nerve leaves the eye, so you do not see that part of the image. This creates the *blind spot* in each eye.

The retina is composed of two classes of light sensitive cells, rods and cones. Cones are sensitive under photopic conditions (high light levels), whereas rods are sensitive to scotopic conditions (low light levels). There are three types of cones, so colors can be distinguished under photopic illumination. There is only one kind of rod, so colors cannot be distinguished; surfaces can appear lighter or darker, but cannot be perceived as colorful.

The eye responds to changing lighting conditions in several ways. The iris adjusts, constricting in the light and dilating in the dark. In addition, the sensitivity of the rods and cones in the retina varies dramatically with illumination changes. This process is called *adaptation.* Specifically, dark adaptation is the process of increasing the sensitivity of both rods and cones, and switching from using cones to rods as the primary sensor. Light adaptation is the process of decreasing the sensitivity of rods and cones, and switching to the cones under very bright conditions.

A camera system, unlike the human eye, can adjust for focus by changing the distance between the lens and the sensor (film or electronic sensor). The distance between the lens and sensor is reciprocally related; the distance between lens and sensor *decreases* as objects are farther away, and *increases* as objects are brought closer. In the limit as the object distance approaches infinity, the image is formed at the focal point of the lens. The focal length of the camera lens is fixed. The converse situation occurs for the human lens. The distance from the lens to the sensor is fixed (approximately 25 mm); therefore we must change the focal length of the lens to form a focused image of objects at different distances. This process is called *accommodation.* The shape of the lens is changed by either tensing or relaxing the ciliary muscles that allow suspensory ligaments to either stretch the lens (longer focal length for viewing distant objects) or allow the lens to relax to a thicker shape (short focal length for viewing near objects). Since we cannot observe the lens directly, we will observe how images change in clarity as the lens accommodates (changes shape) to focus on objects at varying distances.

Each eye has a *near point*, the closest distance that can be seen clearly without a magnifying glass (or microscope, or reading glasses, ...). The distance of the near point is based on several variables, notably the shape of your eye, cornea, and lens; and your age.

1.4 Experimental Procedure:

1. Location of the blind spot:

X

   (a) Hold this paper in front of you at a distance of approximately 250 mm (10 in)

   (b) Close your left eye and stare at the X with your right eye. Hold your finger in front of the X so that your fingernail covers the X.

   (c) Slowly move your finger across the page to the right from the X while looking directly at the X,viewing your finger with your peripheral vision.

   (d) Mark the paper at the distance where the tip of your finger disappears (it should be less than 100 mmto the right of the X). At this point the image of your fingernail has fallen on the blind spot of your right eye. Then keep moving your finger and mark the paper where your finger "reappears."

   (e) Turn the paper upside down, close your right eye, and repeat steps 1 - 4 for your left eye, moving your finger to the left until your fingernail disappears and reappears.

2. Lens Accommodation

   (a) Stand at least 3 m (10 ft) from a wall with a hanging picture or wallpaper on it. Hold a pen at arm's length directly toward the picture or a specific part of wallpaper pattern.

   (b) Close one eye, and focus on the pen. While keeping your focus fixed on the pen, pay attention to the pattern on the wall behind the pen. Record your observations of the clarity of the picture or pattern.

   (c) While still holding the pen at arm's length, change your focus to the wall, and record your observations of the pen's clarity.

   (d) Now approach the wall. Record the eye's approximate distance from the pen and wall at which both (pen and wall) can be seen in focus simultaneously.

   (e) Hold the pen at arm's length. Slowly move the pen closer until you can no longer see it clearly - it goes "out of focus". Record the near point.

(f) If you wear glasses, repeat without your glasses. If you don't wear glasses, borrow a pair from a near-sighted friend and repeat with those glasses.

3. Dark Adaptation

   (a) Start in a very bright environment - either in daylight or under illumination from a strong light bulb. Look at the grayscale picture (on the last page of this lab). Record which steps you can distinguish, i.e., that are seen as a different shade than the adjacent step (this will depend to some degree on the printer you used). Record your results.
   (b) Enter a dark room. The room should be very dark, but you should be able to just see the paper. Immediately mark the steps that you can distinguish as soon as you enter the dark.
   (c) Your sensitivity changes very rapidly in the first minute in the dark; try to record the visibility by noting changes in your perception of the target after about
      i. ten seconds, and,
      ii. after one minute, and
      iii. after two minutes, and
      iv. after five minutes,
      v. after ten minutes
   (d) After ten minutes in the dark room, move quickly back to daylight or strong light. Record the visibility of the steps immediately after moving to daylight. (This will vary with the printer used and how bright the illumination is).
   (e) Your sensitivity changes very rapidly in the first minute in the light; try to record the visibility by noting changes in your perception of the target after about:
      i. 10 seconds, and
      ii. after one minute, and
      iii. after two minutes, and
      iv. after five minutes,
      v. after ten minutes
   (f) Close one eye and cover it with one hand to minimize the amount of light entering that eye.
   (g) Cover your eye tightly for at least three minutes.
   (h) Return to the dark room and uncover your eye.
   (i) Note any differences in sensitivity between your two eyes.

4. Questions to guide write-up:

   (a) Are your eyes constructed symmetrically with respect to the center of your head?
   (b) Are your eyes constructed symmetrically with respect to the center of each eye?
   (c) Why aren't you normally aware of the blind spots?
   (d) Approximately how far "off-axis" is the blind spot? (Answer in mm and degrees)
   (e) Approximately how big is the blind spot? (Answer in mm and degrees)
   (f) Is the blind spot on the part of the retina near the nose (nasal), or near the ear (temporal)? How did you deduce your answer?
   (g) Can your eyes bring objects at a range of distances into focus simultaneously? If so, is there a limit to this range?
   (h) What is your near point (with and without glasses)?

(i) After being in a dark room for several minutes, are your eyes using primarily rods or cones for vision? How can you tell?

(j) Is the adaptation of each eye dependent on or independent of the other? (That is, can one be operating scotopically, while the other is operating photopically?)

The data necessary to answer these questions must be coherently summarized (as, for example, a bulleted list) within the "Observations" section of your report, while the answers/explanations should include a short narrative that form the "Results/Conclusions" section of your report. Your report should be approximately one to two pages in length, double-spaced.

1.5 Optional:

Determine the near point (item 2e) for observers over a range of ages. Plot near point as a function of age for a number of observers varying in age by at least ten years.