Vision: How does your eye work?
Teacher Version

In this lab, we will explore some of the capabilities and limitations of the eye. We will look at the extent of peripheral vision, the size of the blind spot, depth perception, and color vision.

California Science Content Standards:

9. Physiology: As a result of the coordinated structures and functions of organ systems, the internal environment of the human body remains relatively stable (homeostatic) despite changes in the outside environment.

Part 1 - Peripheral Vision, Blind Spot, and Depth Perception

Key Concepts:

- Sight is one of the five senses that we rely upon to observe the world.
- The eyes are adaptable and versatile organs that help us perform our everyday duties. They detect light and send signals along the optic nerve to the brain to process the images we see.
- **Peripheral vision** is the ability to see the fringe or edge of your vision when you focus straight ahead.
- The **blind spot** is a small area on the back of the eye where the optic nerve enters the eyeball that is not sensitive to light. This creates a gap in your vision. The brain "fills" in the blind spot by combining the images from the left and right eyes so you are unaware you something is missing form your field of vision.
- **Depth perception** is ability to see the world in three dimensions. Depth perception is important for us to determine how far an object is away from us. When we are walking, we need to make sure that we perceive an object's distance from us correctly so we won't walk into them.

The lab is split into two stations. One station covers peripheral vision, the blind spot, and depth perception. To test peripheral vision, we will examine how far students can see by counting the number of fingers that are held up as those fingers are positioned farther and farther away from them. To examine the blind spot, we will trace out the diameter of it to measure the size of the blind spot. We will use a simple coin drop test to examine depth perception. The second station (at the computers) covers color vision. Here, you will examine afterimages and optical illusions. Please finish one station before moving onto the next. Answer the questions at the end.

Complete List of Materials:

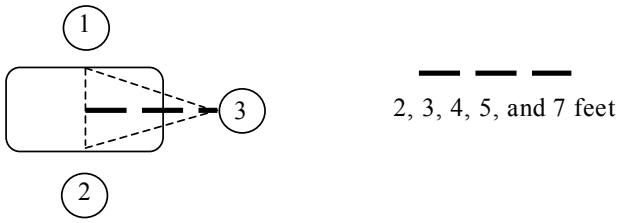
- 1 meter stick or measuring tape for every group of 2-3 students
- Blank sheets of paper
- One cup/container per group
- 10 pennies or buttons per group
- Calculator
- A computer for each student or share computers among a couple of students

I. Peripheral Vision (groups of 3):

In this portion of the lab, we will try to measure how far one's peripheral vision extends.

Procedure:

1. Have the two people testing their eyes sit across from each other (about 3-4 feet apart) and the third person stand an equal distance from both (as diagrammed below).
2. Each of the two sitting people cover the eye that's further from the third person (one person covers their left eye and the other covers their right). The two people sitting down are allowed only to look straight at each other.
3. The third person will then stand 2 feet to the side of the two people sitting, hold up different numbers of fingers and ask each person sitting down to identify the number of fingers. Repeat this three times and record the number answered correctly in the table on the next page.



4. Repeat for a distance of 4 and 6 feet away from seated students.
5. Switch roles until everyone in the group has tested their peripheral vision.

Number Correct

	2 foot		4 feet		6 feet	
	Left	**Right**	**Left**	**Right**	**Left**	**Right**
Trial 1						
Trial 2						
Trial 3						

Q1. About how big is your peripheral vision? Think about a clock, with your nose facing 12:00.

Student answer.
Should be somewhere between 8 and 10 for the left and 2 and 4 for the right.

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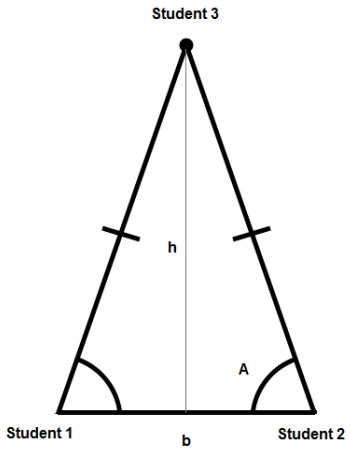
QSA2. Convert this into an angle measurement. Assume that the distance between the two seated people is the base of an isosceles triangle and the distance from each seated person to the standing person is equal.



h – distance to seated person (2, 4 or 6 feet)
b – distance between seated people (3-4 feet)
$\tan(A) = h / (b/2)$
$\tan^{-1}(\tan(A)) = \tan^{-1}(h/(b/2))$
$A = \tan^{-1}(h/(b/2))$

Student answer

Ex. *h = 6 feet and b = 3.5 feet*
$A = \tan^{-1}(6/(3.5/2))$
$A = \tan^{-1}(3.4)$
$A = 73.6°$

QSA3. Peripheral vision, especially in distinguishing color and shape, in humans is weaker than in animals. What is a possible reason for this? (Think about the location of receptor cells on the retina).

Receptor cells on the retina are greater at the center and lowest at the edges. Additionally, the rod cells, unable to distinguish color, are predominant at the periphery and the cone cells are concentrated in the center of the retina.

II. The Blind Spot (groups of 2):

In this portion of the lab, we will measure the diameter of an individual's blind spot.

Procedure:

1. Make a tester by marking + on the far right side of a piece of notebook paper.
2. Stand with your back to a wall, with your head touching the wall.
3. Have someone hold the tester 500 mm (0.5 m or 50 cm) in front of your eye (place the + between your eyes, with the paper extending to the left).
4. Close your right eye and look at the + with your left eye.
5. Place a pencil eraser or bright object on the far left side of the tester.
6. Slowly move the pencil eraser to the right.
7. When the eraser disappears, mark this location on the tester. Call this point "A."
8. Continue moving the eraser to the right until it reappears. Mark this location on the tester. Call this point "B."
9. Repeat the procedure until you are confident that they are accurate.
10. Measure the distance between where the eraser disappeared and reappeared (A to B).

Distance from A to B

Left Eye	Right Eye
Average distance:	Average distance:

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QSA4. Calculate the diameter of your blind spot.

To calculate the width of your blind spot on your retina, let's assume that 1) the back of your eye is flat and 2) the distance from the lens of your eye to the retina is 17 mm. We will ignore the distance from the cornea to the lens. With the simple geometry of similar triangles, we can calculate the size of the blind spot because triangle ABC is similar to triangle CDE. So, the proportions of the lines will be similar.

Follow the example on the next page:

Set up	Example	Calculations
Line AB = distance between points where the eraser cannot be seen. A B Line BC = distance from tester to eye. (500 mm) Line CD = distance from lens to eye. (17 mm) Lens C Line DE = ? (Blind spot width) D E	Line AB = 46 mm A B Line BC = 500 mm Line CD = 17 mm Lens C D E	$\frac{17}{500} = \frac{DE}{AB}$ $\frac{17}{500} = \frac{DE}{46}$; $DE = (46)\frac{17}{500}$; $DE = \frac{782}{500} = 1.56$

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QS2. Calculate the diameter of your blind spot. To do so, use the following equation:
Distance from lens to eye = 17mm
Distance from tester to eye = 500mm

$$\frac{\text{distance from lens to eye}}{\text{distance from tester to eye}} = \frac{\text{diameter of blind spot}}{\text{distance from A to B}}$$

$$\text{diameter of blind spot} = (\text{distance from A to B}) \times \left(\frac{\text{distance from lens to eye}}{\text{distance from tester to eye}}\right)$$

QS3, QSA5. Where was the blind spot relative to your peripheral vision? (Think about the clock and where the blind spot is on the clock).

Student answer.
About 11 for the left eye and 1 for the right eye

QS4, QSA6. What is the diameter of your blind spot? Is it larger or smaller than you would expect?

Student answer.
Most blind spots are 1-3 mm in diameter.

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QSA7. What are scotomas?

Scotomas are blind spots (this is a general term).

QSA8. Why do we not normally notice our blind spot when we have both eyes open?

We do not normally notice our blind spot because with both eyes open, the visual fields of both eyes overlap.

III. Depth Perception (groups of 2):

In this lab, we will explore how depth perception changes when you are using one eye compared to two eyes and when the perceived object is at variable distances from you.

Procedure:

1. Have students sit at a table with a partner.
2. Students place a cup in front of their partner. The cup should be about two feet away from him/her.
3. Partner CLOSES one eye. Other student must hold a penny/button in the air about 1.5 ft. above the table.
4. Move the penny/button around slowly. Ask your partner to say "Drop it!" when he or she thinks the penny will drop into the cup. When your partner says "Drop it," drop the penny and see if it makes it into the cup. Repeat this 5 times, changing the position of the cup by moving the cup left and right. Record the number (out of 5) that made it into the cup.
5. Try it again when your partner uses both eyes.
6. Try it again with the cup farther away (~ 3 feet) from your partner (with one eye open and both eyes open)
7. Try it again with the cup closer (~ 1 foot) to your partner (both with one eye open and both eyes open).
8. Change roles and repeat.

Distance: Cup to Guesser	One Eye Open (coins in cup)	Both Eyes Open (coins in cup)
1 foot		
2 feet		
3 feet		

QS5, QSA9. At what distance did you get the most pennies/buttons in the cup (i.e., you had the best depth perception)?

Student Answer.

QS6, QSA10. Is there improvement of depth perception with two eyes open? If so, explain why.

Student Answer.
There should be a significant improvement. With two eyes, we're able to use binocular vision and other clues to determine the relative depth of two objects with a great deal of accuracy.

QS7, QS11. Is there improvement with the cup is closer to the subject? If so, explain why.

Student Answer.
Have the students think about binocular vision and how the distance affects its function.

Part 2 – Color Vision

Key Concepts:

- **Color Vision**: We are able to see colors when there is sufficient light, but when the light intensity is too low, we can only make out dark and light shapes.
- On the inside of your eyes there are blue, red, and green **cone cells**. These cells are sensitive to each of those three colors. When light of different wavelengths enters the retina, the color of an object is detected by a mixture of these cones cells.
- An **afterimage** is what you see if one type of cone is over stimulated by staring at a single color. It becomes fatigued, so if you stare at a red poster for a long time then quickly look at a white background, the fatigued cones will not work very well. This causes an afterimage to appear.
- Our brain responds to moving images by anticipating motion to continue in the same direction. Since we anticipate the motion of objects, we can sometimes observe patterns that are not truly there. These are optical illusions.
- Face recognition is a very important part of our visual perception. Therefore, our brain responds strongly to images involving human faces, sometimes distorting our perception in interesting ways.

Materials: A computer for each student or share computers among a couple of students

Instructions: Open your computer and find the four Vision stations: Color Vision, Afterimages, Swirling Ring, and Hollow Face. Follow the instructions for each individual station. Fill in the tables below and then answer the questions at the end of this section.

I. Color Vision: In this station, you will look at five different color images that have colored numbers on them.

Fill in the table below with your guess for the number inside the circle for the five intensities of images on the website. Then place the mouse cursor over each image to reveal the actual number and record this number in the table.

	10% Intensity	**15% Intensity**	**20% Intensity**	**25% Intensity**	**30% Intensity**
Guess					
Actual					

QS8, QSA12. At what intensity could you begin to see the colored numbers? Explain what you saw in terms of the types of photoreceptors in the retina.

Student Answer.

QS9, QSA13. What is the retina and where in the eye is it located?

The retina is the innermost layer of the eye. The retina contains photoreceptors in the pigmented part that receive light and then pass the signals to the neural part

QS10, QSA14. Name the two types of photoreceptors in the retina and describe what they do.

The retina contains two types of photoreceptors called rods and cones. Rods only detect whether light is on or off, so they cannot detect colors. Cones are sensitive to color, so they are important in our color vision.

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QSA15. What is photoreception?

Biological responses to stimulation by light, most often referring to the mechanism of vision.

II. Afterimages: Follow the instructions on this station to observe an afterimage.

QS11, QSA16. What were the colors in the afterimage behind each colored square?

Blue behind red. Pink behind green. Yellow behind blue. Purple behind yellow.

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QSA17. What are opsins and how do they work?

Opsins are proteins within photoreceptors that are responsible for detecting light (or photons). Opsin functions by sensing changes in the shape of another molecule (retinal) that straightens

QSA18. Use bleaching to explain the after image.

The afterimage occurs because the cones become fatigued when they receive too much light stimulation. Bleaching occurs because the retinal recovery is not fast enough to accommodate the number of photons being detected, thus many opsins within the photoreceptors lack retinal

QSA19. What is the wavelength of the visible spectrum?

Between 400 nm and 700 nm

QSA20. Arrange the following in increasing order of maximum wavelength absorbed – red cones, green cones, and blue cones.

Blue (~460 nm) < Green (~510 nm) < Red (~700 nm)

III. Swirling Ring Illusion: In this optical illusion, there is a ring with randomly blinking dots that has a very interesting behavior. Follow the directions for this station to observe this optical illusion.

QS12, QAS21. Describe what you saw in these two optical illusions.

Student Answer.

IV. Hollow Face Illusion: Follow the instructions in this station to observe the Hollow Face Illusion (provided by Professor Richard Gregory). Then, look at the hollow mask presentation to see the Hollow Face Illusion.

QS13, QSA22. Describe what you saw in this illusion.

Student Answer.

References

Depth Perception and Blind Spot
http://faculty.washington.edu/chudler/blindspot.html
Cassin, B. and Solomon, S. *Dictionary of Eye Terminology*. Gainsville, Florida: Triad Publishing Company, 1990.
http://www.britannica.com/EBchecked/topic/69390/blind-spot
Color Vision
http://faculty.washington.edu/chudler/chvision.html