Neuroscience for Kids
http://faculty.washington.edu/chudler/neurok.html

Our Sense of Sight: Part 3. Color Vision

Featuring a "Class Experiment" and "Try Your Own Experiment"

Teacher Guide

WHAT STUDENTS WILL DO

- PREDICT and then DETERMINE the colors of some afterimages
- DISCUSS the opponent color and channels theories
- LIST the advantages of color vision over black and white vision
- LEARN how to design experiments that include specific questions, control conditions, and changing one variable at a time, for example:
    - TEST their abilities to distinguish shades of colors
    - TEST their skills at picking out detail with and without color vision
    - INVESTIGATE the subjective nature of color names

SUGGESTED TIMES for these activities: 45 minutes for introducing and discussing the activity, 45 minutes for the "Class Experiment;" and 45 minutes for "Try Your Own Experiment."

SETTING UP THE LAB

Supplies

For the Introduction to the Lab Activities

One or more of the following:
Disposable camera with flash
Several large brightly colored items—some garish, some pleasant (e.g., clothing, household items)

Large (8 X 10 or 11 X14 inch) color print <u>and</u> a black and white copy of this print (this can be a print by a well-known artist, a contemporary poster, a picture from a magazine, etc.)

(See **Introductory Activities** below for how to use these items.)

<u>For the Class Experiment</u>

For each group of four (or other number) students:

- Black adhesive dot, about 2 cm in diameter
- Bright red adhesive dot, about 2 cm in diameter
- Other colors of adhesive dots as available, 4 to 6 colors if possible
- Several white unlined index cards, each 5 x 7 inches
- Timer

<u>For Try Your Own Experiment</u>

- Several series of paint chips from a paint supply store; try to get at least two identical sets
- (You may need to ask for out-of-date chips in order that you need not return them)
- Eight to ten small beakers, clear plastic cups, or flasks, about 200 milliliter volume (more
- if more than one group wants to do this test)
- Water
- Food coloring
- Magazines with colorful pictures
- Collection of pieces of colored paper, with several shades of each color
- *Where's Waldo?* Book
- Large box of crayons (64 or more)

Other Preparations

- For the Class Experiment and Try Your Own Experiment, students can **write results** on a plain sheet of paper.

- **Construct a chart** on the board where data can be entered for class discussion.

- **Decide the size of the student groups**; four is a convenient number. Students can decide how to set up the color-dot cards and how to record data; one data recorder can summarize the group results and write them in the class chart.

- **Decide** the number of colors to test for the Class Experiment

- For Try Your Own Experiment, **prepare materials** in the Supply list and put them out on an "Explore" table after the Class Experiment.

- **Modify activities for exceptional students**:

  - Students who are red-green colorblind can do the afterimage tests for black-white and blue-yellow color pairs.

  - Make sure a student who has low vision is seated in a well-lighted area. If possible, increase the size of the colored dots and white cards for this student.

  - Because concepts of color have no meaning for people who have been blind from birth, have these students participate in getting ready for another experiment for this unit. Such experiments could include teaching the class a few words in Braille or helping prepare a three dimensional model of visual pathways. Students who are comfortable talking about their blindness might discuss how they find their way around while walking, or how they choose clothing when they cannot see colors. Some may not want to share this information.

INTRODUCTORY ACTIVITIES

Give students initial information

Introduce Color Vision to the class according to your teaching practices; e.g., with reading, lecture, and discussion before lab work (the **Teacher Resource** accompanying this unit discusses the Visual System in general, as well as Color Vision.) In addition to covering the anatomy and physiology of the system, for the color vision experiments you will want to discuss the concepts of opponent colors, color channels and afterimages. Other topics that may interest students include: the way people react to particular colors, animal color vision, colorblindness, and other topics you think might come up in the Try Your Own Experiment section.

Introduce color vision experiments with a demonstration

When students enter the classroom on lab day, introduce the activities with an “eye-catching” short activity:

- Take pictures with a disposable flash camera to produce a negative afterimage of the white flash in students’ eyes. In this way you can discuss the dark afterimage students temporarily see after the bright white flash.

- Place several large, brightly colored items at the front of the classroom (for example, items of clothing). This introduction leads into a discussion of the subjective nature of color naming and preferences.

- Pass around a black and white copy (from a high quality copy machine) of an attractive color print of a famous painting, contemporary scene, or good quality picture from a magazine, and directly after it, pass the original print. Use 8 x 10 or 11 x 14 inch sizes if possible. The two images demonstrate how color changes our awareness of the presence or our interpretation of the importance of objects in a scene.

If you use only one of these activities, use the others in the Try Your Own Experiment section.

Use Explore Time to engage students

After the introduction, let students **explore** a table holding the materials for the Class Experiment. Give them five to ten minutes to see what they will be working with, and when they sit down, ask what they could find out about color vision with these materials.

Can I believe my eyes?

CLASS EXPERIMENT

The sections below match those in the Student Guide. The comments guide teachers in preparing and teaching the labs.

LAB QUESTION

If you did not use the flash camera afterimage for your Introductory Activity, remind students about afterimages (which you have previously discussed in lecture). Briefly review your discussion of opponent colors, and help students to write the **following Lab Question** or one that matches it closely:

After staring at a colored circle on a white background, what will an observer see when looking immediately at a plain white background?

PLANS AND PREDICTIONS

Encourage students to add their own knowledge and experiences in order to make predictions after you have provided background information. Ask about how long it takes for the negative afterimage of a flash bulb to go away. Have any of the students seen a color afterimage after looking at one color for a time?

PROCEDURE

1. **Introduce safety precautions:** Follow all standard lab safety guidelines for preparing and teaching the activity; e.g., take precautions to avoid germ spread; wash hands; dispose of chemicals properly; use equipment properly.

2. **Establish** the number of students in each group. **Decide** how many students should be Subjects, and how many should be Data Recorders. All students can do the test and record their own data if desired.

3. **Decide** how many color circles each group should test.

4. **Explain** the steps in the Class Experiment. These are listed in the Student Guide, under **Procedure**.

5. Remind students to **clean up** the lab when they finish.

DATA AND OBSERVATIONS

See that students are recording observations on paper.

Have a student from each group list their results in a prepared chart on the board.

Ask students to calculate, for all Subjects tested, the average time that the afterimage persisted after they initially stared at the red dot for one minute, and the average time after staring at it for two minutes.

ANALYSIS: THINK ABOUT IT!

The following questions can encourage thinking about the activity; add your own questions. (*See also the specific questions in the Analysis section of the Student Guide.)*

- What is the explanation for seeing an afterimage?

- Do you see different shades of color afterimages for different initial shades of colors? Why?

- How do your results compare with those of other groups?

- Can you explain the differences you see among the observations? (Differences in how other people name colors; possibility of some types of colorblindness in people.)

- Do you have any direct evidence from your experiment to show that people have three types of cone cells, or that such things as opponent color channels exist? (There is no direct evidence from these activities; this would require microscopic investigation to identify possible cones, and recording from nerves with tiny electrodes to show how nerve impulses change when a subject looks at different colors. Use these points to discuss the incremental nature of science investigations.)

- Discuss what the results mean in terms of the concepts learned in the Background lecture and discussion on color vision.

CONCLUSIONS

Students should:

- State how the Lab Question was answered in their experiments.

- List three things (or a number you choose) they think are important about today's experiment. Focus students by asking such questions as: How is color vision important to us? What do our brains do with sensory (particularly visual) information? Can you investigate some questions on your own? Do scientists know everything there is to know about color vision?

- List ways to improve this experiment or further things to test.

Can I believe my eyes?

TRY YOUR OWN EXPERIMENT

LAB QUESTION

After students have completed the Class Experiment, indicate the lab bench where additional materials are available for Try Your Own Experiment and let them explore the items. Then **brainstorm** with them for ideas such as distinguishing shades of colors or using color information to pick out objects in a scene.

Questions can help students to formulate plans: Are humans good at telling close shades of colors apart? Do we all agree on names of colors? What things determine whether a person likes or dislikes a particular color? Can the same color look different to different people? (Yes, some people may be missing specific types of receptors, and have some type of colorblindness.) How does color help us to "see better?" (Color provides another type of information—wavelength of reflected light—about objects, in addition to shading. This gives us more differences between objects so we can more easily pick out items from a scene.)

> **See that each group defines a Lab Question, as they did for the Class Experiment.**

PLANS AND PREDICTIONS

SUGGESTIONS FOR EXPERIMENTS

(Add your own ideas to this list. The Student Guide has hints at these experiments but does not contain the detail given here.)

1. Color discrimination:

a. How good are humans at distinguishing close shades of color? Researchers tell us that with our three cone system we can tell apart almost two million gradations of color! Try one of the following tests:

- Get two identical sets of paint chips from a paint store. Choose 10 to 15 consecutive chips in one range of colors, say blue, and code them in increasing darkness or brightness with numbers on the backs. (They may have names on the fronts, but these usually don't give clues about which is darker or lighter.) Then separate these from the binder, mix them, and give them to a partner to sort into the correct sequence. This can be considered the control experiment.

- For the next experiment, use both the original and the second set of chips, mixing two or three identical blue chips into your original set. See if your partner can tell that some of the chips are identical.

- Another experiment would be to try to match all the identical chips in the two sets.

b. Instead of paint chips, use a concentration series of food coloring in beakers of water:

- Write a number code on the bottoms of eight to ten clear glass or plastic containers: put the numbers on opaque tape and stick these labels onto the bottoms of the containers so no one can read them. Measure an equal amount of water (for example, 100 milliliters) into each container, and then into the first, put one drop of food coloring, the second, two, and so on. Mix the containers up so they are in no particular order, and then have your partners try to arrange the containers from lightest to darkest. This can be your control experiment.

- To change some variables, try the following:

  - Use different colors.

  - Start with more or less water in each container (remember to measure the water carefully to make sure it is the same in each

  - Try the experiment under different lights, such as bright sunlight, fluorescent light, or very dim lighting.

2. Subjective nature of color names:

Use the paint chip series, or a collection of ten or so other pieces of colored paper that are shades of a basic color. You could also use a large box of crayons and color onto some white paper, then have people pick out "true red" or "true blue." Predict which shade most people will choose for a defined number of color names. Try color names such as lime green, aqua, or red-orange. Calculate percentages of responses in different categories.

3. Influence of color on what we see or are able to find in a scene:

- For one student in a group of four: Get a color print of a painting or a colorful picture from a magazine. The picture should be somewhat complex and contain quite a number of colors and objects, not just a few. Make a good quality black and white copy on a copy machine. For the control experiment, have your partners look first at the black and white copy—be sure they do not see the color print. Ask them to write down the first five things they notice—as soon as they look at the picture. For the next experiment, show your partners the original color picture and ask them to write the first five things that now are most noticeable. Adding color is the variable you have changed.

- *Where's Waldo in Black and White?* Bring in a *Where's Waldo?* or similar book; copy a page and give the black and white copy to someone in the group to find Waldo. At the same time, let someone search for Waldo in the original color picture, and time the process. This is not a perfect experiment, because some people may be inherently better at this type of puzzle than others, and the person who has found the black and white Waldo cannot be tested to find the color Waldo in the same print. Try to control for this by asking for two students who have done this type of puzzle before, but have not seen this particular picture. Or, use two people who have never done this before.

4. Subjective nature of color preferences:

Using the paint chip series or a series of colored papers, predict the percentage of people who will choose certain colors as favorites, or as colors they most dislike. Then show the colored papers to subjects and record the results. What are some reasons people like or dislike colors?

5. Seeing colors in dim light:

As ambient light becomes dim, colors are more difficult to distinguish because we see colors only by using cones, and cones do not work in dim light. Students can test their abilities to identify colors in dimming light if they have a room with adjustable lighting, preferably a continuous grading of light with a switch they can read or mark for quantitative information. If such a room is available, a group can select an assortment of brightly colored pieces of paper, and another assortment of pastel shades, and test peoples' abilities to identify colors at different light levels. Make sure they have a good plan for how to control and reproduce light levels, and that they test the same person at different levels, mixing the papers up before each identification trial.

6. Afterimages: does information transfer from one eye to the other?

As a quick activity after the class experiment, have students stare at one of the colored circles for 30 seconds while covering one eye. Then they should look at a white piece of paper with the **other** eye, covering the eye that had stared. Have them predict what they will see, before doing the activity. Ask what they see and why. (They will not see an afterimage, because the cones in the covered eye were not fatigued and they are able to register the white paper.)

HOW CAN YOU DESIGN A GOOD EXPERIMENT?

An abbreviated version of the following section is in the Student Guide.

In designing experiments to answer questions like these, keep in mind what a **successful investigator** must do:

- Ask a **very specific question**: not, for example, "Can people tell close shades of a color apart?", but rather, "If I make a concentration series of solutions with water and food coloring, can people arrange the liquids in order?" It's good to have the general question in mind, but ask a narrow question for each experiment.

- Be sure you understand the **control condition** for your experiment, and then **change only one thing, or variable,** in the experiment.

- For example, if you tested for differences in what people notice in a black and white picture versus a color picture of the same thing, you can define the black and white test as the **control** and in the next experiment, add color as your **variable.**

- Some new experiments are themselves just control experiments. For example, if you test people's ability to line up a series of colored solutions in order, that could be your control experiment. If you have time, you can add a variable in the next experiment by changing the lighting conditions (sun or fluorescent) or using a different color in the solutions.

- Researchers try to change only one variable in a new experiment after they do a control experiment. Sometimes this is difficult, but at least they must be aware of other variables and think about what effects they might have.

- Try to make your activity a real **experiment**, with a **prediction**, a **test** for the prediction, **analysis**, and **conclusions**. Some activities are not experiments, but rather are ways of collecting information or data. If you ask people their favorite colors, you can make a chart and show what percentage of people like different colors, but this is not an experiment. To make this activity into an experiment, you can get a number of colored pieces of paper and PREDICT the percentage of people that will like or dislike each color. Then show the colors to a number of people, collect data, analyze, and determine if your prediction was correct. This can be a control experiment. To add a variable, present your subjects with the same colors, but this time use colored shirts or pencils or shoes the same colors as the original set of papers. You are now testing whether the type of object influences the color preference, and the object type is your variable.

- Keep good records of everything you do.

PROCEDURE

- **Introduce safety precautions**:

  Follow all standard lab safety guidelines for preparing and teaching the activity; e.g., take precautions to avoid germ spread; wash hands; dispose of chemicals properly; use equipment properly.

- If time is limited, restrict the number of materials you put out for experimenting.

- Before students begin their experiments, have each group write a simple plan that includes a **question, a prediction, a list of steps** they will take to answer the question, and data sheets and graphs (if needed).

- The list of steps in the experiments should include comments on the control system and on the variable being tested.

- **Approve** each group's experiment before they begin.

- Remind students to keep **good records**.

- Students should **clean up** the lab when they finish.

DATA AND OBSERVATIONS

- Make supplies available to students.

- Suggest that students create any data sheets and graphs they need.

ANALYSIS: THINK ABOUT IT!

The following questions can encourage thinking about the activity; add your own ideas. (*See also the specific questions in the Analysis section of the Student Guide.)*

- Have each group present its findings in a quick oral presentation (two to three minutes).
- Ask students how their data answers their lab questions.
- What was the control experiment or condition for your experiment? What did you change or add as your variable?
- Did you make sure to change only one variable? Were there variables you could not control?

CONCLUSIONS

(See also the questions in the Student Guide.)

Ask students how certain they are of their conclusions. Would they need more evidence to make their conclusions more secure?

Each group should write a final conclusion, making sure it addresses their Lab Question.

MORE *COLOR VISION* ACTIVITIES

How many color names can you write down for red (such as pink, fire engine red, cinnamon…)? Blue? Would everyone agree with the names you have chosen? While most people agree that a given color is a shade of red or blue or green, further naming is quite subjective.

Do other animals see the same colors we do? Are there animals that can see more colors? Do some library or World Wide Web research and report to your class.

Find out about abnormalities in color vision by searching the World Wide Web or your library.

Here are some good **Web sites** to visit for visual system information:

http://www.illusionworks.com/index.html
http://www.illusionworks.com/html/color_aftereffect.html
http://faculty.washington.edu/chudler/chvision.html
http://faculty.washington.edu/chudler/bigeye.html
http://faculty.washington.edu/chudler/retina.html
http://www.accessexcellence.org/AE/AEC/CC/vision_background.html
http://www.nei.nih.gov
http://www.whyfiles.wisc.edu