Colored Shadows

Summary

KEY CONCEPTS

Light, color, eye

CREDITS

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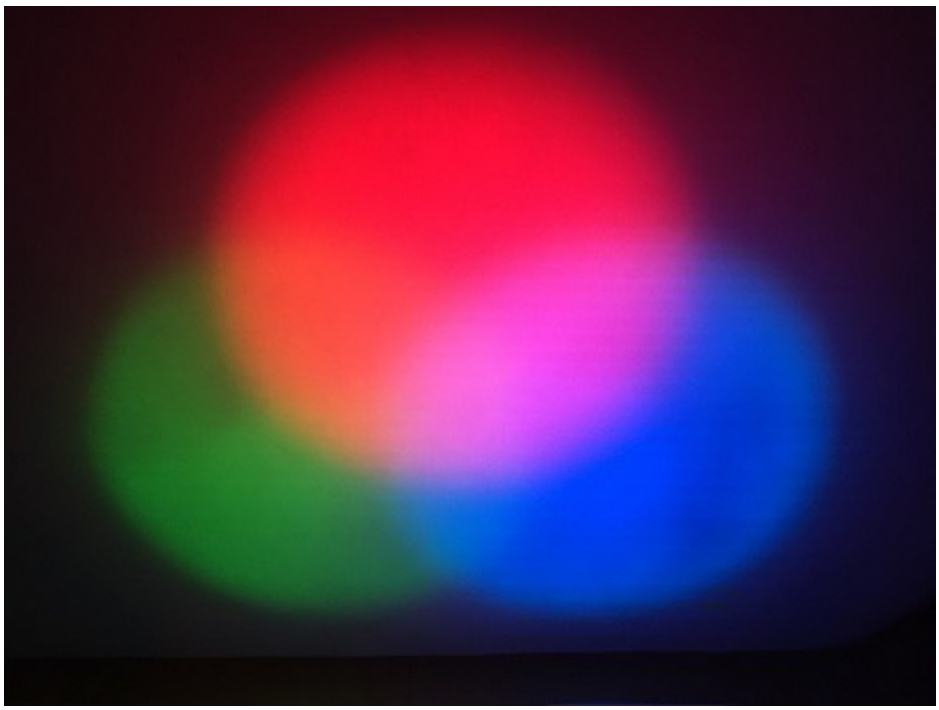

Introduction

Have you ever wondered what the world would look like without colors? Most of us take them for granted since they are everywhere: blue sky, green grass, the yellow sun, and countless more. Your eyes are actually able to distinguish up to 10 million colors! But where do all the colors come from, and how do our eyes perceive them all? Find out with a little help from some shadows, and create numerous colors by mixing red, green and blue light.

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Background

Color vision has fascinated researchers for centuries, and many different color models and theories about color mixing exist. The scientific basis behind color is that visible light has an *electromagnetic spectrum* with *wavelengths* in the range of 400-700 nanometers (nm). If light shines on an object, the object will absorb some light and reflect the rest of it. The wavelengths that are reflected are the ones that your eyes perceive and determine the color you will see. But how does the eye recognize the different wavelengths? For this, humans have special color receptor cells in the retina of their eyes, called *cone cells*. There are three different types of cones cells. Each one responds to a specific spectrum of wavelengths and, therefore, is most sensitive to a certain color (red, green and blue). Once light reaches your eye, each type of cone cell is stimulated differently by different wavelengths. The difference in signals from each cone allows the brain to perceive a continuous range of colors. But how can we actually create colors?

You have probably heard about the so-called “primary colors.” Primary colors can be combined and mixed to create a huge range of other colors. You can mix colors by *additive* or *subtractive* combination. Additive color combination happens when you overlap two or several beams of lights of different colors, a principle that is used in most electronic visual displays. Subtractive combination of colors happens when you shine a light through colored filters, which each will subtract (or absorb) some wavelengths of the original light. The commonly used primary colors for additive mixing are red, green and blue (which are the color ranges that your three different cone types are most sensitive to). By mixing them, you can create three secondary colors and one tertiary color. Get your flashlights ready and see for yourself!

Materials

- A dark room
- One sheet of white paper or white poster board
- Three small flashlights with similar light intensities
- Blue, red and green cellophane
- Three rubber bands
- One pen
- Cardboard box
- Ruler or measuring tape
- Optional: Wide strip of paper (about 5-6 cm or 2 inches)

Preparation

1) From each of the cellophane rolls (red, blue and green), cut out 5 squares that fit over the front end of your flashlight, with a little extra overlap.

2) Take the five squares of one color and fold them over the front end of one of your flashlights. Put a rubber band around the colored cellophane pieces to keep them tightly attached to the flashlight.

3) Repeat step 2 for the other two colors and flashlights.

4) Set the sheet of white paper or poster board up against a wall on a table, as a screen.

5) Place the cardboard box in front of the white screen.

6) Switch off all the lights in the room. It should be relatively dark to see the color effects.

Instructions

1) Take the red flashlight and switch it on. Point the light toward the white screen. *What color is the light that you see on the white paper?*

2) With the light still turned on, rest the flashlight on the cardboard box. Adjust the distance between the box and the screen, as well as the size of your light cone, until you see a nice full circle of light on the white paper screen. Now, take your pen and hold it, vertically, between the flashlight and the white screen. *What do you see when you look at the screen? Is the shadow a specific color?*

3) While keeping the pen in the same position, take the ruler and point one end of the ruler toward the center of the red flashlight. Point the other end toward the screen so it touches the shadow that you see on the screen. *Where is your pen located in relation to the ruler?*

4) Switch the red flashlight off and repeat steps 1, 2 and 3 with the blue and the green flashlight. *How does their light look on the screen? Does the color of the shadow change with each of the colors? Is the pen always at the same location in relation to the ruler?*

5) Take the red and the green flashlight and switch them both on. Put the flashlights next to each other on the cardboard box so that they both point toward the screen. Make sure both light circles are the same size. Now move the red flashlight so that the red circle overlaps with the green one on the screen. *What happens to the green light once it overlaps with the red one? Does the color of the green light change? Which color does the circle on the screen have now?*

6) With the green and red light still overlapping, take your pen again and hold it vertically in between the lights and the screen. *Do you see any shadows of the pen on the screen? How many are there? What colors are they?*

7) Replace the green flashlight with the blue one. Place it on the cardboard box so that the blue and red circles overlap again. *Does the combination of blue and red result in a different color? What does the color look like now?*

8) Take your pen again and hold it, vertically, in between the lights and the screen. *How many shadows do you see this time? Did the colors of the shadows change again?*

9) Now replace the red flashlight with the green one. Combine the color circles again on the white screen. *What color do you see now? Does it look very different from green and blue?*

10) Finally, leave the green and the blue flashlight on the cardboard box and add the red one. Try to combine all three color circles into one. *What does the mixed color look like? Did you expect the color that you are seeing on the screen now? Why do you think the combination of all three colors results in this color?*

11) Hold your pen vertically in between the three lights and the white screen. *What can you see on the screen? Is there more than one shadow? How many? And what are the colors of each of them? Where do you think they come from?*

Extra: With all three flashlights still switched on and combined into one circle of light on the screen, try to make shadows using a wider object than your pen, such as a wide strip of paper. When you hold the paper strip in between the light and the wall, vary the distance between your object and the screen. *Do*

the colors on the wall and the number of shadows change when you move your object closer to the screen? How many different colors can you create?

Extra: Put all three flashlights on the cardboard box facing the screen. This time, point them in a way so that each of the colored circles overlap partially with each other. *Which colors do you see where each circle overlaps with another? What do you see where all the circles overlap?*

Extra: Shine the green and the red flashlight on the white screen and combine their light beams. Take a ruler and put one end of the ruler at the center of the red light. Point the other end of the ruler toward the screen so it touches the white screen. Next, position your pen, vertically, right above the ruler, in between the lights and the screen and look at the shadows you see on the white screen. *What color is the shadow that the ruler touches on the screen? Can you explain why it has this color?* Now point the end of the ruler that was facing toward the red light toward the green light. *Where is the pen located now, in relation to the ruler location?*

Extra: Instead of the white poster board, use different background colors. *Do you get different colored shadows?* Try also changing the colors of your flashlights. *Do different colored lights alter your shadow color palette?*

Observations and Results

How many different colored shadows did you create by mixing the colors? Probably many. This experiment is an example of additive color mixing, which means that you superimposed two or three beams of lights to mix them into a different color. Many television and computer monitors work that way to produce a variety of colors using only the primary colors red, blue and green.

If you only had one light shining on your screen (red, blue or green), the light on your screen should have had the same color. Holding the pen in between the light and the screen results in only one shadow, which is black. To understand shadows, you need to know that light travels in straight lines. You did see that when you connected the light source with the shadow on the wall using a ruler. You might have noticed that the pen is always directly on the same line as the ruler, which means that the shadow on the wall is created exactly where the pen blocks out all the light from the flashlight. Now, when you started to combine two colors, the spots on the wall should have changed into a different color. Each combination of lights results in a different stimulation of your cone cells, and depending on the signals that the cone cells send to your brain, you perceive a different color. Red and green combine into yellow; red and blue become a pinkish color, called magenta; and blue and green turn into a light blue-green, called cyan. These colors are all called secondary colors as they are made from two primary colors. A nice way to show all primary, secondary and tertiary colors from red, blue and green is to only partially overlap all the three light circles on the screen.

When you put the pen in between two combined colors of light and the wall, you see two shadows; each one has the color of one of the two light sources. Again, this is due to the fact, that light travels in straight lines and if you did the extra activity, you should have seen that if you put your pen directly on the line of the ruler pointing from the red flashlight to the wall, the shadow created at the other end of the ruler should have been green. This means that on the path along the ruler, the pen blocked out the red light

and created a shadow. However, when you pointed the ruler to the green flashlight, you might have noticed that the pathway of the green light was not blocked by the pen, which is why the shadow looked green. When you added the third color, and combined all three primary colors, the resulting color is white. We perceive the color “white” when all types of cone cells are stimulated equally, which is the case when you combine all three primary colors.

Ask an Expert

Curious about the science? Post your question for our scientists.

Post a Question

Cleanup

1) You can reuse all the materials from this activity.

Additional Resources

- Rods and cones of the human eye, from ASU School of Life Sciences
- Red-green and blue-yellow: The stunning colors you can't see, from live science
- Colored Shadows, from Khan Academy
- Color mixing, from Wikipedia
- Technicolor shadows: Lessons in light and color, from Science Buddies
- Science Activity for All Ages!, from Science Buddies
