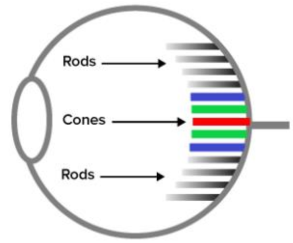
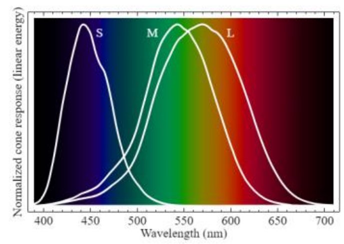
Impossible Colors

- What are the fundamental principles that you want the students to learn about this?



Impossible colors are a type of color that should exist in theory, but that we as humans cannot perceive naturally. In our eyes, we have a number of photoreceptors called Rods & Cones. Cones are the photoreceptors that allow us to perceive colors and they come in 3 varieties, Red, Green, and Blue. When you see the color red, the red cones are stimulated and your brain receives a signal telling you that you are seeing red. Most colors, however, are a combination of other colors. For instance, when you see the color yellow, both your red and green cones are being stimulated at the same time giving you the sensation of yellow.



However, there are some colors that we cannot see because of this system, namely, impossible colors. Impossible colors come in a variety of types, but the two we are focusing on are Hyperbolic and Impossible Combinations. Hyperbolic colors are colors which appear more saturated than they are normally able to be perceived such as Hyperbolic Green. Impossible Combination colors are colors that are composed of colors from opposite sides of a color wheel such as a bluish-yellow.

It is possible to trick your brain into seeing these impossible colors however. The way we do this is by using “afterimages.” Afterimages are created by over stimulating particular cones, fatiguing them so that they do not take in as much of their respective colors leaving an “Afterimage” of a color made from the colors of the cones that were not fatigued. Because of green’s placement on the spectrum, when your eyes are seeing the color green, the red and/or blue cones are also always being stimulated in some amount. Therefore, if you fatigue your red and blue cones, you will create an afterimage of the color green. By mixing this afterimage green with normal green, you can experience an impossibly saturated green, Hyperbolic Green.

- What are physical, hands-on ways to demonstrate these principles?

  To demonstrate these principles, images depicting the eye with rods and cones and images of the light spectrum and where the Red, Green, and Blue cones are stimulated will serve as a good visual aid in describing how people perceive colors and which cones are stimulated when perceiving colors. This will be particularly useful when describing combination colors like yellow and teal. Then, to describe a color like Hyperbolic Green, you can point to the pact on the spectrum graph that shows how the red and/or blue cones are also always being stimulated in some amount when experiencing the color green.

- What type of experiment could students conduct to test this principle?

  You can start by providing students in groups of 3 with an RGB color wheel to familiarize themselves with which colors combine to make other colors and where they are located on the wheel. Then describe an impossible color to the students and have them, as a group, work out using the color wheel a hypothesis as to which color they would need to over stimulate their eyes with and which cones to activate to experience the given color. Then each student will have a button corresponding to a color Red, Green, or Blue and by pressing their buttons they will light lights that will allow them to stimulate the cones they have worked out and test their hypothesis.

- What types of technologies could help with these demonstrations and experiments?

  For a device that allows students to test their hypothesis, we will incorporate a colored light source, NeoPixels, which will allow for a variety of colors and color mixing. This design will require some PCB design to create a place for buttons and a buzzer which will let students know how long they have been holding down their buttons and pairs of NeoPixel glasses for each student to expose their eyes to the colors. We will also use some Arduino programming to get this all working on an ATTiny85. Additionally, we will incorporate some laser cutting of acrylic to produce a stand for our center device to sit as well as all of the glasses attachments such as the ear rests and a glasses shape to diffuse our light sources.

Annotated Bibliography

Source 1: http://hyperphysics.phy-astr.gsu.edu/hbase/vision/colcon.html#c1

This source contains detailed information on how the structure and make-up of the rods and cones in the eye allows you to see light and differentiate colors. The graph we used above to show how there is always some type overlapping how we perceive color in the eye is taken from here, as we feel that it presents the information we are basing our concept upon in a pleasant and easily understood way.

Source 2: http://demoweb.physics.ucla.edu/content/color-mixing

This source elaborates on the concept of color mixing and how overlapping wavelengths of light can trick our brain into mixing them together and perceiving a new color. For instance, if one were to shine a green light and a red light on top of each other, the resulting color would not be greenish red, but instead yellow. We can take advantage of this information to help inform the student on how the cones in their eyes can perceive certain colors even when that actual wavelength of light may not be present, or even exist.

Source 3: https://www.illusionsindex.org/ir/negative-afterimages

This is a really awesome website whose sole purpose is to educate on afterimages. This is the same principle that we are basing our prototype on, in that we are bombarding certain cones on the users until they become fatigued, then showing them the inverse color to create a perceived impossible color within the eye. Using this process, the students will be able to see how exactly the exposure of different colors affects their vision, and how looking at other colors while experiencing that afterimage influences what they see.

Source 4: https://www.youtube.com/watch?v=DRuPF6JtWdw

In this video, Hank Green gives a quick breakdown on how cones in the eye work,and how combining separate wavelengths of light can trick the eye into combining them and producing a brand new color. Magenta is essentially an impossible color in the natural world, known as a non-spectral color. Using this source, we can hopefully adapt Hank’s approach to teaching about the paradox of magenta to the impossibility of many more colors that the student will be able to experience.

Source 5: https://www.youtube.com/watch?v=xJLncut79vE

This video presents the viewer with an array of impossible colors, utilizing the bright screen from a computer to produce afterimages in the viewers’ eye. This is essentially the same process we will be using to trick the students’ brains into seeing these colors. The colors presented here are stygian blue, a blue that actually has the same brightness as black, self luminous red, a red that has the same perceived brightness as white, and hyperbolic orange, which is an orange that appears to be over-saturated past what the eye can't normally see.

Source 6: https://shop.macetech.com/products/rgb-led-shades-kit?variant=35140902551701

This site is a great example of something remarkably close to what we want to design our glasses to look like. However, the main revision to our design would be that the leds’ light is actually intended for the student to see,not people around them. The form factor of the glasses is also ideal, with actual arms to act like real glasses on the eye and not requiring the student to hold them up to their face with one hand. Again, for our design we will be making use of a central base to attach all three pairs so they can be controlled simultaneously and all be shown the same image.

Initial Bill of Materials

https://docs.google.com/spreadsheets/d/1YK8dCs1dL5SualiXSl9gVq_5ePNq0xAmDdPbysJ_SOE/edit?usp=sharing

Name	Qty.	Cost/Per	Qty. Cost	Supplier	URL	Description
ATTiny85-20 PU	5	$1.20	$6.00	DigiKey	link	Programmable microcontroller for interaction
10K Resistor	25	$0.01	$0.25	LCSC	link	Resistor for push button
Colored Pushbutton	25	$0.03	$0.75	LCSC	link	Pushbutton to control LED states
5mm NeoPixel	120	$0.45	$54.00	LCSC	link	LED to show interaction
Battery Clip	5	$0.53	$2.65	LCSC	link	Connects Lipo batteries
300mAh LiPo	5	$3.67	$18.33	Amazon	link	Battery to Power PCB
PCB	20	$0.68	$13.60	JLCPCB	link	PCB to house components
cardstock	4	$1.75	$7.00		link	Used to diffuse and reflect light
4 Pin Wire Clip	15	0.65	$9.75	LCSC	link	connector for wires
4 Pin Wires	15	$0.53	$7.95	LCSC	link	wires from shades to base
COST PER UNIT	$9.50		TOTAL COST	$120.28		