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If You Could See Through My Eyes: The Experience of Color Vision

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Part I – The Visual Transduction Pathway

Think about the color purple. I'm sure that a number of people who are reading this right now are imagining a variety of shades of the color of royalty from a deep violet to a subtle lavender and everything in between. But while it seems to be a fairly straightforward concept, describing a color is a much more daunting task than initially imagined. First, we need to understand what color is and how people perceive color, but even before that, we need to determine if this nebulous thing even exists. To further confound matters, color vision from one person to another is not set in stone; the variety and combination of the cells in the back of your eyes will determine the colors you see, and the way you've experienced the world will teach you how to describe them to others. What started out as a concept that most children learn before they set foot in a schoolroom has quickly morphed into an immensely complex set of issues.

To help address some of the complexity of sight and color perception, we will approach it from a cellular level to first understand how light can be transduced into a nervous signal. We will then use that information to build a basic understanding of color vision deficiencies. Finally, we will explore how color vision deficiencies can be identified through testing and real-world application.

Before any information about color vision deficiencies can be examined, we first need to review the basics of the visual transduction pathway. Using notes from class and information provided by your instructor or outside sources, provide answers to the questions below.

Questions

1. How can visible light be described? What is the range of visible light in humans?

2. Using the prompts below, describe how a red apple appears red.
   a. What is the light doing at the point of the apple? (Which wavelengths are absorbed, which are reflected?)

   b. Describe what happens once the light reaches your eyes and how you perceive this information. (Through which cells? To which part of your brain?)

Part II – Color Vision Deficiencies

Andy is a 35-year-old male. Much to the chagrin of his paternal grandmother, he has been color vision deficient all of his life. As a young child entering into kindergarten he was given the Ishihara pseudoisochromatic plate test, a common metric for testing color vision deficiencies. As he was shown the colored series of dots arranged in a circle, he would struggle to find the numbers he was told were there. Sometimes, even though he saw a number, the number he saw was different from what the test administrator was expecting. Other times, he could see numbers where others couldn't see any. These results confirmed what his color vision deficient mother had known all along, that he too was color vision deficient. Growing up, his difficulties with color vision were ever present but generally didn't affect his life; he could use all colors while coloring as long as the crayons were labeled, he wore solid color clothes that he knew the color of and he avoided the color purple. Still, there were some times that his color vision deficiencies made his life more difficult especially in determining whether bananas were ripe, ensuring that raw chicken was cooked fully and buying clothes for himself. He also firmly believed that the color purple was a figment of marketing rather than a color that was distinguishable from blue.

As he grew older, he noted that most color confusions mentioned by "red-green color blind" people didn't seem to bother him as much as some others. He could easily distinguish the colors red and green whether in a match between two football teams, spotting an orange cone in a green field of grass or in other "common" confusions. Still, other color combinations were difficult for him. Despite knowing that his ability to see color was different from others, he had not known the extent, nor the specific colors that he was unable to see. To combat this, Andy took as many different color vision tests that he could in hopes that he could learn about the extent of his color vision deficiencies. Unfortunately, most of these tests were limited in their ability to differentiate between the varieties of color vision deficiency, and simply noted whether a deficiency existed or not.

Last year, he heard a story about a company that claimed to make glasses that could help colorblind people (for an example of a product see EnChroma, http://enchroma.com). It was alleged that when people affected by color vision deficiencies put on the glasses, they could suddenly see a variety of colors that they had never been able to see before. These "magical" glasses seemed to be able to transform the light coming into your eyes, intensifying some wavelengths that would allow the wearer to see many other colors than previously. Despite the promise of allowing him to see the infamous color purple, Andy was not willing to purchase the glasses on a whim, especially since there was a warning on the company's website that the glasses may not work with all types of color vision deficiency. Curious about the possibility of fixing his color vision issues, he began to do more research and learned that the problems he was facing were likely more complex than not seeing red or green as he assumed.

Questions

3. What are the different types of color vision deficiency and how do they differ? What is the difference between the "-opia" and "-anomaly" versions of a condition? (Give an example if it helps to clarify your response.)

4. Why are protanopia and deuteranopia more common in males than females? Is it possible for females to be afflicted? Why or why not?

5. Why is tritanopia less common in the general population than the other forms of color vision deficiency? Are there different inheritance modes of tritanopia?

6. Since most forms of inherited color vision deficiency are recessive, postulate why color vision deficiencies would not have been reduced to the point of disappearance. Specifically, in what ways could color vision deficiencies be evolutionarily advantageous when compared to a population in which all people perceive the same colors?

7. Using your knowledge of absorbency of the cones how would someone affected by the different deficiencies perceive different colors? Which colors would possibly be confused?

Part III – Observations of Color and Diagnosis

Using the information he had gained from his research on the internet, Andy was able to diagnose his color vision deficiency to some degree. With this knowledge in hand, he decided he would attempt to find the color vision correcting glasses and try them to see if he was able to see colors he was previously not able to see. He ventured to the shop nearest to his house in downtown Chicago, Illinois.

He was greeted by the optician in an office. Immediately, the optician asked Andy a few questions regarding his difficulties with color vision in order to provide a diagnosis and recommendation for the color vision correcting glasses. Andy described the way he sees as follows:

- He has difficulties determining if a banana is ripe or unripe.
- He cannot determine if chicken is fully cooked; nor can he tell if meat is browned,
- He thinks that red wine is "dark."
- He has difficulties when comparing dark blue and purple of the same shade and brown and dark green of the same shade.
- He often uses the label of crayons to determine the color of the crayon rather than the color itself.
- He *claims* that he can see the color red, green and blue.

The optician thought that he had an idea as to the type of color vision deficiency Andy has, but wanted to be sure. The optician gave Andy a few different tests to determine the subtype of color deficiency he was suffering from including a pseudoisochromatic test, a color arrangement test and an anomaloscope test. After looking at the results, the optician put his hand on his chin, thought for a moment and said, "You know, I think that the glasses might help you, but likely they won't do as much for you compared to others. We'll have to see."

Despite this, Andy was excited. He seized the glasses and prepared to leave the office as the optician said, "You should really walk around outside; the glasses work best with high levels of light. You could also try going and looking in the windows at the shops around here; I've heard that the toy store is pretty impressive!"

Andy put the glasses on and proceeded outside.

Questions

8. Given this information, what is your likely determination as to the specific type of color vision deficiency Andy has? Why?

9. What further questions would you ask to develop a more definite answer? For example, you could focus on colors of confusion, tasks that remain difficult, etc.

10. How do the tests work that the optician gave Andy and how would they help diagnose the type of color vision deficiency he has?

Part IV – The Rest of the Family

When Andy started looking around the busy streets of Chicago, nothing really changed in his vision. He experienced no *"Aha!"* moment like the ones portrayed in the videos he had seen. Andy was beginning to become discouraged when he looked up at the green light in front of him, and then at the white icon of a person walking above the crosswalk in front of him. He took the glasses off and put them back on again; the green of the green light was indeed greener than before. He had never noticed that the walking icon wasn't green; it had always looked to him like it was the same color as the green light on the stoplight. Satisfied that the glasses did do *something*, he continued on looking for as many differences as he could. While impressed by the noticeable change that he could see in some aspects, he decided that they weren't so integral to his life that he needed to spend the money to buy the glasses.

Discouraged about the minor changes the glasses had on his color vision, Andy confirmed to himself that he must have a lack of a functional cone rather than a shift in wavelength perceived. He was curious who else in his family was afflicted by this same deficiency. Andy looked further into his familial history of color vision deficiencies and determined that both his mother and maternal grandfather were also color vision deficient as were many other males in his grandfather's family. Andy's father, sister and her children (both girls) are not color vision deficient. Neither are either of his paternal grandparents nor his maternal grandmother or maternal aunt. His wife (the mother of his children) is not color vision deficient.

Question

11. Using the information above, answer these questions: Are Andy's daughters color vision deficient? If he had a son, would the son be color vision deficient? Why or why not?