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Undergraduate

an ethical analysis of **COLOR BLINDNESS** and its implications in the workplace

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Eyes, ears, nose, mouth and skin -- the channels of sensory perception in the human body are vast and complex. Vision allows us to perceive shapes and understand the world around us. When stopping at a traffic light at night unable to identify the relative position of lights, red and green distinguishes whether to stop or go. Green versus ripe tomatoes and rare versus well-done steak prove difficult to distinguish in the kitchen. A day at the beach might result in overexposure to the sun without the necessary warning signs of bright red skin. These are just a few of the problems that color vision deficient individuals face in daily activities. Color identification is undoubtedly a crucial component in our perception of the world, and yet there are a vast amount of individuals who live with color identification deficiencies ranging from red and green to blue and yellow. In this paper I will offer an introduction of the origins of color blindness, provide insight as to the groups of individuals most impacted in terms of lifestyle and employment by its limitations, and discuss current and future technology available to compensate and hopefully cure color vision deficiency.

The two photoreceptors in the human eye, the building blocks of vision, are rods and cones. While rods are crucial mediators of vision in low light conditions and allow perception of black versus white, the focus of this paper will be on cones, which actively contribute to color vision. Cone photoreceptor activity is the foundation to what most humans consider "vision" -- cones vastly outnumber rods in terms of usage in day-to-day activities of which the majority occur in room light-level conditions. In order to best understand the nature of human vision, I will briefly outline the process by which sensory perception is relayed from the eye to the brain.

Within cones (and rods) there exist light-sensitive molecules, or cone pigments, (Rhodopsin in rods) which help transmit neural signals of color identification to the brain. Cone pigments, otherwise known as visual pigments, are made of two components. The

first is a protein known as opsin, while the second is a chromophore known as 11-cis-retinal. While visual pigments share the same chromophore, the opsins are of greatest concern in this article because opsins vary across different types of cones. These play major roles in the determination of which colors the brain perceives.

Vision "begins" when photons of light, reflected on objects, are absorbed by the eye. The 11-cis-retinal undergoes conformational change in reaction to absorption of these light-waves, activating the opsin proteins to trigger changes within the photoreceptor that relates the neural signals to the brain. Our understanding of opsin is the key component to color blindness because it is here where the root of color blindness begins. The opsin genes of red and green, the most commonly unrecognizable colors, are not only located adjacent to one another, but are also 98% identical. Research suggests that the similarities between red and green opsin genes caused homologous recombination throughout human evolution (Neitz, 2009). Most importantly, these recombinations have led to excess creation of red and green pigment genes, which ultimately lead to color blindness via the X chromosome. These genes can either be missing, damaged or in excess and because males have only one X chromosome, males are more likely than females to experience color blindness (functional genes on one of the two X chromosome in females is capable of providing the gene pigments necessary for color detection).

Gender is only one of two disparities in the prevalence of color vision deficiency -- there is equally, if not greater, inequalities in terms of affected race. Color deficiency is most common in European males (at an 8.1% high, almost twice that of other groups such as Asian-American males at a 5.9% high) followed by Asian, African American and finally Native American males (Delpero 2005). Unsurprisingly, less than 1% of women are affected across all genders. While there

is no concrete evidence as to the reasoning behind the discrepancies between racial groups, scholars do speculate that in earlier times color vision allowed for superior abilities in detecting and analyzing targets, which increases one's likelihood of finding food, hunting, selecting a mate, and avoiding danger. Trichromacy (discussed later) offers survival and evolutionary advantages. Research on primates shows that the most basic color perception resides in red and blue cones, which detect lower to middle wavelengths (Delpero, 2005). The more recent and evolutionarily advanced cones, on the other hand, perceive red and green colors of higher wavelengths. It is believed that the earlier developed red and blue dichromatic system allowed for greater spatial and movement perception during low to mid light conditions, which provided superior survivability skills for primates that perceived light in dim conditions, namely hunting/

to perceive color just as well individuals unaffected by CVD, should these individuals be allowed to participate in industries such as aviation and the maritime travel?

First, we must look back to the history of aviation regulation in regards to color vision. In the mid-1960's radar imagery became commercially available in aviation applications and by the 1980's color radar imagery was utilized via the National Weather Service Radars and the Federal Aviation Administration radars throughout the United States. (Milburn, 2004). Color-codes had replaced the former gray scheme and digitized weather layouts were available, promoting the safety of the aviation industry. During this time, color display of weather maps took on the traits we know of today -- the all familiar blinking lights of red and green and various other combinations to

activities. Aviation occupations do not test for less common yellow-blue (tritan) deficiencies, thus leading to the debate as to whether ATCS color vision screening should be required for certain pigments beyond red and green (Vingrys, 1988). One could argue that discriminating individuals based on the pigments of color they can perceive may be grounds for unethical standards. Just as one would not discount a European male as opposed to a Native American male in terms of employment standards, many argue that if red and green deficiencies make one ineligible for certain jobs, then CVD of any pigment should do the same. Opponents argue that because aviation

against discrimination versus the prioritization of individuals' safety are widely debated. There exists a community expectation that public safety be guarded in transportation and this is dependent upon aviation and maritime controllers' ability to interpret colors on current machinery and technology. Individual rights, while important, will likely continue to remain of secondary importance until greater awareness about treatment options for CVD become common knowledge.

While color identification has both revolutionized aviation technology yet restricted some individuals

"Whereas the majority of research on color vision deficiency focuses on the biological realm, CVD also affects the social realm."

foraging for food or escaping from predators in night conditions. One notable example, albeit an extremely isolated observation that cannot be generalized, is the "Island of the Color Blind" in which a group of isolated peoples living on an island suffer from achromatopsia at an 8% overall rate (Delpero, 2005). The inhabitants of the island have superior abilities to survive at night and recognize patterns, and inferior survival skills in daylight conditions. One can only speculate as to how the histories of each racial group have contributed to the likelihood of color vision deficiency in modern times.

Whereas both sexism and racism are widely debated topics, there exists very little awareness about discrimination regarding color vision deficiency (CVD) in the workforce. One recent technological breakthrough is the creation of contact lenses that help improve color identification by altering the way the eye perceives incoming light so that neural impulses, which are "tricked" into identifying color, translate information to the brain (Swarbrick, 2001). These contact lenses, produced by Chromagen, help alleviate deficiencies in detection of green, orange and red. This poses the greater question: if Chromagen's CVD-alleviating contact lenses allow individuals

show weather levels. Confirmation of an individual's ability to detect color-coded signs and maps became absolutely crucial to the aviation process. Color vision became a standard because without it, people's lives were severely at risk. Thus, the requirement of color vision ability in air traffic control and aviation is a recent phenomenon and a widely debated one. Pilots and air traffic controllers needed to identify red and black printing to show flight strips, color weather displays, controller towers which are based on red, green and white navigation lights, identifying aircraft by the aircraft's color or markings during the daytime, and at the most basic level identifying the correct lights, keys, switches and buttons within the aircraft cockpit or aircraft control station (Henry, 1992). Green and red, the two colors most commonly confused in color vision deficiency (CVD) are the most advantageous for instrument design because they are best detected by human eyes. Unfortunately, red-green deficiencies account for over 99.99% of inherited CVD and this makes CVD individuals ineligible for aviation careers.

Much of the controversy surrounding individuals barred from occupation in specific industries is rooted within the question of testing and standards developed to "allow" one to partake in aviation

"...the future for CVD individuals does look bright because the experiment suggests that simply adding a missing gene is sufficient to restore full color vision without rewiring of the brain."

environment and instruments require individuals to recognize red, green and white with rare instances of yellow, tritan deficiencies would prove negligible. Until temporary treatment programs and devices such as Chromagen or genetic cures for color blindness are widely available and well publicized, the aviation and maritime industry standards are unlikely to change, regardless of criticism. As with most ethical debates the line between infringing upon one's rights

from partaking in the industry, color identification knowledge from the human eye has paved the way for extremely innovative applications for military use. Military grade night vision utilizes research on human eye perception to create a complex fusion system with color-sensitive detectors that mimics a true-color display of objects even in near complete darkness (Jason, 2010). The effectiveness of these



night-vision technologies and their ability to recreate environments that the human eye could otherwise not interpret begs the broader question as to if and when these technologies will be implemented for civilian use. While there presently exists color re-creation technology utilized in security cameras, one can only ponder as to the larger role this type of technology might play in assisting those with CVD.

Finally, we focus on the potential cures for color blindness, the implications of existing aids on the market, and what may be in store for the future of CVD. Within the past few years, researchers have discovered a color-blindness gene therapy program that can cure natural color-blindness in monkeys. The gene therapy treatment is injected as a virus into monkeys which restores their color identification, yielding virtually no negative side effects (Conway, 2011). While this type of groundbreaking research has yet to be applied to humans, the future for CVD individuals does look bright. Even if these cures were to prove inapplicable to humans, existing aids such as Chromagen and true-color display technology provide more than ample assistance for individuals affected by CVD. What is problematic is that these products have yet to gain the widespread attention that other health-related aids have received. These products simply need to be publicized and marketed to individuals and could greatly improve the well being of CVD affected individuals.

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