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Screening for Color Vision Deficiency in Health Science Students

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Abstract

Purpose: Various professions require employees to be able to detect different shades of color accurately when visually reading test results with colorimetric end points. To prepare health science students to better meet this requirement, a screening test for color vision deficiency (CVD) was administered to detect any major or minor errors as part of the undergraduate student experience. **Method:** Screening for color vision deficiency was administered using the Farnsworth D-15 Color Vision Test. Students completed the test and their results were scored and interpreted at the time of completion. **Results:** Students *(n=85*) from nine different health science programs completed the Farnsworth D-15 Color Vision Test. Ages of the participants ranged from 18-63 years with 70% of the participants in the age range of 18-23 years. Seventy-one percent of the participants identified as female, 28% identified as males, and 1% identified as non-binary. Two students (one female and one male) had a minor error resulting in a crossover within the test circle on the Gulden test score sheet. There were no major errors identified in the 85 participants. **Conclusion:** While two minor errors were detected in this population, this data is not consistent with other CVD studies. This most likely is due to screening predominately female students, and/or the amount of time allotted for each individual test to be completed. Future studies will include expanding the participant numbers, with a focus on testing more male participants, limiting the number of minutes to complete the screening process, and collecting additional demographic data.

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Screening for Color Vision Deficiency in Health Science Students

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ABSTRACT

Purpose: Various professions require employees to be able to detect different shades of color accurately when visually reading test results with colorimetric end points. To prepare health science students to better meet this requirement, a screening test for color vision deficiency (CVD) was administered to detect any major or minor errors as part of the undergraduate student experience. **Method:** Screening for color vision deficiency was administered using the Farnsworth D-15 Color Vision Test. Students completed the test and their results were scored and interpreted at the time of completion. **Results:** Students *(n=85)* from nine different health science programs completed the Farnsworth D-15 Color Vision Test. Ages of the participants ranged from 18-63 years with 70% of the participants in the age range of 18-23 years. Seventy-one percent of the participants identified as female, 28% identified as males, and 1% identified as non-binary. Two students (one female and one male) had a minor error resulting in a crossover within the test circle on the Gulden test score sheet. There were no major errors identified in the 85 participants. **Conclusion:** While two minor errors were detected in this population, this data is not consistent with other CVD studies. This most likely is due to screening predominately female students, and/or the amount of time allotted for each individual test to be completed. Future studies will include expanding the participant numbers, with a focus on testing more male participants, limiting the number of minutes to complete the screening process, and collecting additional demographic data.

Keywords: congenital or acquired color vision deficiency, visual functions, prevalence, screening

INTRODUCTION

Color vision deficiency (CVD) is the inability to perceive color differences under normal lighting conditions. This condition can be congenital or acquired. Congenital color vision deficiency is more commonly seen in males because it is X-linked and is passed from mother to son. Congenital CVD is the more common cause of CVD in people under sixty years of age.[1,2] Acquired deficiencies can be caused by ocular and intracranial pathologies, drugs, chemicals, diabetic retinopathy, hypertension, glaucoma, macular degeneration, and yellowing of the lens that can result from aging.[3]

The human retina contains two classes of photoreceptors, rods and cones. There are three types of cones, each expressing a different type of photopigment with broad overlapping spectral sensitivity. Each of the three photopigments has a peak spectral sensitivity coinciding with the long-, medium- and short-wavelength portions of the visible spectrum.[4] There are three classes of color vision deficiency: monochromacy, dichromacy, and anomalous trichromacy. An individual with monochromacy lacks two or all three cone photopigments and only sees shades of gray. With dichromacy, the observer lacks one of the three cone photopigments, and finally with anomalous trichromacy, one of the three cones expresses a photopigment with an altered spectral sensitivity. There are three different classes of dichromacy depending on the cone that is affected. Protanomaly has a mutated form of the long-wavelength (red) pigment. Individuals with this mutation are less sensitive to red light and the red portion of the visual spectrum is darkened. The medium-wavelength (green) pigment is mutated in deuteranomaly. This is the most common form of color deficiency affecting 6% of males and 0.4% of females with CVD. These individuals have a reduced discrimination in the red, orange, yellow and green regions of the visual spectrum. Tritanomaly is the rarest form of dichromacy and has a mutated short-wavelength (blue) pigment. The color perception of these individuals is shifted toward the green region.[4,5]

There are many different tests that can be used to diagnose CVD. The best-known test used to screen for red-green color deficiency is the Ishihara test that was developed by Dr. Shinobu Ishihara at Tokyo University in 1917.[5] The Ishihara test is a set of pseudoisochromatic plates with a pattern of differently shaded dots. The Hardy-Rand-Rittler (HRR) test is another pseudoisochromatic test for CVD. The HHR test has an advantage over the Ishihara test as it can screen for red/green and blue/yellow defects.[2] The Holmes-Wright Lantern test uses white, red, and green colors of varying intensities to simulate signal lights to detect color deficiencies.[6] These tests are good for screening for color vision deficiencies.

Hue tests can also be used to test for CVD. The hue tests have individuals arrange colored disks in a progression of color from blue to red. There are many different tests that are considered hue tests: Farnsworth Dichotomous D-15, Farnsworth-Munsell 100 Hue Test, L'Anthony Desaturated D-15, Adams desaturated D-15, and Roth's 28 Hue Test. These tests can screen and help to diagnose the type and severity of CVD.[2,7,8] The Farnsworth Dichotomous D-15 test can be used to differentiate severe losses of color vision from milder deficiencies and normal vision. It can also be used to detect deficiencies due to acquired CVD. The desaturated D-15 is used to supplement the standard D-15 testing to diagnose milder congenital or acquired color deficiencies.[9]

A cone contrast test (CTT) presents randomized series of colored letters visible to a single cone (L, M, or S) in decreasing steps of cone contrast to determine the threshold for letter recognition. The letters decrease from clearly visible cone contrast down to a threshold level in logarithmic steps. The CCT test offers an index of color vision that will accurately detect the type of CVD and grade the severity of CVD.[10]

The gold standard for testing for CVD is the anomaloscope. This test measures the amount of red and green lights that are needed to match a monochromatic yellow field. This test is useful and accurate to distinguish between protan and deutan deficiencies.[6,8]

As technology becomes more prevalent in everyday life, computerized tests and smartphone applications have been designed to test for CVD. Studies on the computerized tests and smartphone applications have shown mixed results. Some applications perform as well as the Ishihara test and others have shown inferior results. Advantages of smartphone applications include they are more affordable, more widely available, and they may show less wear after prolonged use than the Ishihara booklets.[2,11]

These tests have been used to diagnose CVD around the world. Studies have shown the prevalence of CVD in European Caucasians to be 8% in males and 0.4% in females, 5.17% in Filipino males, 1.41% males and 0.37% females in a Pakistan pre-employment screening, 4.1% in school children in Southern Ethiopia, and 13.93% in Northeast Iran.[8,12,13,14,15] The differences of CVD can be due to ethnicity, cultural differences, genetics, and the testing methods used for screening.

The ability to distinguish colors is a requirement for many different occupations. Some of those occupations include the military, aviation, and allied health professions. In one study, screening medical students for CVD found that many were not aware they had a color vision deficiency.[12,16] It is important to screen individuals for CVD who are planning to pursue a career in these different occupations so they can be aware of any issues before accepting a position in their field of choice. There is very little data

addressing the CVD screening of allied health professionals. This would include those going into the Medical Laboratory Sciences, Environmental Health professionals, and others associated with health care. The ability to distinguish colors correctly is very important in all these professions.

From the occupational safety perspective, CVD can impact the ability of workers to adequately, accurately, and safely perform job tasks which require the ability to differentiate different colors or hues of colors. While the Occupational Safety and Health Administration (OSHA) does not have any standards that require normal color vision for any occupation, there are other industry consensus standards that may have requirements for normal color vision (ASME B30.2-2001 states "*…operators of cab-operated and pulpit-operated cranes shall be able to distinguish between colors, regardless of the position of colors, if color differentiation is required for operation").* Other jobs or tasks which could be negatively impacted by CVD include, but are not limited to, accurately reading pH test strips or other test strips showing colorimetric change information, accurately reading detector readouts for sampling of certain toxic or hazardous chemicals, or accurately interpreting information on a sign or placard.[17] It is important for those entering any profession that requires decision making using color changes to be screened for CVD, so they are aware of any deficiencies before they begin their careers.

This research study screened students seeking undergraduate degrees in the health sciences at a midwestern university and included programs in medical laboratory science, environmental health and sustainability, health informatics and management, school health and public health, and occupational safety and sustainability. Research questions included:

1. Using the Farnsworth D-15 test under standard practice conditions for its administration, was there an incidence of color vision deficiency among the sample population?

2. If color vision deficiency was identified among study participants, were there factors or variables which would account for a statistically significant portion of the variability among the test result data?

METHODS

Screening for color vision deficiency was performed using the Farnsworth D-15 Color Vision Test (Farnsworth D-15). This work was approved and overseen by the Illinois State University Institutional Review Board (IRB). This test contains fifteen color disks which a participant must arrange in the correct color order, creating a continuum of gradually changing hue. This testing was completed in a "viewing booth" which is a device designed to simulate, as closely as possible, natural lighting conditions. The general test procedure is as follows:

1) The colored disks are placed on the surface of the viewing booth in a random manner.
2) The participant is instructed to locate the disk within the group of 15 that is closest in color to the starter disk, which remains fixed in the storage box.
3) Once located, the first disk selected is placed in the box adjacent to the starter disk.
4) The participant selects the next disk, which is now closest in color to the one that was just put next to the fixed starter disk.
5) This process is repeated until all the disks on the testing surface are in a line from left to right beginning with the starter disk.
6) The participant is allowed to make any changes in the order of the disks with the goal of making the disks proceed logically from left to right in terms of their spectral hue progression.
7) When the participant signals that they are done with the test, the examiner secures the test by placing the lid on the test box and then turning over the test box to read the numbers on the back of the color hue disks to score the test(s).
8) For each test performed, the order of the disk placement is recorded on the appropriate portion of the Gulden test score sheet using the number on the bottom of the disks. Connecting the dots on the circular plotting form for each test then plots order of the numbers.
9) Interpretation: A passing score results when the sequence of disk placement numbers on the bottom of the disks are in order 1-15. A minor error occurs when there are crossovers occurring around the circle, usually involving 1 or 2 disk positions. Major errors occur when the crossovers go across the circle graph, often defining an axis of the color deficiency type.[18]

Participants in the research study performed the CVD test in an environment that had been selected for its accessibility to participants and researchers, as well as suitable ambient and artificial lighting. Demographic information (age, gender, major area of study) for the participants was collected.

Figure 1. Viewing Apparatus

RESULTS

Eighty-five health science students completed the informed consent document to participate in the research study and then completed the Farnsworth D-15 Color Vision Test for this research project. Nine different health science programs were represented in the group of 85 students. The program most represented was Medical Laboratory Science (69%), followed by Public Health (9%), Health Information Management (7%), Environmental Health (5%), and Safety (4%). The ages of the participants ranged from 18 to 63. Seventy percent of the students were in the age range of 18-23. Seventy-one percent of the students who participated in this study identified as female while 28% identified as males, and 1% identified as non-binary.

Eighty-five students completed the Farnsworth D-15 with the following results. Two students (one female and one male) had a minor error resulting in a crossover within the circle on the Gulden test score sheet. There were no major errors identified in these 85 participants.

No major color vision deficiencies were identified among study participants. Only two participants had minor errors in the testing. Since there were no major color vision deficiencies identified in this population, there were no factors or variables of the test data.

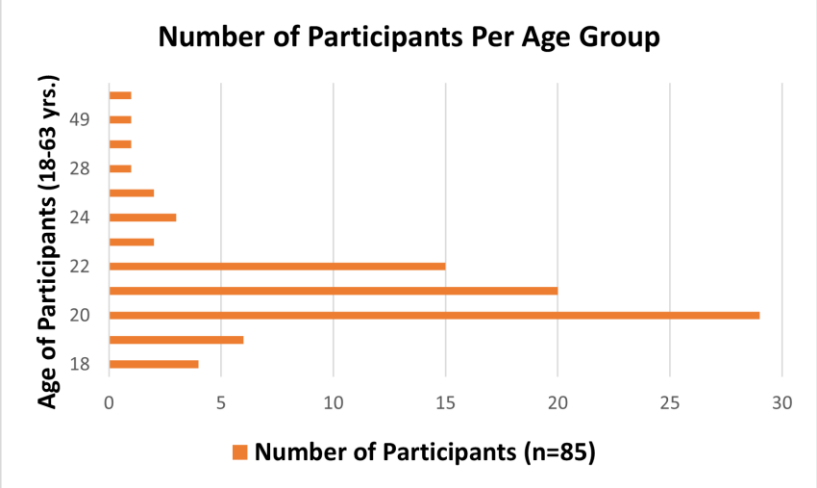

Figure 2. Age distribution among participants

DISCUSSION

Previous studies have identified the incidence rates of CVD to be as high as 5.58% for both male and female participants; 2.4% for both female and male participants; and 3.2% for both male and female participants; with incidence rates of CVD higher among male participants than among females.[1,19,20] In this CVD study, 85 participants completed the Farnsworth D-15 saturated color disk test, and there were only 2 minor errors detected in this sample population. This result is not consistent with previous studies which have found higher incidence rates in both male and female participants across multiple demographics. Power calculation early in the development of the testing methodology of this research study revealed that an *n*=26 would be sufficient to discuss statistical results to a 99% confidence level.

Color vision deficiency variability can be due to ethnicity, cultural differences, genetics, and the testing methods used for screening. The screening method used in this study was the Farnsworth D-15 Color Hue Test, administered according to the recommended testing methods as furnished by the manufacturer.

LIMITATIONS

The design of this study did not include data for the diversity of these participants. CVD is an X-linked condition which means the deficiency is more commonly identified in the male population. Since 71% of the participants in this study were female, this could be one reason the data was not consistent with previous studies. Limiting the participant pool to only Health Science majors contributed to a higher percentage of participants being female.

CONCLUSION

This study screened 85 undergraduate students for color vision deficiency that were enrolled in various programs in the department of Health Sciences, using the Farnsworth D-15 screening test. Of the 85 students screened, only two identified with minor errors. This data does not agree with previous CVD studies. This may be a result of screening predominately female students, the screening method itself, or the instructions given at the time of the testing. Future studies will include expanding participant numbers, with a focus of recruiting more male participants, limiting the number of minutes for participants to complete the screening process, and collecting more demographic data on the participants. It is important to continue screening undergraduate students in health sciences for color vision deficiency since they will be entering professions that depend on their ability to distinguish colors. Many individuals have never been screened for the possibility of a color vision deficiency. Knowing one's limitations in recognizing shades of color may prevent negative outcomes when interpreting colorimetric endpoints visually. If one knows that they have a deficiency in distinguishing shades of colors, it may be possible for them to avoid making errors in the decision-making process when recognition of colors is part of the data used in making decisions.

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