# Universal Design: Supporting Students with Color Vision Deficiency (CVD) in Medical Education

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**Abstract**

Color Vision Deficiency (CVD) is a commonly occurring condition in the general population. For medical students, it has the potential to create unique challenges in the classroom and clinical environments. Few studies have provided medical educators with comprehensive recommendations to assist students with CVD. This article presents a focused review of the literature about the impact of CVD on medical education. Universal Design for Instruction (UDI) principles are leveraged to identify and provide recommendations for mitigating the effects of CVD and rendering medical education curricula more accessible to all students regardless of their CVD status. Examples of recommendations for the classroom, lab, and clinical settings include: adjusting the color of laser pointers, providing high quality grayscale images alongside microscope images, and coaching around strategies for recognizing clinical indicators (instead of color-related signs). The experience of a prominent medical school in the United States, which was faced with a high number of first-year students with CVD and implemented these recommendations, is described. Other medical schools can similarly adapt and implement these recommendations within their own programs.

Keywords: *Color vision deficiency, medical students, histology, cvd, disability, universal design*

Colorblindness is common in the general population, and can produce unique educational challenges for medical students and administrators alike. Colorblindness, or more accurately *color vision deficiency* (CVD), occurs when an individual has a restricted color spectrum that affects the perception of color. Birch (2012) reviewed the three types of colorblindness: red-green, blue-yellow, and the complete absence of color. Red-green CVD is the most common form and is more prevalent in males occurring in 8% of European males, 4% of European females, between 4% and 6.5% of males and 0.7% and 1.7% of females of Chinese and Japanese ethnicity, and 6%-7% of males of African ethnicity (Birch, 2012).

## CVD In the Classroom

The use of color in medical curriculum can pose challenges to learners with CVD. Serrantino, Meeks, Jain, Clifford, and Brown (2015) used their experience developing clinical accommodations, the existing literature, and interviews with CVD learners to address the needs of learners with CVD. In the classroom, the authors suggested that faculty avoid using color to distinguish or note items on presentations and exams. Instead, they should denote or highlight key concepts using arrows or numbers in black ink. As well, they suggested that faculty switch from red to green laser pointers and utilize assistive technology, such as a Daltonizing algorithm, that converts red, green, or blue parts of slides to an identifiable color. Color transparency overlays or specialized glasses, such as Enchroma were also suggested methods to mitigate CVD related barriers (Serrantino et al., 2015).

In certain coursework, most notably during histology, students with CVD may struggle due to difficulty differentiating between colored stains on slides. Al-

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though histology faculty often argue that size, shape, and contextual cues—not color—are the key attributes needed for identifying and distinguishing tissues and structures, research has shown that using high quality grayscale versions of histological images alongside color images allows students with CVD "to discern structures that would otherwise be obscured by surrounding cells or other tissue components" (Rubin, Lackey, Kennedy, & Stephenson, 2009, p. 87). Pramanik, Khatiwada, and Pandit (2012) also suggested that faculty use alternative color staining (not red/green), a grayscale microscope or attached grayscale monitor, and teach with a focus on configurations and other indicators versus using color to differentiate items. Serrantino et al. (2015) also suggested that extra time, as a formalized disability accommodation under the Americans with Disabilities Act (ADA), might be appropriate for students with CVD to reduce barriers by providing time to locate non-color key identifiers.

### CVD In the Clinic

Students with CVD may experience deficits in the clinical setting where students are trained to identify indicators using color, for example, when identifying oral and throat lesions, different tissues (as in surgery), jaundice, or titration end-points (Pramanik et al., 2012). A medical student with CVD may experience disadvantages in cases where a pivotal observation is necessary, such as slight changes in color, patterns of rashes, or failure to identify stage one pressure ulcers (Mughal, Ali, Aziz, Mehmood & Afzal, 2013). As part of his work, Spalding (1999) interviewed 25 physicians with color deficiency and while each reported variations of difficulty based on their respective fields of medicine, several common challenges in observation were evident across all specialties.

In a study of 270 male histopathologists and medical laboratory scientific officers with CVD, Poole, Hill, Christie, and Birch (1997) found that those with CVD made more errors in slide identification than subjects with normal color vision and that the severity of color deficiency was positively correlated with the number of mistakes. As well, subjects with a severe red-green color deficiency made significantly more errors than those with moderate or slight deficiency. Other studies of medical personnel found statistically significant differences between practitioners with CVD and those with standard color vision in their ability to identify (through photographs) fresh versus old blood, rashes, and the position of bacilli in a stained slide (Campbell, Griffin, Spalding, & Mir, 2005).

Assistive tools may be needed to ensure safe practice in the clinic. For example, to mitigate the difficulty distinguishing fresh blood or bile in urine, feces, sputum, and vomit, Spalding (1999) suggested that students measure and monitor blood and fluid levels in patients, pay attention to lighting and shading versus color, (e.g., redness in ear or throat) and that when reading blood and urine test strips, a reflectance meter is used to confirm results. Spalding (1999) also suggested that students with CVD should give more attention to a patient's history prior to exam and that using touch, close observation, or cross-checking (e.g., confirming observations that require color with laboratory tests, peer consult, or other means of confirmation) is essential for all students, but especially those with CVD.

### Universal Design for Instruction

The concept of universal design, originally formulated in architecture, promoted the design of buildings to take into account all its diverse users from the outset (Mace, Hardie, & Place, 1990). Scott, McGuire, and Foley (2003) extended this idea, and those of higher education researchers, creating a nine-principle framework (see Appendix A) to aid faculty planning, known as Universal Design for Instruction (UDI). As in the original architectural concept, the aim of UDI is to minimize the amount of individual accommodations and adjustments that need to be made for diverse learners, instead creating a learning environment with enough flexibility to include all learners from the outset (Scott et al., 2003). This work provides promise for addressing the needs of students with CVD, particularly given the frequency of incidence of CVD in the general population.

## Depiction of the Problem

Despite the prevalence of CVD in the general population, and the potential challenges that come with it, most medical school programs do not orient their curriculum and training practices accordingly, with the needs of persons with CVD in mind. Traditionally, CVD has not been regarded as a disability, however, in the context of health sciences education, there are times when CVD places learners at a substantive disadvantage. When students with CVD experience difficulty learning in classroom and lab settings, or miss critical incidents in the clinic—due to dependence on color indicators in training methods—it can result in patient safety issues and diagnostic errors. In the absence of a UDI-informed approach, and an awareness of the deficits present with CVD, these students might be referred to Disability Services (DS) offices.

Whether CVD constitutes a disability, and therefore should be addressed by DS providers similar to other conditions, is not clear-cut. Under the Americans with

Disabilities Act (ADA) a disability is defined as, "a physical or mental impairment that substantially limits one or more major life activities" (§12102, 2008). Traditionally CVD has not been regarded as a disability. However, in the context of health sciences education, there are times when CVD places learners at a substantive disadvantage in the classroom and clinical settings.

## Participant Demographics and Institutional Partners/Resources

In the Fall Quarter of 2013, a United States medical school enrolled six students with CVD. All reported difficulty during their first year Essential Core courses identifying slides in histology, following laser pointers, and completing histology and practical exams within defined time limits. Disability Services (DS) staff partnered with Essential Core faculty (first and second year didactic courses) to identify barriers and develop interventions. In order to make the courses more accessible, UDI principles were applied where possible to remove CVD specific barriers in curriculum and testing. Moving forward, the medical school agreed to adopt these practices for all courses.

### Description of Practice

The DS office worked with Essential Core faculty, and consulted with the students with CVD to determine what elements of the curriculum and classroom experience were dependent on color. Wherever possible, the medical school followed several key UDI principles. Specifically, UDI Principle 1: Equitable use, "Instruction is designed to be useful and accessible by people with diverse abilities. Provide the same means of use for all students; identical whenever possible, equivalent when not," Principle 2: Flexibility in use, "Instruction is designed to accommodate a wide range of individual abilities. Provide choice in methods of use," and Principle 4: Perceptible information, "Instruction is designed so that necessary information is communicated effectively to the student, regardless of ambient conditions or the student's sensory abilities" (Scott et al., 2003, p.44). The instructors switched all laser pointers from red to green, allowing students to follow lecturer emphasis of critical information or images on PowerPoint slides. As well, the use of red to denote important concepts on teaching materials such as PowerPoint slides, exams, and microscope slides was switched to black. To increase the visibility of differing structures on slides for teaching and during exams, instructors took high-resolution black and white photos of all histology slides and displayed them alongside the microscope for all students to reference. Finally, students with CVD were provided an accommodation of 15 minutes of extra time on the histology portion of their exams.

The researchers developed the *Recommended Strategies for Addressing CVD in Medical Education* (see Appendix B). Students were individually educated about potential difficulties that may arise in the clinic as a result of CVD, and were provided with the aforementioned guidance by their DS provider. Students were encouraged to report back to DS with any difficulties they encounter to discuss potential solutions and/or accommodations.

### Evaluation of Observed Outcomes

The DS office did not experience resistance from faculty in their suggestion to adopt UDI-informed practices, likely a testament to the strong working relationship that has been developed between DS and faculty through the intensive interactive process followed to determine accommodations, ongoing faculty training, and collaborative work resolving student issues. Course coordinators for the first and second year Essential Core courses, as well as anatomy and histology faculty reported implementing these changes easily, noting little to no impact on their preparation time for lecture or exams. After the UDI-informed interventions were in place, students with CVD reported they were able to readily access traditionally color-dependent course material, and that they had learned critical strategies for identifying structures in images without reliance on color. Faculty reported that these changes would be easy to carry into future years.

## Implications and Portability

CVD can result in multiple difficulties in a health science curriculum where color is a critical identifier. In an effort to ensure a learning environment that is accessible to the widest variety of students, programs should consider a universal design approach to removing barriers in the curriculum. Adopting the principles of UDI in medical education reduces the need to determine whether students with CVD are considered disabled, reduces the need for individual accommodation, removes barriers for students with CVD, and is a sustainable and inexpensive approach to inclusion. Implementing UDI-informed practices in medical education promotes accessibility of the curriculum for all students, regardless of any specific disability-related needs. DS providers and learning specialists are well positioned to advise faculty on implementing UDI principles that focus on meeting the needs of diverse medical learners.

In the course of developing this practice, the DS providers and medical school administrators realized that it would be helpful to bring greater awareness about the possible implications of CVD to medical students. Understanding how to mitigate deficits caused by CVD is vital to ensuring that students are able to practice safely, with confidence. Poole et al. (1997) suggested screening medical students for CVD. This practice arguably allows students to have greater understanding of the barriers they may encounter, and opportunity to develop alternative strategies for addressing their CVD in learning and clinical practice. As well, Pramanik et al. (2012) suggested that identification and intervention in the entry stages of medical education are best because students are most receptive to advice about their CVD during this time. After implementing the UDI-informed practices, the DS office worked with Student Health to ensure that screening for CVD would be made available to medical students. In following the UDI Principle 9: Instructional Climate, "Instruction is designed to be welcoming and inclusive" (Scott et al., 2003, p.44), the school developed a statement for the student handbook to welcome open disclosure and exploration of CVD. The statement encourages students to self-identify to their clinical instructors to ensure they receive direct feedback with less emphasis on color, and encourages students to seek screening:

> Colorblindness or Color Vision Deficiency (CVD) is a common condition that can affect your ability to detect certain clinical indicators. If you believe you have CVD, please alert your instructor. Instructors and students can work to craft appropriate strategies for the didactic and clinical settings. Students who suspect they have CVD, but are uncertain, can undergo screening for CVD with Student Health.

Limitations for this intervention include the small sample size and single institution design. This practice was implemented in response to the needs of six students at one medical school. Future research might look to understand whether there are tangible benefits for all students when a UDI-informed approach is taken to changing instruction in medical and other health science programs, to reduce dependence on color. Future research is needed to explore the benefits of implementing early screening for CVD for all medical students, and the effectiveness of a welcoming statement in the student handbook to encourage disclosure.

While CVD has not traditionally been viewed as a disability under the ADA, the authors argue that in the health science context this condition can be disabling. Given the prevalence of CVD in the general population, health science institutions should adopt a universal design approach to ensure that all students are able to access health science curricula. Programs should also offer screenings for CVD in order to provide students with CVD an opportunity to better understand the severity of their condition and plan for both classroom and clinical adjustments. Together, these approaches enhance patient safety by destigmatizing the experience of CVD, and ensuring that students move into clinical practice as health professionals with nuanced skills and the ability to apply sound clinical judgment to patient care.

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**Appendix A**

Principles of Universal Design for Instruction (Scott et al., 2003, p.44)

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| Principle 1: Equitable use | Instruction is designed to be useful to and accessible by people with diverse abilities. Provide the same means of use for all students; identical whenever possible, equivalent when not. |
| Principle 2: Flexibility in use | Instruction is designed to accommodate a wide range of individual abilities. Provide choice in methods of use. |
| Principle 3: Simple and intuitive | Instruction is designed in a straightforward and predictable manner, regardless of the student's experience, knowledge, language skills, or current concentration level. Eliminate unnecessary complexity. |
| Principle 4: Perceptible Information | Instruction is designed so that necessary information is communicated effectively to the student, regardless of ambient conditions or the student's sensory abilities. |
| Principle 5: Tolerance for error | Instruction anticipates variation in individual student learning pace and prerequisite skills. |
| Principle 6: Low physical effort | Instruction is designed to minimize nonessential physical effort in order to allow maximum attention to learning. Note: This principle does not apply when physical effort is integral to essential requirements of a course. |
| Principle 7: Size and space for approach and use | Instruction is designed with consideration for appropriate size and space for approach, reach, manipulations, and use regardless of a student's body size, posture, mobility, and communication needs. |
| Principle 8: A community of learners | The instructional environment promotes interaction and communication among students and between students and faculty. |
| Principle 9: Instructional Climate | Instruction is designed to be welcoming and inclusive. High expectations are espoused for all students. |

## Appendix B

Recommended Strategies for Addressing CVD in Medical Education

**Awareness and screening**

1. Provide CVD statement to incoming medical students to build awareness.
   "Colorblindness or Color Vision Deficiency (CVD) is a common condition that can affect your ability to detect certain clinical indicators. If you believe you have CVD, please alert your instructor. Instructors and students can work to craft appropriate strategies for the didactic and clinical settings. Students who suspect they have CVD, but are uncertain, can undergo CVD screening with student health."
2. Provide free and confidential screening for CVD

**Classroom and lab**

1. Use black font for all classroom presentations; denote special items with arrows or number/letter identifiers versus color.
2. Use green laser pointers (in place of red)
3. Provide high quality grayscale prints of slides
4. Make assistive technology available for students with CVD:
   a) Colored Overlays
   b) Specialized glasses (e.g., Enchroma)
   c) Color converting software programs (e.g., Daltonizing algorithm)
5. Use alternative color staining (not red or green)

**Clinical strategies for students with CVD**

1. Use a reflectance meter when reading test strips
2. Cross-checking with colleagues for color dependent diagnosis
3. Focus on shade versus color
4. Focus on patient history and report of symptoms as a cross-checking mechanism for clinical exam observations