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## Colorblindness: Invisible Disability

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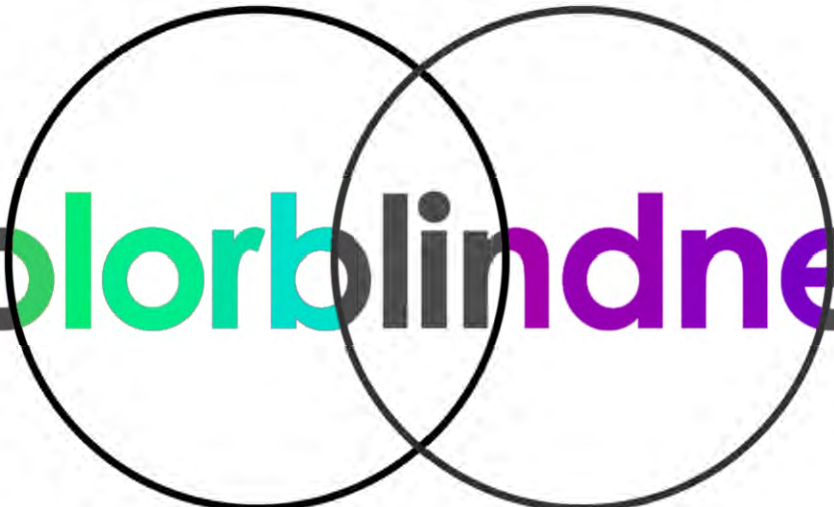
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# Colorblindness

## I N V I S I B L E   D I S A B I L I T Y

by John Stiles

**ABSTRACT:** In nearly every classroom sits at least one student who is unable to distinguish between certain colors. This incurable, genetic, and sex-linked condition is particularly frustrating in science class, a subject in which color discrimination is frequently required. Teachers are often unaware of this invisible disability, which many “colorblind” students try to keep secret in order to avoid embarrassment. There are a number of modifications a science teacher can make to reduce, or in some instances remove, barriers to learning for colorblind students. In addition, a simple, free test may help identify young children who have color difficulties, so they may begin to receive assistance in learning to cope with their inherited vision perception. *This article promotes National Science Education Content Standards A and G and Iowa Teaching Standards 3, 4, and 5.*

### Introduction

Imagine yourself as a student in a class at any grade level, in which the day's lesson involves the unassuming application of color discrimination. While the rest of the students--and the teacher--observe, explain, analyze, and discuss the outcome of a laboratory activity that depends on, for example, the students' abilities to perceive color changes in pH test paper, you sit quietly, covertly taking notes from your lab partner. Or, if you are particularly extroverted, you venture your interpretation, only to be told that your answer is “wrong.” You then attempt to make sense of this result, since your lab partner, with whom you worked closely, has been praised as being “right.”

In the current age of educational enlighten-

ment, in which students with forms of recognized disabilities have gained legal access to science classrooms and activities in unprecedented numbers (Americans with Disabilities Act, 1990; Individuals with Disabilities Education Act, 1973; Individuals with Disabilities Act Amendments, 1997), students with *optical dyschromacy*, or “colorblindness,” still struggle with a genetic disorder that most people do not comprehend.

According to the U.S. Department of Education (2005; see also Keller and Keller, 2001), approximately 14% of school-aged students in the U.S. are considered “disabled.” This statistic, however, does not include the approximately 8% of students (estimates range from 4-12%) who find it difficult to distinguish certain colors (“Visual impairments” are listed

as being in only 0.1% of the student population). By far, the vast majority of those affected by dyschromacy are male, as the disorder is linked to the sex ("X") chromosomes in much the same way as hemophilia (Howard Hughes Medical Institute, 2005). What this means is that in virtually every mixed-gender classroom in America sits one or two students, generally boys, who struggle with a great many activities and assessments that are color-dependent.

It would seem likely that the younger the student, the more confused he would be about this inability that apparently none of his peers has. While it may be tempting to react to colorblindness as a "count-your-blessings" type of disorder (almost always voiced by persons who are "normal-sighted"), it would be unfair to dismiss it due to the many problems it can foment. Emotionally, it can be tremendously embarrassing, particularly if the teacher has no awareness of--or interest in--the disorder.

### Causes

Human color recognition is possible due to three types of light-sensing "cones" on the eye's retina. "Normal-sighted" persons have a certain ratio of signals from the long ("L") wavelength cones (reddish perceiving), the middle ("M") wavelength cones (greenish perceiving), and short ("S") wavelength cones (bluish perceiving), thus allowing their minds to determine the "color" of objects. It is a simple evolutionary accident that has caused the human population to include those who perceive color differently, as one or more of their cone types have peak absorption that differs from the norm (WebExhibits, 2005).

From an evolutionary perspective, studies have confirmed that the appearance of color blindness resulted from a duplication of the once single red-green receptor gene in human ancestors, which then diverged slightly in sequence about 40 million years ago. This led to separate receptors of the green and red type, common to all old world primates, including humans, but not existing in new world primates, which split from the former when the continents separated, isolating the gene pools (Howard Hughes Medical Institute, 2005).

### Simulating and correcting colorblindness

Until recently, there was no way for "normal-sighted" people to be in the colorblind person's shoes by simulating the disorder.

Simulations now exist that approximate what dyschromatic people see (Vischeck, 2005). Developed by Robert Dougherty and Alex Wade at Stanford University, Vischeck computer simulations allow designers of web sites, pictures, and other documents to check their work for colorblind visibility (Vischeck is based on SCIELAB from the Wandell lab at Stanford University). Of course, these are only practical for those who are not colorblind: Colorblind people see more or less the same thing in both examples.

Researchers can now use image-processing techniques to make information in pictures available to colorblind people, enhancing such things as television images, computer displays, electron microscopes, and printed media by concentrating greens or reds without significantly altering the images for normal-sighted viewers. This process is known as "Daltonizing," named for British scientist John Dalton, who was one of the first to study colorblindness.

Daltonizing, however, does not actually "correct" images for colorblind viewers. Although the resulting image is enhanced so that the dyschromatic viewer can distinguish colors more effectively, it still differs from what the normal-sighted or colorblind persons actually see.

### Issues and recommendations

One of the greatest frustrations for colorblind students (and colorblind persons in general) is the inability of "normal-sighted" people to understand the difference in perception by those with the disorder. As a result, colorblind persons are often not given consideration, even having to bear the humiliation of color jokes from peers, as well as indifference shown by those in positions of trust, including teachers. This frustration is in addition to the confusion exhibited when involved in activities that depend on color discrimination, of which there are so many at every level of education. Imagine the fallout if a teacher were to ask a student in a wheelchair to "prove" that she cannot walk! Yet, this demeaning experience often happens to colorblind people, even from otherwise sensitive teachers ("Really? What color is my shirt?").

All children entering kindergarten are screened for a number of physical and cognitive attributes, but rare is the school that includes

colorblindness as one of them. This simple and free test, available on various web sites, is known as the "Ishihara Test," a portion of which is most often seen in biology textbooks when students are learning about sex-linked characteristics. If schools would include the Ishihara as part of kindergarten and new student screening, it would be of great help when prescribing teaching strategies for colorblind students.

A great many of the topics and activities taught in school involve color: graphs, population distributions, topographical maps, coding for books, folders, or student jobs, chemical titrations and pH tests, grouping younger children for lessons ("Everyone wearing green is in this group."), even choosing crayons in the primary grades. The list goes on.

One does not have to be a teacher in a school which has screened children for colorblindness to make changes in strategies involving color. Remember, on average, every group of twenty-five students (a typical class size) will have at least one student who is colorblind. Teachers can begin by being conscious of alternatives when using visual aids. For example, using black and white, gradations of gray, or different black and white patterns can substitute for most graphic representations. If colors must be used, there are certain hues that are better perceived by colorblind students (see below). When describing animals or plants, black and white sketches may be used for general structures. Finally, when colors cannot be substituted, it is appropriate for teachers to have visual representations displayed with the color name next to it, or to use color coding with varying shapes. Students who may not perceive the color in the same way as the rest of the class can

often distinguish between the colors from their perspective and refer to the "correct" color name.

There are certain colors that are best perceived by colorblind persons. In a study at Duquesne University in Pittsburgh, it was found that white on a black background is the best color combination to use when designing instructional materials for colorblind students (Start, 1989). Next, in descending order are middle yellow, dark yellow, light yellow, light blue, middle red, light green, dark red, dark blue, middle blue, middle green, and dark green.

While technologies may one day be commonplace and help students to reduce the confusion and stress accompanying their disorder, teachers can begin now to reduce barriers for their colorblind students (Stiles, 2000). If a school does not routinely screen for colorblindness, it may be a simple matter of one teacher making the suggestion in order to help the many colorblind students who do, and will, attend.

Once students have been identified as dyschromatic, teachers can make modifications in their lessons that concern color without having to abandon the activity. Never ask a colorblind person to "prove" their color perception. Not only is it terribly insensitive, it only reinforces the idea that the person's condition is for the amusement of others. However, a colorblind person may offer to talk about his disorder so that others may learn from it. If that does occur, teachers need to be aware of how such a discussion could deteriorate, and be able to anticipate and head off such possibilities.

One of the most important actions a teacher can take is to talk privately with the student, and ask how he or she can be of help.

#### HELPFUL WEB LINKS FOR MORE INFORMATION:

Ishihara Test for Color Blindness:

<http://www.toledo-bend.com/colorblind/Ishihara.html>

Simulations:

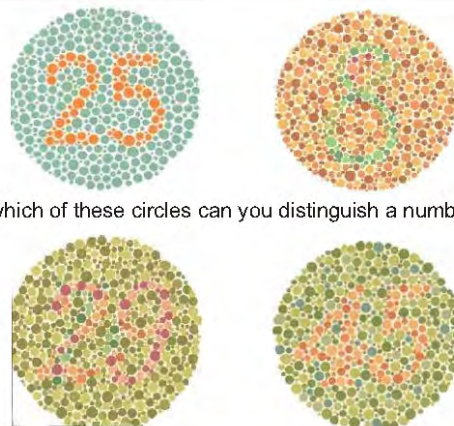
<http://www.vischeck.com>

SCIELAB from the Wandell lab at Stanford university:

<http://white.stanford.edu/~brian/scielab/scielab.html>

Causes of color blindness:

<http://webexhibits.org/causesofcolor/2.html>



In which of these circles can you distinguish a number?



There are often things that can be done, but only the student knows what those are. Inviting parents to discuss options is always important. Surprisingly, sometimes the parents may not even be aware that their child is colorblind. Children can be very good at hiding what they perceive as an embarrassing condition.

Finally, if a teacher is colorblind, talking to students about the disorder accomplishes four things: It shows students that an adult role model has accepted and learned to accommodate a genetic disorder; it helps teach in a practical way about genetics; it more than likely will make colorblind students feel comfortable talking about their disorder with

their peers; it helps the teacher, just as much as it does the students, understand dyschromacy, and how it is nothing to hide.

Persons with colorblindness generally lead a productive, normal life, learning to deal with the frustrations and barriers that color discrimination causes, often with humor. They can even teach themselves to identify a core of once confusing colors, albeit with great concentration. Teachers can help their colorblind students get a head start and enjoy a less stressful educational experience with understanding, patience, and by educating themselves about colorblindness.

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