THE EFFECT OF TRAINING UPON FACULTY STAGES OF CONCERN ABOUT MAKING COLOR VISION DEFICIENCY ADAPTATIONS

By Marlena Hope Pinner

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

Liberty University, Lynchburg, VA

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ABSTRACT

Although color vision deficiency affects an appreciable portion of the human race, those with the condition do not enjoy mandatory educational accommodations. The purpose of this quasi-experimental investigation was to quantify the effect of professional development training on university faculty concerns about adapting their instruction for color vision deficiency. This investigation used a static-group comparison design with a professional development intervention for the experimental group at a liberal arts university (N = 98) in the Southeast of the United States, collecting data through an online fielding of the Stages of Concern Questionnaire. Independent Samples *t* Tests between the two groups revealed no statistically significant differences in means of raw scores (alpha level of .014) for the stages 0 through 5 concerns. However, the results did show a statistically significant increase ($p < .001$) for stage 6 concerns, suggesting that the training did change the concerns of the experimental group participants about exploring and desiring other options for adjusting their instruction for color vision deficiency. Such responses are suggestive that the training may have raised resistance to implementing instructional adaptations for color vision deficiency. These results provide research-based knowledge to guide collegiate leadership in making policy about these optional adaptations, and suggest that future research about making instruction more accessible for color deficient students should focus on institutionally-based, rather than instructor-based, initiatives.

Keywords: color vision deficiency, disability accommodations, dyschromatopsia, inclusion, Stages of Concern

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List of Abbreviations

Americans with Disabilities Act of 1990 (ADA)

American Institutes for Research (AIR)

Concerns Based Adoption Model (CBAM)

Color Vision Deficiency (CVD)

Commission Internationale de l'Eclairage (CIE)

Individuals with Disabilities Educational Act of 2004 (IDEA)

International Colour Consortium (ICC)

Southern Association of Colleges and Schools (SACS)

Southwest Educational Development Laboratory (SEDL)

Stages of Concern (SoC)

Stages of Concern Questionnaire (SoCQ)

United Nations Educational, Scientific and Cultural Organization (UNESCO)

Universal Design (UD)

Universal Design for Instruction (UDI)

Universal Design for Learning (UDL)

Universal Instructional Design (UID)

CHAPTER ONE: INTRODUCTION

Overview

This research investigated the concerns of university educators about providing color vision deficiency (CVD) educational adaptations for their students. Scant research exists about such concerns and the effect of an informational intervention on those concerns (Collins, 2015). Insufficient legal mandates exist to require educational accommodations for individuals with CVD. Neither the Americans with Disabilities Act (ADA) of 1990, nor the Individuals with Disabilities Educational Act (IDEA) of 2004, classifies CVD as a handicap. Without legal requirements, individuals with CVD must rely on the voluntary help of their instructors for ameliorating the impact of CVD on learning.

Background

Approximately 8% of males and 0.4% of females in the human population—roughly one in 12 persons—have difficulty perceiving color (Flinkman & Nakauchi, 2017). In the educational arena, little consideration for individuals with CVD finds its way into pedagogical practice (Maule & Featonby, 2016), and publishers make generous use of color-rich resources without concern for how such usage affects individuals with CVD (Torrents, Bofill, & Cardona, 2011). This lack of consideration is particularly disconcerting at the post-secondary level in that it may affect access to higher education—researchers report lower rates of college matriculation for individuals with CVD (Chan, Goh, & Tan, 2014). Aspects of the context of this investigation arose from history, societal factors, and theoretical considerations germane to education and to how educators implement change.

Historical Considerations

Scientists have acknowledged CVD since 1794 when John Dalton wrote the first treatise describing his own color deficient condition (Maule & Featonby, 2016). However, modern advances in imaging technology have made color materials widely available (Cole, 2004), thereby compounding problems for individuals with CVD. Unfortunately, the changeover to predominately color-based resources has not been accompanied by pertinent changes in classical teacher education—it contains little information concerning the condition and how to adapt instruction pre-emptively for color vision deficient students (Suero et al., 2005).

Societal Factors

Societal norms and testing routines have hampered the effort to bring the need for CVD adaptations to the forefront. Researchers report CVD as a largely misunderstood and underreported condition (Chan et al., 2014; Collins, 2015). Researchers express concern that many students with anomalous color vision, and their parents, do not know that they have the condition (Chan, et al., 2014; Cole, 2004; Collins, 2015; Suero et al., 2005). Furthermore, some individuals are reticent to reveal this condition for fear of the consequences. Some governments and employers ban individuals with CVD from holding positions, such as airplane pilot, police officer, and certain medical specialties, in which individuals might endanger themselves or the public (Chan, et al., 2014).

One of the societal problems surrounding CVD is the matter of testing. Although certain occupational screenings mandate color testing, many do not. The United Kingdom has no such requirement (Maule & Featonby, 2016). In the United States (US), although schools test students for visual acuity, most do not test for color vision (Collins, 2015).

Traditionally, educators and their suppliers have made much use of the ability to discriminate color, always with the student possessing normal color vision in mind. Educators use color in the beginning of a child's education to establish a meaning for a particular light sensory experience, and concomitant meanings thereafter in a manner of codes (Cole, 2004; Suero et al., 2005). In addition, educators use color as a means of discrimination—a method for segregating objects, and like artists, also enjoy using color to evoke an emotional feeling or to create an aesthetic value (Cole, 2004; Collins, 2015). Torrents, Bofill, and Cardona (2011) studied texts and found that most of them were unsatisfactory in accessibility for color vision deficiency in that they use color perception in all the previously described ways to enhance learning activities for students with normal vision.

Theoretical Considerations

The theoretical background of this investigation found its underpinnings in how educators manage students with handicaps, how they deliver accommodations for those students, and how they approach adopting educational paradigm changes. Before the 1975 Education for All Handicapped Children Act (PL94-142), and its subsequent revisions, including the IDEA, children with disabilities were often deprived of valuable instructional and social interactions (Vaughn & Schumm, 1995). The educational theory of inclusion carries the connotation of returning students with disabilities to the general classroom (Spratt & Florian, 2015), although the standard in the law only requires the provision of the least restrictive environment (IDEA, 2004). Despite the fact that there is considerable debate about the efficacy of such practices, it remains a common practice in education in the United States to provide students with handicaps full access to general education classrooms and a variety of support services (Vaughn & Schumm, 1995) tailored to accommodate the needs of the student. The ethical foundation for inclusion theory calls for respect for each individual. Furthermore, Fleming and Tonge (2018) say that adapting for differences is valuable for students with and without disabilities due to the increasing diversity of classroom populations.

Although educators offer various forms of instructional adaptations, researchers have identified the theory of Universal Design (UD) as a suitable approach to the complex issue of CVD (Collins, 2015) that corresponds to the theory of inclusion. Universal design (UD) is an approach that engineers, architects, and occupational therapists originally developed to ensure physical access to all persons, both with and without disabilities (Watchorn, Larkin, Ang, & Hitch, 2013). As it applies to education, UD takes on the monikers of universal design for learning (UDL) or universal instructional design (UID) (Rao, Ok, & Bryant, 2014). Rao, Ok, and Bryant (2014) describe this universal design for educational purposes as pre-emptively modifying instruction to be as accessible as possible to as many individuals' needs as possible.

Lastly, the Concerns Based Adoption Model (CBAM), as originated by Hall, George, and Rutherford in 1977, provides a systematic theoretical progression of educational paradigm change. This research used the latest version of the instrument, the Stages of Concern Questionnaire (SoCQ) (George, Hall, & Stiegelbauer, 2013), that grew out of that model to ascertain the usefulness of an intervention for instigating change by university educators regarding the making of adaptations for CVD. Hall et al. (1977) designed the model to conceptualize the sweeping organizational and educational changes that educational leaders were implementing during the decade of its development. The CBAM model proposes that persons involved in innovations usually, but not always, progress through stages of concern as they address an innovation (George, et al., 2013). These stages can characterize the maturation of an innovation within the hearts and minds of the individuals who are attempting to implement it. It also predicts, by referencing the specific concerns of individuals, how well an organization is moving toward the implementation of an institutional change (Hall & Hord, 2011).

Summary

The results of this study add to the body of knowledge about the complicated topic of the adoption of optional CVD adaptations by university educators. The purpose of this study was to investigate the effect of an informational intervention on the concerns of faculty educators about accommodating for CVD. The intervention described CVD and provided training in CVD adaptation techniques that reference UD. The researcher used the SoCQ to quantify significant differences in the concerns of university educators about implementing optional CVD adaptations by comparing concern responses for the control and intervention groups.

Problem Statement

The problem is that university students with CVD are not receiving instruction from faculty in a manner that is compatible with their physical ability to receive it. Several difficult educational issues surfacing from the CVD condition made it an enticing topic for research. Disability accommodations ensure access to education for individuals with recognized physical and mental disabilities. However, students with CVD do not enjoy the benefits of adaptations, owing to the lack of legal recognition of CVD as a determinate of significant daily life dysfunction (ADA, 1990; IDEA, 2004). Moreover, some research supports the idea that it is not a disability. Ramachandran, Wilson, and Wilson (2014) published a study using a small population of young children and concluded that there was no appreciable correlation between a lack of educational achievement and the presence of the condition. In contrast, Chan et al. (2014) compiled evidence from 60 scientifically researched studies to show educational and occupational health dysfunctions for individuals with CVD. Stoianov et al. (2018) made a similar review of 20 studies with similar findings. Collins (2015) also detailed barriers to equal access in the classroom for students with CVD.

Other issues connected to the CVD condition generate problematic educational issues. From the instructor and university policy maker's point of view, challenges lie in privacy constraints (FERPA, 1974), and in the general reticence of students to reveal disabilities (Moriña, 2017). Publishers of educational materials have not developed CVD friendly texts (Torrents, et al., 2011). In fact, because so many versions of CVD exist, suitable revisions of all resources for all CVD conditions would be difficult to develop, and, given the fashionableness of pervasive color in educational resources, could prove unpopular with the general public (Torrents, et al., 2011).

Furthermore, the concerns of university educators about implementing CVD adaptations, and the effect of an instructional intervention about such adaptations, were unknown. As a result, university leadership had no research-based information to suggest that CVD adaptation initiatives would meet with acceptance among instructors. In summation, the problem was a lack of research on the willingness of university educators to pre-emptively adapt their instruction for students with CVD, and on the effect of an informational intervention on their willingness.

Purpose Statement

The purpose of this study was to investigate the effect of an informational intervention on faculty concerns constructs about accommodating for CVD. The population of this study was the faculty of a medium-sized, coeducational, liberal arts university in the Southeast of the United States, who are instructors or administrators—both full time and part time employees. The sample was a subset of all the university educators who voluntarily participate in the study. The seven CBAM constructs of concern about implementing an innovation, which the model presents as stages that are usually progressive, are: unconcerned, informational, personal, management, consequence, collaboration, and refocusing (George et al., 2013). The intervention described CVD and provided training in CVD adaptation techniques for the instructors. A published researcher, Karla Collins, PhD, who is an expert in CVD adaptations, presented the intervention, and developed a CVD adaptation resource, together with this researcher, to accompany the video portion of the intervention. The results of the SoCQ permitted discrete observations of the seven concern stages by comparing the responses of the control and intervention groups. The results allowed the researcher to ascertain any changes in the concerns constructs of university educators about implementing adaptations that were brought about by the professional development intervention.

Significance

This study is significant in several ways, both in effecting educational practice and the attitudes of educational leaders. Other than studies by medical educational practitioners (Campbell, Griffin, Spalding, & Mir, 2005; Dhingra, Rohatgi, & Dhaliwal, 2017; Serrantino, Meeks, Jain, Clifford, & Brown, 2015; Spalding, 1999), it was unknown if faculty and administrations of institutions of higher learning were willing to make adaptations for CVD. A mixed methods seminal study of elementary school librarians revealed a general ignorance of the condition and its educational consequences, but also a general openness to learning about, and making adaptations for, students with CVD (Collins, 2015). In terms of generating support and use of UD adaptations, if the university educators were to adopt this form of adaptation for CVD, it would strengthen the body of positive literature concerning UD. A recent study of attitudes toward accommodating disabilities in general by using Universal Design for Instruction (UDI) in a college setting indicated that making accommodations is interesting to professors; however, a substantial group of them were either uncomfortable with, or totally ignorant of, the technique (Dallas, Upton, & Sprong, 2014). McGuire and Scott (2006) pointed out that many excellent college instructors already use the principles of UD, and that several studies provide validation for the approach for addressing students of all statuses.

Ascertaining the willingness and attributes of university educators towards making CVD adaptations was a way to provide research-based knowledge to higher education leadership for making policy decisions about these optional adaptations. Adequate characterization of willing educators could potentially provide leadership with predictive assurances about the likelihood that educators within their own institutions would welcome and implement CVD adaptations. This study also added to the body of knowledge about implementing CVD adaptations by the production of a CVD adaptation resource and training videos. Increasing collegiate educator awareness of the value of CVD adaptations could have a positive impact on textbook adoptions and, thereby, on publisher awareness (Torrents et al., 2011). In addition, Maule and Featonby (2016) suggest that awareness might generate initiatives for teacher education.

Research Question

The research question for this investigation was:

RQ: Is there a difference in the concerns of university faculty and administrators about making adaptations for students with color vision deficiency between those faculty and administrators who have received a professional development intervention about making such adaptations as compared to those faculty and administrators who have not received the intervention?

Definitions

1. *Color vision deficiency (CVD)* – Color vision deficiency is the proper term for the condition of color blindness wherein individuals cannot identify or distinguish between colors (Maule & Featonby, 2016).

2. *Concerns Based Adoption Model (CBAM)* – This model portrays the integration of an educational innovation as a progression of seven stages by individuals and organizations (Hall & Hord, 2011).
3. *Stages of Concern Questionnaire (SoCQ)* – The Stages of Concern Questionnaire is an instrument that measures the levels of concern for seven possible concern constructs that an individual has about implementing an educational system change (George, et al., 2013). Hall et al. (1977) originally developed it out of their Concerns Based Adoption Model. The Southwest Educational Development Laboratory, which is now a subsidiary of American Institutes for Research (AIR), has revised it and owns the rights to its use (George, et al., 2013).
4. *Universal Design* – Universal Design is a way of intentionally building accessibility into an entity that the creator purposes for general use, so that as many people as possible get the greatest benefit from the entity (Rao, et al., 2014).

CHAPTER TWO: LITERATURE REVIEW

Overview

Although not an officially defined Americans with Disabilities Act (ADA) disability, adapting education for individuals with color vision deficiency (CVD) is a topic of relevance for college educators. This literature review develops a conceptual context from which the potential for implementing such educational adaptations arises and then informs the reader with a distillation of educational and technical research available about CVD. The first section discusses the conceptual and cultural frameworks surrounding and undergirding the idea of pre-emptively adapting instruction for CVD. The second section brings together a synthesis of recent and seminal related literature in order to present a case for the significance of this investigation through the topics of CVD and learning, educational history, and educator prospective. A third section explores postsecondary views on disability accommodations in general and universal design in particular as an appropriate mode for implementing CVD adaptations. Lastly, this literature review summarizes the status of the research into adapting for CVD, presenting the variables and hypotheses for this study that address a gap in the literature, and thereby add to the body of knowledge concerning higher education accommodation practice and policy.

Conceptual and Cultural Framework

The conceptual context of pre-emptively adapting instruction for CVD lies among a cultural, legal, and pragmatic backdrop. Historically, disability adaptation finds its justification in Bandura's social cognitive theory of education, which asserts that individual differences are valuable assets in the classroom (Gaffney, 2014), and in social justice, which harkens back to the concept of educational equity of access advanced by early educational reformers such as Horace

Mann (Gutek, 2011). Researchers and clinicians make use of a combination of several classical models for an understanding of disabilities to frame responses to them (Llewellyn & Hogan, 2000). Lawmakers have constructed current laws pertaining to disabilities on the basis of the medical model and social models. The basic understanding of the medical approach to disability treatment requires that a medical professional must make a diagnosis of an impairment to which an institution must make a plan for remediation which can normalize, or at least minimize, the difficulties associated with the impairment in a given situation. In this model, the onus for receiving remedial benefits falls upon the individual (Oliver & Barnes, 2012) to obtain a diagnosis and submit it to their institution for remediation (Llewellyn & Hogan, 2000) and makes persons with disabilities dependent (Oliver & Barnes, 2010).

The social model of disability instead reflects back onto society at least part of the responsibility of mitigating the effects that an impairment has upon an individual, noting that society itself is responsible for the environment that defines the person with a handicap as having a disability (Oliver, 2013; Oliver & Barnes, 2010). From this latter understanding of impairments grew disability legislation as well as engineering and educational responses for removing physical barriers. In the educational arena, disability crusading also resulted in the educational discussion of inclusion (Levitt, 2017; Oliver & Barnes, 2010), and the idea of creating supportive environments (Llewellyn & Hogan, 2000). More recently, disability literature recognizes a systems approach to responding to disabilities, saying that multiple influences from society, education, family, and personal factions culminate in the true experience of a person who has an impairment, so that remediation is at best multifaceted and longitudinal (Llewellyn & Hogan, 2000). The cultural framework for the mainstreaming of students with disabilities in the United States dates back to the passage of the 1975 Education for All

Handicapped Children Act, Public Law 94-142. The law, and its 2004 revision, the Individuals with Disabilities Education Act (IDEA), prescribes free public education in the least restrictive environment and grants concomitant rights. The shift away from segregated special education grew into an inclusionary model of general education for students with disabilities. Lipsky and Gartner (1996) first enunciated the inclusion model in 1987, and the international community, as represented by the United Nations Educational, Scientific and Cultural Organization (UNESCO), codified it in the Salamanca Statement (1994) as a guiding principle for governments to inform educational classrooms, teacher training, and community involvement. Although some educators resist the idea of mainstreaming students with disabilities (Hornby, 2011; Vaughn & Schumm, 1995), they also acknowledge the popularity of inclusion among educators. This concept translates into educational inclusion of all students in the mainstream educational system by intentional practice (Spratt & Florian, 2015; Moriña, 2017).

Currently, laws and guidelines exist in several countries to address access for individuals with disabilities, including visual disabilities (Office for Civil Rights, 2011). In the US, the Rehabilitation Act of 1973, section 504 and 508 prohibits the use of color for communicating federal resource content (http:// section508.gov/section-508-standards-guide). The Telecommunications Act of 1996 (47 U.S.C.A. sec. 225) mandates that manufacturers and service providers take into account the needs of individuals with disabilities to access their products if such adjustments are ‘readily achievable’ (47 U.S.C.A. sec. 225) (Jaeger & Bowman, 2002, p. 146). The law also prohibits the exclusive use of color for mediating such access (Jaeger & Bowman, 2002, p. 147). In the UK, the Equality Act of 2010 designates disability access law. In Canada, the Accessibility for Ontarians with Disabilities Act, 2005 (Kumar & Wideman, 2014) guarantees accessibility. In Korea, the disability access laws are the Statute for the Alleviation of Informational Gaps and the Standard Guideline for Establishing Homepages of Governmental Institutes (Jang, Choi, & Hong, 2010). On the internet, the World Wide Web Consortium (W3C), headquartered in Massachusetts, promulgates Web Contents Accessibility Guidelines that say websites should be perceptable, operable, understandable, and reliably interpretable (W3C, 2008). In the international arena, the United Nations' Convention on the Rights of Persons with Disability (2014) prescribes disability accommodations on the basis that the "denial of reasonable accommodation" (p. 84) is tantamount to discrimination.

By extension, the philosophy of equitable access bears consideration regarding the cultural responses to the need to provide adaptations for individuals with CVD in the educational arena (Collins, 2015). However, a problem surfaces in that educators and governments do not uniformly recognize CVD as a disability (Collins, 2015; Kvitle, 2018; Maule & Featonby, 2016), despite meeting the legal criteria of being a substantially limiting condition affecting activities of life (ADA, 1990). Confounding the situation is that although researchers can catalogue numerous instances in which CVD impacts educational access, they readily also admit that individuals with CVD are masterful practitioners of coping skills (Cole, 2004; Collins, 2015; Formankiewicz, 2009; Maule & Featonby, 2016; Ramachandran, Wilson, & Wilson, 2014).

The legal context of adapting instruction for CVD lacks consistency with other disabilities in the United States. Since 2004, the Individuals with Disabilities Act (IDEA) has mandated accommodations for students having 13 documented disabilities who are matriculating in public schools. No such requirement exists for private educational institutions or for students after they reach the age of 18 (IDEA, 2004). Nor does the IDEA recognize CVD as a disability despite the fact that it affects a significant portion of the human population worldwide (Flinkman & Nakauchi, 2017). The Americans with Disability Act (ADA, 1990) provides civil rights to individuals with disabilities, and The Rehabilitation Act of 1973, section 508, requires that governmentally promulgated information be understandable for all individuals, regardless of disability status. This sets a requirement for government-produced materials to be accessible for individuals with CVD.

Pragmatically, the theory of educational inclusion informs adaptations for CVD in that it delineates an acceptable method for designing educational systems that are responsive for students with and without the condition. The impractical part of accommodating for CVD is that because so many types and severities (Fernandes & Urbano, 2008) of the condition exist, optimal solutions can be difficult to identify (Flinkman & Nakauchi, 2017).

A plausible solution for how to address CVD in educational settings, sans a legal mandate and without singling out individuals with CVD, lies in the theory of Universal Design (UD). It is an approach that engineers, architects, and occupational therapists originally developed to ensure physical access to all persons, both with and without disabilities (Watchorn, et al., 2013). As it applies to education, UD takes on the moniker of universal design for learning (UDL) or universal instructional design (UID) (Rao, et al., 2014). Rao et al. (2014) describe this universal design for educational purposes as a structure upon which instructors make use of alternative options and educational supports to create and implement adaptable lessons. The technique pre-emptively modifies instruction to be as accessible as possible to as many individuals' needs as possible (Rao et al., 2014). With the supremacy of privacy concerns, universal design also presents a convenient alternative to universal screening for CVD.

Related Literature

A review of literature related to the general knowledge about adapting for CVD in higher education encompasses several topics of interest. First, it requires addressing the nature of the condition—its biological identity and sources, prevalence, methods of detection, and the current state of technical advances that impinge upon it. Secondly, previous studies lend an understanding of the import of the study through research about the impacts of CVD on learning, plus historical and educator perspectives. Lastly, a discussion of pertinent research into disability accommodations in higher education, with the addition of information on current educational supports and UD, completes a circumspect accounting of the background that is necessary to place this study in existing knowledge.

Nature of Color Vision Deficiency

The very nature of CVD is complex, requiring an understanding of the subtleties of the condition to appreciate the difficulties inherent in making educational adaptations for it (Maule & Featonby, 2016). Most educators do not clearly grasp the effects and implications of the CVD condition, making the countering of systemic educational prejudices difficult (Collins, 2015). Ironically, the effect of CVD on the lives of affected individuals is the focus of only a few studies worldwide, despite the fact that CVD affects individuals in affective and logistical issues of life (Stoianov et al., 2019). Chakrabarti (2018) suggests an explanation—the severity of CVD varies. In its mildest forms it nearly resembles normal vision and constitutes approximately 75% of cases, and individuals with CVD use coping mechanisms to ameliorate their deficits (Chakrabarti, 2018). In fact, Rahi, Cumberland, and Peckham (2009) published a longitudinal study of individuals from the 1958 birth cohort that did not find a statistically significant difference in incidence of vehicular or employment accidents or in educational attainment.

Normal color vision. The phenomenon of color reception is complex (Neitz & Neitz, 2012) and not fully explained, so color theories abound. The complexity of the physics and the psychology behind it partially explain the difficulty in making a straightforward solution to the problems incurred in CVD. In his pioneering work, Land (1959) views color as a psychological phenomenon that derives from the reception of varied wavelengths of visible light to which the retinal ganglion and brain assigns colors, irrespective of the actual spectral color. According to his theory, the assignment of color perception relies on the reception of a minimum of two differing wavelength stimuli (Land, 1959). This understanding informs the anatomical and physiological description of retinal reception of the visible spectrum, which lies within the 380 to 700 nm part of the electromagnetic spectrum (NASA, 2010). The three cone receptors are thusly labeled as responding to small visible wavelengths (S cones), medium visible wavelengths (M cones), and long wavelength cones (L). The fourth light processing receptor protein, rhodopsin, is responsible for distinguishing light versus dark and night vision. The cells containing it are the rods. The S cones are sensitive to blue light and the shortest wavelengths of light at the high energy end of the visible spectrum; the M cones are sensitive to green light and wavelengths in the middle of the spectrum; and the L cones are sensitive to red light and the longest wavelengths of light at the low energy portion of the spectrum. Deeb (2005) states that the maximum receptive wavelength for the S cones is 420 nm, for the M cones is 530 nm, and for the L cones is 560 nm. However, the idea that the neurological processing of the stimulations of these three color-receiving cones is the basis of color vision is actually less than fully descriptive. In a paradigm shifting experiment, Roorda, Sabesan, Schmidt, Sincich, and Tuten (2017) added yet another twist to the discussion of how color vision happens. They stimulated one cone of a human retina at a time with a laser and found that both red and green cones come in two varieties—one type that responds to a radiant stimulus to elicit the perception of their respective color responses, and one type that responds to the same radiant stimulus to elicit the perception of white light (Roorda, Sabesan, Schmidt, Sincich, & Tuten, 2017). Additionally, they found that the white evincing cones outnumbered the color evincing cones. The retina, therefore, systematically creates light perception by creating a detailed light and dark outline of what is being viewed, and then supplies the appropriate color fill according to the wavelength received for the neurological transformation of such received information into color perception (Saey, 2016).

Yet another complicating factor in the use of color for transmitting information lies in the fact that color discrimination depends on accurate color specification. The idea of color systems and color space is critical to the design of color environments. Several color spaces and systems exist as a result of the impossibility of the task of precisely quantifying the color perceptions of humans (Oshima, Mochizuki, Lenz, & Chao, 2016). Some color spaces and color systems are based on psychophysics, which are descriptions on the basis of the physics of color production, and some on psychology, which are delineated more on the basis of human color perception (Troiano, Birtolo, & Armenise, 2016; Yanagida, Okajima, & Mimura, 2014). A list of common color spaces and systems is in Table 1.

In terms of physics, defining a color requires a mathematical description of a hypothetical single point in a three-dimensional color space (Chen & Liao, 2011) at least partially defined by wavelength. The psychological systems find their bases in perceived brightness and hue. Formulas exist for moving color definitions between the psychophysics color systems, and tables exist for translating between psychophysics and psychology color systems (Yanagida et al., 2014), although every color possibility is not accounted for in both systems. The phenomenon of color vision arises from two basic operations (Keene, 2015). First, the specialized sensors, the cones, on the retina must properly receive and process light stimuli of varying wavelengths into

Table 1

Color Spaces and Systems

Designation	Basis	Components	Uses/notations
CMYK	psychophysics	cyan, magenta, yellow, black	color printing[a]
sRGB	psychophysics	red, green, blue	standard description for devices & monitors[a]
CIE XYZ	psychophysics	red, green, blue	electronics/empirical description of stimuli[b]
CIECAM02 (CIE L*a*b*[b], CIE L*u*v*[b] & CIE L*c*h*[b])	psychophysics	luminance, red-green axis, blue-yellow axis	point differences reflect human perceptions[b] and device independent
HIS	psychology	hue, saturation, intensity	electronic devices; approximating human color interpretation[a]
Munsel	psychology	hue, lightness, chroma	graphic design[c]
NCS	psychology	hue, lightness, chroma	natural colors[c]
PCCS	psychology	hue, tone (lightness plus saturation)	graphic design; chroma by saturation ratio[c]

[a]Chen & Liao (2011)
[b]Mereuta, Aupetit, Monmarché & Slimane (2014)
[c]Yanagida et al. (2014)

nerve impulses. Secondly, the brain must accurately receive and process impulses from the sensory cells via ganglion and subsequently the optic nerve (Simunovic, 2016). Optically, color vision derives from the interplay of electromagnetic stimulations of the three cone protein opsins that respond to red, green, and blue light (Maule & Featonby, 2016). A fourth red type cone does exist in a small portion of the female population, and these women are reported to have enhanced color vision (Deeb, 2005). The cones are the primary sensors responsible for color perception; however, the rods are also responsible for color discrimination under certain conditions (Buck & Knight, 2010; Simunovic, 2016). Some individuals with CVD have difficulties discriminating thin black lines. In some protans, Ueyama et al. (2004) reported that some mutations in the gene array for cone opsins can be deleterious to the formation of rhodopsin, which is the protein molecule that is sensitive to light in the rods. The rods receive light to discriminate shades of black and gray in the dark.

Anomalous color vision. As previously noted, the concept of color vision is a complex one because it is a physics phenomenon overlain with human psychological constraints. For that reason, anomalous color vision results when one or more of the three primary cone receptors are absent or fail to fulfill their roles to varying extents (Maule & Featonby, 2016), or the neurological or psychological aspect is not functioning well. As a result of the compilation of these multiple processes, numerous neurological defects and acquired conditions can bring about various forms of CVD, but it bears pointing out that not all of the consequences of CVD are deleterious. Doron et al., (2018) report that individuals with anomalous trichromacy excel at spatial contrast and acuity in comparison to individuals with normal vision. Moreover, Doron et al. (2018) document that individuals with this form of CVD can skillfully identify camouflaged objects.

Vision practitioners classify the most common forms of CVD by the cone receptor that is missing, using the suffix *–opsia*, or that is defective, using the suffix *-anomaly* (Maule & Featonby, 2016). Protanopia or protanomaly signifies red cone irregularities, deuteranopia or deuteranomaly signifies green cone irregularities, and tritanopia or tritanomaly signifies blue cone irregularities (Maule & Featonby, 2016; Szczurowkski & Smith, 2018).

Maule and Featonby (2016) outline the irregularities for each type of CVD. As one can note from this listing, red-green confusion also encompasses hues that are composed from those two hues (Wong, 2011). Persons with Protanopia, commonly have difficulty distinguishing (Maule & Featonby, 2016):

1. Black with many shades of red.
2. Dark brown with dark green, dark orange, and dark red.
3. Mid-greens with some oranges.
4. Some blues with some reds, purples and dark pinks. Someone with protanopia is likely never to have seen purple as normal vision sees this colour, but sees ‘purple’ as blue. (p.3)

Persons with Deuteranopia typically have difficulty distinguishing: “1. Mid-reds with mid-greens, 2. Blue-greens with grey and mid-pinks, 3. Bright greens with yellows, 4. Pale pinks with light grey, 5. Mid-reds with mid-brown, 6. Light blues with lilac” (Maule & Featonby, 2016, p. 3). In Tritanopia, individuals confuse “light blues with greys, dark purples with black, mid-greens with blues, and oranges with reds” (Maule & Featonby, 2016, p. 3). In practice, these paradigms of confusion further complicate due to wavelength crossover and possible rod contribution (Simunovic, 2010). Szczurowski and Smith (2018) report that in the rare condition *Achromatopsia*, the individual sees no color due to the total lack of, or dysfunction of, all three types of cones. Table 2 summarizes the types of CVD.

Etiology. A person can have CVD as a result of several reasons. The etiologies of the anomalies that prevent normal color vision are two-fold: the inheritance of non-optimally functioning or missing cones or the acquisition of such cones through eye damage, acute or degenerative disease processes, or environmental conditions (Szczurowkski & Smith, 2018). Inherited CVD occurs as the result of genetic aberrations that are not treatable; however, promising gene therapy research has provided a cure for CVD in monkeys (Mancuso et al., 2009).

A variety of deletions, substitutions, and rearrangements of the gene array on the X chromosome that codes for the L and M opsin proteins produces the mutated receptors that are responsible for congenital red-green CVD (Ueyama et al., 2004). The genes for the M and L wavelength gene arrays lie within the Xq28 band (Khalid, Chughtai, Mian, & Shah, 2017). The gene that codes for the S cone lies on the autosomal chromosome 7q32, and as such, CVD resulting from a faulty S cone is much rarer because it is not sex-linked (Deeb, 2004). The frequencies of the sex-linked versions follow straightforward genetic pedigrees (Maule & Featonby, 2016). Males who have CVD inherit the faulty mutated gene via a gene on their mother's X chromosome. The mother has to either be a carrier of the mutated gene or suffer from CVD herself—having both of her X chromosomes with faulty genes for the red or green color receptors (Maule & Featonby, 2016).

Deeb (2005) describes the human color vision mechanism and its phenotypic and genetic diversity on the molecular level. In short, the opsins and their included chromophores are situated on the membranes of the cones and are responsible for translating as little as one photon of the electromagnetic spectrum into electrical potential shifts that the nervous system translates

Table 2

Types of Color Vision Deficiency

Designation	Diagnosis	Prevalence Male:Female	Condition	Notes
Trichromats	Trichromacy	90-96% worldwide	Normal color vision	Reception of L, M, S cones from 380-700 nm[a]
	Anomalous Trichromacy			
	Protanomaly	1.08%[a]:0.03%[b]	Red deficiency	L cones λmax shifted 7 nm or less[c]
	Deuteranomaly	4.63%[a]:0.36%[b]	Green deficiency	M cones λmax shifted 12 nm or less[c]
	Tritanomaly	0.0002% worldwide	Blue deficiency	S cones
Dichromats				
	Dichromacy			
	Protanopia	1.01%[a]:0.02%[b]	Severe red loss	L cones missing or inoperative
	Deuteranopia	1-2%[c]:0.01%[e]	Severe green loss	M cones missing or inoperative
	Tritanopia	0.01%[c]: 0.01%[c]	Severe blue loss	S cones missing or inoperative
Monochromats				
	Blue Monochromacy	0.001% (males)[b]	Severe red, green loss	L, M cones missing or inoperative
Achromacy				
	Rod Monochromacy	0.003%[d]	Total color blindness	Only rods are functional[d]

[a]NASA (2010)
[b]https:// www.color-blindness.com
[c]Deeb (2005)
[d]www.colour-blindness.com/variations/total/
[e]Cole (2007)

into color perception. This shift is mediated by the chromophore's switching between the *cis*-11 form to the all *trans* form (Deeb, 2005).

The great diversity of CVD affectation arises from several sources (Deeb, 2005). First, the structures of the red and green opsins are remarkably similar, coming from genes that are capable of transformations and translocations, producing alternate genetic arrays. The mutated opsin structures responsible for anomalous CVD differ only by a few amino acid substitutions in the cones of individuals with CVD. However, those minor changes in the amino acid sequence alter the seven helices that are attached to the chromophore in the membrane bundle of the cone and affect its operation, shifting the effective spectrum by critical nanometers. Secondly, in addition to the multiple forms of the genetic array, only the red and first green gene, even if it is a mutated hybrid form, are translated into the opsin proteins. Lastly, when the genetic switch that controls the expression of the red-green genetic array has deletions, the gene becomes non-functional, and the individual can lose reception of an entire segment of the electromagnetic spectrum.

The conditions which can cause acquired CVD are many. Logically, predominately among these are neurological and eye diseases and age-related conditions (Simunovic 2016; Szczurowkski & Smith, 2018). However, environmental poisons and drugs can also cause CVD (Szczurowkski & Smith, 2018). The acquired loss of color vision can indicate neurological changes in response to xylene exposure in shipyard workers (Lee, Paek, Kho, Choi, & Chae, 2013). Heydarian, Mahjoob, Gholami, Veysi, and Mohammadi (2017) report that arc welders can acquire differential blue/yellow deficiency from over exposure to short wavelength light and manganese gases. These differing etiologies complicate the task of making classroom adaptations for persons with CVD—basically because the physics of light reception coupled with the multiplicity of possible neurological conditions defy an untailored solution that works well for all types of CVD (Flinkman & Nakauchi, 2017).

Additionally, CVD correlates with other dysfunctions. Color vision deficiency, as identified by the Ishihara plate test, is an early indicator of the vascular variant of Alzheimer's disease (Arnaoutoglou et al., 2017; Kaeser, Ghika, & Borruat, 2015). The presence of CVD also correlates with other neuropsychological disorders (Berger et al., 2016). Coren and Harland (1995) report that negative psychological effects can follow students into university. Students can appear to have less academic ability (Albany-Ward & Sobande, 2015), even though Larsson and von Stumm (2015) report no correlation exists between the CVD condition and intelligence test scores. Kvitle (2018) admits that educational professionals can misdiagnose students with CVD as having a learning disability.

Prevalence. Many researchers have verified the frequency of CVD in different sectors of the human population. The genetically predicted ratio for a sex-linked trait is 16 males to 1 female (De Paor, Karabinos, Dickens, & Atchison, 2017). However, the frequencies and ratios of CVD vary world-wide as a result of genetically confined populations. Western European and Middle Eastern cultures demonstrate the predicted inherited frequencies of approximately 8% for males and 5% for the general population, while the Far East and regions around India demonstrate lower frequencies (Fareed, Anwar, & Afzal, 2015; Szczurowkski & Smith, 2018). Such a probability predicts the presence of an individual with CVD in every regular US classroom of 30 students ("Advice Sheet," n.d.).

Testing. One of the problems surrounding CVD is the matter of detection by testing: its routineness and instruments. Privacy limitations under the Family Educational Rights and Privacy Act (FERPA) of 1974 accentuate the need for universal testing (Chan et al., 2014) because self-disclosure is the only legally acceptable manner of receiving information about this disability (FERPA, 1974). Unfortunately, that legal mandate is preclusive for the many individuals that do not know that their version of color is aberrant (Goh, Chan & Tan, 2014). Although certain occupational screenings mandate color testing, the testing of school-aged children is spotty at best. The United Kingdom has no such requirement (Maule & Featonby, 2016). In the United States, although schools test students for visual acuity, most do not test for color vision (Collins, 2015). Medical schools do not routinely test their students, even though their student bodies reflect the frequencies of the general public (Goh et al., 2014). Cole (2015) disputes the conclusions of Ramachandran et al. (2014) that dismiss the need for CVD screening. He reports that half of the individuals with dichromacy and a quarter of the individuals with anomalous trichromacy admit difficulties related to their condition (Cole, 2015).

Researchers and medical professionals use several testing instruments. The oldest and most familiar is the series of test plates originally developed by Ishihara in 1917 and validated by Pickford (1949). Researchers and practitioners still use the hardcopy test plates, although an electronic version is now available. Another test that researchers use is the D-15 Farnsworth panel (Flinkman & Nakauchi, 2017), and its desaturated version, the Lanthony D-15 test (Good, Schepler & Nichols, 2005). These two tests are less important as screening tests than they are indicators of the severity of CVD (Khalid et al., 2017), and they are not easily administered to children. The Holmes-Wright lantern test is a screening test used in rail, avation, and maritime settings (Birch, 2013; Chan, et al., 2014). The Hardy-Rand-Ritter (HRR) pseudo isochromatic test plates have the advantage of being able to detect anomalous trichromacy in addition to protan and deutan abnormalities (Ilhan, Sekeroglu, Doguizi, & Yilmazbas, 2018). To address the need for child-friendly CVD diagnostics, researchers have created digital games that detect CVD in children (Nguyen Lu, Do, Chia, & Wang, 2014; Takemata, Tanaka, Takeda, & Minamide, 2016). The standard test of color vision is the anomaloscope (De Paor et al., 2017), but it is logistically difficult to administer.

Instructional and technological remediation. The compensation of color for individuals with CVD has several confounding factors: light source, illumination, the nature of the visualized object, and the individual. In addition, some qualities of the existing 16,777,216 discernably different hues are indescribable in words (Jang et al., 2010). Jenny and Kelso (2007) warn cartographers that the “number of colors that red-green confusing readers can unambiguously distinguish is rather small” (p. 63). As a result of this complexity, the research on remediation techniques for CVD varies widely. Some focus on instructors and traditional methods, while others are technological. King-Sears (2009) points out that pedagogy is a key element in adapting educational resources that are not disability oriented. Similarly, Kvitle (2018) calls for increasing educators’ awareness of CVD, and of methods for increasing accessibility for individuals living with CVD. Jaeger and Bowman (2002) point out that some hardware and software packages already include features that instructors may use for making UDL access adjustments. Kvitle (2018) recommends remediation of extant educational settings by adjusting lighting, and by transforming normal vision materials through choosing CVD-friendly palettes, and adding designs, labels, or patterns to otherwise color-exclusive representations. Frane (2015) lists several recommendations for ensuring CVD accessible resources: refrain from contrasting red with green, use adequate color saturation, use varying degrees of saturation to represent contrasts rather than varying hues, use alternate cues instead of indicating objects by color name, avoid red with black combinations, and avoid using fine lines or fine strips of color. Optimizing the illumination spectrum can also aid color discrimination for dichromats (Bao, Tanaka, Tajima, 2015), and help individuals with dichromacy maintain colour constancy—constant color perception of differing objects—as well as helping individuals with normal vision, using daylight illumination (Alvaro, Linhares, Moreira, Lillo & Nascimento, 2017).

Researchers have designed online methods to check electronic content for color accessibility. Reinecke, Flata, and Brooks (2016) studied the color perceptions of websites and infographics of 30,000 online participants from the general population. They concluded that ambient lighting can eliminate the effective perception of a color website or infographic by 50% for 10% of the population—a statistic not explainable solely from the frequency of individuals with CVD (Reinecke, Flata, & Brooks, 2016), and call for color design modifications for the benefit of the public. For example, the use of common alt tags—alt attributes and titles—on computer images can enhance their use by individuals who are visually impaired (Dukes III, L. L., Koorland, M. A., & Scott, S. S., 2009).

Several researchers have investigated screening techniques. Szczurowkski and Smith (2018) validated the use of virtual reality tools to feign CVD so that persons with normal vision can anticipate the needs of individuals with CVD. The online tool *Vischek*, (Dougherty & Wade, 2008) demonstrates how a submitted resource appears to a person with CVD. Reinecke et al. (2016) used feedback from 30,000 participants to invent *ColorCheck*, a digital content screener that identifies where color differentiation confusion can occur. Mereuta, Aupetit, Monmarché, and Slimane (2014) have researched text and background colors on websites to recommend CVD friendly constructions. Several other online tools for ensuring educational resources are CVD operational are also available (Bingham, Dietrich, & Goelman, 2019): Color Contrast Checker (https://webaim.org/resources/contrastchecker/), Daltonize.org (http://www.daltonize.org/p/about.html), and ColorBrewer (http://colorbrewer2.org).

Technological advances offer hope for both increased access and more normal color vision to individuals with CVD. Szczurowkski and Smith (2018) classify tools that are helpful to individuals with CVD as aids for those designing CVD inclusive environments, tools for use by individuals with CVD, instruments for screening for CVD, or aids for increasing awareness of CVD. Wu, Tseng, and Cheng (2019) comment that CVD filters can take the form of light filtering glasses (or contact lenses at https://www.artoptical.com/lenses/specialty-gp-lenses/special-lens-options/x-chrom/) or wavelength altering software, but note that the latter is difficult because algorithms suffer from a conundrum—how to shift light to CVD perceptible wavelengths while maintaining the original colors. Hsieh et al. (2015) devised a method using pixel resonance to accentuate contrast perception for tritanopes and people with normal vision. Wu et al. (2016) invented a system to help with color discrimination that uses texturing of screen displays of red color that are visible to individuals with L-wavelength CVD, but not to individuals with normal color vision. It is available at http://www.csshe-scees.ca/cjhe.htm. Later, Wu, et al., (2019) expanded this texturing approach by standardizing the parameters for adding textures to aid the recognition of red colors on computerized and light emitting diode (LED) applications.

Jang, Choi, & Hong (2010) designed a method for individuals with red-green deficiencies using the second of the Ishihara plates for graphics appearing on electronic devices. Their compensation method consisted of rules for color adjustments of the International Colour Consortium (ICC) standard. The ICC establishes a software file that is a standard for color trueness across manufacturers in the digital field. The approach of Jang et al. (2010) consisted of allowing those with CVD to adjust their own personal version of that color equivalence file in order to correct their color perceptions. Unfortunately, this method only applies to red-green deficiencies, is reductive in that ranges of colors are truncated by the generated profiles, and is not useable for movies. Suetake, Tanaka, Hashii, and Uchino (2012) proposed a "lightness modification" (p. 2093) that increases color discrimination for individuals with CVD by shading the outlines of objects. Their method takes advantage of the Craik-O'Brien effect, wherein the perception of two contiguous, but barely differing, shades of color appear more distinguishable when separated by a lighter border (Suetake, et al, 2012).

Simon-Liedtke and Farup (2016) compared four Daltonization methods for modifying color graphics and natural images for individuals with CVD. They used visual-search tasks to quantify the degree of method success. The results of the automated trials confirmed that the Kotera transformation gave the best accuracy in distinguishing color contrast for both normal sighted and CVD sighted individuals; however, the transformation did result in unnatural colors—blue leaves, for example (Simon-Liedtke & Farup, 2016). Adobe Photoshop CS5 software has a test for CVD accessibility (http://adobe.com/accessibility/products/photoshop.html) that people with normal vision can use to approximate deuteranopia and protanopia (Frane, 2015). Nunez, Anderton, and Renslow (2018) have devised an open-source colormap called *cividis* that is useful for individuals with CVD and with normal vision because it "enables nearly-identical visual-data interpretation for both groups, is perceptually uniform in hue and brightness, and increases in brightness linearly" (p. 1). The only drawback is that the color spectrum is small, ranging only from blue to yellow. Kvitle (2018) asserts that while simulations of the perceptions of individuals with CVD are useful for normal vision approximations, they could be actually misrepresentations due to three factors: the simulations are generated from color theory algorithms, individuals with CVD comprise a largely variegated population, and simulations are generally image-type specific—designed exclusively for natural scenes or for graphic representations.

Two companies, 2AI Labs and EncChroma, have fielded color-correcting filter glasses to the public (De Paor et al., 2017). Chen and Liao (2011) designed a "high-speed field-programmable gate array device" (p. 71) that individuals with CVD can wear on their heads to enhance their perception of colors without the loss of luminance that color-correcting glasses cause because of their darkness. Melillo, et al., (2017) have also tested an advanced wearable "augmented reality" (p. 1) device for CVD correction. New applications for mobile phone cameras can help correct color for those with CVD in real time feeds (Maule & Featonby, 2016; Szczurowkski & Smith, 2018). In 2015, Tamura, Okamoto, Nakagawa, Sakamoto, & Shigeri investigated using Light Emitting Diode (LED) illuminations to provide better color access for individuals with deuteranopia. More recently, Flinkman and Nakauchi (2017) created an LED illuminator invention which enabled deutan individuals to pass the Ishihara plate test.

Previous Studies

The few previous studies extant about the concept of adapting students with CVD in educational contexts bear review. In addition, relevant investigations concerning the general topic of disability adaptations at the collegiate level are pertinent. Lastly, the topic of making adaptations for CVD through the systemic approach of Universal Design in university settings lends insight.

Color vision deficiency and learning. A few studies have chronicled the educational characteristics of individuals with CVD in comparison to individuals with normal vision. Some studies have reported conflicting results (Chan et al., 2014). Individuals with CVD can experience difficulties in accomplishing educational or classroom tasks (Chan, et al., 2014;

Kvitle, 2018). Difficulties may surface in various ways by subject (Chan, et al., 2014; Kvitle, 2018). In art, the student may choose inappropriate colors; in chemistry, the student may have difficulty identifying chemical test results and spectral colors (Chan, et al., 2014). In biological classes, the student may not be able to distinguish plant species, stained microscopic specimens, and graphic presentations; in physics, it may be difficult to identify wires and resistors by color and to use a prism (Chan, et al., 2014). In math and geosciences, the problem may be in the proper reading of maps, graphs, and charts; in physical education, individuals may not readily recognize color-coded targets or team uniforms (Chan et al., 2014).

Interestingly, many students remain ignorant of their CVD conditions, even to the point of when they leave secondary school. Kvitle (2018) reports that "twenty to 30 percent of adults" (p. 834) experiencing CVD do not realize their condition, and Cole (2007) adds that at least twice that number did not realize their condition while in school. Maule and Featonby (2016) have suggested that this fact could explain some of the difficulties of doing research in this field.

Furthermore, individuals with CVD can be reluctant to disclose their condition because they do not want to admit their foible or because they fear discrimination (Chakrabarta, 2018; Spalding, 1999). This tendency is not unique to individuals with CVD. Riddell and Weedon's (2014) case study of a university student reveals that even at the postsecondary level, there can be a reticence to disclose a disability. Only 35% of postsecondary students with disabilities will self-disclose their disability to their institution of higher learning (Newman & Madaus, 2014).

In their seminal research, Grassivaro Gallo, Panza, and Lantieri (1998) studied a control-matched group of adolescents with CVD. Using school marks as indicators of academic achievement, they found a statistically significant ($p < .01$) probability of less success in academic subjects for the students with CVD. Likewise, Suero et al., (2005) conducted studies at elementary levels that showed a lesser degree of achievement for students with CVD.

Perhaps among the most noteworthy of the studies concerning the effects of having CVD are the psychological ones. Maule and Featonby (2016) report that students with CVD feel less capable than students with normal vision. Even more revealing is the classic study by Espinda (1973) that showed a correlation between documented educational disabilities and the presence of CVD. Espinda (1973) found that the occurrence of CVD in students having documented disabilities was significantly higher ($p < .05$) than the general population. In addition, Espinda was able to correlate referrals for inappropriate behavior in the classroom to the presence of CVD. Maule and Featonby (2016) drew similar conclusions. In a study of 1,732 Malaysian primary school students, Thomas, Kaur, Hairol, Ahmad, and Wee (2018) also found that the students with CVD ($n=44$) had statistically significant higher scores for behavioral and emotional constructs on the Child Behavior Checklist for Ages 4-18. Although their CVD group was small, their findings intimate that students with CVD experience a higher incidence of behavioral and emotional problems in comparison to students with normal vision (Thomas et al., 2018). It is also conjectured that possibly weighing into the perspectives of students with CVD in secondary levels is the realization that certain professions are not possible for them (Chan et al., 2014).

Additionally, the effects of CVD appear to be differentially severe according to educational content in the primary and secondary levels of education and to professionally-oriented studies at the post-secondary level. Young children suffering from CVD are disadvantaged due to the prevalence of color use in classrooms (Chakrabarta, 2018; Grassivaro, 1998), resulting in less confidence and more frustration (Chan, et al., 2014). Although all visual representations, including computer-based educational tools, that make use of color can be sources of confusion (Collins, 2015), color is an especially difficult concept to broach with individuals having CVD when the color is actually part of the content, not merely representative of content ideas. This is particularly true of scientific content. Teachers intent on instructing students in the art of scientific observation depend heavily on the making of visual observations.

Several studies indicate that accurate assessment of color is critical to some scientific experiments and science-oriented careers (Chan et al., 2014; Szczurowkski & Smith, 2018). In medical school education, this phenomenon is particularly acute. Medical professionals can experience deleterious effects of their CVD condition during their education and their practices (Dhingra, et al., 2017; Goh, et al., 2014; Spalding, 1999), and narrow their specialty choices (Chakrabarta, 2018; Chan, et al., 2014). Medical students report having appreciable challenges in learning microbiology, histology, microscopy, and hematology (Goh, et al., 2014; Rubin, Lackey, Kennedy, & Stephenson, 2009). They also confided that the making of medical diagnoses was difficult without properly being able to discern skin and ear drum coloring (Goh, et al., 2014; Serrantino, Meeks et al., 2015). Khalid, Chughtai, Mian, and Shah (2017) point out that dentists rely on their red-green color discrimination to match dentine hues. As a result of many studies, researchers recommend the early screening and subsequent coaching of medical professionals in biomedical postsecondary institutions (Dhingra, et al., 2017; Dohvoma et al., 2018; Pramanik, Sherpa, & Shrestha, 2010).

The extant literature variously reports the effect of color on learning because of the variety of factors involved in the use of color for educational presentations, and the complexity of human processing. Clariana and Prestera (2009) confirm that colors used as background on digital screen-displayed lessons enhance memory in terms of structural knowledge. This is of specific note in postsecondary education because cognitive theory recognizes structural knowledge as “integral to learning and performing higher order mental operations like problem solving” (Jonassen, Beissner, & Yacci, 1993). In their study of digital presentations of natural scenes, Bredart, Cornet, and Rakic (2014) concluded that color enhanced the accuracy of recall for both individuals with and without CVD, suggesting that colors, even the aberrant colors that individuals with CVD perceive, affect cognitive processing. However, only the individuals with normal vision reported that they relied on color for remembering a scene (Bredart, Cornet, & Rakic, 2014).

Historical perspectives. In the United States, educational settings of the past were actually more conciliatory toward students with CVD because the use of color was not as generally available as it is today. For instance, an increase in the use of color in educational settings has complicated the plight of individuals with CVD (Kvitle, 2018; Maule & Featonby, 2016; Thomas et al., 2018) because colored markers on whiteboards or full color computer screens have replaced blackboards that had broad white chalk lines (Kvitle, 2018). It is arguable that advances in color printing and educational supplies have developed a need for reconsidering the legal necessity of mandating CVD adaptations (Torrents, Bofill, & Cardona, 2011). Lee (2010) confirms a doubling in the frequency of use of pictorial representations in texts during the last 50 years. Several researchers assert that the increased use of color in technology has increased the disparity in visual access for individuals with CVD (Jang, et al., 2010; Suetake, et al., 2012; Wu, et al., 2019).

Educator perspectives. Lastly, two particularly interesting studies that pertain to the vantage point of educators bear discussion. The first is the one conducted by Suero et al. (2005). In that study, they found that teachers perceived that students with CVD succeeded less in academic achievement than students with normal color vision, despite the fact that the students made similar scores on standardized tests (Suero et al., 2005). The most remarkable construct involved in that observation was the lack of a preconditioning knowledge—the teachers were ignorant of the color vision status of the students, and still evaluated the students with CVD as achieving less than the control group with no CVD (Suero et al., 2005).

A second point of interest emerges from a qualitative study of university students with disabilities by Morgado Camacho, Lopez-Gavira and Moriña Díez (2017). The students requested, among other things, more participatory input into their education (Morgado Camacho, Lopez-Gavira & Moriña Díez, 2017). The application to CVD is that there must be a point of awareness, and assent to adaptations. Teachers cannot involve their students more in their own instruction if CVD stands in the way (Collins, 2015).

Digital perspectives. Individuals with CVD face a variety of issues related to viewing color on their digital devices. Text representations, background colors (Clariana & Prestera, 2009), and photos all represent separate difficulties for individuals with CVD (Jang et al., 2010), as well as how adaptations meld with their previous perceptual knowledge and learning. Additionally, of paramount importance to digital viewing are illumination conditions (Alvaro et al., 2017; Bao et al., 2015). Various electronic transformations, including pixel remapping algorithms, have been developed to aid individuals in color discrimination on digital media (Bao et al., 2015; Hsieh et al., 2015; Jenny & Kelso, 2007; Nunez, Anderton, Renslow, 2018; Simon-Leidtke & Farup, 2016; Sutake et al., 2012; Wong, 2011; Wu et al., 2019; Yanagida et al., 2014). A major impediment to addressing this technologically is the fact that many individuals with CVD do not know the extent of their color deficiency (Jang et al., 2010). Jang et al. (2010) have developed a customizable compensation profile for the ICC standard device color file so that individuals with CVD can set their computers' display to produce a degree of color modification.

In their study, their interactive compensatory computer file helped around 50% of the participants with CVD to detect greater contrast of green and red. In addition, the modification also produced a three-dimensional effect. Unfortunately, neither this nor other adaptations work for movies (Jang et al., 2010).

Ribeiro and Gomes (2019) point out that this remapping approach can lead to color changes that are confusing in regard to perceptual learning and previous knowledge for individuals with CVD. Their research shows that when adapting content that is signage, science, or information oriented, using contour enhancement that retains the original CVD color perception is a satisfactory modification that preserves perceptual orientation and increases contrast. They also interpret their data to say that indoor and outdoor photos are better left without adaptation (Ribeiro & Gomes, 2019).

Disability Accommodations

Because this study proposes to investigate the attitudes of collegiate educators concerning making CVD adaptations, which are optional, it is useful to review the current state of postsecondary educators' attitudes toward accommodating disabilities, disability training, and concomitant educational supports. It is especially pertinent to ascertain what researchers report about their attitudes in regard to using UD because UD is the most often mentioned model for the implementing of CVD adaptations. Existing literature on how postsecondary instructors adapt for CVD is limited to medical andragogy. Meeks, Jain, and Herzer (2016) report the use of the following adaptations: switching from red to green laser pointers, replacing red with black for an emphasizing color, using high quality gray scale versions of color images, and allowing extended time for testing. Several researchers emphasize the use of counseling in medical education, both in instructional delivery and in professional specialty choice (Dhingra et al., 2017; Dohvoma et al., 2018; Meeks et al., 2016; Serrantino et al., 2015).

Postsecondary perspectives. Although the IDEA requires free appropriate public education (FAPE) for students through secondary school, no such requirement remains for postsecondary institutions. Under the ADA, postsecondary schools are only required to ensure that no discrimination based on disability occurs if they are accepting federal funds (Jaeger & Bowman, 2002). After a student presents documentation of a disability, postsecondary institutions must provide appropriate academic adjustments (Office of Civil Rights, 2011) that are tied to remediating the specific disability assessment (Jaeger & Bowman, 2002). For example, adjustments may include audio testing, copies of instructor notes, extended time for testing, or testing in a separate room. Unfortunately, since CVD is not approved as a disability, none of these adjustments are possible and furthermore, most of these standard accommodations would not help an individual with CVD (Maule & Featonby, 2016).

Two opposing alternatives for accommodating for disability in the postsecondary classroom surface: the medical approach, which gives the responsibility for receiving accommodations to the student to request and document, and the interactional social constructivist approach which requires the educational institution, as a component of society, to consider its responsibility to be accessible and usable to the greatest number of individuals (Johnson & Fox, 2003). The latter model hearkens to the call for inclusive education formulated in the IDEA and ADA, but with the major difference of an independent standard of accomplishment that is concomitant with postsecondary achievement that emphasizes making delivery adaptation, instead of major content modifications (Johnson & Fox, 2003). The available research presents a strong consensus for university faculty and staff training in order to initiate organizational changes that will positively influence attitudes towards disability accommodation. Murray, Lombardi, Wren, and Keys (2009) did a quantitative study of a university faculty's attitude about accommodating students with disabilities. They found that faculty members who had previously had training on disabilities had more positive attitudes (Murray, Lombardi, Wren, & Keys, 2009) about making accommodations. A follow-on study (Murray, Lombardi & Wren, 2011) showed similar results from 112 university staff members. Moriña, Cortes-Vega, and Moriña (2015) came to similar conclusions from their biographical-narrative study. The study of Dallas, Upton & Sprong (2014) supported and extended the extant knowledge concerning university faculty acceptance of disability accommodations, finding attitudinal differences according to identification of specific academic content area and years of teaching. They also report that the majority of the study's respondents desired training in the making of accommodations and UD (Dallas, et al., 2014).

Universal design. In the US, the Higher Education Opportunity Act of 2008 proffers UD for special educational settings (Rao et al., 2014). Moriña, et al. (2015) assert that universities need to mediate this movement toward UDL disability accommodation in higher education through policy changes and strategic planning. Fleming and Tonge (2018) argue for the same by pointing out that in order to handle the increasing numbers of students with disabilities, and that universities would benefit if they would act as organic unit in order to mainstream support for the disabled. They warn that university educational disabilities offices will no longer be able to handle the task alone (Fleming & Tonge, 2018). However, UD offers the hope that all students with disabilities can benefit from policy changes and instructor involvement at the postsecondary level. Furthermore, Moore, Smith, Hollingshead, and Wojcik (2017) point out that leadership commitment to UDL is vital for implementation to proceed to institutional levels. Garcia-

Campos, Canabal, and Alba-Pastor (2018) and Kvitle (2018) note that for UDL to gain usage, it must figure into teacher training competencies.

Universal Design for Learning (UDL) is a framework of instructional recommendations that encourages inclusiveness in educational settings by anticipating and preemptively planning for the needs of diverse learners (Garcia-Campos, Canabal, & Alba-Pastor, 2018). The adjective *universal* applies to this model of instruction in that its intent is to provide accessibility to all by providing multiple instructional modalities, in contrast to prescribing one solitary method that might prove successful to every student (Higbee, 2009). The three main thrusts to creating a UDL curriculum are "(1) representation, (2) action and expression, and (3) engagement" (Garcia-Campos et al., 2018, p. 2). Garcia-Campos et al. (2018) further categorize the tasks that arise from these principles as belonging to recognition, strategic, and affective networks. Although the recognition aspect is the most readily noted in the discussion of the effects of CVD, the strategic use of color, and the psychological effects of being color deficient, place each of these domains into the arena of affective educational engagement.

The UDI principle of perceptible information requires that course content be deliverable to all students, regardless of sensory disability, and amenable to assistive technology (Dukes et al., 2009). Rao, Edelen-Smith, and Wailehua (2015) describe this as "cognitive access" (p. 35). Deliverability can even include scripted descriptions of power point slides to preclude misunderstanding due to disability. In theory, the pro-active application of UDI principles to course design and implementation allows for responsiveness to various student disabilities while maintaining course standards and integrity (Scott, McGuire, & Foley, 2003). A study by Hall, Cohen, Vue, & Ganley (2015) does indicate that UDL in online settings improve outcomes for learning disabled students, and a study by Kumar and Wideman (2014) that applied UDL to a first-year undergraduate science course found that the resulting student reactions confirmed that students with and without disabilities benefit from a design that intentionally includes multiple means of representation, expression, and engagement. A later study by Rao, Edelen-Smith and Wailehua (2015) did confirm online students' appreciation for the options and instructor interactions that UDL provides, and a meta-analysis of 18 recent peer-reviewed journals by Capp (2017) indicated that using UDL is beneficial for all students. Carabajal, Marshall, and Atchison (2017) suggest that using UDL principles can increase the safety of students in laboratories.

Universal Design is not, however, a panacea. The King-Sears et al. (2015) study of high school chemistry students was inconclusive about the effect of UDL in engendering positive learning outcomes. Also of concern is the lack of cross-cultural settings with UDL implementations (Al-Azawei, Serenelli, & Lundqvist, 2016). Simulations of what individuals with CVD see are only one avenue for making design modifications possible. Researchers are inventing other creative methods to widen the accessibility of visual materials. Antarasena (2011) researched a creative approach to universal design that accommodated students who were blind, and included students with CVD. Antarasena's (2011) multisensory approach to the concept of color took the form of numbers instead of names for color values.

Educational supports. In the adaptation for CVD in educational settings, educational support arenas bear discussion (Collins, 2015). Among these are libraries, textbooks, and universal design of instruction. Libraries are places of import when it comes to disability access. In respect to how students with CVD experience libraries at the middle school level, the mixed methods research of Collins (2015) reveals some valid observations. Collins (2015) notes that in Virginia, the middle school librarians were unaware of the needs of CVD students and of possible methods to assure access to library offerings. The recommendations that evolved from this study are basic to all educational support, but are particularly critical in for that study's population. The study notes that librarian attitude is paramount, as is recognition of the roles that color plays in the school environment in sending messages to students, in providing a discriminator, and in evoking visual appeal (Collins, 2015). The use of color coding for differentiating hard copy resources and for computer-based resources can be particularly confusing if other cues are not present (Collins, 2015).

A similar, but more intransigent problem, lies in the lack of CVD consideration in textbooks (Maule & Featonby, 2016). A study that Torrents, et al. (2011) conducted reveals that the early elementary textbooks published for Spanish children need redesigning. A scientific colorimetric analysis of 24 mathematics textbooks and cataloging of their assignment activities revealed a nearly complete failure to adapt for the needs of students with CVD (Torrents, et al., 2011). Furthermore, the American Psychological Association's publication manual also does not mention writing with consideration to individuals with CVD (Frane, 2015).

Summary

The available research is clear that CVD is a complex condition that expresses itself in several varieties and degrees of affectation (Maule & Featonby, 2016). Equally clear is that no legal mandate exists to accommodate for CVD in the United States, at any level of education. However, of educational importance is the emerging evidence that color can be pivotal in evincing memory of structural knowledge, which is essential in engendering higher-level learning (Clariana & Prestera, 2009).

Researchers of attitudes towards disability accommodations at the university level report positive feedback, and desire for training, but ignorance of UD methodology (Dallas et al., 2014). Universal Design is a possible model for constructing adaptations for CVD because its broad approach responds to the intricacies of the condition (Collins, 2015). It moves a person from dependence into independence in accessing educational content. Its implementation is also legally prudent in that legislation restricts institutions from defining standards specifically for students with CVD because that would amount to regarding those individuals as having a disability (ADA, 1990). Universal Design obviates the need to direct adaptations to specific conditions, allowing many students equal access.

The gap that this study targeted was the lack of data concerning the attitudes of instructors in a private university towards adapting their teaching methods for students with CVD. Training for awareness of CVD and possible adaptation techniques need presenting. Moreover, Wong (2011) notes that taking into consideration the presentation of colors that confuse individuals with CVD is “good graphic design practice” (p. 441) because saturation and brightness also matter for all viewers. However, university policy makers first need sound research-based data in order to inform their decisions. Dallas et al. (2014) conducted a study similar to this proposed investigation that measured university faculty’s attitudes toward inclusive pedagogy for disabled students, but no research exists for examining faculty attitudes with reference to making adaptations for CVD in a private university context. This research supplies observations and analysis pertinent to that current void.

This investigation goal was to quantitatively characterize the attitudes of instructors toward adapting their teaching for students with CVD in a university setting. The static group comparison design included a professional development intervention by Karla Collins, PhD, that described CVD and potential UD adaptations. The independent variable was the group of collegiate educators—control or experimental, and the dependent variables were the seven constructs of concerns about CVD adaptations within the SoCQ (George, et al., 2013).

CHAPTER THREE: METHODS

Overview

The purpose of this study was to investigate the effect of an informational intervention on the concerns of faculty educators about adapting their instruction for CVD. This study arose from two problems: CVD correlates negatively with access in higher education (Chan, et al., 2014) and university students with CVD are not receiving instruction from faculty in a manner that is compatible with their physical condition, owing to the fact that it is not a recognized disability (ADA, 1990; IDEA, 2004). The significance of this study lies in its ability to address the gap in the research that describes the concerns of university faculty toward adapting for CVD and provides collegiate policy makers with research-based knowledge concerning the efficacy of professional development about making instructional adaptions for CVD using UD. This methods chapter describes the research design, the research question, the null hypotheses, the participants and setting, the instrument, the procedures, and the data analysis.

Design

This investigation used a static-group comparison design with a professional development intervention for the experimental group. This quantitative design was appropriate for several reasons. The static-group comparison design is preferable for attitudinal studies to preclude interference from test sensitization and familiarity. Campbell and Stanley (1963) assess this design as positive on the factors of history, testing, instrumentation, and regression; they assert that the design is flawed in respect to selection of participants, participant mortality, and interactions of selection upon the intervention. However, in this study, participant mortality was controlled by the online access to the intervention and the questionnaire, which was the observation instrument. In order to limit the effects of current events, the time allotted for the study was limited to weeks. The most evident criticism of this design is the lack of a pretest to establish the validity of the control group for comparison purposes. In addition, the generalizability of the results is limited to educationally similar contexts.

The purpose of this design was to produce actionable knowledge using empirical methods which measure, with specificity, the effects of a professional development intervention describing CVD adaptations. Because leaders affect organizational culture when determining policy decisions (Hall & Hord, 2011), such specificity gives university administrators the potential to develop an organizational stance using an evidence-based practice (Gall, Gall, & Borg, 2015). The participants in this research were limited to the pool of available and compliant educators at the setting university, and therefore, were not entirely randomly selected. In addition, the researcher could not guarantee random assignment of the participants within the demographic categorical groups (Gall, Gall, & Borg, 2015). Nevertheless, within these constraints, as in the Shah, Isaia, Schwartz, and Atkins (2019) study, the assignment of participants was guided by randomization procedures.

The researcher manipulated the condition of CVD adaptation knowledge by supplying an intervention training to a randomly assigned half of the sample. Comparison of the questionnaire results between the intervention and the control groups provided the opportunity to quantify the effect of the intervention, accounting for any intervening effects for the participant groups as a whole (Campbell & Stanley, 1966). Although the control group observation attempted to prevent an unidentified variable from influencing the questionnaire results, it stopped short of providing a true pre-observational measurement of faculty attitudes for the intervention group. However, having the intervention followed by the questionnaire for the experimental group, and delivered during the same time period as the control group's questionnaires, does support tentative conclusions about the effect of professional development on the attitudes of educators. The static-group comparison research design is illustrated in Table 3 (Campbell & Stanley, 1963).

Table 3

Research Design

Static-Group Comparison Design	
X[b]	O[a]
	O[a]

[a]Observation
[b]Intervention

The independent variables are categorical: the control group or the experimental group of collegiate educators. The dependent variables are the educators' responses on the seven constructs of concerns within the SoCQ about the innovation of CVD adaptations (George et al., 2013).

Research Question

RQ: Is there a difference in the concerns of university faculty and administrators about making adaptations for students with color vision deficiency between those faculty and administrators who have received a professional development intervention about making such adaptations as compared to those faculty and administrators who have not received the intervention?

Null Hypotheses

$H_0$1: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to

Stage 0 items on the Stages of Concern Questionnaire.

$H_0$2: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 1 items on the Stages of Concern Questionnaire.

$H_0$3: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 2 items on the Stages of Concern Questionnaire.

$H_0$4: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 3 items on the Stages of Concern Questionnaire.

$H_0$5: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 4 items on the Stages of Concern Questionnaire.

$H_0$6: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 5 items on the Stages of Concern Questionnaire.

$H_0$7: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 6 items on the Stages of Concern Questionnaire.

Participants and Setting

The researcher drew the participants for the study from a convenience sample of faculty from a university in the Southeast of the United States during the 2019-2020 school year. For the purposes of this study, a faculty member was defined as an individual who instructs students for academic purposes at any level of the setting university, graduate or undergraduate. This study also incorporated administrators who instruct classes. This participant pool included all those with status as a full or part time instructor, whether instructing in traditional face-to-face classrooms or in online contexts. The questionnaire was fielded in February of 2020 at the setting university and had a 36% return rate.

The setting university is a rural one that boasts accreditation by the Commission on Colleges of the Southern Association of Colleges and Schools (SACS) and associates with the Southern Baptist Convention. It offers online and residential courses in undergraduate and graduate degree programs. The university confers undergraduate degrees in the academic areas of science, math, business, Christian studies, communication, education, fine arts, and the humanities. The graduate programs offer Master's degrees in business, education, ministry, and a medical program granting physician's assistants diplomas. The university offers several cooperating degrees with other local universities, including ones in nursing and engineering. The existence of a medical program master's degree (physician's assistant) lends this study another point for comparison with extant medical pedagogy studies that address adaptations for CVD. The student population is approximately 2,500, with online, commuter, and residential students. A list of the racial demographics for the school population is in Table 4. The sampling procedure included a mass faculty email inviting volunteer participation by willing full time and part time faculty. The final sample size was 98, as determined by the number of volunteers and their ultimate attrition in the intervention group. The goal for the total number of participants in the study was 100, divided equally between the experimental intervention group and the control group. This goal exceeded the number that Warner (2013, p. 209) prescribes as the minimum number of participants necessary. The population accessible to the researcher was the faculty and teaching administrators of the setting university, both full time and part time, which consists of 276 faculty—139 male and 137 female.

Table 4

Racial Statistics of Setting University

Characteristic		University 2018[a]	United States Census 2016[b]
Race	Black	7%	13%
	Asian	1%	6%
	White	78%	77%
	Hispanic	3%	18%
	Native American	0.4%	1.3%

[a] As supplied by the university administrator
[b] United States Census Bureau (2016, July 1). Retrieved May 13, 2018, from http://www.census.gov/quick facts/fact/table/US/PST045216

The frequencies for the participant groups are shown in Table 5. The two participant groups were extremely similar. The demographic characterization of the participants is nearly identical for the control and experimental groups, making the comparison of their responses optimally valid. The preponderance of the participants were face-to-face instructors teaching science or math with teaching loads over 12 hours; they reported that they have ten or more years of teaching experience, are Caucasian, had no prior knowledge of CVD adaptations, and are 41-69 years of age.

The participants in this study were not entirely randomly selected. The participants were volunteers from a limited pool of available and compliant educators at the setting university. Participants were a convenience sample of volunteers who answered the recruitment email. However, random assignment was made into the control or experimental groups. Nevertheless, within these constraints, as in the Shah, Isaia, Schwartz, and Atkins (2019) study, the assignment of participants to the two groups was guided by randomization procedures.

Table 5

Participant Groups Frequency Comparison

Characteristic	Control	Experimental
Participants (*n*)	49	49
Age		
21-40 years	11	12
41-69 years	36	35
Program		
Undergraduate	44	46
Graduate	5	3
Face-to-face delivery	46	42
Instruct for Humanities	10	10
Instruct for Science/Math	17	14
Teaching status		
Full time overload	23	28
Full time no overload	14	14
Over 10 years teaching experience	35	32
Race		
Caucasian	45	46
Black	1	1
Hispanic	1	0
Asian	2	0
Other	0	2

Intervention

The intervention consisted of three short video clips by Karla Collins, PhD, of Longwood University and an adaptations resource describing adaptations and offering answers to frequently asked questions. Collins is a published researcher and presenter on color vision deficiency in educational settings. The videos explained the nature of CVD, the framework for CVD adaptions using UD, and gave specific techniques for making adaptations for the classroom that allow students with CVD to enjoy equal access to instructional materials (See Appendix A). The videos are available on You Tube at https://youtu.be/JlimMDJV_hw, https://youtu.be/rV2fZ12muIs, and https://youtu.be/BBhyMmgl1DM, and those links were sent to the experimental group participants via email, along with a pdf file of the adaptations resource. The adaptations resource was also available in hardcopy to all participants upon request after the conclusion of the study.

The intervention was tailored for this investigation into the changing of educators' attitudes towards adapting for CVD. It met the standards of good practice extant in research about professional development directed toward influencing instructor attitudes (Zepeda, 2019) and corresponded to the conceptual bases for measuring and implementing change by focusing on UD and the principle constructs of the Concerns Based Adoption Model (CBAM). The intervention video presentations by Collins related the pertinent facts about UD and the nature of CVD, presenting compelling knowledge about the needs of students with CVD. Zepeda (2019) states that adult "learners become ready to learn when they experience a need to know something to perform more effectively" (p. 3). Collins used anecdotes and engaging interactive games to help the instructor participants to experience the CVD condition and to develop empathy, all of which Zepeda (2019) notes as basic principles of adult training. Lastly, the asynchronous digital nature of the intervention permitted the instructor participants the flexibility that Zepeda (2019) says that adult learners value. Therefore, by design, it aligned with how Bullard, Rutledge, and Kohler-Evans (2017) describe effective professional development—"data-driven" and "engaging" (p. 51).

The research about the effect of instructor training is confirming. Murray, et al. (2009) report that college instructors with "some form of training" (p. 97) registered better attitudes toward making accommodations for students with disabilities. In their study of sixteen instructional development trainings between 1978 and 2007 which were aimed at impacting the attitudes of instructors in higher education, Stes, Min-Leliveld, Gijbels, and Van Petegem (2010) report overwhelmingly positive results. They also indicate that workshop-type training is suitable for "training on concrete techniques" (Stes, et al., 2010, p. 27), which corresponds to the type and subject of this intervention. As for the delivery means, a study done by Bitan-Friedlander, Dreyfus, and Milrom (2004) also reported positive results from training that was administered through computers, and evaluated with the SoCQ.

The inclusion of instruction about UD in the intervention provided a rationale for preemptively adapting instruction for students with CVD. This video module places the proposed innovation within the context of a widely accepted approach for establishing equity of access for all students. Dallas et al., (2014) report that training in the concept of UD engenders the likelihood of using it in the classroom to serve postsecondary students with disabilities.

The choice of the framework of the CBAM "allows assurance that potential actions can be taken to facilitate successful change" (Bullard, Rutledge, & Kohler-Evans, 2017, p. 51). The intervention training targeted the first two constructs of the CBAM that address knowledge with awareness and information. These two constructs are the basic essentials on the theoretical continuum of the stages that an individual experiences when adopting change. Reio (2005) concurs that information is vital to combat pessimistic feelings toward a proposed innovation. Murray et al. (2009) report similar findings about the primacy of knowledge in influencing instructors' feelings about accommodating for learning disabilities. This intervention supplied the instructors' need of information about the nature and prevalence of CVD and about possible instructional adaptations. Allowing instructors to see how CVD affects their students under non-adapted, normal conditions during the intervention gave the educators an appreciation for how their students might struggle. Christesen and Turner (2014) assert that instructors are more likely to support change if they believe that the innovation will help their students.

The intervention training featured choice by offering several simple methods for adapting instructional material for students with CVD. In addition, the training made it clear that even the decision to make adaptations is completely optional due to the lack of a legal mandate. Christesen and Turner (2014) report that instructors value choice in how they implement innovations and are predisposed to be more favorable to innovations when choices are available. Zepeda (2019) concurs, noting that professional development is best self-directed. The simplistic solutions also met the requirement of minimal instructor burden for instructor implementation, which is important to the decision to implement an innovation according to Christesen and Turner (2014).

Instrumentation

The instrument for this study was Hall, George, and Rutherford's (1977) Stages of Concern Questionnaire, as revised for online distribution by George, Hall, and Stiegelbauer (2013), and the programmer for the online version, Brian Litke (George, et al., 2013). See Appendix B for SEDL license agreement. It was able to quantify the concerns of the educators towards the innovation of making adaptations for students with CVD, with and without a professional development training. The instrument grew out of issues of change implementation in education in the 1960s and 1970s and originated from the Southwest Educational Development Laboratory (SEDL), Austin, TX (George, et al., 2013). The SEDL organization, owners of the instrument, merged with American Institutes for Research (AIR) in 2015 (AIR, 2019). This section of the dissertation addresses the background, description, statistical reliability, and validation of the instrument.

Background

This instrument has seen frequent and varied usage since its first development by Hall et al. (1977). Recently, Burke, Schuck, Aubusson, Kearney, and Frischknecht (2018) used it to quantify the concerns of Australian teachers in adopting classroom technology. Bullard et al. (2017) used the SoCQ to study professional development in teacher candidates. Berg, LoCurto, and Lippoldt (2017) used it to study the adoption of technology by nurses. Bogue, Marrs, and Little (2017) used it to quantify school psychologists' concerns with responsiveness to intervention (RTI) programs. Chen and Jang (2014) compared the SoCQ results with the technological, pedagogical, and content knowledge of Taiwanese high school instructors. In studies with aspects similar to this proposed one, Christesen and Turner (2014) used the SoCQ to quantify the attitudes of educators attending a professional development program, and Al-Furaih, and Al-Awidi (2018) used the SoCQ to quantify educators' readiness to employ smartphones in the classroom.

This instrument was appropriate because it can quantify specific expressions of concern (George et al., 2013) about an educational innovation—in this case, adapting for CVD in the educational practices of collegiate instructors. The instrument was suitable for gleaning information about faculty attitudes towards implementing CVD adaptations because the instrument is capable of identifying degrees of progression towards acceptance of the use of adaptations for CVD in general classroom teaching.

The SoCQ is one of the integral parts of the Concerns Based Adoption Model for organizational change. This model proposes that when persons engage in innovations, they theoretically progress through stages of concern as they implement an innovation (George et al., 2013). However, Hall, and Hord (2011) point out that when one views change as an event, the theoretical progression through the constructs of concern is not as clear. These constructs of concern in ascending theoretical order begin with the informational stage (concern stage 0) where the individual indicates little concern about or involvement with the innovation, accounting for participant attitudes of irrelevance towards the innovation. The second stage in the progression is the individual stage (concern stage 1), where the individual indicates a general awareness of the innovation. The third stage is the personal stage (concern stage 2), where the individual is uncertain about the demands of the innovation, his or her adequacy to meet those demands, and/or his or her role with the innovation. The fourth stage is the management stage (concern stage 3), where the individual focuses on the processes and tasks of using the innovation and the best use of information and resources. These issues relate to efficiency, organizing, managing, and scheduling. The fifth stage is the consequence stage (concern stage 4), where the individual focuses on the innovation’s impact on students in his or her immediate sphere of influence. The sixth stage in the progression (concern stage 5) is collaboration, where the individual focuses on coordinating and cooperating with others regarding the use of the innovation. The seventh stage in the progression (concern stage 6) is refocusing, where the individual focuses on exploring ways to reap more benefits from the innovation, including the possibility of making major changes to it or replacing it with a more powerful alternative. The seven progressive stages separate into four divisions: "unconcerned, self, task, and impact" (George et al., 2013). The unconcerned division reflects the degree to which the innovation seems irrelevant to the participant. The self division measures attitudes that are informational in nature and personal factors. The division that the instrument describes as task is management. The impact division measures attitudes as consequence, collaboration, and refocusing factors.

Description

The SoCQ is an attitudinal scale that quantifies the issues and degrees of concerns that individuals have with innovations. The SoCQ consists of 35 statements, five per stage of concern, with a Likert-like scale of eight values, 0 to 7, that quantify the respondent's agreement with the statement. The authors of the instrument permit researchers to add participant demographic questions, and the researcher did add demographic discriminators. The scales content is as follows: 0 records a participant response of "irrelevant;" 1 or 2 records a response of "not true of me now;" 3, 4 or 5 records a response of "somewhat true of me now," and 6 or 7 records a response of "very true of me now" (George, et al., 2013). The individual concern stage raw score sums for the five items per stage range from 0 (unconcerned) to 35 (very concerned). The instrument was capable of identifying degrees of acceptance for the innovation—in this case for acceptance of using adaptations for CVD in their general classroom teaching since the CBAM theory predicts an increase in the latter two constructs when the concerns of the self construct are addressed. The results were also predictive of which policy or leadership actions might well encourage acceptance of the innovation (Hall & Hord, 2011).

Statistical Reliability and Validity

The SoCQ is an instrument of demonstrated measurement excellence. Its initial fielding included a pilot study and a qualitative check (George, et al., 2013). Several cross-sectional and longitudinal studies affirmed the content and predictive validity of the instrument (George, et al., 2013). The researchers addressed content validity (N = 363) and found an 83% correlation for the total score on the instrument, a 72% correlation for the stage scores (George, et al., 2013). Several other studies confirmed the construct validity of the instrument as a whole to track changes in concerns in relation to the tenets of the CBAM. In these studies, the "test/retest reliabilities range from .65 to .86" (Hall & Hord, 2011, p. 80), and the "alpha coefficients range from .66 to .83" (Hall & Hord, 2011, p. 80), demonstrating internal consistency.

Procedures

The procedures for this study follow the requirements of Liberty University. First, the researcher developed a prospectus and proposal. After submitting the proposal, the researcher defended the proposal for approval, acquired permissions from the setting university and SEDL (Appendix B), and submitted the Institutional Review Board (IRB) application for official approval from Liberty University and the setting university. Upon approval from both IRB's (Appendices C and D), the researcher executed the proposed research plan. The following narrative outlines the procedure used for executing the research plan, along with the protocol for maintaining the security of the data and the confidentiality of the participants.

Research Procedure

The researcher purchased the use of the SoCQ. The researcher purchased 100 SoCQ online questionnaires from the SEDL website (http://www.sedl.org/pubs/index.cgi?searchfor=SoCQ&l=search), and secured copyright permission and access for the interpretation of the data. At the SEDL website, the researcher set up a username and password, and named a cohort each for the intervention and control faculty groups for a total of two cohorts. The intervention group received the intervention training via email and U-Tube and then took the SoCQ. The control group simply took the SoCQ during the same time period as the intervention group.

This process also necessitated two introductory emails (Appendix E) and two selection emails (Appendix F) that invited the faculty member or administrator, randomly assigned, to participate in either the control or the intervention group. The setting institution sent the emails from an approved sender of the list serve, as required by the policy of the setting institution. A statement in the email also assured the participant that there was no implied or expressed compulsion for initial participation or continued participation in the intervention or in filling out the questionnaire. The email contained a password and link to the assigned cohort, in addition to a description of the research. A privacy statement informed the participant of the confidentiality of their responses, in accordance with the Privacy Act of 1974, both by the researcher and SEDL (SEDL, 2019). The email also contained a consent form attachment, and described the offer of a token $10 gift card, given in gratitude to the participant for participating. The email's link to the SEDL website automatically brought the participant to the appropriate cohort of the SoC questionnaire.

Within each cohort, the researcher set up introductory texts, sample instructions, and a thank you text that was included with each fielding of the questionnaire. The researcher entered the name of the intervention for inclusion into the questionnaire verbiage as "adapting instruction for color vision deficiency." The researcher set up custom prompts that queried the participant for the demographics of building/program identity, hours of teaching overload (teaching more than 12 hours of class load), department of teaching, race, age bracket, familiarity with CVD adaptations, and years of teaching experience. In addition, the researcher added discriminator responses for collegiate level (graduate or undergraduate), classroom delivery (onsite or online), and medical or non-medical program.

The researcher set up the option to have response notifications sent directly by email to her. The data collection and analysis by SEDL operated in real time, giving the researcher the opportunity to assess the rate of participation. Finally, the researcher set the closing date for both of the cohorts to be approximately three weeks after the sending of the questionnaires to the intervention and control groups. The researcher had the capability to download the raw data in an Excel® spreadsheet format without participant identifiers at any time (George, et al., 2013).

Karla Collins, PhD, of Longwood University, a published researcher and presenter on color vision deficiency in educational settings, presented the faculty interventions in the form of three prerecorded video professional development presentations via YouTube links in the selection emails (Appendix F). In addition, the researcher created, in coordination with Collins, an electronic version of the hardcopy adaptations resource (See Appendix G) that the participants in the experimental group received attached to the same email as the intervention links. The adaptations resource described the CVD condition, adaptations based on the theory of universal design, and web resources for evaluating presentation material in light of CVD. The intervention group received a selection email with the link to the presentations and adaptations resource with a request to view all the contents of the videos and the resource before clicking on the link to the intervention cohort of the SoCQ questionnaire housed at SEDL. The control group received the selection email with only the link to their cohort of the SoCQ questionnaire housed at SEDL. After permitting participants time to enter their responses, the researcher made a final Excel® file download to conduct statistical analyses with the SPSS® program, as the approved proposal prescribed, and received the profile analyses from SEDL.

Data Security and Confidentiality

The researcher provided a design for the security of the data and the confidentiality of the participants. The questionnaire data is secure for several reasons. The researcher could assure the participants that the acquired data remained confidential because the researcher only disclosed group results, and because the researcher did not retain personally identifiable information with the data sets. The privacy policy of SEDL prevents their use or dissemination of the data in unauthorized ways (SEDL, 2019), in accordance with the Privacy Act of 1974. Furthermore, the nature of the inquiry precluded the possibility of negative consequences for the participants—neither the law nor educational practice mandates adaptations for CVD. The researcher stored data sets and analyses on a password protected computer. Lastly, the researcher pledges to destroy the data by March of 2023.

Data Analysis

To assess the effectiveness of the intervention training in changing the concerns of faculty about adapting for CVD, the SoCQ data for the control and experimental groups were compared. The means of the summed raw scores for each participant's Likert data for each concern construct were analyzed for differences using *t* tests. The experiment-wise significance level was set at an alpha of .05 for statistical considerations; however, the alpha for the *t* test comparisons was set to .10 and adjusted to .014 using the Bonferroni procedure by dividing .10 by 7, the number of *t* tests that were conducted. The Bonferroni procedure is a conservative statistical technique to reduce the possibility of making a Type I error when a study uses several *t* tests (Warner, 2013).

Researchers and statisticians have debated the appropriateness of using parametric tests for Likert data for decades. The choice of a *t* test for the comparisons of the Likert derived raw score means for the intervention and control groups was appropriate for several reasons. The *t* test is highly robust. Rovai, Baker and Ponton (2013) state that *t* tests can still yield accurate *p* results despite a lack of homogeneous variance and normality. The assumption of homogeneity of variance can be violated, given the groups' response curves do not show extreme variations in skewness. Deviation from normality can also be acceptable if sample sizes do not vary, and Miller (as cited in Rovai et al., 2013) reports that responses can differ up to "standard deviation ratios of 2" (Rovai et al., 2013, p. 292). Carifio and Perla (2008) insist that Likert data consisting of sums of associated Likert items are legitimately assessed by parametric measures because such data "can approximate ratio data, in theory and actuality" (p. 1150). Furthermore, in their parametric treatment of Likert data, Miricioiu and Atkinson (2017) concluded "that with 'large' (>15) numbers of responses and similar (but clearly not normal) distributions from different subgroups, parametric and non-parametric analyses give in almost all cases the same significant or non-significant results for inter-subgroup comparisons" (p. 26). Cohen's *d* was used to calculate the effect size for the *t* test results. It has the advantage of being easily relatable to the scale of the questionnaire because it can be understood in terms of the standard deviation of the data (Rovai et al., 2013).

These tests require an assumption of random sampling and independent observations, if the results are to be generalizable (Rovai et al., 2013). Because the sample was a convenience sample from one university, the results are cautiously generalizable only to similar settings and participant groups. Prior to analyzing the data for a relationship to the null hypotheses, the researcher addressed all assumptions for sample, variables, observation independence, and sample size for each test. In addition, the researcher conducted data screening to detect inconsistencies and outliers, and for logical indications from the demographic data that the convenience sample deviated from expected randomness in group assignment and participation.

CHAPTER FOUR: FINDINGS

Overview

The findings of this study describe the data from the Stages of Concern Questionnaire (SoCQ) that were collected to ascertain whether training changed the experimental instructor group's attitudes about making adaptations for color vision deficiency (CVD). The SoCQ is designed to measure the constructs of the Concepts Based Adoption Model (CBAM) which seeks to explain the development of participant concerns during organizational change. The informational training intervention was delivered digitally and consisted of an informational document module plus three video presentation modules that were developed by Karla Collins, PhD, of Longwood University. The core content presented in the intervention described the nature of CVD, the advantages for using Universal Design (UD) to adapt for it, and options for classroom adaptations. This analysis compares the means of the concerns stage sums using an independent samples *t* test between the control and experimental groups. These findings are arranged into a descriptive statistics section, including a description of the participants, and a results section, which articulates the inferential statistics that address the null hypotheses.

Research Question

RQ: Is there a difference in the concerns of university faculty and administrators about making adaptations for students with color vision deficiency between those faculty and administrators who have received a professional development intervention about making such adaptations as compared to those faculty and administrators who have not received the intervention?

Null Hypotheses

$H_0$1: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 0 items on the Stages of Concern Questionnaire.

$H_0$2: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 1 items on the Stages of Concern Questionnaire.

$H_0$3: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 2 items on the Stages of Concern Questionnaire.

$H_0$4: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 3 items on the Stages of Concern Questionnaire.

$H_0$5: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 4 items on the Stages of Concern Questionnaire.

$H_0$6: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 5 items on the Stages of Concern Questionnaire.

$H_0$7: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 6 items on the Stages of Concern Questionnaire.

Descriptive Statistics

Descriptive statistics were obtained on the dependent variables, raw concern score sums, for each group within each stage of concern. The descriptive statistics are listed in Table 6.

Table 6

Descriptive Statistics

Stage	Group *	Mean	Std. Deviation
Stage 0	Control	19.02	6.654
	Experimental	16.31	6.305
Stage 1	Control	20.31	7.531
	Experimental	18.20	6.137
Stage 2	Control	17.18	9.393
	Experimental	15.71	7.348
Stage 3	Control	10.88	5.596
	Experimental	12.59	5.733
Stage 4	Control	14.43	9.062
	Experimental	17.04	5.443
Stage 5	Control	14.14	8.566
	Experimental	14.18	6.227
Stage 6	Control	9.22	6.491
	Experimental	15.29	4.632

[*] For each participant group $n = 49$

Results

The null hypotheses considered the difference of concerns between two faculty groups, control and experimental, about making adaptations for CVD in their teaching. The data for the *t* tests were analyzed by comparing the participants' sums of the five items for each concern stage. The SoCQ uses the sums of the five items per stage of concern, which are statistically reliable in ascertaining a value representative of the one construct, to determine group collective response to the concern construct under consideration. This way of handling the raw avoids the pitfall of defining the average of the group's responses as a decimal equivalent of the response range represented by Likert numbers. The range of raw score sums for each of the participant's responses per construct stage is essentially 0 to 35—the highest possible Likert response of 7 times the number of items per construct stage, which is 5.

The means of the sums of the raw scores for each stage for the control and experimental groups were compared using Independent Samples *t* Tests. Using the sums of the raw scores enabled the data to be treated as interval measurements for the Independent Samples *t* Tests. It also brought about an enhanced sensitivity that enabled a more nuanced evaluation. Statistical significance was set to .05 for the study, with the exception of an alpha level of .10 for the *t* tests. The alpha level of .10 was further restricted to a significance level of $p < .014$ by using the Bonferroni correction that calls for dividing the alpha level by the number of t tests, which in this case worked out to be .10 by 7. The Bonferroni procedure is a conservative statistical treatment to reduce the possibility of making a Type I error when a study uses several *t* tests (Warner, 2013).

Null Hypothesis One

$H_0$1: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 0 items on the Stages of Concern Questionnaire.

Data screening. Data screening was conducted on each group's dependent variable. The researcher sorted the data on each variable and scanned for inconsistencies. No data errors or inconsistencies were identified. Box and whisker plots were used to detect outliers on each dependent variable. No outliers were identified. See Figure 1 for box and whisker plots for control and experimental groups for stage 0 score sums.

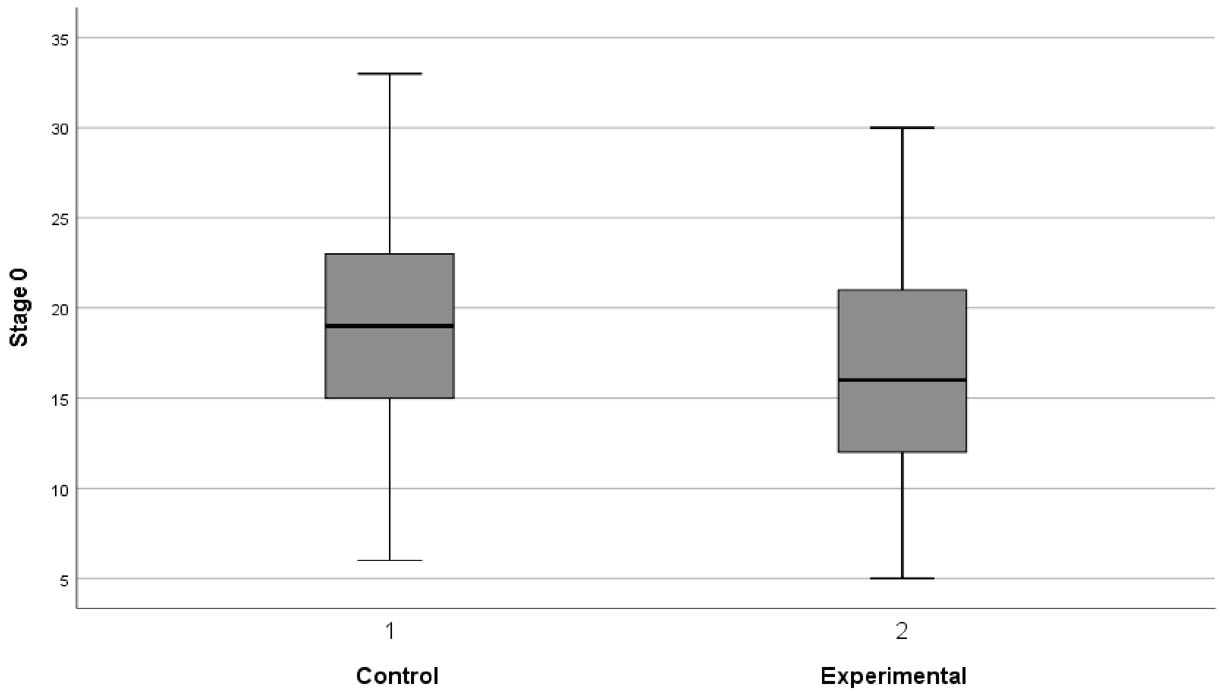

Figure 1. Stage 0 Raw Score Sums Data Box Plot.

Assumptions. An Independent Samples *t* Test (*t* test) was used to test the null hypothesis. The *t* test requires that the assumptions of normality and homogeneity of variance are met (α = .05). Normality was examined using a Shapiro-Wilk test because the sample size was less than 50. No violations of normality were found. See Table 7 for Tests of Normality.

Table 7

Tests of Normality for Stage 0 Score Sums

Group	Shapiro-Wilk Statistic	*df*	Sig.
Control	.971	49	.275
Experimental	.976	49	.416

The assumption of homogeneity of variance was examined using the Levene's test. No violation was found where $p = .933$. The assumption of homogeneity of variance was met.

Results for null hypothesis one. A *t* test was used to test the null hypothesis regarding differences in SoCQ stage 0 score sums between control and experimental groups at a southeastern university. See Table 8 for the SPSS output. Equal variance was assumed. The null hypothesis was not rejected ($\alpha = .014$) where $t(96) = 2.073$, $p = .041$, 99% CI [-.727, 6.156], and $d = +.42$. The effect size was medium (Warner, 2013). Due to the Bonferroni correction, the results for this stage were not considered significantly different for the control and experimental groups comparison. The control group ($M = 19.02$, $SD = 6.654$) did not have significantly different raw score sums than the experimental group ($M = 16.31$, $SD = 6.305$) did when responding about their "concern about or involvement with" (George et al., 2013, p.8) implementing adjustments for color vision deficiency in their instruction.

Table 8

Results for t Test for Stage 0 Score Sums

t	*df*	Sig. (2-tailed)	Mean Difference	SE Difference	99% CI of Difference Lower	Upper
2.073	96	.041	2.714	1.310	-.727	6.156

Null Hypothesis Two

$H_0$2: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 1 items on the Stages of Concern Questionnaire.

Data screening. Data screening was conducted on each group's dependent variable. The researcher sorted the data on each variable and scanned for inconsistencies. No data errors or inconsistencies were identified. Box and whisker plots were used to detect outliers on each dependent variable. No outliers were identified. See Figure 2 for box and whisker plots for the control and experimental groups for stage 1 score sums.

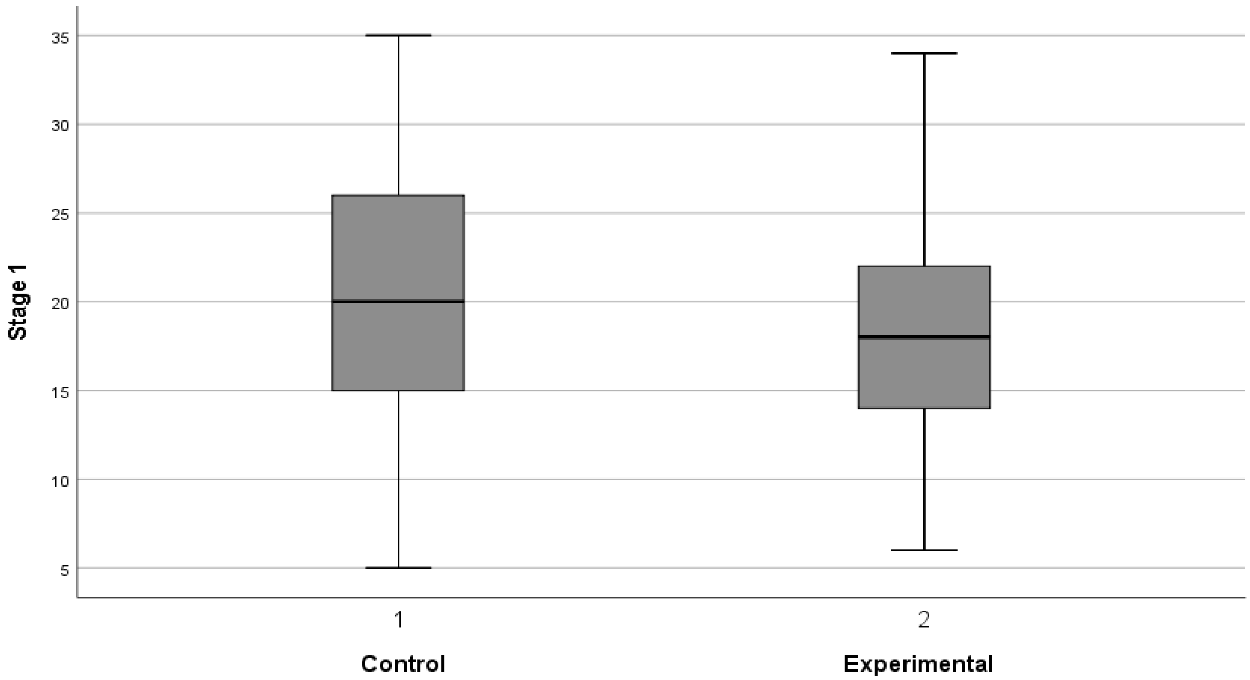

Figure 2. Stage 1 Raw Score Sums Data Box Plot.

Assumptions. An Independent Samples *t* Test (*t* test) was used to test the null hypothesis. The *t* test requires that the assumptions of normality and homogeneity of variance are met (α = .05). Normality was examined using a Shapiro-Wilk test because the sample size was less than 50. No violations of normality were found. See Table 9 for Tests of Normality.

Table 9

Tests of Normality for Stage 1 Score Sums

	Shapiro-Wilk		
Group	Statistic	*df*	Sig.
Control	.983	49	.714
Experimental	.988	49	.885

The assumption of homogeneity of variance was examined using the Levene's test. No violation was found where $p = .110$. The assumption of homogeneity of variance was met.

Results for null hypothesis two. A *t* test was used to test the null hypothesis regarding differences in SoCQ stage 1 score sums between control and experimental groups at a southeastern university. See Table 10 for the SPSS output. Equal variance was assumed. The null hypothesis was not rejected ($\alpha = .014$) where $t(96) = 1.515$, $p = .133$, 99% CI [-1.545, 5.749], and $d = +.31$. The effect size was medium (Warner, 2013). The control group (M = 20.31, SD = 7.531) did not have significantly different raw score sums than the experimental group (M = 18.20, SD = 6.137) did when responding about their concern about, or interest in, learning (George et al., 2013) about implementing adjustments for color vision deficiency in their instruction (stage 1).

Table 10

Results for t Test for Stage 1 Score Sums

t	*df*	Sig. (2-tailed)	Mean Difference	SE	99% CI of Difference	
				Difference	Lower	Upper
1.515	96	.133	2.102	1.388	-1.545	5.749

Null Hypothesis Three

H_03: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 2 items on the Stages of Concern Questionnaire.

Data screening. Data screening was conducted on each group’s dependent variable. The researcher sorted the data on each variable and scanned for inconsistencies. No data errors or inconsistencies were identified. Box and whisker plots were used to detect outliers on each dependent variable. Two outliers were identified for the experimental group. See Figure 3 for box and whisker plots for control and experimental groups for stage 2 score sums.

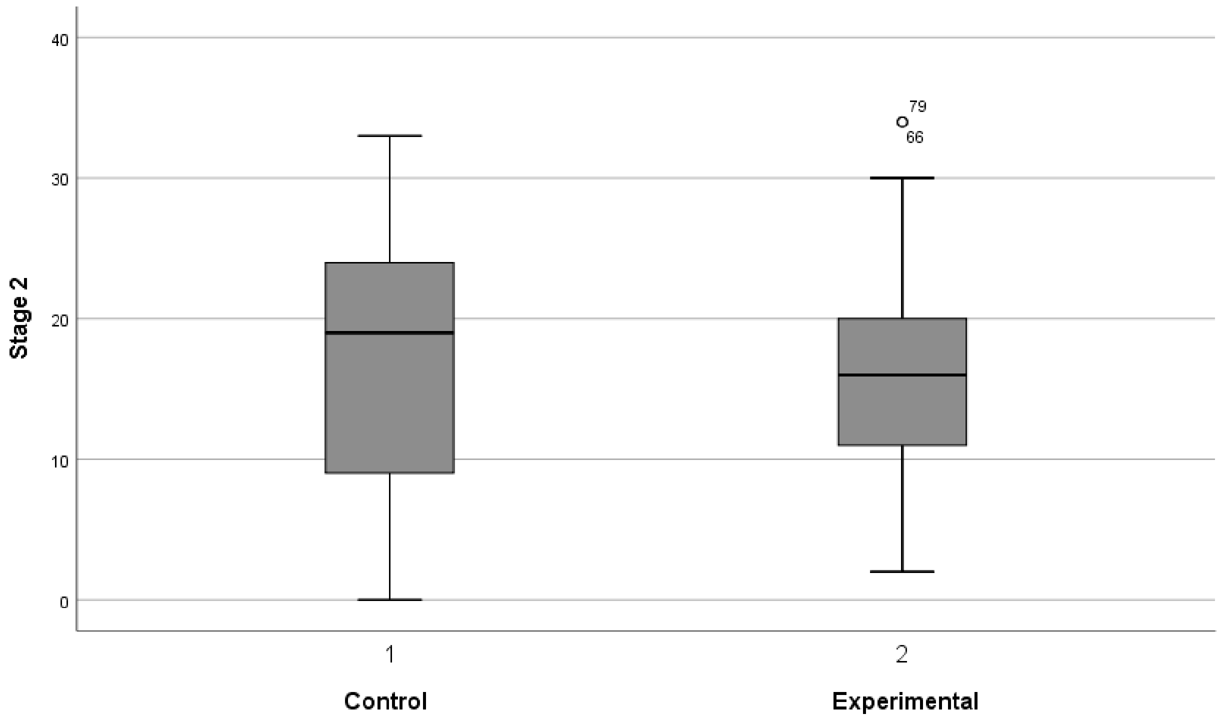

Figure 3. Stage 2 Raw Score Sums Data Box Plot.

Assumptions. An Independent Samples *t* Test (*t* test) was used to test the null hypothesis. The *t* test requires that the assumptions of normality and homogeneity of variance are met ($\alpha = .05$). Normality was examined using a Shapiro-Wilk test because the sample size was less than 50. The control group score sums were not normally distributed; however, with skewness of -.149 (*SE* = .340) and kurtosis of -1.129 (*SE* = .668), the distribution does not significantly deviate from normal. See Table 11 for Tests of Normality.

The assumption of homogeneity of variance was examined using the Levene's test. The Levene's statistic was significant where $p = .008$. The assumption of homogeneity of variance was not met.

Table 11

Tests of Normality for Stage 2 Score Sums

	Shapiro-Wilk		
Group	Statistic	*df*	Sig.
Control	.952	49	.043
Experimental	.969	49	.227

Results for null hypothesis three. A *t* test was used to test the null hypothesis regarding differences in SoCQ stage 2 score sums between control and experimental groups at a southeastern university. See Table 12 for the SPSS output. Equal variances were not assumed. The null hypothesis was not rejected (α = .014) where *t*(90.743) = .862, *p* = .391, 99% CI [-3.013, 5.952], and *d* = +.18. The effect size was small (Warner, 2013). The control group (*M* = 17.18, *SD* = 9.393) did not have significantly different raw score sums than the experimental group (*M* = 15.71, *SD* = 7.348) did when registering their concerns about the requirements for implementing adjustments for color vision deficiency, and about their ability to meet those requirements (stage 2) (George et al., 2013).

Table 12

Results for t Test for Stage 2 Score Sums

t	*df*	Sig. (2-tailed)	Mean Difference	SE Difference	99% CI of Difference	
					Lower	Upper
.862	90.743	.391	1.469	1.704	-3.013	5.952

Null Hypothesis Four

$H_0$4: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to stage 3 items on the Stages of Concern Questionnaire.

Data screening. Data screening was conducted on each group's dependent variable. The researcher sorted the data on each variable and scanned for inconsistencies. No data errors or inconsistencies were identified. Box and whisker plots were used to detect outliers on each dependent variable. Two outliers were detected for the experimental group. See Figure 4 for box and whisker plots for the control and experimental groups for stage 3 score sums.

Assumptions. An Independent Samples *t* Test (*t* test) was used to test the null hypothesis. The *t* test requires that the assumptions of normality and homogeneity of variance are met ($\alpha = .05$). Normality was examined using a Shapiro-Wilk test. Shapiro-Wilk was used because the sample size was less than 50. No violations of normality were found. See Table 13 for Tests of Normality.

The assumption of homogeneity of variance was examined using the Levene's test. No violation was found where $p = .419$. The assumption of homogeneity of variance was met.

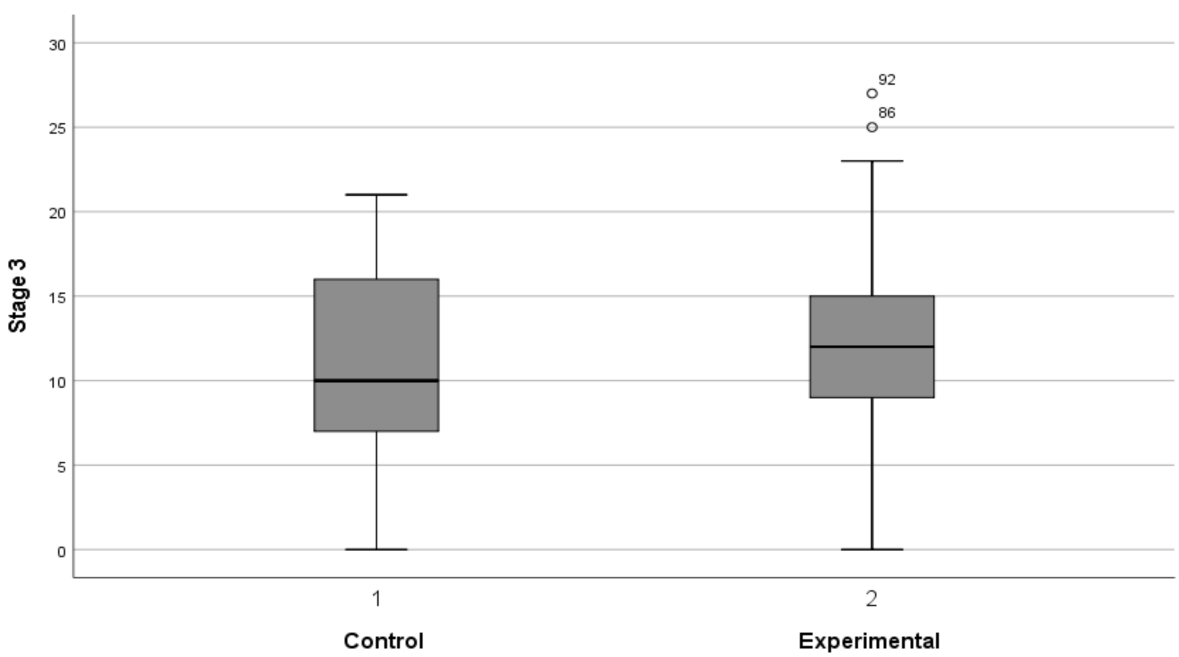

Figure 4. Stage 3 Raw Score Sums Data Box Plot.

Table 13

Tests of Normality for Stage 3 Score Sums

Group	Shapiro-Wilk Statistic	*df*	Sig.
Control	.959	49	.089
Experimental	.974	49	.345

Results for null hypothesis four. A *t* test was used to test the null hypothesis regarding differences in SoCQ stage 3 score sums between control and experimental groups at a southeastern university. See Table 14 for the SPSS output. Equal variance was assumed. The null hypothesis was not rejected (α = .014) where $t(96) = -1.498$, $p = .137$, 99% CI [-4.722, 1.294], and $d = -.31$. The effect size was medium (Warner, 2013). The control group (M = 10.88, SD = 5.596) did not have significantly different raw score sums than the experimental group (M = 12.59, SD = 5.733) did when responding about “the processes and tasks” (George et al., 2013, p.8) needed to adjust their instruction for color vision deficient students (stage 3).

Table 14

Results for t Test for Stage 3 Score Sums

t	*df*	Sig. (2-tailed)	Mean Difference	SE Difference	99% CI of Difference Lower	99% CI of Difference Upper
-1.498	96	.137	-1.714	1.145	-4.722	1.294

Null Hypothesis Five

H_05: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to Stage 4 items on the Stages of Concern Questionnaire.

Data screening. Data screening was conducted on each group's dependent variable. The researcher sorted the data on each variable and scanned for inconsistencies. No data errors or inconsistencies were identified. Box and whisker plots were used to detect outliers on each dependent variable. No outliers were identified. See Figure 5 for box and whisker plots for the control and experimental groups for stage 4 score sums.

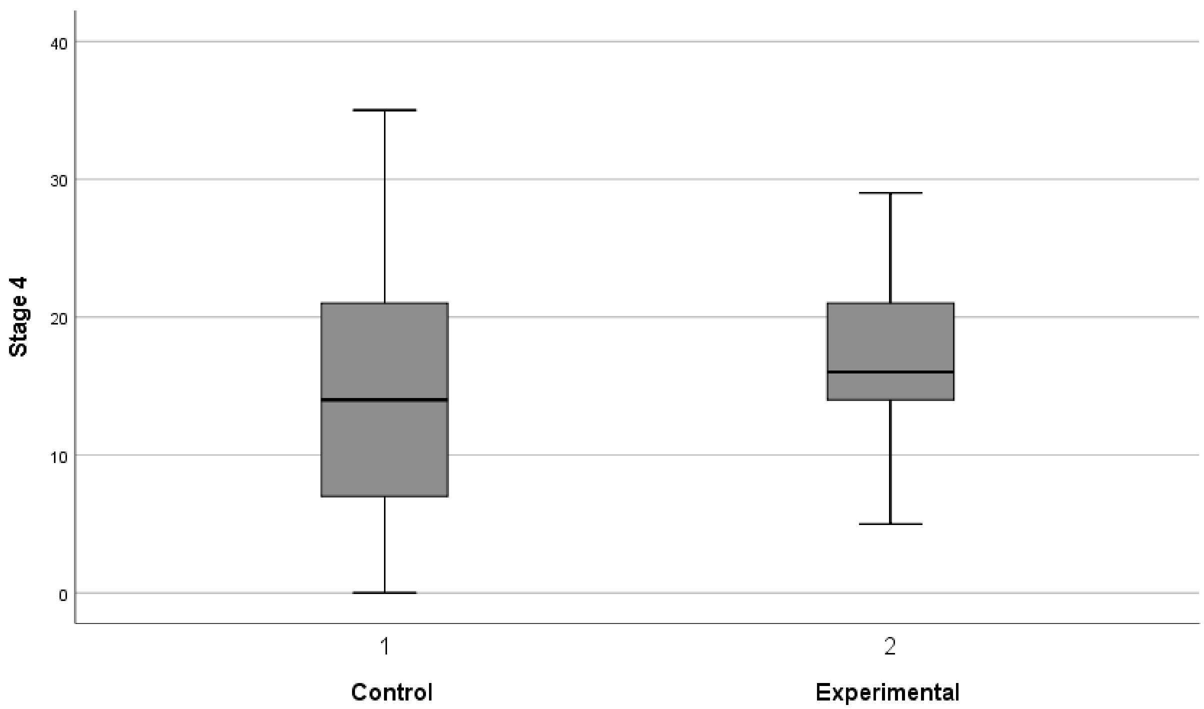

Figure 5. Stage 4 Raw Score Sums Data Box Plot.

Assumptions. An Independent Samples *t* Test (*t* test) was used to test the null hypothesis. The *t* test requires that the assumptions of normality and homogeneity of variance are met ($\alpha = .05$). Normality was examined using a Shapiro-Wilk test because the sample size was less than 50. No violations of normality were found. See Table 15 for Tests of Normality.

The assumption of homogeneity of variance was examined using the Levene's test. The Levene's statistic was significant where $p < .001$. The assumption of homogeneity of variance was not met.

Table 15

Tests of Normality for Stage 4 Score Sums

	Shapiro-Wilk		
Group	Statistic	*df*	Sig.
Control	.966	49	.170
Experimental	.978	49	.483

Results for null hypothesis five. A *t* test was used to test the null hypothesis regarding differences in SoCQ stage 4 score sums between control and experimental groups at a southeastern university. See Table 16 for the SPSS output. Equal variances were not assumed. The null hypothesis was not rejected (α = .014) where $t(78.641) = -1.730$, $p = .088$, 99% CI [-6.599, 1.374], and $d = -.04$. The effect size was small (Warner, 2013). The control group (M = 14.43, SD = 9.062) did not have significantly different raw score sums than the experimental group (M = 17.04, SD = 5.443) did when responding about their concerns about how adjusting their instruction for color vision deficiency would affect their students (stage 4) (George et al., 2013).

Table 16

Results for t Test for Stage 4 Score Sums

t	*df*	Sig. (2-tailed)	Mean Difference	SE Difference	99% CI of Difference Lower	Upper
-1.730	78.641	.088	-2.612	1.510	-6.599	1.374

Null Hypothesis Six

$H_0$6: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to stage 5 items on the Stages of Concern Questionnaire.

Data screening. Data screening was conducted on each group's dependent variable. The researcher sorted the data on each variable and scanned for inconsistencies. No data errors or inconsistencies were identified. Box and whisker plots were used to detect outliers on each dependent variable. No outliers were identified. See Figure 6 for box and whisker plots for the control and experimental groups for stage 5 score sums.

Assumptions. An Independent Samples *t* Test (*t* test) was used to test the null hypothesis. The *t* test required that the assumptions of normality and homogeneity of variance are met ($\alpha = .05$). Normality was examined using a Shapiro-Wilk test. Shapiro-Wilk was used because the sample size was less than 50. No violations of normality were found. See Table 17 for Tests of Normality.

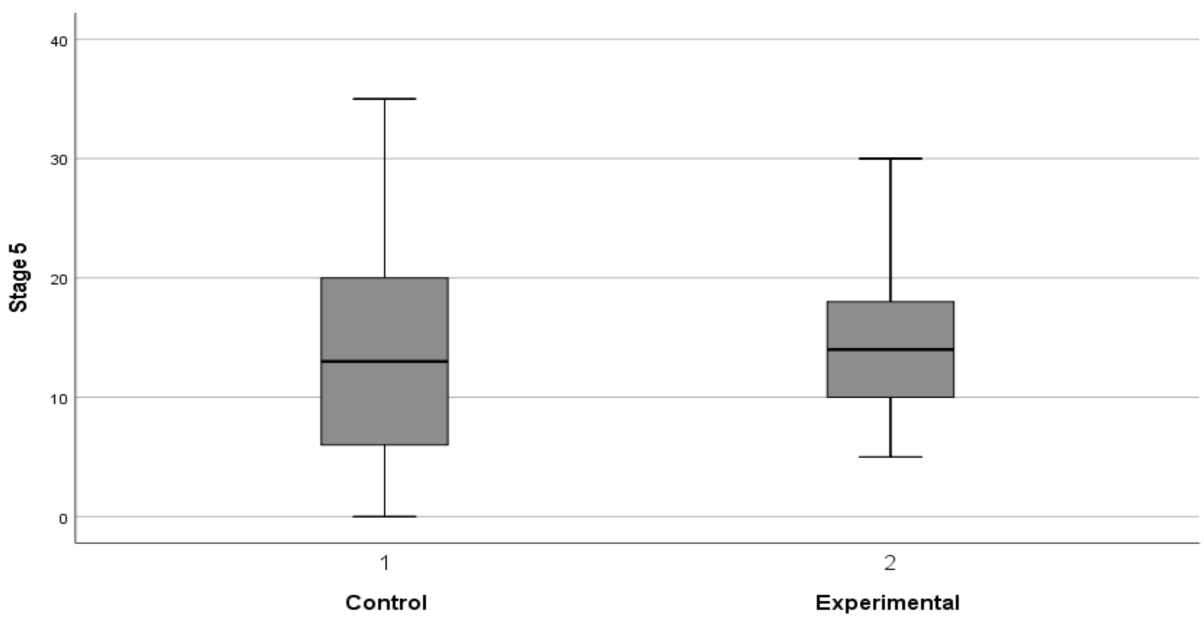

Figure 6. Stage 5 Raw Score Sums Data Box Plot.

Table 17

Tests of Normality for Stage 5 Score Sums

Group	Shapiro-Wilk Statistic	*df*	Sig.
Control	.954	49	.052
Experimental	.962	49	.115

The assumption of homogeneity of variance was examined using the Levene's test. The Levene's statistic was significant where *p* = .017. The assumption of homogeneity of variance was not met.

Results for null hypothesis six. A *t* test was used to test the null hypothesis regarding differences in SoCQ stage 5 score sums between control and experimental groups at a southeastern university. See Table 18 for the SPSS output. Equal variances were not assumed. The null hypothesis was not rejected (α = .014) where *t*(87.658) = -.027 and *p* = .979, 99% CI [-4.024, 3.943], and *d* = -.01. The effect size was small (Warner, 2013). The control group (*M* = 14.14, *SD* = 8.566) did not have significantly different raw score sums than the experimental group (*M* = 14.18, *SD* = 6.227) did when responding about their concerns about the collaboration (George et al., 2013, p.8) needed to adjust their instruction for color vision deficient students (stage 5).

Table 18

Results for t Test for Stage 5 Score Sums

t	*df*	Sig. (2-tailed)	Mean Difference	SE Difference	99% CI of Difference Lower	Upper
-.027	87.658	.979	-.041	1.513	-4.024	3.943

Null Hypothesis Seven

$H_0$7: There is no significant difference in faculty concerns about adapting for color vision deficiency between the intervention group and the control group as shown by their responses to stage 6 items on the Stages of Concern Questionnaire.

Data screening. Data screening was conducted on each group's dependent variable. The researcher sorted the data on each variable and scanned for inconsistencies. No data errors or inconsistencies were identified. Box and whisker plots were used to detect outliers on each dependent variable. No outliers were identified. See Figure 7 for box and whisker plots for the control and experimental groups for stage 6 score sums.

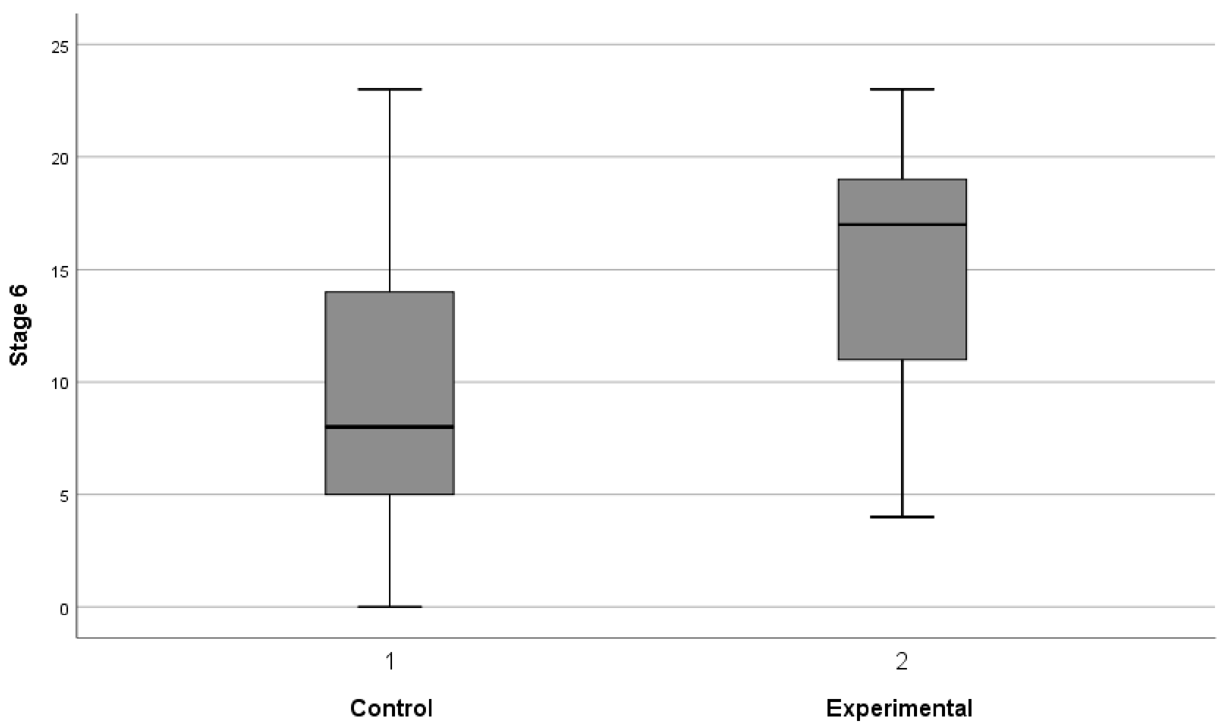

Figure 7. Stage 6 Raw Score Sums Data Box Plot.

Assumptions. An Independent Samples *t* Test (*t* test) was used to test the null hypothesis. The *t* test requires that the assumptions of normality and homogeneity of variance are met ($\alpha = .05$). Normality was examined using a Shapiro-Wilk test. Shapiro-Wilk was used because the sample size was less than 50. The control group and experimental group score sums were not normally distributed. However, with a skewness of .568 (*SE* = .340) and a kurtosis of -.622 (*SE* = .668) for the control group data, and with a skewness of -.488 (*SE* = .340) and a kurtosis of -.669 (*SE* = .668) for the experimental group data, their distributions do not significantly deviate from normal. See Table 19 for Tests of Normality.

Table 19

Tests of Normality for Stage 6 Score Sums

Group	Shapiro-Wilk Statistic	*df*	Sig.
Control	.933	49	.008
Experimental	.946	49	.026

The assumption of homogeneity of variance was examined using the Levene's test. The Levene's statistic was significant where $p = .023$. The assumption of homogeneity of variance was not met.

Results for null hypothesis seven. A *t* test was used to test the null hypothesis regarding differences in SoCQ stage 6 score sums between control and experimental groups at a southeastern university. See Table 20 for the SPSS output. Equal variances were not assumed. The null hypothesis was rejected ($\alpha = .014$) where $t(86.821) = -5.320$, $p < .001$, 99% CI [-9.062, -3.061], and $d = -1.1$. The effect size was very large (Warner, 2013). The control group ($M = 9.22$, $SD = 6.491$) had significantly different raw score sums than the experimental group ($M = 15.29$, $SD = 4.632$) did when responding about concerns about exploring other options (George et al., 2013, p.8) for adjusting their instruction for color vision deficiency (stage 6).

Table 20

Results for t Test for Stage 6 Score Sums

t	*df*	Sig. (2-tailed)	Mean Difference	SE Difference	99% CI of Difference Lower	Upper
-5.320	86.821	< .001	-6.061	1.139	-9.062	-3.061

Summary

In summary, a convenience sample of 98 faculty from a southeastern university completed the online version of the SoCQ to record their concerns about making nonmandatory adaptations to their classroom instruction for the benefit of students with color vision deficiency (CVD). Half of the participants were randomly assigned to view a professional development training about the topic. The null hypotheses for this study posited that the intervention would not change the attitudes of the participants in the experimental group about making instructional adaptations for colorblindness, as reflected in their responses on the SoCQ about their concerns. Independent Samples *t* Tests compared the means of the two groups. Null hypotheses $\mathbf{H_0 1}$**-** $\mathbf{H_0 6}$, failed to be rejected at an alpha of .014. However, null hypothesis $\mathbf{H_0 7}$ was rejected at $p < .001$, with a very large effect size ($d = -1.1$). Null hypothesis $\mathbf{H_0 7}$ addressed a comparison of the means scores for the stage 6 concerns—those reflecting participant concerns about exploring other options (George et al., 2013, p.8) for adjusting their instruction for color vision deficiency. Although the assumptions of equal variances and normality of distribution were not met for stage 6 data, Diekhoff and Miller (as cited in Rovai et al., 2013) state that *t* tests can still yield accurate *p* results despite a lack of homogeneous variance and normality with adequate, equal sample sizes. Rovai et al., (2013) state that the assumption of homogeneity of variance can be violated, given the groups' response curves do not show extreme variations in skewness, and the skewness of these data sets are similar. The control group's skewness statistic is .568 and the experimental group's skewness statistic is .488. Miller (as cited in Rovai et al., 2013) relates that deviation from normality is acceptable when the sample sizes do not vary and responses can differ up to "standard deviation ratios of 2" (p. 292). In this case, neither group's skewness and kurtosis statistics divided by their standard error exceeded a *z* of 2.

CHAPTER FIVE: CONCLUSIONS

Overview

These conclusions summarize the meaning of the results of this study. This chapter discusses the findings as they relate to previous studies and places them in the body of knowledge about adapting instruction for student differences and about the Concerns Based Adoption Model (CBAM). Lastly, this chapter addresses the limitations of the study and makes recommendations for future research.

Discussion

The purpose of the study was to investigate the effect of an informational intervention on the concerns of faculty educators about adapting their instruction for color vision deficiency (CVD). The results of the study do reflect attitudinal changes, but not necessarily in a positive way. Few studies exist about implementing educational adaptations for CVD, and few scientific articles in general are published about it at the collegiate level with the exception of those noting the effects of CVD in medical education settings (Campbell et al., 2005; Dhingra et al., 2017; Serrantino et al., 2015; Spalding 1999).

Literature Perspectives

Aspects of the results of this research do build upon and expand the findings of previous studies. The seminal study in published literature about training educators concerning adaptations for students with CVD was done by Collins with elementary school librarians (Collins, 2015). This study affirms her findings from a mixed methods research design in two respects: both studies found that educators are minimally aware of the prevalence and educational impacts of CVD, and that training did affect the attitudes of the educators. However, Collins' (2015) feedback from her focus groups tended to be supportive of adapting for the benefit of students with CVD, and this study suggests resistance. In a related study, Murray et al. (2009) report that college instructors with "some form of training" (p. 97) registered better attitudes toward making accommodations for students with ADA recognized disabilities. The findings of this research extend the scope of such ideas in that the data may be viewed as suggesting that an increase in awareness and attitudinal changes about classroom considerations may not be enough to overcome educational practice inertia in college instruction when considering CVD adaptations that are optional.

These results from the Stages of Concern Questionnaire (SoCQ) do fit neatly into the CBAM theory of the stages of attitudinal maturation during organizational change implementation, and add yet another organizational issue to the long list of innovation implementations or trainings which have been characterized by the SoCQ (Al-Furaih & Al-Awidi, 2018; Berg et al., 2017; Bogue, Marrs & Little, 2017; Bullard et al., 2017; Burke et al., 2018; Chen & Jang, 2014; Christesen & Turner, 2014; George et al., 2013). This model was originally designed in response to the many educational innovations that materialized in the 1960s and 1970s (Hall et al., 1977), but has been used to investigate change innovations in many types of organizations. In short, the SoCQ, the instrument devised as the foundational tool of the CBAM, can characterize the attitudes of educators as they approach or implement strategic educational innovations—in this case the proposed optional adaptations for the benefit of students with CVD. The concept behind this model of change describes a progression of concerns—although not rigidly prescribed—that an educator experiences in adopting a new way of educating. The idea is that educators are at first primarily unconcerned (stage 0) or concerned with how the innovation will personally affect them (concern stages 1-2). As they mature in their knowledge and response to the change initiative, their concerns then shift from the innovation being irrelevant or affecting self to primarily being concerned about managing the tasks required for the change (concern stage 3). Finally, items in the concern stages 4-6 are designed to track when educators begin to be concerned about the impact that the innovation will have on their students, their collaborative efforts with other educators, and how the innovation itself might be modified or substituted in order to be more effective (George et al., 2013, p. 8).

Awareness

One clear benefit arising from this study was the raising of awareness of CVD at the collegiate level and of instructional adaptations that exist for CVD. The demographic data show that 88% of the control group and 90% of the experimental group were not aware of adaptations for CVD. The 49 members of the experimental group did receive training explaining the condition and ways to adapt their instruction for the benefit of students with CVD. The impetus for this study grew out of an awareness produced by a faux pas unwittingly committed by this researcher in a university classroom. In short, after filling a white board with notes written in colored marker to explain a chemistry concept, a student who self-identified with CVD raised his hand to state that he was unable to read any of the writing on the board. The remedy for that student was simply to rewrite the information on the board in thick black marker—thus began this quest to understand instructional access for students with this condition.

Means Comparisons for Individual Concern Stages

Comparing the means of the sums of raw scores for the five individual items per each of the seven stages of concern stage by *t* tests facilitated answering the research question, which is simply whether the training changed the instructors' attitudes toward adapting for CVD. Using these sums of item scores for each stage of concern per participant of concern permitted a comparison of the two groups; however, the cost of using the sums was the removal of the possibility of detecting a specific Likert response average for individual items on the SoCQ. The benefit of using the raw score sums for interpreting the results is that it is consistent with the most conservative view of how to statistically evaluate Likert responses, which are not technically interval data.

Two aspects of this study stand to indicate the strength of the internal reliability of the group comparison design. First, the demographics for the control and experimental groups are quite similar. Second, the results for concern stage 5, collaboration, are the nearly identical for both groups. This is logical and expected—there would be no reason to suppose that either group would have differing concerns about collaborating on the hypothetical implementation of adapting for students with CVD since that topic was not addressed in the intervention training.

Stage of Concern Results

With a Bonferroni reduction to .014 for a significance level in place, only the null hypothesis describing stage 6 concern, which measured the participant's desire to modify or substitute the innovation (George et al., 2013, p. 8), could be rejected. Therefore, the final conclusion of this study is that the professional development training whose desired end was to sway college instructors to change their instruction for the benefit of their students with CVD, was not successful. Instead, the data suggest that the training may have actually brought about resistance to the idea of making adaptations for CVD. George et al. (2013) state that significant increases in stage 6 concerns are "a warning . . . that should be heeded as an alarm" (p. 42) that bodes ill for the acceptance of the innovation. This result provides a core piece of evidence from which implications for policy-making collegiate educators can be drawn.

Implications

The findings of this research cause one to consider the broader implications of educational accessibility for students with CVD. Clearly, laws in the United States and other countries exist to guarantee instructional accessibility in primary and secondary schools, and the ADA stands to enable accessibility for students who are physically or educationally disabled on college campuses. However, since color vision deficiency is not considered a disability under the ADA statute, the responsibility for ensuring intrinsically integrated supports for CVD, the most prevalent of genetic sensory alterations, falls to the voluntary favor of instructors and administrators.

Because leadership's role in assuring accessibility for students with CVD at the college level is crucial, and the usefulness of this research lies primarily in its ability to make predictions that are actionable for academic leaders who are considering the effects of CVD on their students. The CBAM (George et al., 2013) proposes and gives evidence that effective change involving instructional innovations are securely rooted at the instructor level of an organization, and indicates that the motivation for making such instructional changes lies in some combination of personal desire and administrative order. The results of this study would suggest that raising basic awareness is insufficient to produce the kind of personal reactions that are capable of overcoming the inertia of resistance to changing instruction on the college level.

Lacking a legal mandate, the only way to intentionally address the needs of students with CVD in the college classroom is to convince academic leadership of its importance and provide evidence of how best to influence faculty to implement adaptations. Although CVD is not currently an ADA recognized disability, much of what has been published about the effects of CVD can be found in literature reviews that document the repercussions of CVD as disabling in certain situations (Chan et al., 2014; Stoianov et al., 2018) and the increasing prevalence of difficulties as the use of color in the classroom increases. The societal trend toward making accommodations is not waning, and the use of color is increasing in education because of its increased availability and esthetic appeal. Heightening awareness of the condition might stir interest in leadership, but one also might speculate that educational leadership is not anxious to spend limited training funds to train their faculty in how to improve accessibility for students with CVD when there is no legal mandate to do so. Decreasing enrollment in private brick and mortar institutions could make the funds difficult to justify. To complicate matters, this research would suggest that such training efforts may be met with resistance from faculty on the point of implementation. Instead, leadership wanting to provide more equitable instruction for students with CVD could infer from this research that it might be more effective to use institutionally-based initiatives such as offering CVD screening to students at minimal cost to the institution through online resources available in the public domain, or preemptively making blanket campus decisions that include CVD-friendly technology.

Nevertheless, before rejecting the idea of using classical online continuing education type training out of hand, it may be well to consider three caveats that characterized this research and may have influenced the participants' attitudes towards making adaptations. The majority of the participants responded that they were teaching class overloads, and that could explain their resistance to making adaptations to their lessons. Also, the fact that the participants were questioned about making the adaptations as an optional, voluntary modification should be taken into consideration. The results do suggest that online training, such as is common in academic continuing education circles, may be successful in engendering attitudinal changes.

Finally, it must be noted that this research was fielded on the cusp of a worldwide viral pandemic. At that point in the history of the United States, governmental and educational leaders were attempting to construct a response for the prevention of the rapid spread of a highly communicable virus in traditional classrooms. The faculty of the setting university were evaluating their classes' scope and sequences, and making plans to move imminently from face-to-face instruction to an online format. Although it is impossible to quantify the effect of that pressure on faculty attitudes towards adapting their instruction for CVD, it is not unreasonable to think that because they were facing such abrupt remakes of their classes, they may have been more resistant to the idea of considering yet another change, especially an optional one. The purpose of this research was to ascertain whether a training session, such as is common to educational circles, would engender the kind of personal attitudinal change that might precede faculty implementation of instructional benefits for students with CVD in the college classroom. Succinctly, the results suggest that although the training may have raised awareness and understanding of the condition in the participants of the experimental group, it also may have raised resistance to implementing instructional adaptations. At a minimum, this study lends credence to the idea that, although an important first step, simply raising awareness is not sufficient to guarantee a strong enough motivation for making instructional adaptations. Several other factors could have influenced the apparent resistance. Given the mounting evidence that CVD is a significantly altering condition, possibly the most egregious of these is the lack of a legal mandate. Although clearly outside the sphere of this investigation, in order to procure beneficial adaptations for students with CVD an effective initiative might be to lobby for CVD to be included as a disability so that legal impetus could fuel changes that would enhance the learning experiences of students with CVD.

Limitations

Limitations of this study include the relatively small sample size that precludes statistically sound comparisons of subgroup responses. The study is also somewhat limited in the application of the results to populations of larger or smaller universities, and especially to those universities that have faculty of more diverse demographic backgrounds. In addition, the number of participants earing one particular demographic—faculty teaching an overload (more than 12 hours)—is significantly high in the setting university so as to raise questions about broadly interpreting the results. The study done by Dallas et al. (2014) suggests that overloads negatively influence educator attitudes about making legally required accommodations.

The general limitation of a static-group comparison design applies to this study: it is not possible to make direct assignment of causation, as other factors may have influenced the results. Rovai et al. (2013) also point out that this design can be weak as a result of "instrumentation, selection, interactions with selections, and experimental mortality" (p. 94). However, the instrument is a proven one, the online format precluded selection interaction, and experimental mortality was avoided by the short term of the fielding. The selection was indeed non-randomized because the participant pool was limited to those volunteering to do the study, so it remains a possibility that those who responded were not representative of the entire population. Gall et al. (2007) state that the main threat to the validity of this design lies in the possibility that any differences found can be attributable to inherent differences in the groups, rather than to the study intervention. This seems unlikely to have happened in this study because the demographics of the control and experimental groups were so nearly identical (Table 5), and because comparisons of most of the concerns constructs did not result in significantly different results.

Using the SoCQ instrument as it is marketed from AIR had the advantage of having the great depth of four decades of implementation history and of having prodigious proof of statistical validity and reliability from its rigorous creation and many years of use. In order to maintain that pristine statistical pedigree, AIR specifically warns against changing the wording of any of the items. Upon that recommendation, this researcher did not modify the questionnaire items, adding only to the demographic questions. However, one participant did comment that the wording of some of the items was unclear, and that could have lessened the effectiveness of the attitudinal quantification.

Recommendations for Future Research

Future studies could include repeating the study at a larger institution. The scope of this study was limited to the results from the *t* tests of the seven stages of the CBAM. A true analysis of responses by demographic factions could not be made due to insufficient sample sizes, and drawing a conclusion from one demographic in isolation is not reasonable. However, a second fielding of this study using a large enough sample population might be enlightening as the findings of this study may allude that educators carrying overloads are less accepting of the solutions proffered by the training (stage 6). Such a study would have the possibility of extending the research of Dallas et al. (2014) who comment that educators teaching overloads are less likely to be compliant with ADA mandated accommodations. Dallas et al. (2014) found that age, tenure, and subject material influence educator’s attitudes toward making accommodations for ADA acknowledged conditions.

Securing a different population for a follow-on investigation would be desirable. A possible succession to this study would entail finding a university that currently does encourage its faculty to make CVD adaptations and to use the CBAM levels of use instrument from AIR to ascertain an actual measurement of the use of these optional CVD adaptations. Alternatively, choosing a faculty with a large online presence would also allow for a broader discernment of educator attitudes toward CVD instructional adaptation.

In the future, adaptations for CVD may become nonnegotiable, and at that point, attitudinal studies will be replaced with mandatory training programs. In the meantime, the next foray into understanding how instructors might be influenced to help their students with CVD could take the form of a qualitative study or even a mixed methods research design, such as was done by Collins (2015). The research could begin with a baseline quantitative survey—perhaps the SoCQ modified for clarity—followed by a hands-on intervention training with a subsequent qualitative segment to discover faculty misgivings, raise awareness, and pinpoint issues producing resistance. Such an approach would have the potential to generate more knowledge about what factors cause nonacceptance and highlight those things that are amenable to adjustment by leadership for the benefit of students having color vision deficiency.

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APPENDICES

Appendix A contains the Professional Development Video links with their transcripts. Appendix B is the License Agreement for Online Stages of Concern Questionnaire. Appendix C is the IRB permission letter. Appendix D is the IRB stamped consent from Liberty University. Appendix E is the recruitment email and follow up email soliciting volunteer participation. Appendix F contains the selection emails. Appendix G is the Color Blindness Adaptations Resource Module that was sent to the experimental group participants.

Appendix A: Professional Development Video Links with Their Transcripts

The intervention consisted of the adaptations informational text module plus three professional development video modules by Karla Collins, PhD., Associate Professor of Education & School Librarianship of Longwood University, VA, and the transcripts of those videos. The first video module described CVD and demonstrated the condition via a color recognizing game. The second video presented Universal Design as a plausible solution to the dilemma of how to adapt educational presentations to be inclusive of students with CVD. The third video presented some of the possible adaptations for instructors to use in their classrooms.

The URL's for these videos are: https://youtu.be/JlimMDJV_hw, https://youtu.be/rV2fZ12muIs, and https://youtu.be/BBhyMmgl1DM. Below are the transcripts of these video modules, which are licensed under Creative Commons Attribution-Noncommercial-Share Alike (2019) stipulations.

Transcript of Module Video 1, Color Vision Deficiencies: A Hidden Disability?

By Karla B. Collins, PhD

Associate Professor, Education & School Librarianship

Longwood University

What do you do when a student tells you, "I know you're writing on the board, but I can't make it out?" The whiteboard is full of writing in blue marker, and this student is not able to see what is there. Color vision deficiencies are real and impact a significant number of people.

Agenda. Welcome to the first instructional module. In this session we will talk about color vision deficiencies. I'm Dr. Karla Collins, and I'm an associate professor of Education and School Librarianship at Longwood University in Farmville, Virginia. My mixed methods research topic is related to what school librarians know and believe about color vision deficiencies, and how color is used in school libraries. I am also the sister and mother of boys with color vision deficiencies.

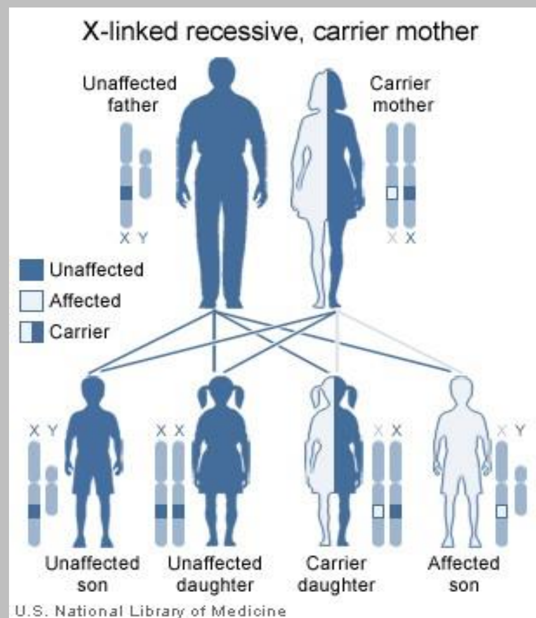
Background. Today, we're going to talk about the background information of color vision deficiencies, why it matters in your classrooms, and we will go through some simple simulations so you can experience what you might see with color vision deficiencies. The condition was first discovered by John Dalton, a chemist in the late 1700s and early 1800s. He presented his ideas in his “Extraordinary Facts Relating to the Vision of Colors with Observation,” where he described his and his brother’s experiences with being colorblind. The term *daltonism* is now sometimes used to refer to red-green color vision deficiencies.

The term *color vision deficiencies* means the inability to identify or distinguish between colors (Maule & Featonby, 2016). We often hear it described as *colorblind* when talked about in general conversation, and *colorblind* is frankly easier to say, so I'll use those terms, *color vision deficiency* and *color blind* interchangeably in this training. However, it should be noted that true color blindness is very rare and technically refers to the inability to see any color at all, only seeing in shades of grey. This rare condition is not the topic of our conversation for this training. If I use the term *colorblind*, I'll be referring to the condition of color vision deficiency, the inability to identify or distinguish between colors.

According to various studies, 8 to 10 percent of the male population is affected by color vision deficiencies and less than 1 percent of females. Later, we'll look at how these percentages compare to some commonly known disabilities. To put this in perspective, in a class of 25 students there is likely at least one person who sees the world differently. In an average-sized school or small college, statistically there could be enough boys with color vision deficiencies to easily fill a classroom. However, color vision deficiencies often go undiagnosed, and it's not uncommon for a person with CVD to be unaware of it until questioned by someone else.

Genetics Behind CVD. Both of my brothers are colorblind, and neither one knew it until they were young adults. One was going for a private pilot's license when he found out that he could not see the colors change on the lantern test. That began his journey of discovering that what he sees is not the same as what many of us see. CVD is not considered a disability, under the Americans with Disabilities Act, so it is not a condition that requires educators to make accommodations available, and we'll come back to this point later in our training. Most color vision deficiencies are genetic: a sex-linked trait that is most often passed from mother to the son on the X chromosome. According to Jay Meeks, a leading researcher in this field, this is the most common single genetic disorder in both men and women. Let's take a minute to look at how this works. As the diagram shows, boys have a 50/50 chance of receiving an affected X chromosome from a carrier mother. A boy with an affected X chromosome would have some form of color vision deficiency. My family is a good example of this. I'm a carrier mother, my oldest son did not receive an affected X but my identical twin boys did, and they're color blind. My mother was also a carrier and passed the affected X to both of her sons and to at least one of her daughters—me. I'm not affected, just a carrier. In order for a girl to be affected, she would have to have an affected father and a carrier mother, each giving an affected X chromosome to the daughter. Otherwise, this dominant unaffected gene would take over, and this explains the difference in occurrence between males and females.

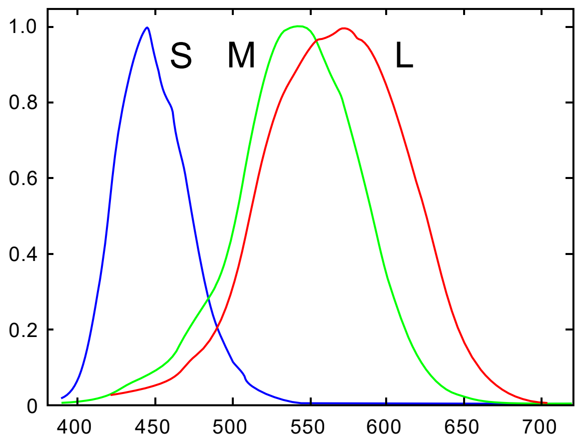
Genetics Behind CVD



Public Domain, National Institutes of Health

My affected boys will pass an affected X to their daughters, who could in turn pass it to their children. In addition to the genetically linked deficiencies, there are a number of other conditions that could cause a person to acquire color vision deficiencies. Usually later in life, conditions such as cataracts and Parkinson's disease can cause it. Some medications and the aging process may also cause color vision abnormalities in the human eye.

Color and the eye. Photoreceptor cells, rods and cones, are responsible for vision. Rods help us see in low-light while cones help us distinguish colors. When the photoreceptor cells are not functioning properly or missing, color vision deficiencies occur as I mentioned, rods help us to see in low-light they have nothing to do with color. Which is why we cannot distinguish colors in the dark. Everything appears to us in shades of gray. Cones are the receptors that allow humans to see colors from the visible light spectrum. When light is passed into the eye, the cones detect the wavelengths and pass that information to the optic nerve signaling our brain to identify the color based on the wavelength. The brain will perceive a different color. For example, if the eye cannot detect the long wavelength, no red will be perceived in the color of what is seen. Therefore, purple will be perceived as blue. There have been lengthy debates about whether, for this reason, if there is really such a thing as color, or if it's just something made up in our minds. We will not get into that debate, but it might give you something to ponder later on.



Vanessaezekowitz at en.wikipedia [CC BY-SA]

Types of color deficiencies. This chart will be available in your resources module so you can look at it in more detail later, but just to give you an overview, it shows various forms of color vision deficiencies.

Types of color deficiencies

Type	Description	Affects	Example
Trichromacy	All rods and cones work properly		Ability to see full range of colors
Monochromacy	Absence of short (blue), medium (green), and long (red) wavelength cones.	1 in 10,000	Inability to see any colors
Anomalous Trichromacy - One or more color sensitivity is slightly off due to the malfunction of one type of cone. Results in slight color deficiency.			
Protanomaly	Red-weak.	1 out of 100 males; 0.1% of females	Purple appears blue
Deuteranomaly	Green-weak.	5 out of 100 males; 0.4% of females	Difficulty telling differences in the red-orange-yellow-green spectrum.
Tritanomaly	Blue-weak.	.0001%	Can be acquired through eye damage.
Dichromacy - One or more cone is absent. Most severe of the red-green defects.			
Protanopia	Red (L) cones absent.	1 out of 100 males; 0.1% of females	Effects perception of blue, violets, and purples because of the dimmed red.
Deuteranopia	Green (M) cones absent.	1 out of 100 males; 0.1% of females	Cannot differentiate between red, orange, yellow, and green.
Tritanopia	Blue (S) cones absent.	.0002%	Can be acquired through eye damage.

(Collins, 2019)

Humans are trichromats, meaning we have three cones, and the ability to see the full range of colors of all three wavelengths. Most other mammals are dichromats, having only two color receptors. A very small portion of people are monochromats, with only one type of cone. These are the people who are truly colorblind, and see only in shades of grey when a cone is present, but not working correctly. It's a type of anomalous trichromacy, when the three photoreceptors are present, but only working with two wavelengths causing the person to be weak in the affected area. Sometimes a cone is missing entirely, leading to a more severe color vision deficiency that falls into the category of dichromacy. The chart gives three variations with anomalous trichromacy and within dichromacy. It also presents an estimate of how common each might be and some additional information about what might be seen. You will also note that a defective or missing blue cone is the rarest and most severe form of trichromacy and dichromacy and is typically an acquired condition, not genetic. It's important to keep in mind that it's unlikely for two people to have the exact same color vision deficiency. Even my identical twin boys tested differently when given the HRR (Hardy, Rand, & Rittler, 1954) test for color vision deficiencies. While they likely have the same type of deficiencies, the severity differs. This will impact our later discussion about addressing the needs of students in the classroom.

Simulation. These images were created with Idea's color vision tool, which was designed to assist web developers and choosing good colors for their websites. The images simulate what a person with color vision deficiencies might see compared to someone with normal color vision there will be a link to this website in the resources module.

Why does this matter? So why does it matter? As color is becoming easier and less expensive to produce, it's becoming more prevalent in instructional materials. Think about textbooks from 30 years ago. What were the pictures and diagrams like compared to textbooks now? I want to read a couple of quotes to you to encourage your thinking (from Douma, “Simulating vision problems” blog post, 2009):

> The ability to distinguish colors is arguably more critical today than at any time in human history. Color is ubiquitous in many tools people use in their jobs, from computer monitors to LED displays to color business charts and graphs. Indeed the design of the modern world—from web sites with colors that “pop” to road signs that are color coded to ensure less driver distraction—is dedicated to those who can differentiate colors. Even in the world of sports, the ability to distinguish the colors of an opposing team’s uniforms is crucial to both the ability to enjoy a game as a player or a spectator.

A quote from Dwyer’s research (1991) relates the impact on children shows the potential emotional impact:

> For children with moderate to severe colour vision defects, the impact of colour is reduced both as an attentional and as a learning cue. However, since most colour vision defects in young children go undetected, misperceptions of colour might be misinterpreted by parents and teachers, thus producing frustration and anxiety. (p. 37)

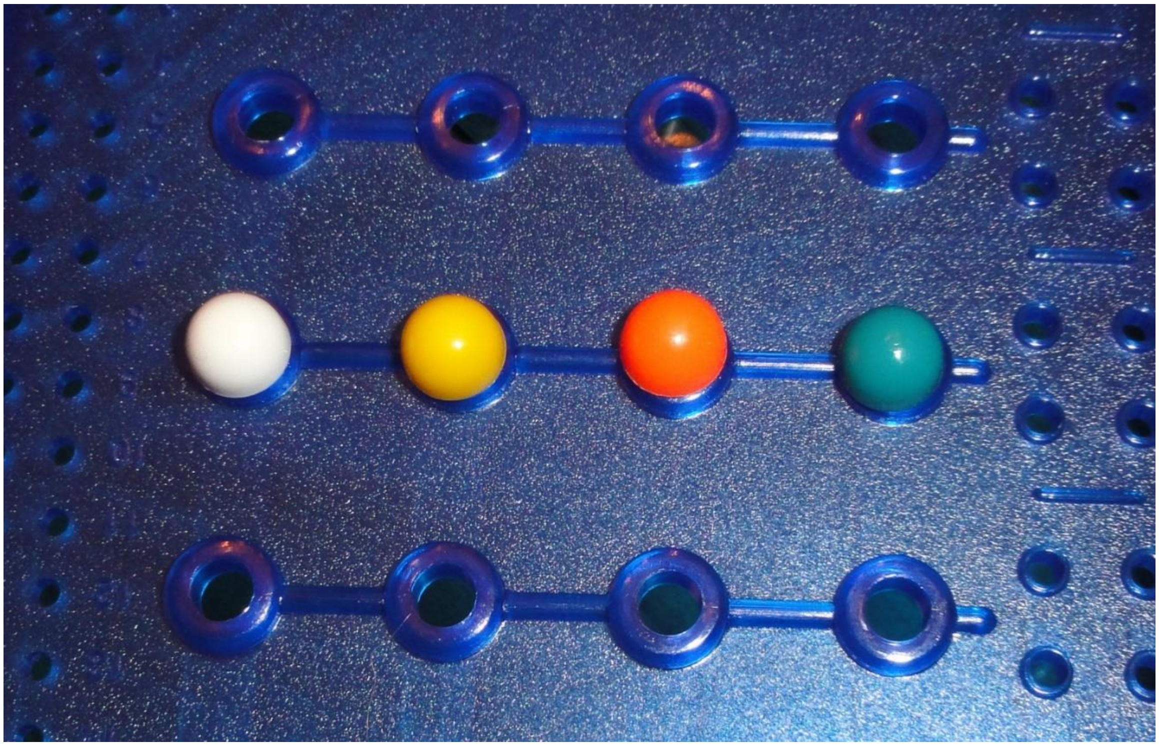
Think about how a misinterpretation of a student's reaction to color information might impact that student and the teacher. The teacher might assume that the student is intentionally giving the wrong answer. When in reality, the student is answering according to what he sees. As mentioned earlier, it is not uncommon for color vision deficiencies to be undetected, leaving the door wide open for unintentional consequences that impact understanding and learning.

State vision screening. You might wonder how a student can get through K-12 school without being tested for this condition. This is because the requirements for color vision screening in public schools vary greatly from state to state. Some states do require color vision screening as part of the state mandated vision screening, usually upon entering primary school. Pennsylvania's requirement goes into the importance of this screening and says that the impact of the knowledge of a student's ability to perceive colors should be of significant to classroom teachers. It goes on to talk about the importance of those in elementary grades in seeing visual cues. Virginia is among a number of states that require vision screening, but color vision screening is only recommended not required. I do know of one school division in Virginia that just recently mandated screening for all of their students for CVD. Arizona is an example, and not the only one, of states that do not mandate vision screening at all. Interestingly, Arizona's code does include language about the importance of color vision. They give a definition of the term, and then they go on to say it’s important for parents or guardians teachers and others to be informed about this condition as the condition can be reasonably accommodated under section 504 of the Americans with Disabilities Act.

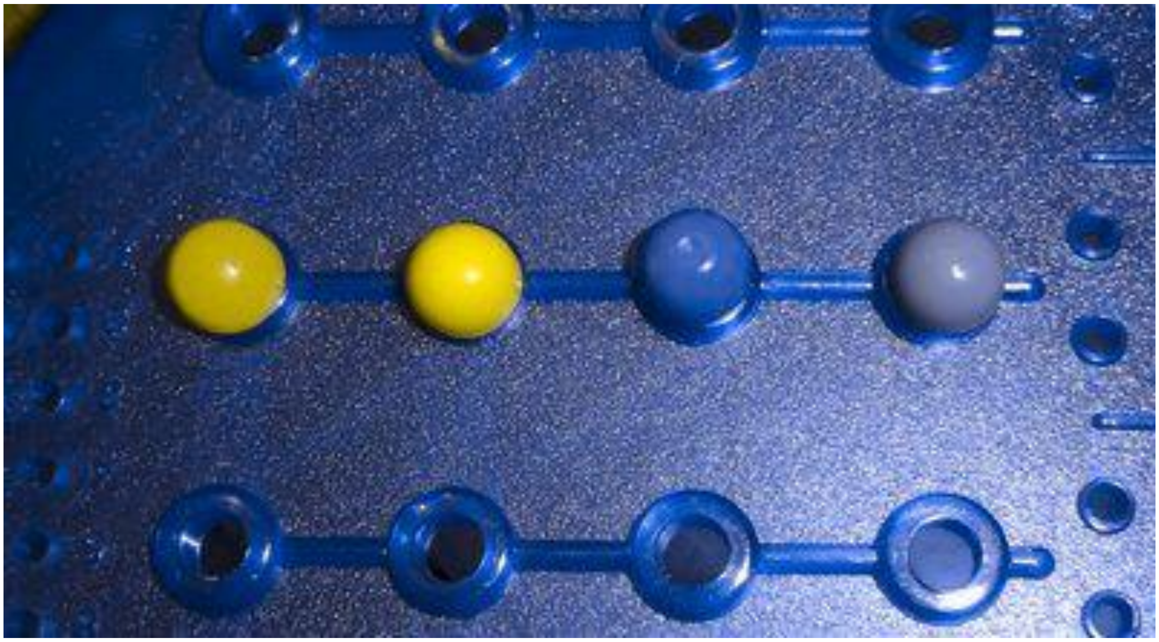
I recently had a conversation with someone from another state that did not understand how a person could not know about a color vision deficiency. This person was tested repeatedly by her pediatrician when she was younger. I explained that this was not the practice everywhere; it is very possible and quite common for a person to reach college and adulthood without knowledge of a color vision deficiency. I used this person's father as an example—his CVD was under undetected until young adulthood.

The research says. Let's look back at the rate of CVD as compared to other commonly accommodated conditions. I want to be clear that I'm not suggesting that color vision deficiency is a disability or that it impacts life and learning as severely as the learning disabilities listed here. I'm merely using this information to give a point of reference for how many people are affected by CVD as compared to disabilities that we might hear about more often, by looking at these numbers. It is clear that the prevalence of color vision deficiencies is common or more common than many of the disabilities that are often accommodated in the classroom.

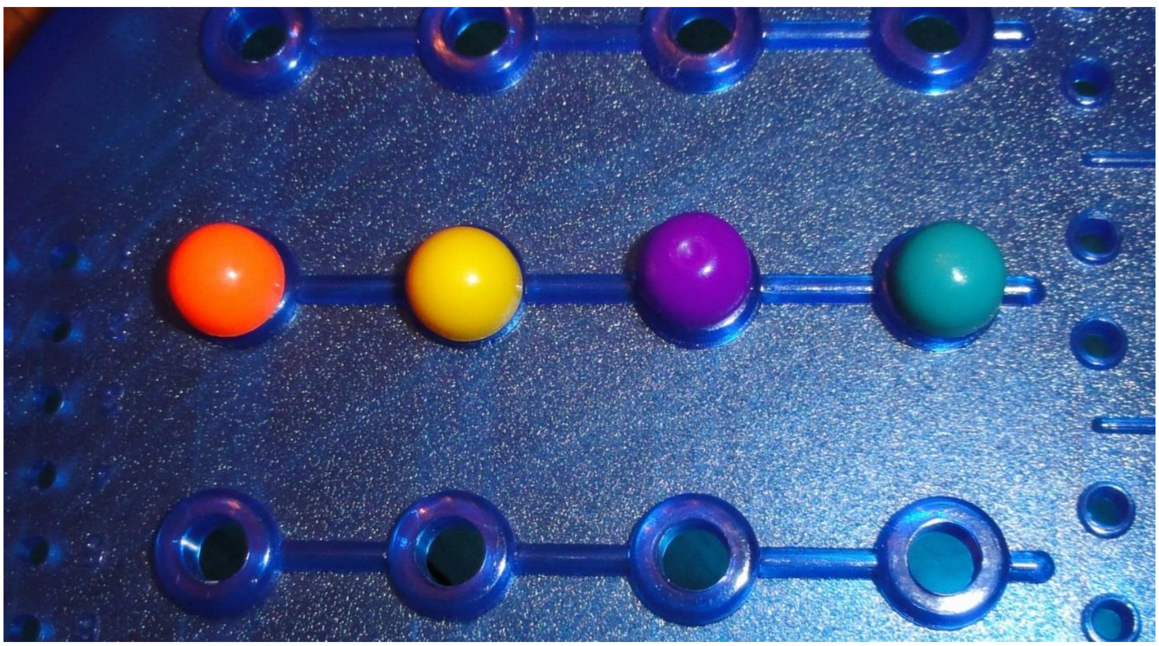
Let's play a game! You might remember the old game master mind. The goal was to match the colors of the person on the other side of the board. So when you look at these pegs, what are the colors of these pegs? With normal color vision, and without differences due to screen resolution and projection, you should see white, yellow, orange, and teal or aqua or turquoise a greenish blue.



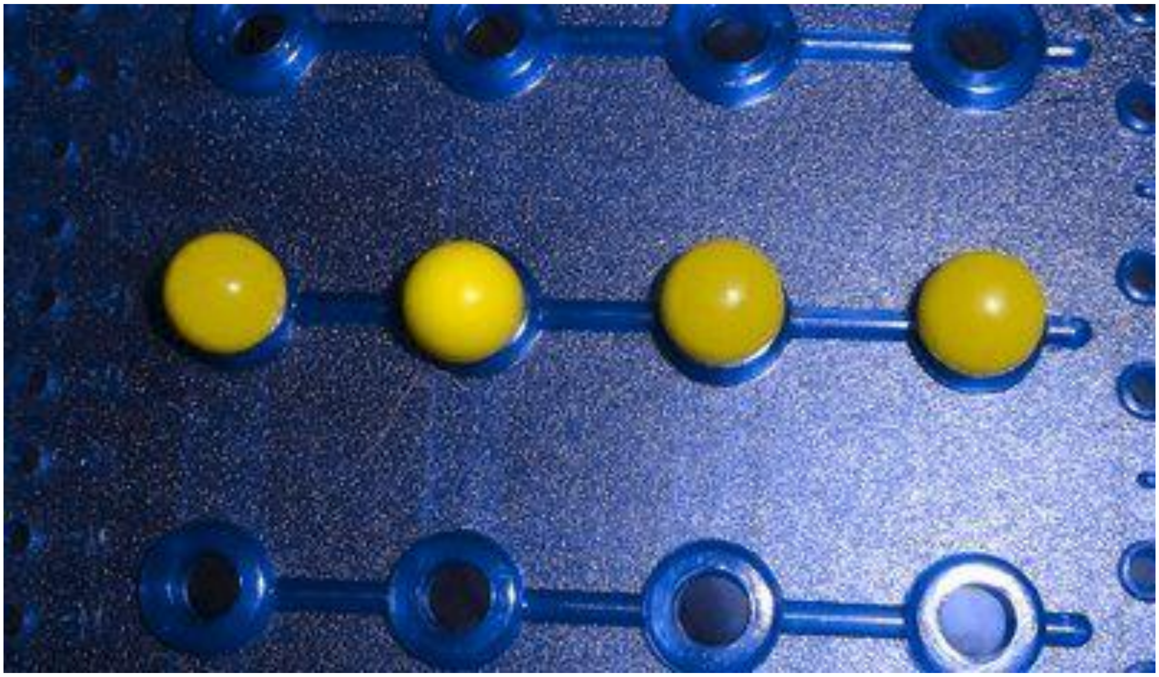
The following pegs are in a different order, and the color is adjusted to remove either green or red.



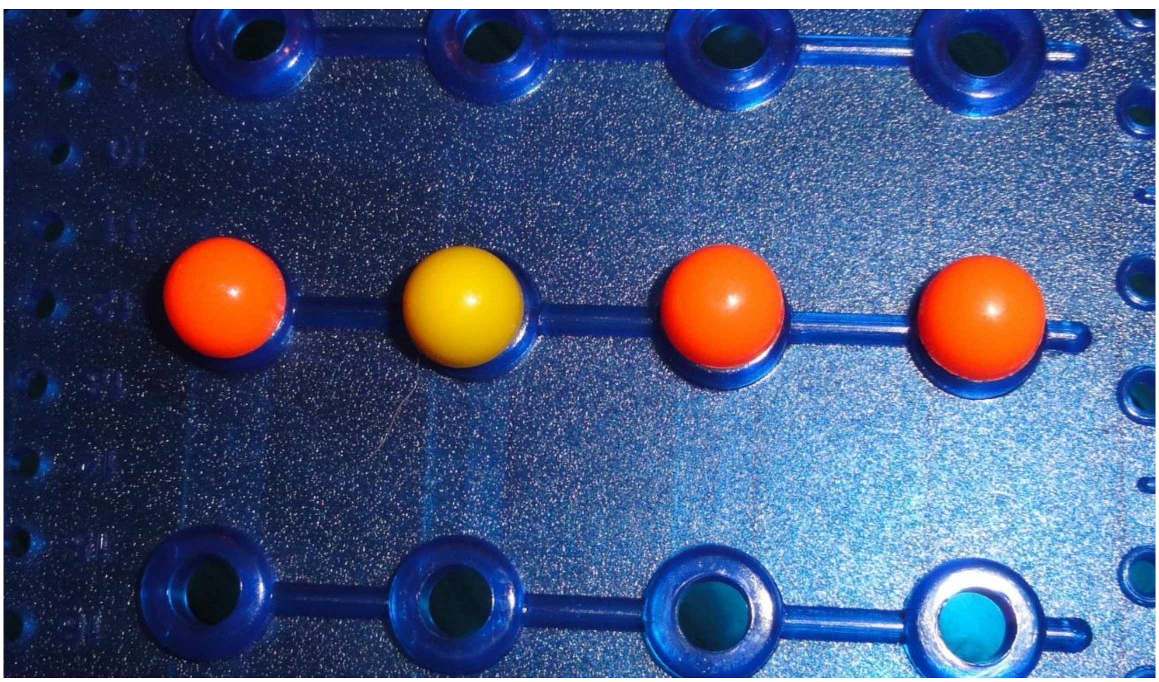
So what are these colors? Did you guess? Did you guess orange, yellow, purple, and turquoise?



What about these? If you saw these pegs, would you know what color names to assign?

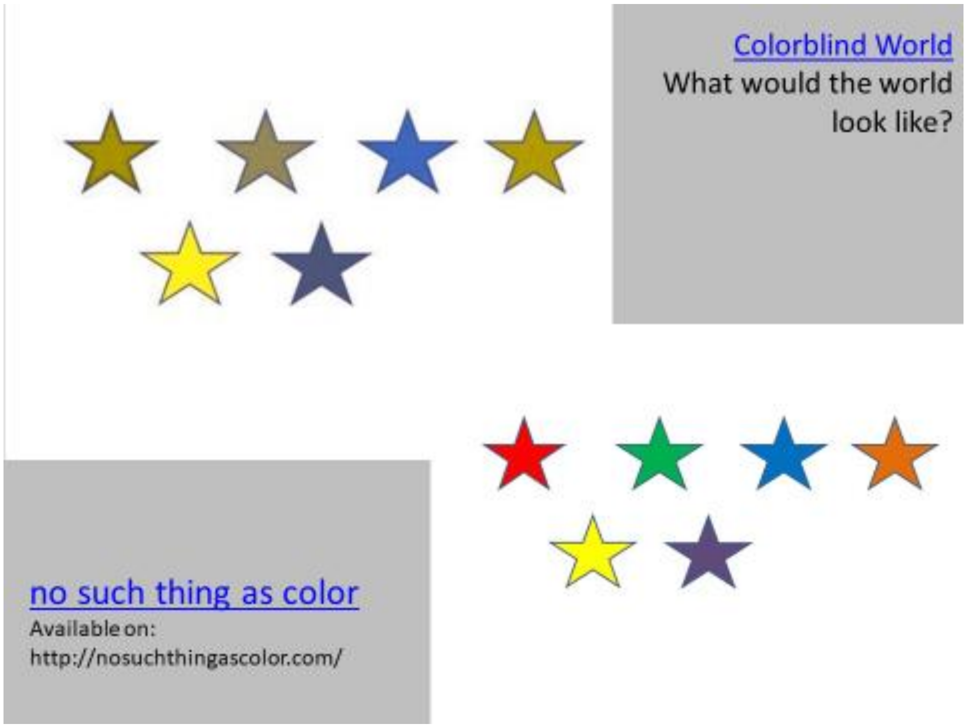


Did you guess orange, yellow, orange, orange?



When I showed this to someone with color vision deficiencies, he thought for a long time before he explained that the two on the right are the same, but he was not sure about the one on the left. He knew yellow, and he could tell that the two close together were the same. He explained that he can usually tell that colors are different if they're beside each other, but distance between the colors makes it more difficult to differentiate.

Can you identify the colors in the stars on the bottom right of this screen?



What color names would you give to each one? Which do you think is red? What about the green? I recently turned this into a family game, with some good sports in my family. When shown to someone with normal color vision, she was able to name the colors on the bottom right of the screen quickly and accurately. However, someone with color vision deficiencies took a long time to think about each star, other than the yellow. He knew that one right off, and someone with cataracts also took a long time before just giving up and saying, “I just can't see it.” For some more ideas of how color might be used, and how those with CVD may see the word, take a look at the color blind world website that's linked in the resources. Then view the *No Such Thing as Color* interview. Also see the links in the resources for some insight into the thoughts and experiences of a person living with color vision deficiencies.

A Hidden Disability? So is color vision deficiency a hidden disability? Many sources define a *hidden* or *invisible disability* as a disability that may not be immediately apparent to others. This term is commonly associated with neurological conditions such as traumatic brain injury or chronic pain conditions. There are no outward signs of the condition that would alert others. Upon first sight, it is not clear that the person is dealing with a disability.

To be clear, and as I mentioned earlier, CVD is not recognized as a disability under the Americans with Disabilities Act. However, I think it is safe to describe it as a hidden disability, based on the limiting effect of the condition, and the potential impact on daily life. The important thing to remember is that what an outsider sees may not be the whole story. One cannot determine what another person sees or how they perceive what is seen. We cannot, and must not, make assumptions that everyone sees the world the way we see it. Color is in the eye of the beholder.

Helpful websites for more information. Please go to the resource module for many links to additional information about color vision deficiencies. Links to the websites mentioned in this presentation are also included in the adaptations resource module.

- Color vision simulator: http://www.idea.org/blog/2009/05/18/simulating-vision-problems/
- To test color design:
  - http://www.iamcal.com/toys/colors/
  - http://www.vischeck.com/
- Neitz: http://www.neitzvision.com/content/home.html
- Waggoner: http://colorvisiontesting.com/

Now that you have a good background into color vision deficiencies, move on to the next module in which we will cover Universal Design for Learning.

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Transcript of Module Video 2, Universal Design for Learning

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So how do you help someone who sees the world differently? Especially when even they don't know they do? The best we can do is to prepare in advance for potential differences.

Agenda. In this module I'll introduce the idea of Universal Design for Learning (UDL). We will begin with background information, and then we'll talk about the principles of Universal Design for Learning and then its application in higher education.

Background. This idea was developed based on the concept of universal design and architecture from the early 1970s. The idea of universal design was to create spaces that are usable by all or most without further modifications. Design it right from the beginning, and you do not need to go back and adapt it. Later, a good example of this in architecture is adding a ramp onto a sidewalk. The ramp can be used by anyone who will benefit, and it will then benefit many others. The original intention was for the sidewalk to be accessible for those with mobility issues. However, I would be able to pull a wagon or a cart of books onto the sidewalk much easier because I could use the ramp. It's easier to design the ramp when you're making the sidewalk than it is to go back and cut out a workable lamp later on.

Principles of Universal Design for learning. In the late 1980s, the Center for Applied Special Technologies, or CAST, brought this concept into education and developed the idea of Universal Design for Learning. This idea helps to make learning spaces universal, not just accessible. So you’re learning spaces and your learning materials are more accessible for everyone. A good definition is: “The intentional design of courses and learning spaces that include and address a wide variety of learning styles and individual needs" (Creamer, 2007).

So take a moment to think about your students. Think about your classes. What area some differences among students in your classes? Do you all of their learning preferences? Do you know all of their backgrounds? Do you know what prior knowledge they bring into your classroom or prior experiences they bring into your classroom? Do you know their abilities or their disabilities? Do you know all of the ways they might be different from each other?

Universal Design for Learning "anticipates diversity in the learners and takes their needs into consideration from the very beginning of course planning" (Zhong, 2012). So let's think of a good example in a college classroom. A history professor is teaching a class on pop culture. You've designed a fully interactive lesson in which the students are going to experience the disco era by learning some disco dance moves. You're excited about it until Joe comes into class, and he's on crutches. He broke his leg in the big game over the weekend, and suddenly your heart sinks. How is Joe going to participate in disco day when he's on crutches? You're scrambling at the last minute to try to come up with something that Joe can do so he can have fun learning also along with the rest of his class.

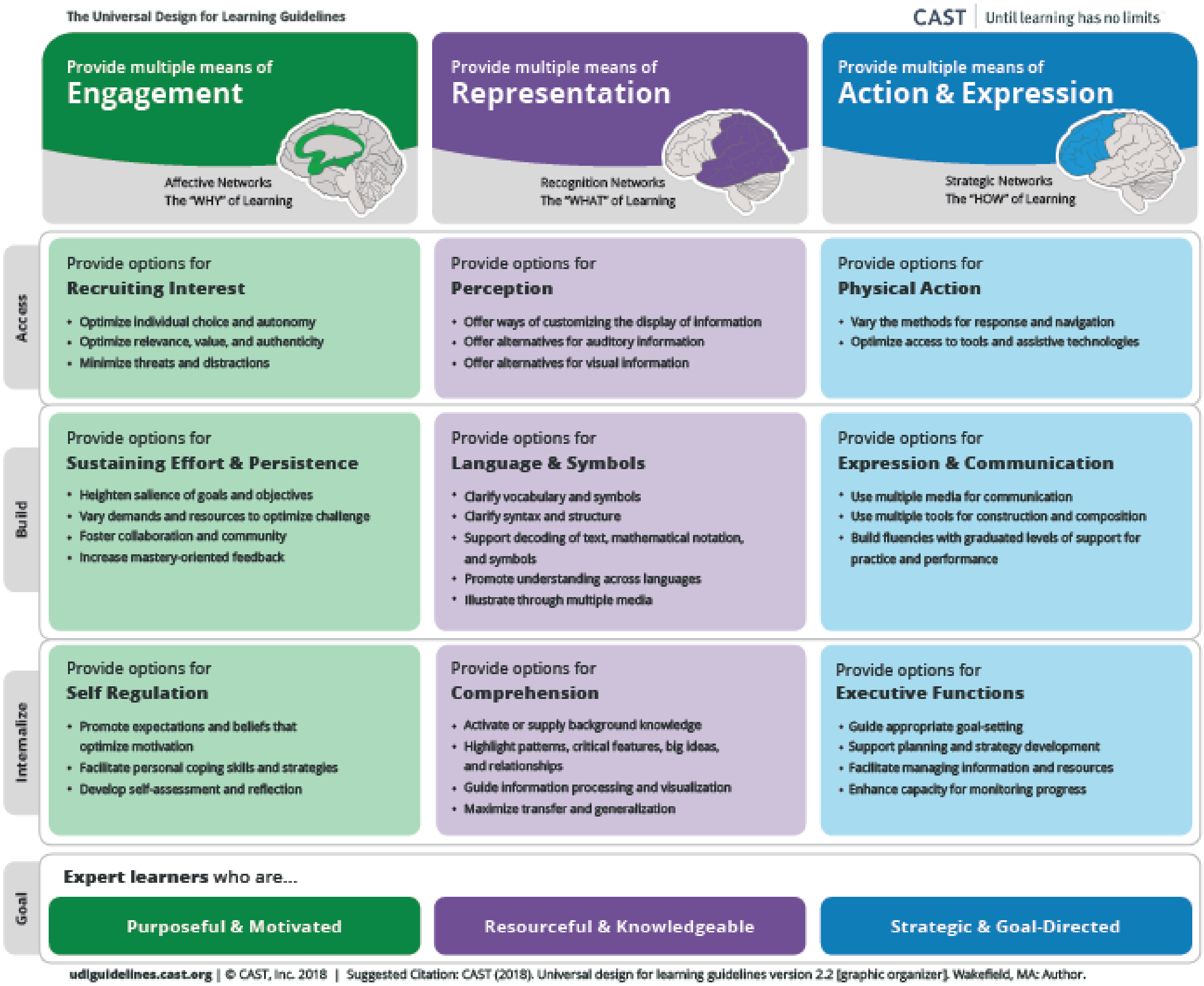
Now rewind and plan this lesson universally. When you're planning you think about how someone with limited mobility could participate—maybe you have some tambourines at their ready. Maybe you plan for a student to be the DJ. You might even want some adoring swooning fans to be part of the audience. Now when Joe comes in you immediately know that you have something for him to do and your attitude has changed. You have time to focus on Joe and I'm listening to a story about the big game instead of stressing out about how to make your lesson work. Your plan included option for options for diverse students so all could be accommodated. You've anticipated potential needs, even though you were not aware of those needs ahead of time. You were ready with a variety of options in case they were needed, and if Joe wasn't injured, you could still have someone choose to be a tambourine player or not.

In a chemistry lab, the students need to read the burette at the right angle so you can see the meniscus level. Short students are those in wheelchairs cannot accurately read a burette with a normal lab bench height. A universally designed lab space would have benches at various levels to allow all students access to the lab without adaptations.

Universal Design for learning principles. There are three principles of Universal Design for Learning. The first is to provide multiple means of engagement. This is the "why" of your lesson. These hooks are the things to get them excited and engaged in their learning. The second is multiple means of representation this you're learning materials. These are your teaching strategies, the way you present your information. The third one is multiple means of action and expression. This is the how the student works products—the ways that they show you that they've learned. Maximize every student's opportunities to interact with the information.

The key concepts in Universal Design for learning are that you have to include flexibility in your planning, and you have to plan ahead. You have to think about all of the potential needs of the students before they get to your classes. If you follow these principles, then you are maximizing every student's opportunities, multiple opportunities to interact with the information you're providing multiple ways for them to engage, for them to get the information, and for them to show that they've truly understood what you've been teaching. The CAST website has a ton of great information that will be really helpful to you as you're thinking about universally designing your lessons. It shows the multiple means of engagement, representation, and action and expression; and it gives you examples for each one.

So let's look in a little more detail about each one.



Engagement. For engagement how can you motivate the students to be actively engaged? Think about the students thinking why should I learn this? Some points to consider—find ways to appeal to the student interest, multiple ways. The students don't have the same interests, so you're going to need to address their interests in many ways. Consider opportunities to increase choice. Are there a variety of ways that you can get them engaged? Can some watch a video to gather information? Can others listen to a podcast or something in audio form to get the information? Can you also have some reading options for those who want to read the information? Encourage students to work together, especially in this engagement piece, where their output is not really part of it. It's what they're putting into it, and what they're bringing into it. So if you can encourage them to work together to get engaged in the topic, then they'll be ready when they come into the class.

Representation. The second principle is representation. How can your instruction increase learning and help students gain independence in the learning process? This is really the bulk of your instruction, so this is where I have the most points for consideration. Use various means for presenting your information. Don’t just use lecture, but use some other options as well—throw in some technology tools.

Think about potential barriers ahead of time. If there's a student in the class who might have hearing difficulties, what are some other ways that you can make sure that they get that information? Encourage students to reflect on their process of learning and think back about what they've learned. Clarify vocabulary in the language of learning. My favorite example for this is going back to elementary school days with the Nursery Rhyme Little Miss Muffat. Children can learn this rhyme, but just because they know the words and the rhyme, they likely have no idea what Miss Muffet sat on. What is a tuffet? When presenting this to young children it would take just a few seconds to show a picture of a tuffet and explain that it's a soft covered stool. You can even bring a tuffet into the class so the students could sit on it like Miss Muffet. You could do the same thing with curds and whey, provide the experience in a variety of ways and the students will begin to visualize Miss Muffet upon her tuffet, eating her curds and whey. I know that's a very primary example, but it illustrates the point. You need to activate prior knowledge or provide that prior knowledge. You need to provide scaffolding for them so they can increase their learning, and you need to offer a variety of visualization strategies.

Action and expression. The last principle is action and expression. How can students act on their learning? What are the variety of ways in which learning can be demonstrated? So points to consider here include opportunities to informally demonstrate learning. Throughout your class, throughout your learning process, fit in times where students can talk to you or share in some way what it is that they're learning so far. Again, provide that scaffolding for them. Provide options in the final product when possible. If it's not required for everybody to do their final product the same way, open it up for different options and different chances to show what they've learned in different ways. Vary the method of sharing what was learned and encourage the students to set goals and reflect on their learning.

Application in higher education. So why does this matter in the college classroom? The Individuals with Disabilities Education Act (2004) mandates that students in pre-K through 12 schools be provided with free appropriate public education (FAPE), but no such mandate is in place for higher education. However, most students do not suddenly lose the need for accommodations when they graduate high school. They still have the needs, and they're on their own to advocate for themselves.

In higher education it often falls onto the student to provide information to the college or university about disabilities and learning differences. However, if an institute of higher education is viewed as a component of society and part of the mission is to educate our students for the betterment of society, the responsibility for providing an accessible learning environment also falls to the instructor. Something to think about—do you know every identified learning problem of every student in your class? What about learning preferences physical limitations? Medical needs? Home situations? Students come to you from a variety of situations with a variety of experiences and prior knowledge.

Somehow you have to provide the best learning opportunities for each student—no matter what he or she is bringing into the classroom. You're often not made aware of the needs unless that's shared by the student, and many students do not readily share their needs. They might not want to be seen as different, or they might be an in a situation such as with color vision deficiencies where they might not be aware that their needs are different from the needs of others.

The goal for a Universal Design Learning college classroom. The goal for UDL in a classroom in college is to move from adaptation to anticipation. It's a changing in a mindset. So instead of making adaptations once you find out about the needs, you're anticipating the needs of the learners, and providing instruction and learning environments that will meet those needs your scaffolding.

It is impossible to fully learn without the ability to perceive information. The instructor needs to design instruction to effectively communicate information "regardless of ambient conditions or the student's sensory abilities" (McGuire & Scott, 2006). If a student is unable to perceive the information due to a sensory perception condition, such as color vision deficiencies, the only option is to memorize, which does not lead to long-term, deep learning. My twins, with color vision deficiencies had to memorize that red and blue are put together to make purple. They don't see that reaction happen. So for them that's memorization. It's not long-term. They don't remember for the long term until they've worked with that information. It's a deeper, different type of learning. Universal Design for Instruction, or Universal Design for Learning is a good framework for reflective practice. It's a way to gauge how you're preparing your instruction.

So what can you do? Think about a lesson that you teach regularly. What are some ways you can apply the principles of Universal Design for Learning in your lesson? Can you think of ways that you can provide multiple means of engagement? What do you do now? How can you it increase those opportunities? Can you think of multiple ways you can represent the information, additional materials you might add? Or additional activities? Maybe throwing in some of those technology tools, and thinking about those products—the way the students express their learning. How can you provide multiple means of expression? Providing an open classroom environment will encourage your students to share with you their needs and their concerns before you start those lessons. The more information you have, the more you are able to provide for the needs of your students. So start thinking universally. Start thinking as you're planning: what are the ways that I can prepare my students for whatever need they might have to maximize their learning?

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Transcript of Module Video 3, What Color is a Rainbow?

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So what color is a rainbow? This was a conversation that I had with one of my twins when he was eleven years old. There was a beautiful double rainbow in front of us in the sky. You could see all the colors in the rainbow, and so I said, “How many colors can you see? I know that you know the color spectrum; you've learned that in school. But how many colors do you actually see? And he said, “I see two: one is green and the other is blue or maybe purple. I said, “Well, what color do you see above the yellowish green? And he said “Umm, sky.” All he was seeing in the rainbow, the beautiful rainbow that was in front of me, was two shades of color.

Each year in school we've had to tell their teachers about their color vision deficiencies and the teachers always say, “I've never had anybody in class who's been color vision deficient.” We always have gone through the description of how “yes,” they probably have. Now that the boys are in college it's on them if they want their professors to know they have to tell them. They do not readily ask for help, and they'd rather muddle through then ask and admit that they need help. Even when taking a class in heating and air, which requires correctly wiring things, one would rather get it right through trial and error than ask a partner or the teacher. I've quit trying to figure out why. They’re adults.

What is the purpose of color? There are three different purposes for color, and it's important to think about how that color is being used to determine how much adaptation you need to make. If the color is providing information, make sure that there's another means of getting that information. So if you're color coding, and red has a particular meaning, make sure that you have that meaning written out somewhere in words or in symbols or in another way of telling that information. The color might just be representing something. If that's the case, is it important that they know what is being represented through the colors? If so, you might want to provide, or you should provide, another means of doing the presentation. Or is the color only used for aesthetic purposes? For the majority of the population we want things to look pretty. We use colors to help things look pretty. But if that's really the only purpose of the color, then you might not need to make adjustments just for those that see color differently.

What are some considerations that make these adaptations controversial? First of all, there's a lack of a legal requirement. As we talked about before, color vision deficiencies are not considered disabilities under the Americans with Disabilities Act, and there is no legal requirement to make accommodations at the college level. The disability has to be self-disclosed by the student.

The complexity of the condition is important. There are so many different forms of color vision deficiencies. It can take so many different forms, and it looks so different to different people. So it's a very complex condition, and we're also concerned in higher education at preserving the academic rigor. We don't want to water down our content. We don't want to make things simpler, but we do want to make things accessible. Every student in the class should have access to the information that you're providing in your class.

If color is a subjective experience, and students with color vision deficiencies are good at coping, why bother making adjustments? First of all, color discrimination has been shown to be vital to memory. People learn better when color helps them organize their thoughts and their information. There are consequences that can be mitigated by making adaptations. So if you know that the color is going to be a distraction or be a problem in learning, then you can stop that. Control for that before you have your learning opportunity. So how can you enhance access for all students? Remember, there are many different possible ways people might see color.

How can one enhance access for all students? It's not a one-stop shop, so be intentional about your design. Use high contrast. Think about the colors that you're using. Think about the combinations of those colors. You might even ask some students about color combinations that you're considering using, to make sure that it's accessible to all in the class. Be aware of potential problems. A student might seem to be acting out, might seem to be misbehaving, or might seem to be intentionally giving you the wrong answer. But it might be that he or she does not understand or even see the information that you're providing. So a simple discussion outside of class might help resolve this. It might help you get to the background of what's really going on.

As we talked in Universal Design for Learning, allow them to be creative in the responses in the ways that they provide information back to you, and take a look at your textbooks and other learning materials to identify potential problems potential points of confusion before you assign those materials. If you have a textbook that has a lot of color graphs or color maps, are they using other ways of providing that information, such as texture and design, or labeling with words or numbers? Make use of specific talents of students. There are studies that show that some students with color vision deficiencies demonstrate an increased ability to recognize pattern. There are some studies that also show some are able to see objects in camouflage better. They're looking more at things other than color. They're looking at texture. They're looking at line. They're looking at design. But they're not looking at the color, so they're able to determine these other things. Those are talents you can use in the classroom.

Add shading and texture using color lightness at the boundaries of objects helps enhance that color. Choose your color palettes carefully so you want to avoid common combinations that you know are problems for students with or for people with color vision deficiencies. Red /green, for example, is a common one; green/yellow might be a problem; pink and blue might even be a problem. It's sometimes amazing to talk to students or people with color vision deficiencies and find out what colors they don't see well and what those good palettes might be.

Use multiple ways to convey information. I think this is probably the most important tip if that information is important use a way other than just color to convey that information: labels, words, numbers, patterns, textures. Use whatever makes sense in that instance to help convey that information.

Allow time for processing. Now there are studies that show that time is not going to help students necessarily see the color. It's not going to give them new information because they're able to look at it for longer, but if they see subtle differences in color or in shades of color, then they might be able to use the extra time to figure out those differences.

So is the answer to just put everything in grayscale? Well, grayscale can be useful sometimes. Having things in grayscale, such as pathology and histology, can help you see the structure without the color getting in the way, even for the sake of the students with normal color vision. Almost 90% of our population has normal color vision. So shades of grey may not be optimum for learning. We've already talked about how color does help in memory and in learning. Also keep in mind that there are a variety of levels and different types of color vision deficiencies. For 75% of those with color vision deficiencies, it’s not so severe that they would need a grayscale. Instead of not using any color, and also for the sake of those with normal color vision, it's important to have that color to keep them engaged and to help as an organizational tool.

So what aspects of color transformation are critical? First of all consistency. So think: are the color transformations that I'm using consistently used across the application, and what about naturalness? Are these colors as close to natural colors as possible? And what about contrast? Are the different colored components able to be differentiated? Do I have strong enough contrast? There are more resources and more information in the adaptation resource module, including links to adobe Photoshop check. Some of these other resources will help you with transformation of color.

What can you do about it? So the best thing I can tell you is to think about color, and think about the fact that there may be students who see things differently. Use color. It's a great organizational tool for most people, but provide alternatives to get that information in multiple ways. High contrast is always good in your signs, your handouts, and your PowerPoint presentations. High contrast is best. Keep in mind that bright white pages might be too bright for people with some vision problems. So it's important to dull down the page slightly instead of using that bright white background. Explain what's going on in pictures or have the students explain it. So if there's a picture that you're showing to the class, talk about it, and talk about that picture or image together. Allow for creativity, and be flexible with what you expect from the students, instead of being quite as rigid with expectations for their products. Provide layers of education. Help them along the way to see their progress—to make sure that they're understanding what's going on.

I thank you for the time that you've provided to look through and listen through these presentation modules. I hope that you've learned about color vision deficiencies, Universal Design for Learning, and ways that you can apply this information in your classroom. Thank you very much.

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Appendix B: License Agreement for Online Stages of Concern Questionnaire

AMERICAN INSTITUTES FOR RESEARCH

Stages of Concern Questionnaire Administration
License Agreement

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Quick Navigation Links

- Main Menu
- My Clipboard
- System Security Features
- SoCQ Manual
- MS Word version of SoCQ

My Cohorts

Experimental group for CVD adaptations 2019 (mq4tnc)

- cohort report (0 responses)
- Individual reports (0 responses)
- Subgroup reports (0 responses)

Appendix C: IRB Permission Letter

LIBERTY UNIVERSITY
INSTITUTIONAL REVIEW BOARD

January 22, 2020

Marlena Hope Pinner
IRB Exemption 4048.012220: The Effect of Training Upon Faculty Attitudes Towards Making Color Vision Deficiency Adaptations

Dear Marlena Hope Pinner,

The Liberty University Institutional Review Board has reviewed your application in accordance with the Office for Human Research Protections (OHRP) and Food and Drug Administration (FDA) regulations and finds your study to be exempt from further IRB review. This means you may begin your research with the data safeguarding methods mentioned in your approved application, and no further IRB oversight is required.

Your study falls under exemption category 46.101(b)(2), which identifies specific situations in which human participants research is exempt from the policy set forth in 45 CFR 46:101(b):

> (2) Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:
>
> > (i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;

Please note that this exemption only applies to your current research application, and any changes to your protocol must be reported to the Liberty IRB for verification of continued exemption status. You may report these changes by submitting a change in protocol form or a new application to the IRB and referencing the above IRB Exemption number.

If you have any questions about this exemption or need assistance in determining whether possible changes to your protocol would change your exemption status, please email us at [redacted].

Sincerely,

G. Michele Baker, MA, CIP
Administrative Chair of Institutional Research
Research Ethics Office

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Appendix D: Stamped Consent

The Liberty University
Institutional Review Board
has approved
this document for use from
1/22/2020 to –
Protocol # 4048.012220

CONSENT DOCUMENT

The Effect of Training upon Faculty Attitudes towards Making Color Vision Deficiency Adaptations

Marlena Hope Pinner
Liberty University
School of Education

You are invited to be in a research study of the attitudes of collegiate educators towards making colorblindness adaptations for students, which are completely optional. You were selected as a possible participant because you are a faculty member at [redacted]University. Please read this form and ask any questions you may have before agreeing to be in the study. Marlena Pinner, a doctoral candidate in the School of Education at Liberty University, is conducting this study.

Background Information: The purpose of this study is to find out if a virtual professional development training about colorblindness, and possible instructional adaptations for it, will make any changes in faculty's attitudes towards making optional adaptations for colorblindness. The results of this study will be interesting because such adaptations are completely optional—neither the law nor educational practice compel teachers to adapt for colorblindness.

Procedures: If you agree to be in this study, you will be randomly assigned to one of two groups: the experimental group that will view professional development training materials and afterward take a questionnaire online or the control group that will just take the questionnaire online. Please note that if you are assigned to the control group, you will be able to access the training materials, but only after you have taken the questionnaire online.

If you agree to be in this study as a part of the control group, I would ask you to follow the link to take the online questionnaire at the American Institutes for Research (AIR) website. This should take approximately 5 minutes.

If you agree to be in this study as a part of the experimental group, I would ask you to do the following, which will take approximately one hour total:

1. Read the *Color Blindness Adaptations Module* that describes possible adaptations for colorblindness. This should take approximately 10 minutes.
2. Follow the link and watch the YouTube video *Color Vision Deficiencies: A Hidden Disability*. This should take approximately 18 minutes.
3. Follow the link and watch the YouTube video *Universal Design for Learning*. This should take approximately 16 minutes.
4. Follow the link and watch the YouTube video *What Color is a Rainbow? Ideas for Classroom Accommodations.* This should take approximately 13 minutes.
5. Follow the link to take the online questionnaire at the American Institutes for Research (AIR) website. This should take approximately 5 minutes.

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Protocol # 4048.012220

Risks: The risks involved in this study are minimal, which means they are equal to the risks you would encounter in everyday life.

Benefits: By completing the professional development training, the participants in the experimental group may benefit by gaining an understanding of the plight of the colorblind students under their instruction. The participants in the control group can request the professional development training materials after data collection has ceased.

Benefits to society include possible research-based information to help educators in higher education better serve their students with colorblindness.

Compensation: Participants will be compensated for participating in this study. An Amazon e-gift card of $10 will be offered, facilitated through your email, at the end of the online Stages of Concern Questionnaire. To maintain anonymity, your email address will not be connected to your responses on the Stages of Concern Questionnaire.

Confidentiality: The records of this study will be kept private. Research records will be stored securely, and only the researcher and the dissertation faculty chair will have access to the records. Your responses will be anonymous because your identifying information will not be requested on the questionnaire. Neither the American Institutes for Research (AIR) nor this researcher will have the ability to connect the IP address of the computer you used to complete the survey with your responses on the questionnaire. General demographic data will only be used to place your responses into participant groupings for study purposes.

The responses to the questionnaire will be evaluated by AIR, without the possibility of assigning individual identities to response records. Data will be stored on a password locked computer and may be used in future presentations. After three years from the date that the questionnaire access is closed, all electronic records will be destroyed.

The questionnaire is owned, administered and analyzed by AIR; AIR has security measures in place to protect the information that would be housed there as a result of a participant taking the online survey. Neither AIR nor the researcher will share data with third parties.

The security statement for AIR defines several layers of security protocols. The online administration site for the experimental and control groups will have a password-protected logon. Data obtained by the online questionnaire is housed in a secure server. Access to the database is restricted to an administrator and support staff who "are bound by a confidentiality and nondisclosure agreement" (https://www.air.org/). Access to data during questionnaire submission and during subsequent report retrieval by the researcher is secured by SSL encrypted connections.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with Liberty University or [redacted] University. If you decide to participate, you are free to not answer any question or withdraw at any time, prior to submitting the survey, without affecting those relationships.

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Protocol # 4048.012220

How to Withdraw from the Study: If you choose to withdraw from the study, please exit the survey and close your internet browser. Your responses will not be recorded or included in the study.

Contacts and Questions: The researcher conducting this study is Marlena Pinner. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact her at [redacted] or [redacted]. You may also contact the researcher's faculty chair, Dr. Gary Kuhne, at [redacted].

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board [redacted] or email at [redacted].

Appendix E: Recruitment Email and Follow Up Email

Recruitment Email

January 28, 2020
Dear [redacted] Educator:
I am writing to ask you to participate in my doctoral research.

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctoral degree in education. The purpose of my research is to determine if a brief virtual professional development training about colorblindness, and possible instructional adaptations for it, will make any changes in faculty's attitudes towards making instructional adaptions for colorblindness. The results of this study will be interesting because such adaptations are completely optional—neither the law nor educational practice compel teachers to adapt their instruction for colorblindness.

You were selected as a possible participant because you are an educator at [redacted] University. If you agree to participate, you will be randomly assigned as a member of the control group or the experimental group. If you are part of the control group, you will be asked to take an online questionnaire that should take approximately 5 minutes to complete. If you are part of the experimental group, you will be asked to take a professional development training that will take approximately an hour to complete. It will consist of reading an informational document and watching three short videos, taking an estimated 57 minutes to complete. After finishing the training, you will be asked to take an online questionnaire that should take approximately 5 minutes to complete. Your questionnaire responses will be completely anonymous, and no personal identifying information will be collected.

To participate, please email me at [redacted] and just type the word "study" in the subject line. After I have received your email, you will be randomly placed in either the control group or the experimental group. I will then email you the corresponding training link and/or questionnaire link to complete your participation in this study. The opportunity to participate in this study will expire on February 19, 2020—please respond as soon as you can.

A consent document with additional information about the study is attached to this email. It will not need to be signed or returned to me. Your email address will only be used to send you the training links and/or to direct you to the questionnaire.

If you choose to participate in this study, you will receive an Amazon $10 e-gift card after completing the questionnaire.
Thank you.

Sincerely,
Marlena Pinner
Attachment: Consent Document

Recruitment Follow Up Email

February 5, 2020
Dear [redacted] Educator:
I am writing to ask you to participate in my doctoral research.

Last week an email was sent to you on January 31, 2020, inviting you to participate in this research study. This follow-up email is being sent to remind you to respond to this invitational email if you would like to participate and have not already done so. The deadline for participation is two weeks from now, and your participation is earnestly desired.

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctoral degree in education. The purpose of my research is to determine if a virtual professional development training about colorblindness, and possible instructional adaptations for it, will make any changes in faculty's attitudes towards making instructional adaptions for colorblindness. The results of this study will be interesting because such adaptations are completely optional—neither the law nor educational practice compel teachers to adapt their instruction for colorblindness.

If you agree to participate, you will be randomly assigned as a member of the control group or the experimental group. If you are part of the control group, you will be asked to take an online questionnaire that should take approximately 5 minutes to complete. If you are part of the experimental group, you will be asked to take a professional development training that will take approximately an hour to complete. It will consist of reading an informational document and watching three short videos, taking an estimated 57 minutes to complete. After finishing the training, you will be asked to take an online questionnaire that should take approximately 5 minutes to complete. Your questionnaire responses will be completely anonymous, and no personal identifying information will be collected.

To participate, please email me at [redacted] and just type the word "study" in the subject line. After I have received your email, you will be randomly placed in either the control group or the experimental group. I will then email you the corresponding training link and/or questionnaire link to complete your participation in this study. The opportunity to participate in this study will expire on February 19, 2020—please respond as soon as you can.

A consent document with additional information about the study is attached to this email. It will not need to be signed or returned to me. Your email address will only be used to send you the training links and/or to direct you to the questionnaire.

If you choose to participate in this study, you will receive an Amazon $10 e-gift card after completing the questionnaire.
Thank you.

Sincerely,
Marlena Pinner
Attachment: Consent Document

Appendix F: Selection Emails

Control Group Selection Email

Dear Control Group Participant,
Thank you for agreeing to be a part of this study. You have been randomly assigned as a member of the control group.
Please go to the Stages of Concern Questionnaire at https://www.sedl.org/concerns/index.cgi?sc= to complete and submit your responses to the questionnaire (approximately 5 minutes in length). *If this link does not respond, please go to this site hyperlink https://www.sedl.org/concerns/ and enter* [redacted] *in the password box.*
The questionnaire is anonymous, and neither the American Institutes for Research nor I have a way to connect your identity to your questionnaire responses.
Please complete the questionnaire by February 19, 2020.
Thank you very much for your help,
Marlena Pinner

Experimental Group Selection Email

Dear Experimental Group Participant,
Thank you for agreeing to be a part of this study. You have been randomly assigned as a member of the experimental group and are asked to complete the professional development training and then complete the online questionnaire.
Please read the attached *Colorblindness Adaptations Module* and then follow the YouTube links below to watch all three short professional development videos by Dr. Karla Collins.

1. Color Vision Deficiencies: A Hidden Disability at https://youtu.be/JlimMDJV_hw (approximately 18 minutes in length).
2. Universal Design for Learning at https://youtu.be/rV2fZ12muIs (approximately 16 minutes in length).
3. What Color is a Rainbow? Ideas for Classroom Accommodations at https://youtu.be/BBhyMmgl1DM (approximately 13 minutes in length).

After finishing the training, please go to the Stages of Concern Questionnaire at https://www.sedl.org/concerns/index.cgi?sc= to complete and submit your responses to the questionnaire (approximately 5 minutes in length). *If this link does not respond, please go to this site* https://www.sedl.org/concerns/ *and enter* [redacted] *in the password box.*
The questionnaire is anonymous, and neither the American Institutes for Research nor I have a way to connect your identity to your questionnaire responses. Please complete the questionnaire by February 19, 2020.
Thank you very much for your help,
Marlena Pinner
Attachment: Colorblindness Adaptations Module

Appendix G: Colorblindness Adaptations Module

This is the experimental group Selection-Email attachment.

(Note: Following each hyperlink is not required.)

Frequently Asked Questions

1. How can instructors make simple preemptive adjustments that help colorblind students?

- Use high contrast: avoid using several dark colors or several pastels because their color saturation levels are similar (Frane, 2015).
- Use thick lines, even in your choice of fonts, or use fonts with serifs (Frane, 2015).
- Use color palettes with varying depths of color to indicate differences instead of choosing different colors (Frane, 2015).
- Use labels, shading, textures, or designs in addition to colors when designing materials (Frane, 2015).
- Explain color representations so students need not rely on the color cues (Collins, 2019).
- Audit your texts and materials to look for potential problems; for example, use a graph that has a red line and a green line, but has no labels (Frane, 2015).
- Be aware of the colors in your instructions, and do not rely on color terms only (Frane, 2015).
- Shade the edges of colored elements lighter to make them more distinguishable (Suetake, Tanaka, Hashii & Uchino, 2012).
- Refrain from colors for contrasts that are confusing for colorblind individuals—see the table below.
- Test your materials using "Photoshop: View > Proof Setup > Colorblindness" (Frane, 2015, p. 198). Open a second window to enable you to view the original material alongside the Photoshop-generated version, and then replace individual colors that are still too close in

saturation or too unnatural: "Photoshop: Image > Adjustments > Replace color" (Frane, 2015, p. 198).

2. What are the most important aspects to consider when adapting a color representation?

- Pick colors consistently (Collins, 2015).
- Pick colors from colorblindness-friendly palettes (available at http://colorbrewer.org) that approximate natural colors (Simon-Liedtke & Farup, 2016); for example, no blue leaves.
- Pick colors that have high contrast and high saturation (Frane, 2015).

3. How can I test my color design for friendliness to colorblindness?

Go to http://www.iamcal.com/toys/colors/ to view the color palettes of individuals with each type of colorblindness. If the color you are using is not included, the person with colorblindness will not see it.

4. How can I test my images for how they will look to the various types of colorblind individuals?

Use the Color Blindness Simulator at https://www.color-blindness.com/coblis-color-blindness-simulator/ by pasting your image in the window and selecting the colorblindness type.

5. Why is adapting for colorblindness controversial?

Neither the law, nor educational practice, require it. Also, since there are many types of colorblindness, knowing how to make adaptations can be less than obvious.

6. Is color educationally valuable?

Background colors on digital screen-displayed lessons enhance structural memory—the type that is key for higher level learning (Clariana & Preston, 2009). Color enhances recall for both individuals with and without colorblindness, suggesting that color, even aberrant color, affects cognitive processing (Bredart, Cornet, & Rakic, 2014).

7. Why is Universal Design for Learning useful in adapting instruction for colorblind students?

Universal Design makes it unnecessary to identify colorblind students because it relies on anticipating a broad range of student needs so that lessons are built without barriers instead of trying to retrofit them for individual needs (National Center, 2011). Since instructors should refrain from openly asking students if they are colorblind, the preemptive approach of Universal Design is optimal.

8. Which color combinations are typically difficult for individuals with colorblindness?

Typically Difficult Color Combinations

Red contrasting against green—use blue instead of green[a]
Red contrasting orange[d], or against dark colors or black, especially text and background combinations[a]
Dark brown contrasting "with dark green, dark orange, and dark red" (Maule & Featonby, 2016, p. 3)[d]
Deep purple elements contrasting with black[d] or red elements in histological stained specimens—use high quality grayscale monitors or printouts[b]
Green contrasting with yellow, brown, blue, gray, or black;[c] mid-greens contrasting with blues and "some oranges" (Maule & Featonby, 2016, p. 3)[d]
Blue contrasting with gray, pink,[d] or "with some reds, purples and dark pinks" (Maule & Featonby, 2016, p. 3);[d] some light blues contrasting with lilacs[d]

[a]Frane (2015)
[b]Rubin, Lackey, Kennedy & Stephenson (2009)
[c]Collinge (17 January, 2017) Retrieved from https://usabilla.com/blog/how-to-design-for-colorblindness/
[d]Maule & Featonby (2016)

9. Are there negative consequences for students with colorblindness?

Difficulties can surface in various ways by subject (Chan, et al., 2014; Kvittle, 2018):

chemical tests, inappropriate color choices, plant species identification, and graphic representations. Medical students have challenges in microbiology, histology, microscopy, and hematology (Goh, Chan, & Tan, 2014; Rubin, Lackey, Kennedy, & Stephenson, 2009). Medical students can experience difficulties making medical diagnoses without properly being able to discern skin and eardrum coloring (Goh, et al, 2014). Matching dentine hues can be difficult for dental students (Khalid, Chughtai, Mian, & Shah, 2017).

10. How can I test my color vision?

Go to https://www.color-blindness.com/color-blindness-tests/#rgbanomaloscope for access to several online versions of color vision tests.

11. Are their technological aids that colorblind students can use?

Special dark glasses and contact lenses can lessen the impact of the condition (Wu, Tseng & Cheng, 2019), but may be too dark to be of classroom use (Chen & Liao, 2011). Depending on condition type and severity, there are applications for Android and iOS devices. Unfortunately, these algorithmic transformations assign the same replacement color to several colors or assign a non-natural replacement color (Simon-Liedtke & Farup, 2016); ambient lighting effects can also make problems (Reinecke, Flatla & Books, 2016).

Thank you for reading the adaptations module!

Types of color deficiencies

Type	Description	Affects	Example
Trichromacy	All rods and cones work properly		Ability to see full range of colors
Monochromacy	Absence of short (blue), medium (green), and long (red) wavelength cones.	1 in 10,000	Inability to see any colors
Anomalous Trichromacy - One or more color sensitivity is slightly off due to the malfunction of one type of cone. Results in slight color deficiency.			
Protanomaly	Red-weak.	1 out of 100 males; 0.1% of females	Purple appears blue
Deuteranomaly	Green-weak.	5 out of 100 males; 0.4% of females	Difficulty telling differences in the red-orange-yellow-green spectrum.
Tritanomaly	Blue-weak.	.0001%	Can be acquired through eye damage.
Dichromacy - One or more cone is absent. Most severe of the red-green defects.			
Protanopia	Red (L) cones absent.	1 out of 100 males; 0.1% of females	Effects perception of blue, violets, and purples because of the dimmed red.
Deuteranopia	Green (M) cones absent.	1 out of 100 males; 0.1% of females	Cannot differentiate between red, orange, yellow, and green.
Tritanopia	Blue (S) cones absent.	.0002%	Can be acquired through eye damage.

(Collins, 2019)

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