



MSU Graduate Theses

Spring 2019

The Effects of Color Choice in Web Design on the Usability for Individuals with Color-Blindness

Theresa Marie Sparks

Missouri State University, Theresa0431@live.missouristate.edu

As with any intellectual project, the content and views expressed in this thesis may be considered objectionable by some readers. However, this student-scholar's work has been judged to have academic value by the student's thesis committee members trained in the discipline. The content and views expressed in this thesis are those of the student-scholar and are not endorsed by Missouri State University, its Graduate College, or its employees.

Follow this and additional works at: <https://bearworks.missouristate.edu/theses>



Part of the [Technical and Professional Writing Commons](#)

Recommended Citation

Sparks, Theresa Marie, "The Effects of Color Choice in Web Design on the Usability for Individuals with Color-Blindness" (2019). *MSU Graduate Theses*. 3352.

<https://bearworks.missouristate.edu/theses/3352>

This article or document was made available through BearWorks, the institutional repository of Missouri State University. The work contained in it may be protected by copyright and require permission of the copyright holder for reuse or redistribution.

For more information, please contact bearworks@missouristate.edu.

**THE EFFECTS OF COLOR CHOICE IN WEB DESIGN ON THE USABILITY FOR
INDIVIDUALS WITH COLOR-BLINDNESS**

A Master's Thesis

Presented to

The Graduate College of
Missouri State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Arts, Writing

By

Theresa Marie Sparks

May 2019

THE EFFECTS OF COLOR CHOICE IN WEB DESIGN ON THE USABILITY FOR COLOR-BLIND INDIVIDUALS

English

Missouri State University, May 2019

Master of Arts

Theresa Marie Sparks

ABSTRACT

Websites are not accessible to many individuals with color-vision deficiency or color-blindness; this is because of poor color and design choice. One must design websites with these individuals in mind. In this study, it was found that color choice on aspects such as body text, background, and links did have an effect on how individuals with color-blindness were able to use and read websites.

KEYWORDS: web accessibility, color-blindness, color-vision deficiency, web design, accessibility

**THE EFFECTS OF COLOR CHOICE IN WEB DESIGN ON THE USABILITY
INDIVIDUALS WITH COLOR-BLINDNESS**

By

Theresa Marie Sparks

A Master's Thesis
Submitted to the Graduate College
Of Missouri State University
In Partial Fulfillment of the Requirements
For the Degree of Master of Arts, Writing

May 2019

Approved:

Lyn Gattis, Ph.D., Thesis Committee Chair

Leslie Seawright, Ph.D., Committee Member

Marianthe Karanikas, Ph.D., Committee Member

Julie Masterson, Ph.D., Dean of the Graduate College

In the interest of academic freedom and the principle of free speech, approval of this thesis indicates the format is acceptable and meets the academic criteria for the discipline as determined by the faculty that constitute the thesis committee. The content and views expressed in this thesis are those of the student-scholar and are not endorsed by Missouri State University, its Graduate College, or its employees.

ACKNOWLEDGEMENTS

I would like to thank the following people for their support during the course of my graduate studies: Dr. Lyn Gattis, Dr. Leslie Seawright, and Dr. Marianthe Karanikas.

TABLE OF CONTENTS

Introduction	Page 1
Literature Review	Page 4
The Use of Colors on the Web and Screens	Page 4
Color-Vision Deficiency and Colors	Page 7
Readability and Usability	Page 9
Universal Design, Web Standards, and Accessibility	Page 11
Current Recommendations	Page 14
Methods	Page 18
Research Design	Page 18
Website Creation	Page 21
Procedure	Page 26
Administering the Survey	Page 26
Administering the Interview	Page 28
Results, Analysis, and Discussion	Page 30
Coding Process	Page 30
Results	Page 30
Discussion	Page 36
Study Limitations	Page 39
Conclusion	Page 42
Literature Cited	Page 45
Appendices	Page 47
Appendix A. Additional Views of the Peachpuff Pet Care Website	Page 47
Appendix B. Additional Views of the Buttercup Pet Care Website	Page 48
Appendix C. IRB Certificate	Page 49
Appendix D. Informed Consent	Page 50
Appendix E: Survey Questions	Page 53
Appendix F: Interview Questions	Page 54

LIST OF FIGURES

Figure 1. Standard, Portan, and Deutan Color Palettes	Page 8
Figure 2. Buttercup Pet Care Home Page	Page 22
Figure 3. Peachpuff Pet Care Home Page	Page 23

INTRODUCTION

Websites are unusable and inaccessible to a large portion of the population because of poor design choices. Many of these poor design choices made often have to do with the use of color. Eight to ten percent of the male population in the world has some form of color-vision deficiency (van der Geest, 2005). Out of all the people with some form of a color-vision deficiency (CVD, or color-blindness), 99% are red-green deficient (Newman, 2000) making it the most common form of color-blindness. My own father is red-green deficient and often asks for my help when reading information on websites; he is the reason I wanted to further investigate good design practices and help create better websites for individuals with color-blindness. If, because of poor color choices, these individuals cannot navigate websites to find the information they need—if color is the only indicator of a link—their hunt for information is interrupted, and they have missed out on the information the website provides.

The relationship between CVD and website navigation is a problem we can understand by means of information seeking theory (Pirolli & Card, 1999). Pirolli and Card present seeking information as a hunting analogy. Pirolli and Card (1999) say one searches for information the way one would forage for food. This means that people forage the Internet for information. If a website looks like something that may answer their question, meaning it has a strong scent, the person will follow the scent by clicking on the website. The scent has to do with what value the information seeker assigns to the potential source. If the scent is strong, the seeker will follow it to the website to see if it does, in fact, contain the information they are looking for. When the user follows the scent to the website, the next step for the user is to determine if the information presented on the website fits their diet. In this context, diet refers to the type of information that

the user is looking for—the information that will satisfy their information hunger. The place where the information is found is referred to as the patch. The user will then search through the patch, or the website, to determine if it fits their diet. The user then makes the decision to search for a different patch, or website, that may have better information at the risk of leaving the one they are currently in.

If the colors are unusable, however, the scent leads them to the wrong place; their information hunt is interrupted, and the user's time is wasted. Morville and Rosenfeld (2008) relate this theory to web usability by saying information should be presented easily and quickly. Web usability directly relates to how quickly people, including people with color-blindness, forage and find information on the web. Designers must use the appropriate colors for people with color-blindness so their forage for information is not interrupted and they are able to find the information they need as quickly as possible, which is the users' end goal. Better color choice that keeps individuals with color-blindness in mind will make websites more accessible and help users find the information they need. People with color-vision deficiency need to be able to navigate websites efficiently and effectively to get the information they need.

For this study, I wanted to know how specific color choice affects the usability of a website and how easily people with a color-vision deficiency can find and navigate certain aspects of a website depending on the color palette used in the design. I examined how color choices recommended in literature in the field affected the usability of two separate fully functional websites I made for individuals with color-blindness. One of the websites implemented the recommendations found in the literature, and the other website did not. I focused on the topics of body text color and contrast, link color and contrast, and overall usability and readability. Color and usability, not reading comprehension, was the main focus of

this study; the word content for both websites contained the same text, photos, and set up. The text used for the websites was the preset text embedded in the website builder, so participants had nothing to read. Only the set of colors and contrast varied for both websites. By focusing on color and usability, I will help improve accessibility for these users. Usability focuses on how easy the website is to use. Can the user navigate the website without instructions or extra help? Accessibility means that the website can be accessed and is fully and readily available to people who are differently abled (Providenti, 2004). Readability, on the other hand, deals with how easy the content is to read or if the user can read the content at all (Holtze, 2006).

I then developed an online, anonymous survey to gauge how well a person with color-blindness could read and use each of the websites and uncover which website the participants would prefer to use and why. After the participants viewed the two different websites, they filled out the anonymous survey. A follow-up interview was also conducted with one of the participants. The purpose of the interview was to gain a better understanding of how a person with color-blindness navigates and views the web.

I start with a review of the literature about the topics of web design and design for people with color vision deficiencies in the field. After a review of the literature, I discuss the methods used in this study and the procedure of administering the survey and the interview. Finally, I conclude with the results of the survey and interview and a discussion portion that ties the results in with the literature and Pirolli and Card's information foraging theory.

LITERATURE REVIEW

People with color-vision deficiencies see the world differently from persons without the deficiency. Their daily lives are affected by this seemingly small impairment, and navigating the web can be especially difficult for these individuals. However, few studies have been done on this particular topic or about how color choice affects the usability and readability of websites for people with color-vision deficiency. As web designers, we are told the importance of designing with all individuals in mind, and to make our websites accessible, but we are often not told why or how to achieve this level of accessibility. We are not shown the actual impact our color choices have on readability and usability with regard to website design for individuals with color-vision deficiency.

In the following literature review, I refer to topics about accessibly designing websites specifically for users with color-blindness. I start with a discussion on how colors are used on the web and screens, followed by a description of what color-vision deficiency is, and the current recommendations found in the literature in order to design accessible websites for people with color-blindness.

The Use of Colors on the Web and Screens

Color is used for many things on the web including aesthetic purposes, rhetorical purposes, and usability purposes. The way web designers use these colors can determine whether or not an individual with color-blindness can use the website. When choosing optimal colors for screens, not just for individuals with color-blindness, web designers encounter a couple of major obstacles. In the early days of the Web, the initial discussion on safe colors for the Web included

just using colors that HTML supported, which meant that they were able to be displayed by nearly every web browser. (Web-safe colors are simply colors that are supported by HTML, not colors appropriate for users with a color-vision deficiency.) By doing this, web designers could ensure that their color choices were displayed to all audiences the way they wanted them to be (van der Geest, 2005).

But now, in 2019, the web designer must take into account the device the user is using and the settings the user might have in place that could affect the way the colors look. This happens because there is so much freedom for the user to choose the screen and the settings. Colors can look different from one computer screen to the next; computer screens vary widely in pixels that are displayed along with the DPI (dots per inch) that is displayed along with the settings the user chooses. These features, in turn, affect how colors are seen on these different screens. Smartphones also play a role in this. Now, most users are searching for information or surfing the web using their smartphone. Smartphones also have the same issue as computer screens; each smartphone has a different display that causes colors to look different (van der Geest, 2005). If a user had a cheap computer with a low-resolution monitor and was using it to design a website, the colors may not show as true or as clearly as they should. When a web designer is using two colors that they think contrast significantly, some users might fail to see the contrast fully, including users with color-blindness, because of the quality of the monitor they possess.

Web designers also use color for usability purposes and to help users navigate their website in the shortest time possible. As Holtze (2006) describes,

One aim of Web design is to get the users to the information they want as efficiently as possible; therefore, the success of the page is inversely proportionate to the number of distractors. The default for most computers is black text and white background. As shown in the Ling and van Schaik experiment, any deviation from this combination slows people

down. The eyes of the user are drawn to areas of color—areas of deviation from the norm. As more colors appear on the screen, the user’s eyes may dart from color to color instinctively seeking information in the highlighted areas. If the information sought is not there, the user has wasted time and may feel aggravated. (p. 95)

This idea of helping users navigate websites in the shortest time possible relates directly back to Pirolli and Card's information foraging theory. The poor use of color has interrupted the user's forage for information; the scent has proven to be wrong and has forced the user to pass this patch over for another patch that may fit their information diet better. (Patch refers to the source where the information is found.) Thus, it is important to use good color practices for both users with normal color vision and users who have a color-vision deficiency.

Color is also an important aspect when people are determining the credibility of websites, both in people with normal color vision and people with color-vision deficiency. A study done by Fogg, Sohoo, and Danielson (2002) showed that over 2,500 participants in their study cited color as the single most important factor when determining the credibility of a website. Color has extreme visual power and is something people notice first when looking at a website; consequently, web designers should use it sparingly and to only draw attention to the aspects that need it (van der Geest, 2005).

Because color can help, or hinder, navigability and credibility, that does not mean color should not be used at all. Color should be used well and not in large amounts; it should only be used to draw attention to what needs it. van der Geest (2005) says that “color should be well applied, but not necessarily in large amounts. Then why not limit the range to colors that are well accessible for colorblind users?” (p. 77). If color choice is already limited by good design practices, it would not be difficult for web designers to use colors that are accessible to users with color-vision deficiency.

Color-Vision Deficiency and Colors

It is important to understand exactly what color-vision deficiency, or color-blindness, is in order to design and develop usable websites and help this specific population get the information they need and are looking for. Color-blindness is not the inability to see color. According to *Gray's Anatomy* (1985), the eye contains three different types of cones that pick up different colors and wavelengths of light; a person is said to have some type of color-vision deficiency when one or more of these cones do not work correctly. All three cones must work in conjunction with each other to allow the eye to perceive colors correctly. Color-blindness happens when one or more of the three cones react to the color information it receives differently. This causes the individual to perceive colors incorrectly. Many people in the U.S., and the world, are affected by this impairment, but many websites with poor color choice are still being designed and are in use. Many of these websites are still in use because web designers are uninformed about color-vision deficiency and therefore continue to choose colors as if everyone can see the colors equally. My father is color-blind and often has to ask me to help him navigate websites because the designers of that website did not use color appropriately for people with color-blindness.

Actual color-blindness, or the inability to see color at all, is extremely rare; what we call color-blindness is this defect in the cones that cause color to be perceived incorrectly (van der Geest, 2005). van der Geest (2005) goes on to say:

For example, the cones of some colorblind people who look at a green object react as if they perceive green and red. Red and green make yellow, so the green object appears yellow. This is what we in everyday language call colorblind, but actually there are very few people really color-blind: Most people with color-vision deficiencies can see colors, but cannot distinguish easily between red and green. (p. 75)

Since an individual with color-blindness cannot easily distinguish between red and green, they may also have difficulty with varying shades and colors that contain red or green in them.

Many different types of color-blindness exist; however, the most common type of color-vision deficiency is red-green (Newman, 2000; Rigden, 1999; van der Gees, 2005); in fact, 99% of people with color-vision deficiency are red-green deficient (Newman, 2000). Of the world male population, 8% are colorblind. It is more common for men to have colorblindness because the colorblindness gene is recessive and carried on the X chromosome (Rigden, 1999). Of the 8% of the men that are colorblind, 1% are red-blind (protanope) and 1.1% are green-blind (deutanope) (Rigden, 1999). Figure 1 shows the standard web-safe color palette along with how protanopes and deutanopes see that same color palette; the web-safe color palette means colors HTML supports, not colors that are visible to persons with CVD. These people have a hard time distinguishing between red and green or distinguishing between any colors that have varying hues of red or green.

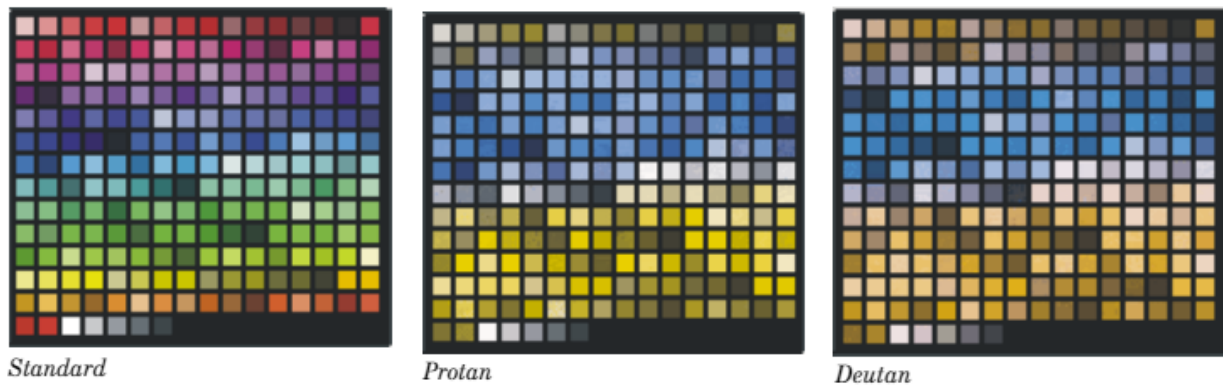


Figure 1: On the far left is the standard set of web-safe colors and how a person without any color-vision deficiency would view them. The Protan palette shows how a person with red-blindness would see the same colors in the Standard palette. The Deutan palette shows how a person with green-blindness would see the same colors in the Standard palette.

A common practice among websites is to use red or green to denote meaning such as signifying required fields in an online form with red (Riley-Huff, 2012). As Figure 1 shows, the varying shades of red and green look extremely similar; it is impossible to distinguish between them, which would make it impossible for a person with color-blindness to understand the context or use the information presented to them. Because of this practice, these websites are not making their information usable to the majority of people with color-vision deficiency. Since most of the people with color-vision deficiency are red-green color-blind, why are web designers alienating such a large portion of their audience with components that can be easily fixed? If web designers were taught what color-blindness is, and what colors look like to users with color-blindness, this would not be such a widespread issue. Web designers should stay away from using any form of red to denote meaning in a website. Unfortunately, many websites do use red to denote meaning. In online forms, fields in red often mean required fields. I have noticed within the past few years, though, that required fields often have an asterisk beside them in addition to being red; this is a good design practice with color-blind individuals in mind.

Readability and Usability

Readability and usability are different things but relate to each other in terms of how an individual with color-blindness perceives and can use a website. According to Holtze (2006), the main, and most important, aspect of readability has to do with the contrast between the body text and the background. To keep websites readable for people with a color-vision deficiency, red and green, or varying hues and shades of red and green, should not be used in close proximity to each other, and the web designer should make sure enough contrast exists between background colors and text (Holtze, 2006). Usability, on the other hand, is "the degree to which users seeking

information find a website relevant and easy to use" (Chow et al., 2014). If varying colors of red and green are used heavily in body text, links, or navigation, these aspects could make a website completely unusable to a person with color-blindness. Readability and usability go hand-in-hand. If a website is not readable, it is not easy to use. If a website is not easy to use, it is, in most cases, not readable. These concepts of readability and usability also relate to the concept of accessibility. If websites are not easily readable or usable, that means the website is not accessible. If it is not readable or usable, the person who is differently abled or has color-vision deficiency would not find the website accessible because the information is not readily available to them.

Usability and readability are in direct relation to Pirolli and Card's (1999) information seeking theory. The way one looks for information on the web can be related to how people used to hunt and forage for food. When a user thinks of a question or has a need for information, they get an information hunger. They then turn to the internet to forage for information that will satisfy their information hunger. This can be thought of in terms of scent, diet, and patch.

If a user who is color-blind is automatically not able to use a website, the scent has proven wrong, and they have wasted their time. Morville and Rosenfeld (2008) relate this information seeking theory to web usability. They say that information should be presented and structured in such a way on a website that the information scents are strong and clear enough for the individual to quickly find the correct pathway that will lead to the information they are looking, or are hungry, for. If websites do not use colors with color-blind individuals in mind, the website is no longer usable and it hinders their progress to the pathway that will satisfy their information hunger. Color-blind individuals often have their progress to the correct information pathway hindered because of web designers' poor color choice.

Design, Web Standards, and Accessibility

Universal design inherently sounds like design that is for everyone. Universal design, at its core, is the idea of creating content and designing for “barrier-free access” (Guder, 2014). According to Guder (2014), certain design principles can be used in order to produce universally accessible content whether that content is digital or physical. Null (2014) presents these principles as aesthetics, adaptability and accessibility, supportive design, and safety-oriented design in regards to library website design. Even though these principles have been created and applied to library websites, they still apply to overall web design and include good design practices. However, color is mentioned only briefly in principles of universal design, and never with regard to how it affects website usability for people with color-vision deficiencies. It is important for color choice to be included in universal design so products and content are being designed for individuals with color-vision deficiencies as well as users who are differently abled.

Much of the literature I have found discusses web standards and universal design for library websites, but many of these can apply to websites in other contexts; the same web standards and good design still apply. I believe much of the literature I have found regarding accessibility and design standards deal specifically with library websites because library websites *have* to be usable to the entire population; that is a library’s main audience. All web designers need to start thinking of the entire population as their target audience in order to provide the best possible experience for all kinds of individuals regardless of ability.

Web accessibility is starting to be made mandatory by legislation under Title III of the Americans with Disabilities Act (Providenti, 2004). The standards for HTML and CSS set forth by the W3C should be reviewed and used in order to construct websites that are usable for

people with visual impairments (Providenti, 2004). The W3C started an initiative called the Web Accessibility Initiative. The Web Accessibility Initiative publishes *Web Content Accessibility Guidelines*. The 1.0 guidelines were published in 1999, 2.0 was published in 2008, and 2.1 was published in 2018. The 2.1 guidelines are the most recent. The 1.0 guidelines give a few helpful recommendations on designing for people with color-blindness which will be discussed in greater length later in this literature review, but the 2.0 and 2.1 guidelines do not expand on those recommendations.

However, web standards and accessibility legislation often overlook individuals with color-blindness because color-blindness is not considered a disability or a visual impairment by law. It is not considered a visual impairment even though color-blindness affects common aspects of life including traffic lights (which are denoted by red and green), traffic signs (which are often green or yellow), flyers, posters, documentation (which could include important medical information), and websites. Meinard Noothoven van Goor, a Dutch advocate for the color-blind and a veteran, is color-blind himself. He tells the story of how he almost killed himself when he was a soldier in 1965 because color standards were not being used:

As a soldier, he drove a car on a road that crossed the runway on a military airfield. When he approached the runway, the lower of two traffic lights burned, so the color-blind soldier assumed it was safe to cross – and was almost run over by a plane. After that time, the Dutch Air Force standardized its traffic lights: red on top, green at the bottom. (van der Geest, 2005, p. 75)

When I learned my own father was color-blind, one of my first questions was how, at traffic lights, he knew when to stop and when to proceed. He told me it was because he knew red was on the top, which meant stop, and that green was at the bottom, which meant go even though both colors looked the same to him.

Web standards still have a long way to go in creating field standardizations that are inclusive to color-blind individuals, but there is hope. As of 2005, the Dutch Norms and Standards Institute (NEN) was working on a set of guidelines and standardizations in order to help web designers choose colors for color deficient individuals and to provide a set of color standards (van der Geest, 2005).

The NEN guidelines propose two strategies in order to standardize color usage for the benefit of individuals with color-blindness. They call these two strategies "redundant coding in addition to color coding and selecting optimal colors" (van der Geest, 2005). Color coding refers to the notion that color is used specifically in web design to denote meaning (like using red in a form to denote required fields). Redundant color-coding means using an additional cue in conjunction with the color (like saying required or including an asterisk next to a red field in a form). van der Geest (2005) says the NEN guidelines include four types of visual cues that web designers can use in addition to color coding. These four visual cues are:

1. "Specific form or position (rectangular versus round button, top versus bottom button)"
2. "Distinctive size (small versus large button)"
3. "Supporting text (STOP next to a red button, GO next to a green button)"
4. "Additional light signal (flashing red button versus non-flashing green button)" (p. 75).

Using these guidelines and strategies would make it much easier for a person with color-blindness to forage for the information they need on the Internet. As of now, in the U.S., we have the *Web Content Accessibility Guidelines*, but even with updates from the first 1999 version, the concepts of color in web design and designing for people with color-blindness have not been expanded upon except for a few small improvements.

Current Recommendations

Even without field standardizations, some recommendations can be made with regard to color choice. Many of the articles included in this literature review have given ways a web designer can use color to the best of their advantage while also providing an accessible experience to a user with a color-vision deficiency. However, few usability tests have been conducted in order to find out how these recommendations hold up in an actual usability test with individuals with color-blindness. Because so many different types of color-blindness exist, with red-green being the most common (Holtze, 2006; Rigden, 1999), web designers cannot design for every type of color deficiency. That is why so much importance, in the literature, is placed on learning about color-blindness, learning about the most common types, and learning the best practices in regard to web design.

The recommendations for color choice for web design are not very in-depth or inclusive, but they seem to be a good place to start when designers are developing websites for people with color-vision deficiency. The drawback is that usability test evidence to prove that these recommendations and best practices actually increase website usability for people with color-blindness is scant. Many authors recommend using text that contrasts highly with the background color (Rigden, 1999; Holtze, 2006; van der Geest, 2005). Visual clues are also important; visual clues need to appear next to colors such as the word stop next to a red button, and the word go next to a green button (van der Geest, 2005). Color should never be used to denote meaning (Riley-Huff, 2012). Links should use varying shades of blue and yellow with high enough contrast between them for color deficient individuals to distinguish between followed and unfollowed links and to be able to distinguish the links from the surrounding body text (Rigden, 1999). Holtze (2006) also stresses the importance of not using colors that are spectrally opposite

to each other (e.g. red and blue). If a web designer put red and blue close to each other on a computer screen, it would cause what Ojanpää and Näsänen (2003) call chromatic aberration. Chromatic aberration happens when a color with a short wavelength is placed next to a color with a long wavelength—like red and blue. The text or image with these offending colors may appear blurry because the eye cannot focus on the extremely different wavelengths simultaneously, hence the blurred effect (Ojanpää & Näsänen, 2003). Reading something that may appear blurry is hard enough for a person with normal color vision but can make the image or text completely unreadable to a person with a color-vision deficiency. A person with a color-vision deficiency may see chromatic aberration differently, and with different colors, than a person with normal color vision. This can happen because colors look vastly different to a person with color-vision deficiency.

The Web Accessibility Initiative in their *Web Content Accessibility Guidelines 1.0* (1999) give web designers a few helpful tips for making websites accessible to users with a color-vision deficiency; however, these tips are very similar to the others found in most of the literature. These guidelines state that web designers must make sure that the information of their website can be understood without the use of color. There are two recommendations the guidelines emphasize. The first is that the web designer should use some feature other than color to mark something (“Web Content Accessibility Guidelines 1.0”, 1999). This means using an asterisk along with the color red to mark a required field in a form. Newman (2000) also says that links should include an underline and not just color to distinguish them as a link. Without an underline, a user with color-blindness may not be able to determine the link from the rest of the body text. The second recommendation includes using highly contrasting colors for the text and

background, which much of the other literature also recommends (“Web Content Accessibility Guidelines 1.0”, 1999).

Since the 1999 *Web Content Accessibility Guidelines*, there have been two updated versions. The Web Accessibility Initiative at the W3C has put out versions 2.0 in 2008 and 2.1 in 2018. However, a search for “color” in the 2.0 guidelines produces the same recommendations given in the 1.0 version of the guidelines (“Web Content Accessibility Guidelines 2.0”, 2008). The same search in the 2.1 guidelines includes only the new criteria that were not previously listed in the 2.0 guidelines. The only new mention of color has to do with having “a contrast ratio of at least 3:1 against adjacent colors” (“Web Content Accessibility Guidelines 2.1”, 2018). An example would be a user having trouble filling out an order form on a website because they could not see where the text boxes were. By using this 3:1 contrast ratio, the user would be able to see the borders and, therefore, complete the order form (“Web Content Accessibility Guidelines 2.1”, 2018).

Few scholarly sources provide evidence to support these recommendations other than a few photographs and color palettes that Rigden includes in her article. Holtze (2006) attempts to list a few resources available to web designers to use to check the color of their websites for users with color-blindness; however, not a single link worked when I attempted to search for these resources. Because of the unreliability of some web-based tools, web designers should learn good design and accessibility practices and be able to apply them to their own designs as well as look at usability evidence to make sure what they are designing is accessible.

Since there is not much usability evidence when it comes to color palettes and color choices for individuals with color-blindness, I wanted to test some of these theories and recommendations. I designed a study to test if specific color choice improved the readability and

usability of a website for a person with color-blindness. I implemented the recommendations that I found most recurring in the literature and feasible for amateur web designers to implement into two websites. After constructing my two websites, one with the recommendations and one without, I conducted a usability survey to see if the recommendations of these authors do improve readability and usability for users with color-vision deficiency.

METHODS

I am studying web color and usability because I want to know how color choice affects web usability for people with color-blindness in order to provide a better overall web experience for those users. By focusing on and improving usability, it will then make the websites more accessible to a variety of users who have different abilities. I used the color recommendations presented in the literature to construct two fully functional websites (Holtze, 2006; Newman, 2000; Rigden, 1999; van der Geest, 2005); I wanted to see if the recommendations that were given really do improve website usability for a person with color-blindness. In this study, I used a qualitative and quantitative approach by administering an online, anonymous survey that acted as a short usability test for these two websites as well as a follow-up interview with one of the participants. The survey gauged how each participant felt about specific usability aspects for each website and asked the participants to identify which of the two websites they preferred to use. The interview was constructed with the purposes of discovering first-hand how an individual with color-blindness navigates the web, what they think about web design, any troubles they may face while searching for information on the Internet, and their reflections on living with color-blindness.

Research Design

This section will discuss how I set up my investigation. It will discuss several aspects including general information about the sample and sample selection. It will also review collection type, how I collected the data, and the reason I chose to use a mix of a qualitative and

quantitative approach to my research question as well as a detailed description of the creation of the websites.

Sample. I previously conducted a pilot study with this research question and used a small sample pool to test my questions. Based on the pilot study I improved my survey, made two fully functional and interactive websites rather than simple screenshots of webpages, attempted to increase my sample size through the use of a recruitment process, and added an interview. To the best of my knowledge and of the participants' knowledge, each participant had some form of a medically diagnosed color-vision deficiency. In the question following the informed consent statement in the survey, the participants were asked to confirm that they had some form of a medically diagnosed color-vision deficiency before proceeding with the survey.

The sample consisted of four participants. Part of the sample consisted of a sample of convenience as two of the participants are known by the investigator. The other two participants were recruited anonymously online. The interview participant was chosen as he is known to the investigator.

Recruitment Process. For the recruitment of participants, email, Facebook, and face-to-face interaction proved to be effective tools. It was important for me to find a way to recruit individuals with a color-vision deficiency without ruining anonymity. I did a lot of oral recruitment by asking many people if they were or if they knew someone who was color-blind. This method proved effective. Another method that proved effective was posting the survey link with a short message to many groups that contained many people on Facebook; a couple of the groups contained over 20,000 members each. By doing this, I avoided direct contact with the potential participants and my message was seen by many people.

Collection Type. For this study, I used both qualitative and quantitative methods of data collection.

Survey. First, I used an online, anonymous survey composed mainly of Likert scale questions with a few open-ended questions. I wanted to gather the opinions and feelings of my participants on the usability of the two websites as well as percentages and statistics on the Likert scale answers. I included three open-ended questions that asked the participants their first impressions of the websites and which website they would prefer to use. I included these questions before the Likert scale questions so I could understand their first impressions and feelings from the information foraging theory standpoint (would the participants automatically leave this website in search for a better patch?) as well as to avoid survey fatigue. I wanted to see if color would affect their perception of scent to a certain website where they could obtain information. Using a quantitative method of data collection in conjunction with the qualitative helped provide context and a broader picture. Since I had a larger pool of participants than in the pilot study, it made sense to quantitatively count the answers the participants gave in order to be able to give statistically relevant data. Both forms of data collection were used for contextual purposes.

Interview. I used a qualitative collection method with the follow-up interview because the results were anecdotal in nature. When creating the interview questions, I came up with easy questions to get the conversation started and to lead my participant in the direction of topics the literature discussed. I did this because I wanted to see if the information I gained from a person with color-blindness matched up with the information found in the literature. I knew it would be genuine information gained from the participant since I knew the participant did not know what

the literature said and had not done extensive research in the field or know much about web design. The interview participant was chosen as he is known to the investigator.

Website Creation

For this study, I created two fully functional websites using the website builder, Wix. These websites were created with the purpose of providing the participants something to view and interact with. The websites were Peachpuff Pet Care and Buttercup Pet Care. These names have no significant meaning. I chose these names for memorability and so the websites were not simply named Website 1 and Website 2. Each website had very similar makeup and design. (Buttercup Pet Care can be viewed in Figure 2 on page 22, and Peachpuff Pet Care can be viewed in Figure 3 on page 23. A more detailed view of the Peachpuff Pet Care website can be viewed in Appendix A. A more detailed view of the Buttercup Pet Care website can be viewed in Appendix B.) The only difference between the two websites was in body text color, background color, button color, and link color. For the websites, I used dummy text. This was done with the intent to eliminate distractions and make the participants focus mainly on color. For the purposes of this survey and this study, I focused mainly on body text, links and buttons, and usability. (I have included buttons in the category of links since buttons are a type of link, only formatted a little differently.)

The Peachpuff Pet Care website was created in accordance with recommendations found in the literature (Holtze, 2006; Newman, 2000; Rigden, 1999; van der Geest, 2005). The literature recommends using high contrasting colors for background color and text color in order for the text to be easily read and comprehended. The literature also discusses using varying shades of blue and yellow for the links with high enough contrast for the individual with color-

blindness to be able to distinguish between links and body text and for buttons to be easily distinguishable from the background. For the Peachpuff Pet Care website, I made sure to implement the literature recommendations by using colors color-blind individuals may not have difficulty seeing and making sure to contrast the body text, links, and buttons with the background. For the Buttercup Pet Care website, I used colors for the body text, background, navigation, and links that did not contrast well. In the following passages, I describe these color combinations in more detail.

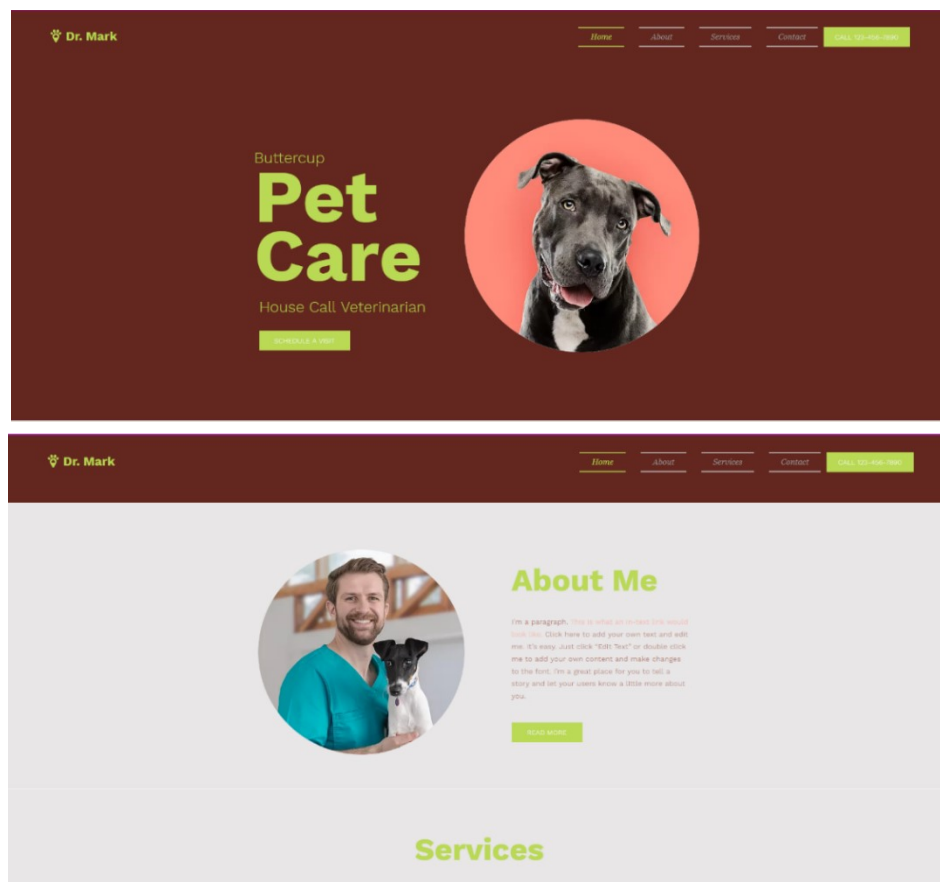
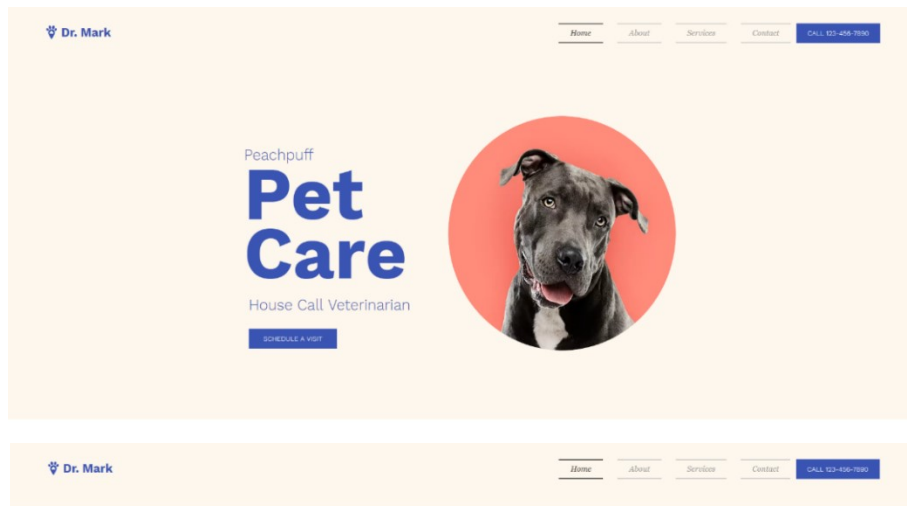


Figure 2: This is the Buttercup Pet Care website. This website was *not* created in accordance with the literature recommendations. For this website, I used colors that would be, according to the literature, difficult for a person with colorblindness to use and see.



About Me

I'm a paragraph. This is what an [inline link](#) would look like. Click here to add your own text and edit me. It's easy. Just click "Edit text" or double click me to add your own content and make changes to the font. I'm a great place for you to tell a story and let your users know a little more about you.

READ MORE

Services

Figure 3: This is the Peachpuff Pet Care website. This website was created in accordance with the literature recommendations. For this website, I used colors that would be, according to the literature, be easier for a color-blind person to see, use, and interact with.

Body Text. For the Buttercup Pet Care website, I chose body text colors that contradicted the literature recommendations. The background color and body text color were not highly contrasting, which means a color-blind individual may have a more difficult time reading the text presented on the website. I also used quite a few varying shades of red, green, and yellow, which most people with color-blindness would find difficult since most individuals with color-blindness are red-green deficient; this would cause the colors to look similar to each other and be difficult for a person with color-blindness to read. For the Peachpuff Pet Care website, I chose

body text colors that aligned with the literature recommendations. I made sure the body text greatly contrasted with the background color and also stayed away from colors on the red and green spectrum. I did this because most individuals with a color deficiency are red-green deficient. By staying away from colors on the red and green spectrum, it was my hope that the participants would have an easier time distinguishing between them and therefore make the website more readable and usable.

Links. I focused on link color in the body text and how it contrasts with the body text and the background color. The literature recommended using links in blue, yellow, and purple tones and also making sure they contrasted greatly with the background color and the body text. It was also mentioned that color should not be the only indicator of a link.

For the Buttercup Pet Care website, I used link colors that contradicted the literature recommendations. I used colors outside of blue, yellow, and purple choices that did not contrast highly with the body text and background color. I did not include any indicator, other than color, for the participants to be able to differentiate between links and the surrounding body text. For the Peachpuff Pet Care website, I used link colors in alignment with the literature recommendations. I was very mindful of the colors I was choosing and made sure they contrasted highly with the background color and body text. I also included an underline in the links as another indication that they were links and not just a continuation of the body text. In creating these two websites with different sets of colors, my main goal was to better understand how color choice affected usability for individuals with a color-vision deficiency.

For the buttons and navigation in each website, I followed the similar process as the links. In the Buttercup Pet Care website, I made the buttons and navigation contrast poorly with the background color and did not use any indication other than color to show that a feature was

clickable. For the Peachpuff Pet Care website, I did the opposite; I made these aspects highly contrasting and used other features besides color to show what was clicked and what was clickable.

PROCEDURE

I administered the survey through an online tool called Microsoft Forms using my assigned Office 365 account through Missouri State University. This method of collection allowed for the responses to be anonymous and confidential and stored on Missouri State University's secure server. Microsoft Forms also allowed for the results to be collected in aggregate through the use of an Excel spreadsheet for easy and anonymous viewing.

Administering the Survey

Instructions, links to the websites, and the informed consent statement were all included in the survey to make everything all in one location and therefore easier for the participants to complete. I also designed it this way so I was able to easily advertise the link to the survey or send the link to potential participants but still have minimal contact to keep anonymity intact.

I took human protection measures by obtaining IRB approval for this study as well as asking the participants to read and agree to an informed consent statement in the survey before completing the rest of the survey. The IRB number is IRB-FY2018-282. This study was approved on October 31, 2018. The IRB certificate can be viewed in Appendix C. The informed consent statement informed the participants of several important features. The informed consent statement outlined

- (1) what they (the participants) were going to be asked to do during the study,
- (2) that all their information would be kept anonymous and confidential,
- (3) that all their answers did not contain any identifying information and would be stored on a secure server provided by Missouri State University, and
- (4) that they were allowed to stop participating in the study at any time without loss of benefits or damage to their relationship with the investigator.

The participants were required to click “I agree” or “I disagree” before completing the rest of the survey. The full informed consent statement can be found in Appendix D.

The survey was administered through a couple of different platforms including Facebook and email. A few responses were collected through the Facebook administration. I created a blanket statement about my study, then included the link to the survey, and made several postings in several Facebook groups. The results of the survey were sent to me in a spreadsheet without names, email addresses, or any identifying information (as long as the participants did not provide any identifying information). The spreadsheet was sent to me in this format so I would not know which answers corresponded to which participant.

At the beginning of the survey, I posed the scenario to the participants that they were searching the internet for pet care; their search brought them to these two websites (Peachpuff Pet Care and Buttercup Pet Care).

The participants were not asked to read the text. They were merely asked to determine how easy it was for them to differentiate between the background color and the body text color and view certain aspects of the websites from the viewpoint of color specifically. The participants were specifically asked how easy the body text, links, and navigation were to read as well as the functionality and usability of booking a pet care service so I could get a better idea of usability as it relates to color for a user with color-vision deficiency.

Overall usability was evaluated by a section of questions in the survey. Overall usability focused on the website as a whole and how all the colors worked together, not just a single section or part. In the survey, the participants were asked to rate their feelings on how usable the overall website was to them.

The survey questions can be viewed in Appendix E.

Administering the Interview

A voluntary interview component was conducted after the survey portion. After the participant completed the survey, I sat down with him and conducted a follow-up interview. (I say “him” because I did not think gender would be identifying information since most individuals with color-blindness are male; the participant agreed and has allowed me to identify him by gender.) I chose to conduct the interview after the survey portion to preserve the anonymity of his survey answers. Protection measures were also taken with the interview portion of the study. IRB approval was obtained for an interview. The participant also signed an informed consent statement that outlined what the interview was about, what the participant would be asked to do, how long it would take, and outlined confidentiality. The confidentiality portion stated that names or identifying information would not be used. It also stated that the interview would not be recorded; I would only be taking notes, but I obtained permission to use direct quotations in my research. There were no questions asked that were similar to the survey. This was done to preserve the anonymity of the interviewee’s survey answers. I did not want to hear the participant’s interview responses then look at the survey responses and be able to tell that they matched and figure out the interviewee’s survey responses.

Written consent was obtained to conduct the interview and to use direct quotations and results of the interview in my thesis. The interview was administered at a neutral location of the participant’s choosing in Springfield, Missouri. The interview questions were verbally asked, and I took notes on the responses; an audio recording of the participant was not gathered or used. The participant was notified that his responses would be used but that his identity would be preserved and no identifying information would be used.

The interview consisted of five preset questions. I chose to only go into the interview with five questions because I wanted the experience to be more organic, relaxed, and conversational. The technique worked as I was able to gather more information than the survey questions specifically asked. The purpose of the starter questions was to provide a better understanding of how an individual of color-blindness uses the Internet and navigates websites. I also wanted to understand what an individual with color-blindness looks for in websites and what they wish web designers would do.

The interview questions can be viewed in Appendix F.

RESULTS, ANALYSIS, AND DISCUSSION

This section will discuss the results I obtained from my anonymous survey about the usability of two different websites for color-blind individuals and the results from my follow-up interview. I will discuss whether the specific color choices and recommendations pulled from the literature appeared to have an effect on the website usability as well as discuss the results of the interview. I will also discuss how the results and data from the survey and follow-up interview relate back to my research question as well as explore any limitations to the study.

Coding Process

The coding process used in this study was an open coding process. An open coding process allowed me to look for patterns and similarities in the participants' answers. Since the participants were so few in number, it was easy to use an open coding process to categorize the participants' answers and look for patterns; this was done to both the open-ended questions and the Likert scale questions. The open-ended questions provided more context, but there were still some patterns to be seen in both the Likert scale questions and the open-ended questions.

Results

This section will describe the results found in the survey and interview portion of the primary research. This section will only present the results; the following discussion section will discuss the results in the context of the research question and the literature. Overall, the participants much preferred the Peachpuff Pet Care website over the Buttercup Pet Care website. The Peachpuff Pet Care website used the literature recommendations of contrasting colors and

staying away from varying shades of red and green. The Buttercup Pet Care website contradicted those recommendations.

Questions one, two, and three detailed aspects of the survey. Question one had the full informed consent and required the participants to agree before continuing with the survey. Question two asked the participants to confirm they had some form of a medically diagnosed color-vision deficiency. Question three simply provided the links to the two websites.

Open-Ended Questions. Questions four, five, and seven were open-ended questions. These questions asked about the participants' first impressions of the two websites along with which website they would prefer to use and why. All the participants had good first impressions of the Peachpuff Pet Care website. They said the colors were clear and easy to read/use. One participant specifically mentioned the text was easy to read on the Peachpuff Pet Care website. Another participant mentioned that the Peachpuff Pet Care website was "easier to focus on, unlike Buttercup."

The first impressions of the Buttercup Pet Care website were overwhelmingly negative. Not a single participant had anything positive to say about the Buttercup Pet Care website. One participant described the set of colors as "jarring" and "distracting." Another participant said it was readable but "caused more difficulty." Another participant said, "It felt like it was straining my eyes. Once I could focus on one set of colors, it would go to two totally different colors. There was just too much going on in terms of color." In fact, other participants also mentioned the use of too many colors and the colors blending together, which is not conducive to readability or usability.

Questions six and seven asked the participants which website they preferred to use and why. One participant said the Peachpuff Pet Care website seemed "like a more natural choice"

and was “not as clashing.” Another participant said, "The blue caused less strain on my eyes, was easier to read, and was all-around more pleasant." Every participant said they would prefer to use the Peachpuff Pet Care website; one participant said they would not use the Buttercup Pet Care website at all.

Body Text. In question eight, participants rated how they felt about the readability and usability of the body text of each website in the online, anonymous survey. The participants were asked to rate the readability of the body text of each website. The ratings they were to choose from were “Extremely easy,” “Very easy,” “Somewhat easy,” “Not so easy,” and “Not at all easy.” (This rating scale was used for all of the Likert scale questions in the survey.)

Overall, the participants thought the body text was easier to read on the Peachpuff Pet Care website than the Buttercup Pet Care website. Three out of four participants rated the body text on the Peachpuff Pet Care website as “Extremely easy,” while one out of four rated it “Very easy.” Conversely, half of the participants rated the readability of the body text on the Buttercup website as “Somewhat easy.” One out of four participants rated it as “Not so easy,” while the other one out of four rated it as “Not at all easy.” The participants preferred the way the body text was designed on the Peachpuff Pet Care website over the Buttercup Pet Care website.

Links and Buttons. In questions nine and ten, the participants were asked to rate how easy it was to distinguish between body text and links and how easy the buttons were to read and use on the websites. For both of these aspects, the participants thought the Peachpuff Pet Care was better and easier to use. On question nine, which dealt with distinguishing links from body text, half of the participants rated that it was “Extremely easy” on the Peachpuff Pet Care website. The other half of the participants rated that it was “Very easy” on the Peachpuff Pet Care website. For the Buttercup Pet Care website, half of the participants rated it as “Not so

easy” to distinguish between the links and the text; one out of four rated it as “Not at all easy,” and the other one out of four rated it as “Very easy.”

Question ten asked the participants how easy it was to read/use the buttons on the website that linked to various aspects of the two websites. The participants thought the buttons were easier to use on the Peachpuff Pet Care website, that used the literature recommendations, than on the Buttercup Pet Care website that contradicted the literature recommendations. One out of four participants rated the buttons on the Peachpuff Pet Care website as “Extremely easy” and three out of four participants rated it as “Very easy.” For the Buttercup Pet Care website, three out of four participants rated it as “Not so easy,” while one out of four rated it as “Somewhat easy.”

Usability. Questions eleven, twelve, and thirteen dealt with overall usability as well as the usability of certain aspects of the two websites. The participants were asked to locate the services page and then click through as if they were going to book a service. They were then asked to rate, in terms of color, how easy it was for them to complete this task on each website. On the Peachpuff Pet Care website, half rated this task as "Extremely easy" and the other half rated it as “Very easy.” On the Buttercup Pet Care website, three out of four rated the process as "Not so easy" and one out of four rated it as "Not at all easy."

When participants were asked to interact with and use the navigation bar on both websites, most participants thought the navigation bar on the Peachpuff Pet Care website was easier to read and use than the navigation bar on the Buttercup Pet Care website. Three out of four of the participants rated the Peachpuff Pet Care website as “Extremely easy,” and the other one out of four rated it as “Very easy.” For the Buttercup Pet Care website, one out of four rated it as “Not so easy,” half rated it as “Not at all easy,” and one out of four rated it as “Very easy.”

For the final question of the survey, the participants were asked to rate the overall usability and readability of each website. Overall, the participants thought the Peachpuff Pet Care website was easier to read and use than the Buttercup Pet Care website. Three out of four of the participants rated the Peachpuff Pet Care website as “Very easy” when it comes to usability; one out of four rated it as “Extremely easy.” The Buttercup Pet Care website was rated as “Not so easy” by half of the participants. One out of four rated it as “Not at all easy” and the other one out of four rated it as “Somewhat easy.”

Overall, on every aspect of body text, links and buttons, and usability, the participants of this survey preferred to use the Peachpuff Pet Care website over the Buttercup Pet Care website. In terms of body text, the participants preferred the Peachpuff Pet Care website, but not overly so that the body text on Buttercup Pet Care website would dissuade them from using it. However, when it came to the links, buttons, and overall usability, the participants much preferred the Peachpuff Pet Care website over the Buttercup Pet Care website. The preference of the Peachpuff Pet Care website may have had something to do with the use of the secondary indicators, such as underlining links, that the *Web Content Accessibility Guidelines 1.0* recommends (1999).

Interview. The results of the interview portion were extremely informative and helpful to the research question. The results were helpful in understanding how a person with color-blindness searches for information on the Internet and what they think of web design and current practices. Overall, the results of the interview corroborated what the literature said; I will discuss this further in the Discussion section. The interviewee said he often had trouble reading things on websites because so much just looks “yellow-ish tan” to him. When asked what that meant, he

said many colors look “yellow-ish tan” to him, so when web designers use those colors that turn into “yellow-ish tan” for him, he cannot read the content.

Without prompting, he said he liked it when web designers used black or blue text on a light or white background because it was easier to read, that these colors didn’t blend together to look like that “yellow-ish tan” color. He also said that often times the background looks tan and the text looks yellow, which makes the text totally unreadable. He said, if this were the case, he would have to angle the computer screen and try to read it.

When asked what he wishes more web designers would know and would do, he specifically brought up the concepts contrast between the background color and the text color. He said he wishes all web designers would use blue or black text on a light or white background and avoid the colors that can blend together and cause things to look “yellow-ish tan.”

When asked how often his color-blindness affected his usability of websites, he said a quarter (one-fourth) of the time. He said it happened enough that he notices it and “can’t just scan over it and go to the next part.” He gave one incredibly poignant quote that stuck out to me: “[You] just hope the next website has [the] pertinent information that you missed in the first one” (personal communication, March 14, 2019).

As the last part of the interview, we discussed when he found out he was colorblind and how it affects his everyday life. I decided to include these questions in the interview to show that color-blindness is something that not only affects using websites but affects many aspects of life. He said he has known he was color-blind for the majority of his life because he found out he was color-blind when he did a physical for ninth-grade wrestling. However, I know another person that did not find out he was color-blind until he joined the Marines, meaning he went through most of his life and his formative years without knowing he was color-blind.

The interviewee also shared a few experiences with me about how his color-blindness has affected his life. The first story he shared was about how he worked at a scrap yard and was tasked with sorting brass. He said there was yellow, red, hard, and bronze brass. However, these colors all looked “yellow-ish tan” to him (because of their content of red), so he had to learn by sight what these metals were used for. He would know that this type of ball bearing was used on water meters so that meant it was yellow brass. He never was sure the accuracy of his sorting, but he said he never got any complaints.

A dangerous story he shared with me (similar to the story in van der Geest’s article) was about traffic lights. He said that rural highway intersections often lack the street lights with the three lights that we are used to seeing on main roads. He said it is often just a single light hanging on a string, so he is never sure if it is a flashing yellow light, which means to proceed with caution, or a flashing red light, which means to stop before proceeding. He does not know if the light is flashing red or if it is flashing yellow. He said he oftentimes hopes a car comes up at the same time he does so he can see how they react and know how to proceed.

Discussion

This section will discuss the survey and interview results in the context of the literature and Pirolli and Card’s information foraging theory.

Survey. The results of my survey and study relate directly back to the information seeking theory presented in the literature review. Pirolli and Card (1999) present the information seeking theory as a theory that users hunt for information as they would forage for food. A user searching for information follows the scent of the potential source of the information they need. Morville and Rosenfeld (2008) relate this theory to website usability. A user has a desire for

information as they would food. He or she turns to the Internet to fulfill their desire; the kind of information they are looking for is their diet. When the user comes across a website, they determine if the information presented fits their diet. If the information does fit their diet, they determine if they want to stay in this patch (the patch is where the information is found) at the risk of finding or not finding a better patch.

Poorly designed websites for individuals with color-blindness may interrupt their forage for information. The individual may find the website because it puts off a strong scent that it could be the information the user is looking for (that this website patch fits their diet), but the user will never get the chance to determine whether or not the website and its information fit their diet; they will never get to decide this because of poor color choice. If a color-blind individual were presented with the Buttercup Pet Care website on their search for information about pet care and veterinarians, they would most likely deem that website not part of their diet because it would be unusable or difficult to read. Even if the information presented on the website were the information they were looking for, they would pass it over for a different patch that was easier to read and therefore more useful. Because of this, it is important to design websites with what users with color-blindness need in mind; it is important to learn the recommendations found in the literature and understand Pirolli and Card's information foraging theory and how it relates to web usability. Knowing these things will help web designers use color choices beneficial to users with color-blindness, but it will also help web designers know why they are making these choices. If web designers know why certain tactics and colors should be used, it could help tremendously in the process of building and designing better and more accessible websites.

The results of this study relate back to the recommendations presented in the literature. As shown in the survey questions about body text, these color-blind users found the Peachpuff Pet Care website with higher contrast between the background color and body text color to be easier to read. This affirms the assertion made in the literature. In fact, the results of this survey affirm every assertion found in the literature that I focused on (body text contrast, links, and overall usability). The literature stated using shades of blue, yellow, and purple for the links would be best as well as not using color as the only indication of a link; my results found this to be true. The Peachpuff Pet Care website, which implemented the recommendations from the literature, was much easier for the color-blind participants of this study to read and use.

Interview. The interview was extremely helpful and related back to what the literature presented. In a few instances, the participant said things or talked about concepts that I had read directly in the literature, such as the concepts of contrast. It was eye-opening to hear someone with these troubles and accessibility issues talk about it from a first-hand experience while I only knew these things because of the research I had already done in the field. Everything this participant told me aligned with what the literature said about making websites accessible for users with a color-vision deficiency, even down to how colors look for a user with the most common types of color-vision deficiency, which can be found in Figure 1.

The participant of the interview talked mostly about contrast which is something many of the authors in the literature review talked about as well. Most authors seemed to say that this was the most important aspect and so did the participant. He said he mostly has trouble with the text because of the lack of contrast so everything just seems to blend together making it completely unreadable to him.

When the participant mentioned hoping the next website he found would have the information he missed in the first one, he was describing Pirolli and Card's information foraging theory without knowing it. Because of this user's color-blindness, his search, or forage, for information on the Internet was disrupted and made more difficult. The scent to a specific website may have been strong, but because of color choices he was unable to determine whether the website contained the information he thought it would. Because of this, he has to leave that patch and try to find a different one that has the information that he knows will fit his information diet. The original website may have fit his information diet, but he would never know it because the web designer made it inaccessible to him.

Concerns. Only one participant expressed concerns about the color palette chosen aside from the color-blindness standpoint. One participant brought up an issue with the Buttercup Pet Care website that I had not thought of. They had an issue with the color palette used, not only from the accessibility standpoint but also the professionalism standpoint. As van der Geest (2005) said, color is important for a user when determining the credibility of a website. The participant said they most likely would not use the website because the colors were not professional and therefore the business did not seem credible. They said it was not the number one deterrent, but they thought it was important enough to note. Websites that use a color palette difficult for individuals with color-blindness could also be deterring users with normal color vision because the website does not seem credible or professional.

Study Limitations

There are two major limitations to this study. The first major limitation relates to the sample size. There were only four participants in the study. A recruitment process was used, but

it did not prove to be particularly effective. Through recruitment, I was able to personally contact several individuals with a color-vision deficiency. However, I was not able to control whether or not they took the survey. The pilot study that was conducted had half of the participants; I had chosen such a small sample size purposefully to test out my research question and methods and to determine if it would have been effective in determining usability related to color choice. I had obtained good results with the pilot study, so I determined that this would be worthy of retesting. This time, I was able to obtain double the participants; however, it is still not wholly representative of the population of individuals with a color-vision deficiency. Since I was able to replicate this study with more participants and still obtain similar results, it still suggests that there is validity to the results and the color recommendations found in the literature.

Further research with a larger pool of participants will be more representative of the color-blind population. This will, more realistically, show whether the recommendations found in the literature about color choice really hold up in an actual usability test with more participants. The use of interviews with more participants or more open-ended questions would better gauge how participants are interacting with the color choices of these websites and why they feel a certain way about the color. Further research needs to be done in order to resolve these two major limitations, but my replication of this study with the similar results still provides a good place to start and provides valuable information conducive to further research. Also, if I were to repeat this study, I would like to expand the scope even further by not just specifically focusing on color; I would like to focus on reading comprehension in conjunction with color.

I also feel like it would be beneficial to the research question to gather a focus group of individuals with color-blindness in order to conduct group interviews and usability tests; however, the number one issue with this is finding enough people with color-blindness to

conduct this as well as getting them all in the same place at the same time. Even though difficult, this method would be beneficial because I would be able to watch the participants go through the websites in real time. This would allow the participants to voice their concerns immediately and to voice any thoughts they might have about the usability of the websites. It would also allow me to watch them go through the websites and see where they have trouble navigating the websites.

CONCLUSION

For this study, I explored the topic of web color and usability because I wanted to know how color choice affects web usability for people with color-blindness in order to provide a better overall web experience for people with color-vision deficiency or color-blindness. To do this, I constructed an online, anonymous survey that measured the usability of two different fully functional websites that I created. One of the websites was created in accordance with the recommendations found in the literature. The other website contradicted those recommendations. I focused on the recommendations about body text color and contrast, link color and contrast, and overall usability and readability. The participants were asked to view the two websites and then to answer questions on the survey related to body text color, link color, and overall readability.

The results of the survey and interview portion affirmed that the color recommendations made in the literature do, in fact, improve the readability and usability of websites for people with color-blindness. It can be concluded that these recommendations would improve the usability and readability on webpages for a certain number of color-blind individuals. The results show that how a person designs a website and the colors chosen really do affect how a color-blind person reads the website, perceives the information, and interacts with a website. If a color-blind person comes across a website that is difficult for them to read, he or she may move on to a different website even if that means forgoing the information he or she may have been looking for.

There are a couple of limitations to this study. The biggest limitation was the sample size. For further study and research, it would be beneficial to add participants. However, all

participants must be color-blind. Adding participants would allow for further investigation of the literature recommendations I reviewed. It would allow me to get a better look at the color-blind population. Because of the sample size, it cannot be generalized that all color-blind individuals will find these recommendations helpful and conducive to readability in websites.

A few areas open for additional research exist. Other recommendations from the literature can be explored and tested with a color-blind population. The recommendations I explored only had to do with the color choice of body text and links. It could be beneficial to explore other color topics and see how those affect the usability and readability. To address the study limitations, it might also be beneficial to add more participants in the future and also include more open-ended questions or more interviews to better gauge how the participants are viewing the websites.

Even though there are several areas open for additional research, this study still provided important usability information on how color choice affects a color-blind person's experience on the web. It was shown that color choice really does affect how usable a website is to a person with color-blindness. When designing a website, designers must do research about color choice for color-blindness and implement those recommendations to improve the overall usability and web experience for people with color-blindness.

My sample size ended up being fairly small; however, it was double the size than the pilot study and included an added interview portion. Because of the small sample size, it is not a generalized consensus of the colorblind population, but it still provided some more information on my research question and built upon the concepts in the pilot study. My hope is that my research is helping bring this issue to the forefront of designers' minds and helping web designers improve accessibility. Because the purpose of websites is to help users find

information quickly to satisfy information hunger, websites should be designed with accessibility for all individuals, including color-blind individuals.

LITERATURE CITED

- Chow, A. S., Bridges, M., & Commander, P. (2014). The website design and usability of US academic and public libraries: Findings from a nationwide study. *Reference & User Services Quarterly*, 53(3), 253-265.
- Fogg, B. J., Soohoo, C., & Danielson, D. (2002). How do people evaluate a web site's credibility? Results from a large study. Retrieved February 2004, from [Http://www.consumer-watch.org/news/report3_credibilityresearch/StanfordPTL.Pdf](http://www.consumer-watch.org/news/report3_credibilityresearch/StanfordPTL.Pdf)
- Gray, H. (1985). *Gray's anatomy of the human body*. C. Clemente (Ed.). Philadelphia, PA: Lea & Febiger Publishing.
- Guder, C. (2014). Universal design and the library website. *Public Services Quarterly*, 10, 229-237.
- Holtze, T. L. (2006). The web designer's guide to color research. *Internet Reference Services Quarterly*, 11(1), 87-101.
- Morville, P., & Rosenfeld, L. (2008). *Information architecture for the world wide web: Designing large-scale web sites*. Sebastopol, CA: O'Reilly.
- Newman, C. (2000). Considering the color blind. *Web Techniques*, 5(8), 59-61.
- Null, R. L. (2014). *Universal design: Principles and models*. Boca Raton, FL: CRC Press.
- Ojanpää, H., & Näsänen, R. (2003). Effects of luminance and colour contrast on the search of information on display devices. *Displays*, 24, 167-78.
- Pirolli P., & Card, S. K. (1999). Information foraging. *Psychological Review*, 106(4), 643-675.
- Providenti, M. (2004). Using web standards to promote accessibility. *Kentucky Libraries*, 68(3), 16-19.
- Rigden, C. (1999). The eye of the beholder- Designing for colour-blind users. *British Telecommunications Engineering*, 17, 1-6.
- Riley-Huff, D. A. (2012). Web accessibility and universal design: A primer on standards and best practices for libraries. *Library Technology Reports*. 29-35.
- van der Geest, T. (2005). Mixing up colors: Colors in the interface. *Information Design Journal & Document Design*, 13 (1), 74-78.

Web content accessibility guidelines 1.0. (1999). Retrieved from <https://www.w3.org/TR/WAI-WEBCONTENT/>

Web content accessibility guidelines (WCAG) 2.0. (2008). Retrieved from <https://www.w3.org/TR/WCAG20/>

Web content accessibility guidelines (WCAG) 2.1. (2018). Retrieved from <https://www.w3.org/TR/WCAG21/>

APPENDICES

Appendix A: Additional Views of the Peachpuff Pet Care Website

The screenshot shows the 'House Call Services' page. At the top, there is a navigation bar with the logo 'Dr. Mark' on the left and links for 'Home', 'About', 'Services', and 'Contact' in the center. A blue button with the text 'CALL 123-456-7890' is on the right. The main heading is 'House Call Services' in large blue font. Below this, there are three service cards. Each card features a circular image of a pet: a dog for 'Dental Care', a cat for 'Checkup', and a dog for 'Grooming'. Each card includes the service name, duration, and price, followed by a blue 'Book It' button.

Service	Duration	Price
Dental Care	20 min	\$25.00
Checkup	30 min	\$100.00
Grooming	35 min	\$35.00

The screenshot shows the 'Contact' page. The navigation bar is identical to the previous page. The main heading is 'Contact' in large white font on a blue background. Below the heading, there are four columns of contact information: 'Phone' (123-456-7890), 'Email' (info@mysite.com), 'Hours of Operation' (Mon - Fri: 9am - 8pm, Saturday: 9am - 4pm), and 'Area of Service' (San Francisco & the Peninsula). Below this information is a contact form with fields for 'Name *', 'Email *', 'Subject', and 'Message', and a 'Send' button.

Phone
123-456-7890

Email
info@mysite.com

Hours of Operation
Mon - Fri: 9am - 8pm
Saturday: 9am - 4pm

Area of Service
San Francisco & the Peninsula

Name *
Email *
Subject
Message

Send

https://www.wix.com/lpviral/enviral?utm_campaign=vir_wixad_live&adsVersion=...

Appendix B: Additional Views of the Buttercup Pet Care Website

The screenshot shows the 'House Call Services' page. At the top, there is a dark red navigation bar with the logo 'Dr. Mark' on the left and navigation links 'Home', 'About', 'Services', and 'Contact' in the center. A green button with the text 'CALL 123-456-7890' is on the right. The main content area has a light gray background with the title 'House Call Services' in large green font. Below the title are three service cards, each featuring a circular image of a pet: a dog for 'Dental Care', a cat for 'Checkup', and a dog for 'Grooming'. Each card includes the service name, duration, and price, and a yellow 'Book It' button.

Service	Duration	Price
Dental Care	20 min	\$25.00
Checkup	30 min	\$100.00
Grooming	35 min	\$35.00

The screenshot shows the 'Contact' page. It features a dark red background with the 'Dr. Mark' logo and navigation links at the top. A green button with the text 'CALL 123-456-7890' is on the right. The main content area has a dark red background with the title 'Contact' in large green font. Below the title are four columns of contact information: 'Phone' (123-456-7890), 'Email' (info@mysite.com), 'Hours of Operation' (Mon - Fri: 9am - 8pm, Saturday: 9am - 4pm), and 'Area of Service' (San Francisco & the Peninsula). At the bottom, there is a contact form with fields for 'Name *', 'Email *', 'Subject', and 'Message', and a 'Send' button.

Phone: 123-456-7890
Email: info@mysite.com
Hours of Operation: Mon - Fri: 9am - 8pm, Saturday: 9am - 4pm
Area of Service: San Francisco & the Peninsula

https://www.wix.com/tpviral/enviral?utm_campaign=vir_wixad_live&adsVersion=...

Appendix C: IRB Certificate

Date: 5-5-2019

IRB #: IRB-FY2018-282
Title: Color Choice and Web Usability
Creation Date: 10-10-2017
End Date: 10-30-2019
Status: Approved
Principal Investigator: Lyn Gattis
Review Board: MSU
Sponsor:

Study History

Submission Type	Initial	Review Type	Expedited	Decision	Approved
Submission Type	Renewal	Review Type	Expedited	Decision	Approved
Submission Type	Modification	Review Type	Expedited	Decision	Approved

Key Study Contacts

Member	Lyn Gattis	Role	Principal Investigator	Contact	██████████@missouristate.edu
Member	Lyn Gattis	Role	Primary Contact	Contact	██████████@missouristate.edu
Member	Theresa Sparks	Role	Investigator	Contact	██████████@live.missouristate.edu

Appendix D: Informed Consent

You are invited to join a research study to look at how color choice affects website usability for individuals with any form of color-blindness or color-vision deficiency. In this research study, we are investigating through a usability test and anonymous survey how color choice affects the usability of a website for individuals with color-blindness.

If you decide to participate, you will be asked to view two different webpages with differing sets of colors and answer an anonymous survey about the two webpages. We think this will take you no more than 20 minutes. The survey will mostly consist of multiple choice, Likert scale questions. There will only be a few open-ended questions.

The investigators may stop the study or take you out of the study at any time they judge it is in your best interest. They may also remove you from the study for various other reasons. They can do this without your consent.

You can stop participating at any time. If you stop, you will not lose any benefits.

Risks

This study involves no greater risks than everyday life.

There may also be other risks that we cannot predict.

Confidentiality

We will take the following steps to keep information about you confidential and to protect it from unauthorized disclosure or damage:

- All information will be kept on the Office 365 secure server the university provides.
- Your name will not be attached to any of your survey answers.
- Your survey answers will be kept anonymous and confidential.
- Your name will never be used.
- Details that could reveal your identity including age, appearance, profession, education level, etc. will never be used.

Your Rights as a Research Participant

Participation in this study is voluntary. You have the right not to participate at all or to leave the study at any time. Deciding not to participate or choosing to leave the study will not result in any penalty or loss of benefits to which you are entitled, and it will not harm your relationship with Theresa Sparks, who is the investigator.

If you wish to withdraw from the study early, please let Theresa Sparks know with a short email. This will not affect your relationship with Theresa Sparks and will not result in loss of benefits.

Contacts for Questions or Problems

Call Theresa Sparks at xxx-xxx-xxxx or email Theresa Sparks at xxxxxxxx@live.missouristate.edu if you have any questions about the study, any problems, unexpected physical or psychological discomforts, any injuries, wish to withdraw from the study early, or think that something unusual or unexpected is happening.

Consent of Participant

By completing and submitting this survey, I affirm that I have thoroughly read and understand the Informed Consent Statement above and agree to be a participant of this study.

Survey Instructions

The purpose of this survey is to gain a better understanding of how people like yourself (people with color-blindness or color-vision deficiency) navigate the web. You are an important demographic that can have difficulties using websites because of a designer's color choices. I want to know how different color choices affect the way you can or can't use websites in order to provide a better web experience.

Directions

All answers are anonymous and confidential. I have created two different Pet Care websites; pretend you are in search of a veterinarian. One website I created implements the color recommendations I found doing research of the literature and the other website does not use those color recommendations. The websites you will use are Peachpuff Pet Care and Buttercup Pet Care, which are linked in the survey. Please view and interact with each website, then complete the survey below. Before participating in the survey, please read the informed consent statement below.

This survey will take no more than 20 minutes. For best results, please take the survey on a laptop or desktop device; however, the survey is mobile friendly.

Appendix E: Survey Questions

1. Informed Consent
2. To the best of your knowledge, do you have some form of medically diagnosed color-vision deficiency?
3. Links
4. In terms of color, what was your first impression of the Peachpuff Pet Care website?
Ex) Did you like the way it was designed? If you were looking for pet care, would this be a website you would use or would you automatically leave?
5. In terms of color, what was your first impression of the Buttercup Pet Care website?
Ex) Did you like the way it was designed? If you were looking for pet care, would this be a website you would use or would you automatically leave?
6. Which website would you prefer to use?
7. Why would you prefer to use the website you picked in question 6?
8. How easy was it to read the body text?
9. How easy was it to distinguish between links and body text?
10. How easy were the buttons to read/use on each website?
11. Locate the Services page and quickly click through booking a service. In terms of color, how easy was it for you to find/use this page?
12. Look at, scroll over, and interact with the navigation bar. In terms of color, how easy was it for you to read/use the navigation?
13. Overall, how easy was it to read/use each website?

Appendix F: Interview Questions

1. How often do you notice having problems reading information from the Internet because of your color-blindness?
2. As a person with color-blindness, what is something you wish web designers would do in regard to color?
3. What is your design pet peeve?
4. How often do you notice your color-blindness being an issue in everyday life?
5. When did you find out you were color-blind?