

Color and Contrast in E-Learning Design: A Review of the Literature and Recommendations for Instructional Designers and Web Developers

Rick T. Richardson, M.Ed.

Adjunct Faculty & PhD student in Instructional Design
Department of Organizational Learning & Performance
College of Education
Idaho State University
Pocatello, ID 83209-8081
richric3@isu.edu

Tara L. Drexler, M.Ed.

PhD student in Instructional Design
Department of Organizational Learning & Performance
College of Education
Pocatello, ID 83209-8081
drextar2@isu.edu

Donna M. Delparte, Ph.D.

Assistant Professor
Department of Geosciences
Idaho State University
Pocatello, ID 83209-8081
delparte@isu.edu

Abstract

Judicious choice of color for text and backgrounds of web and e-learning tools can increase the readability of on-screen text and have the added benefits of minimizing extraneous cognitive load and boosting learning retention. A review of empirical research on color and contrast identifies a set of recommendations for establishing luminance contrast between on-screen text and backgrounds that will inform instructional design and web development practices. Visual cueing, as an element of multimedia theory, and web page complexity also play important roles in maximizing readability. Web Accessibility Initiative (WAI) and Section 508 guidelines for making web pages usable by individuals with physical and/or visual impairments are not uniformly applied to current design practices; this review uses color blindness to as an example and recommends several online tools to select appropriate page background and text colors, two areas that receive limited attention in current WAI guidelines. Suggestions for future research on the intersection between color and contrast and how it can improve readability for all users, including individuals with visual impairments such as color blindness, and multimedia cognitive load theory are proposed.

Keywords: instructional design, web development, extraneous cognitive load, visual cueing, color, contrast, color blindness, Web Accessibility Initiative (WAI), Section 508.

Introduction

With an increasing numbers of e-learning opportunities, instructional designers and web developers should consider the challenges associated with readability and learning retention when designing e-learning and/or web content.

After defining terminology and processes associated with color and contrast, this review will examine the research literature on the effects of these two visual concepts on screen text readability. The section that follows links readability to learning retention through an understanding of multimedia and cognitive load theories. The remainder of this section will collate recommendations from the literature for effective use of color and contrast to improve web page readability before exploring why these recommendations are not commonly addressed in web design.

The second part of this review examines current Usability and Access (U & A) guidelines for making web sites accessible to all users, especially those with visual disabilities, and articulates the importance of promoting uniform coding and display standards. Although no one specific populations of visually impaired web users are addressed in this review, individuals with atypical color response (color blindness) will be used as an example in this second section. Limited efforts have been made to improve accessibility for visually impaired web users; hence, several recommendations to address this problem will be discussed as they apply to color blindness.

Color and Contrast in Web Design

Effects of Color and Contrast on Readability

A survey of the literature on color usage with computer displays revealed two avenues of research: color and contrast vis-à-vis readability and color preference. Although both involve a degree of subjectivity on the part of the viewer, emphasis will be placed upon readability research of on-screen text, rather than color preference. This review will briefly address the interplay of readability and preference after reviewing prominent research on color and contrast.

Colors are located within precise ranges of the visible spectrum. If a color is not blended with the other primary colors (red, green, and blue) and is not mingled with a tint (white) or a shade (black), this pure color is referred to as a hue (Roberts, 2009). Colors can also be differentiated based on their chromaticity. Chromaticity, also known as saturation, is a measure of a color's intensity as either a darker or a lighter shade relative to its hue. The relative brightness of a particular color, determined by the amount of tint or shade added to a color, thereby increases or decreases a color's saturation/chromaticity (Roberts, 2009). Grays have the lowest saturation values as they are in middle of the color spectrum, blending equal amounts of white and black. Gray backgrounds maximize the saturation of any colors in the foreground, thereby heightening their contrast (Pett & Wilson, 1996). Colors thus serve as organizational structures through their ability to contrast, or stand out, relative to their background. The degree of contrast can also be measured in terms of luminance.

Luminance is another measure of contrast and measures the difference between the brightness of foreground elements, such as text, relative to background. The NASA Ames Research Center Color Usage Research Lab identifies luminance contrast as the single most important determining factor in legibility of text and symbols (Mogford, n.d. <http://colorusage.arc.nasa.gov/guidelines.php>). As shown in Figure 1, luminance contrast between background and text can have a powerful effect on readability. The Luminance Contrast Color Guidelines suggest a luminance contrast ratio of 3:1 between symbols and backgrounds. These guidelines attempt to provide enough flexibility in contrast values to allow design decisions that emphasize levels of importance and account for user environmental conditions. Research by Lin (2003) supports the importance of luminance contrast on readability.

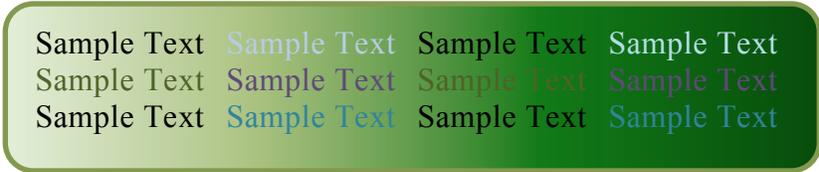


Figure 1. Degrees of luminance contrast relative to a fixed background

In a seminal study, Murch (1987) compared various background and foreground text colors for readability, finding black text on a green background as the most legible (100%), followed by blue text on a white background (94%), and white text on a black or blue background (75%). Figures 2 and 3 present results for the most preferred and the least favorable color combinations.

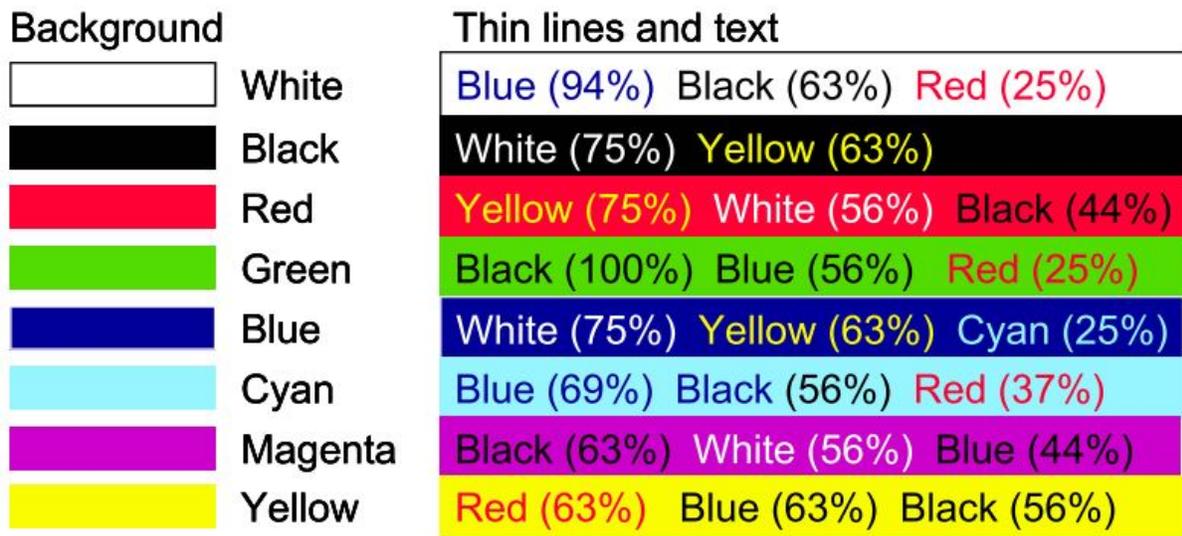


Figure 2. Most preferred text color choices relative to background color (Murch, 1987, as cited in Vanderdonckt & Beirekdar, 2005)

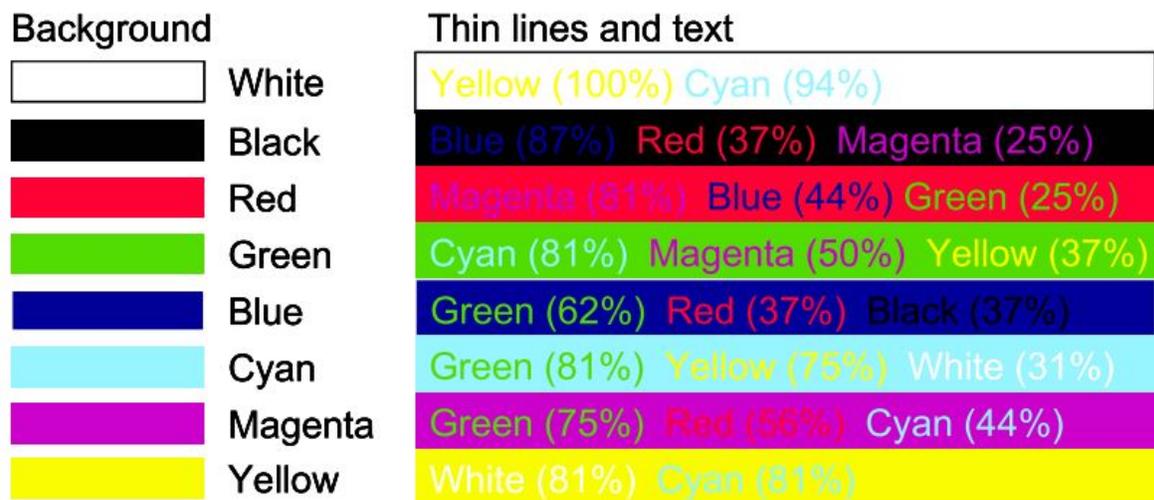


Figure 3. Least preferred text color choices relative to background color (Murch, 1987, as cited in Vanderdonckt & Beirekdar, 2005)

Hill and Scharff (1997) also reported the highest degree of readability for black text on a green background. Hall and Hannah (2004) reported the effects of background and font combinations on readability of educational websites: black text on white background, white on black, light blue on dark blue, and cyan on black. Black text on a white background was found to be more readable than the other combinations, though white on black also rated as highly readable. Lynch and Horton (2008) also recommended a white background with black text for maximum contrast. In other research, neutral colors, such as grays and pastels, were found to be preferable for backgrounds, with higher brightness values for important details (Deubel, 2003). In these studies, high luminance contrast was a key factor in enhancing readability (Lin, 2003).

On the other hand, Hill & Scharff (1997) compared high and low contrast values combining color and contrast to font types and word styles and found that there was no one combination that consistently provided best results, and that color, contrast, font, and text style all interacted to affect readability. Nevertheless, they found that a lower contrast of black text on grey enhanced readability, which corresponded with Deubel's (2003) findings on font and background color.

Variations in text-background readability findings emphasizes the interconnected of readability vis-à-vis color preference, (Hall & Hannah, 2004). Since color preference is highly subjective (Hall and Hannah, 2004) this factor tends to inform color choices in web site design (Papachristos, Tselios, & Avouris, 2005.). Some researchers (Coursaris, Swierenga, & Watrall, 2008) have argued that gender preferences may impact readability assessment of web pages, yet this claim is controversial. Erdogan's (2007) research, for example, found minimal gender differences in perception of on-screen displays with different color backgrounds and varying degrees of contrast. In this study, 15 combinations of web page backgrounds were evaluated with Times New Roman, and Verdana fonts as foreground. Gender did not indicate a clear preference for any particular combination of foreground and background colors, although females preferred higher contrast displays than did males. Differences were noted, however, that visually impaired students preferred higher contrast (black or red text on a white background) compared to those who with normal vision (yellow text on a green background). These findings indicate that visually impaired users have different needs. For all users, the interplay of text style and background color can have other effects—beyond readability—which can influence learning.

Effects of Color and Contrast on Cognitive Load and Learning Retention

Understanding the role of color and contrast in terms of its effect on cognitive processing is emergent. According to Roberts (2009), "even though the use of color in the production of instructional materials is widespread, its relative effectiveness as an aid in improving student achievement still remains inconclusive and at best contradictory" (p. 26). Nonetheless, the literature, although limited in this area of inquiry, has demonstrated some potential connections between readability and enhanced cognitive processing. Visual design, in terms of text style and color interplaying with a background color or the degree of visual complexity displayed on a web page can either enhance or degrade screen readability, thus increasing extraneous cognitive load and interfering with learning retention (Mayer, 2014; Sweller, 1994).

There are several studies pertinent to influences of color and contrast on learning retention. Schwier and Misanchuk (1995) examined groups of ninth graders' geometry learning via computer by comparing instruction using a monochromatic display, a color display using consistent color cues, and a third display using random color cues. Posttest results demonstrated that consistent color cues produced higher achievement scores. Hall and Hannah (2004) reported the effect of color on retention as well as readability: lower contrast combinations such as light blue on dark blue provided a small, but measurable positive effect on retention. This finding suggested that a slightly lower contrast ratio might actually improve retention for web-based instruction. Another study (Hill & Scharff, 1997) also found that a lower contrast ratio of black text on grey enhanced readability, as measured by faster reaction times in text recognition tests. Another dimension is the effect of visual complexity of text and graphics on cognitive load.

Visual complexity—a combination of the amount of text and how it is displayed, the range of colors used, and other stylistic and navigational features, such as graphics, tables, and hyperlinks—may serve as an indicator of cognitive load (Harper, Michailidou, & Stevens, 2009) and is determined by the number and variety of visual stimuli in conjunction with the viewer's familiarity with said stimuli. Harper *et al.* (2009) grouped web pages into three levels of visual complexity. Simple web pages focused on a single topic, contained less than 40 links, used a light colored background color, and featured concise text explanations and a minimum of graphics. Page content fitted on a single screen, so no scrolling was required. Neutral pages contained mostly text (more than on a simple page); a white or light colored background, and featured more visuals. Light colors predominated, but darker primary colors were found on parts of the page. Complex pages featured large quantities of text, links, images, and menus that covered multiple subjects and a larger variety of intense background colors were employed. It is important to note that using a table can make a complex page into a neutral page because of the organizing structure a table provides. Geissler, Zinkhan, & Watson (2001) used similar factors to differentiate the visual complexity of web pages: number of links and graphics (including animations) and home page length. They referred to "information overload" (Geissler *et al.*, 2001, p. 5) because of a user's reduction in effective communication due to visual complexity. Harper *et al.* (2009) reported similar findings whereby increasing visual complexity contributed to additional cognitive load for users. Therefore, cognitive processing demands rise with increasing numbers of visual elements, even text. With respect to text recognition, Medina argued that large amounts of text add complexity, because the brain interprets each letter as an image. Reading—consequently—"creates a bottleneck" (Medina, 2008, p. 234) for cognitive processing of any kind of visual data. Therefore, visually complex web pages, both in terms of text, colors, graphics and structural elements, such as columns or tables, might imply high levels of cognitive load, perhaps even cognitive overload, which can interfere with comprehension and retention of knowledge (Clark & Mayer, 2011; Mayer, 2014; Sweller, 1994). On the other hand, patterns can reduce visual complexity, if its constituent elements can be readily differentiated, as Harper *et al.* (2009) noted with regard to the use of tables to organize information. Consequently, making web pages less visually complex might increase their readability, particularly for visually impaired users. There has been a recent trend toward use of hyperlinks that are differentiated from regular text by use of color (the Moodle Learning Management System, for example) rather than the traditional underlining format. Colored links can increase visual complexity when low luminance contrast values occur between background and the hyperlinked text. As a visual cue, however, colored hypertext can simultaneously enhance readability if the former condition is not violated. This example highlights visual complexity as a phenomenon that is not fully understood and therefore not rigorously applied in web page design (Geissler *et al.*, 2001; Harper *et al.*, 2009).

Improving the Use of Color and Contrast with Cognitive Cues

Multimedia and cognitive processing theories can inform options to improve readability of on-screen visuals and text. Cueing, for example, provides auditory or visual signals to shorten the learner's response time necessary to focus attention on key information (Roberts, 2009). Although cues can also be auditory, this analysis focuses on only visual cues. Visual cueing may include judicious use of color, highlighting, pointing arrows, variable font size, icons, or other graphical symbols (Roberts, 2009). Retention of some verbal information, which includes reading text, can be enhanced if visual imagery accompanies it; the user can form a mental image of the spoken word and thereby reduce the latency period of recall (Roberts, 2009; Tabbers, Martens & van Merriënboer, 2004). This use of dual coding prevents either verbal or visual channels from becoming overloaded as visually complex web pages, text-background colors, or luminance contrast values that detract from readability may overload the visual channel (Clark & Mayer, 2011). Cueing helps in both learning retention and decreased response time for activities such as searching a screen for visual cues (Roberts, 2009). For example, color cues help differentiate between figure and ground within an image and can isolate text from its background by drawing the learner's gaze. Luminance contrast can also be applied to ensure that visual cues are prominent due to their positive impact on readability (Lin, 2003). If cueing can reduce the time required to locate information, it is more likely to be retained in working memory, thereby reducing overall cognitive load (Clark & Mayer, 2011; Roberts, 2009). The learner can then focus their cognitive processing on learning and remembering rather than decoding visuals (images and/or text). Although research on visual cueing has

demonstrated increased learner retention (Tabbers *et al.*, 2004), additional empirical studies linking readability and minimizing extraneous cognitive load are needed. As evidence supporting the importance of more readable on screen visuals and text is promulgated amongst instructional designers and web developers, web pages can become more accessible, particularly for visually impaired users. The next section offers a series of recommendations to enhance readability.

Recommendations for Instructional and Web Designers to Improve Readability

Suggestions for applying research-based evidence on color and contrast to enhance readability will be discussed in terms of text and background, followed by recommendations specific to web page layout. The findings discussed in this section are summarized as recommendations in Table 1. Text should be represented with dark colors, to maximize contrast between font and background (Deubel, 2003). Lynch & Horton (2008) as well as Hall and Hannah (2004) specifically recommend black text on a white background. Fonts used should be sans serif, as they have been associated with increased readability (Jacko *et al.*, 2000). Higher brightness values and increased luminance contrast (ideally 3:1 ratio between text and background [Mogford, *n.d.*] for important details serve as visual cues (Roberts, 2009). However, the need to avoid visually complex designs for web pages, because they can lead to cognitive overload among users (Harper *et al.*, 2009), suggests that a limited number of visual cues (applied to text or animations) are used and the colors associated with these cues are used consistently, otherwise “overuse detracts from the strength of the benefits of color” (Mogford, *n.d.*). Color coding can, however, interfere with cognitive processing since the learner tends to associate certain concepts with a particular color yet repeating the same color for a different concept, can also increase extraneous cognitive load (de Köning, Tabbers, Rickers & Paas, 2007).

With respect to backgrounds, Duebel (2003) suggests using less saturated, neutral colors, such as grays and pastels for backgrounds with higher brightness values for important details. Natural tones provide subtle degrees of complementarity and contrast and are recommended as a color palette to select from when choosing color schemes. Figure 4 provides an example of subdued, natural colors that would be appropriate for backgrounds.



Figure 4. Example of neutral, earth tones appropriate for backgrounds (http://community.saa.co.uk/gallery/artwork/pebbles-and-marbles-by-l-m-r-travers-smith_43284.html)

Duebel also recommends against blue-orange, red-green, and violet-yellow combinations of text and/or backgrounds. Since text should be represented in dark colors, background colors thus serve as organizational structures via their ability to allow text to contrast, or stand out, relative to their background. Increasing this degree of luminance contrast enhances readability, as already

discussed. This is consistent with Harper *et al.*'s suggestions to use a light background color, employ images that relate to the content, minimize the amount of text (all of the text is available on one page with a minimum of scrolling required), and apply a limited number of color cues. These recommendations highlight the characteristics of a simple and thus highly readable web page due to the lack of visual complexity.

Recommendations Specific to Web Page Design

Graphic web design principles establish page boundaries, segment and aggregate discrete elements within a page, and establish a range of contrasts which facilitate recognition of primary and secondary information. Therefore, clearly designed web pages establish sections which are devoted to particular functions and retain this organizational framework through successive, linked pages. Lynch and Horton (2008) suggested that uniform connectedness and proximity are essential to effective web page design. This means that content can be divided thematically or functionally into groups that allow the user to quickly identify relevant information. Also, this structure incorporates enough white or negative space to separate sections, thereby enhancing the visual contrast that enables users to navigate efficiently to the desired content. However, Coursaris & Kripintris's (2012) research indicated that devoting more than 50% of a web page to white space was regarded by users as detrimental to perceptions of the web page's aesthetic appeal and usability. Lynch and Horton suggest a more modest value; 95% of the page devoted to content space, leaving a 5% border around the perimeter for visual relief. Although one might argue that imposing a rigid framework for ordering content on a web page may be creatively restrictive, this hierarchy of contrasts establishes a clear distinction between the figure (the essential detail) and ground (peripheral detail) as variations in contrast draw the eye to key navigational landmarks such as section headings, sidebars, etc. Since users perceive visual information in a hierarchical manner, from large to small features; foreground elements such as text or graphics with a contrasting background are visually more appealing as they are the first elements to catch the reader's attention—contrast is thus an important factor in the immediacy of recognition. With respect to text, its legibility is dependent on its contrast with the background, as already discussed. Lynch and Horton (2008) recommend a white background with black text for maximum contrast due to its high saturation in addition to avoiding overuse of primary colors. Using Cascading style sheets permit a standard format to be easily maintained across multiple web pages, allows for consistency of text and background. Why then have so few web sites adopted these guidelines for the benefit of all users, not just those with visual impairments? The next section will explore the slow pace of implementing standardized guidelines for improving accessibility to web users, particularly those with visual impairments.

Table 1.

Summary of Recommendations for Visual Design of E-learning and Web Pages

Visual Design Recommendation	Empirical Evidence
Text	
<ul style="list-style-type: none"> • Use dark colors for text • Black text on a white background 	<p>(Duebel, 2003)</p> <p>(Lynch & Horton, 2008; Hall and Hannah, 2004, Hill & Scharff, 1997)</p> <p>(Lynch & Horton, 2008; Hall & Hannah, 2004; Murch, 1987)</p>
<ul style="list-style-type: none"> • White text on a black background 	(Murch, 1987)
<ul style="list-style-type: none"> • Black text on green background 	(Murch, 1987)
<ul style="list-style-type: none"> • Blue text on white background 	(Murch, 1987)
Backgrounds	
<ul style="list-style-type: none"> • Neutral colors (grays or pastels) for backgrounds <ul style="list-style-type: none"> • Avoid blue-orange, red-green, violet-yellow color combinations for text and background 	(Duebel, 2003)
<ul style="list-style-type: none"> • Avoid overuse of primary colors 	(Lynch & Horton, 2008)
<ul style="list-style-type: none"> • Gray background maximizes contrast 	(Pett & Wilson, 1996)
<ul style="list-style-type: none"> • 3:1 luminance contrast between text and background and key visual cues 	(Mogford, <i>n.d.</i> ; Roberts, 2009; Lin, 2003)
Font: sans serif	(Jacko et al, 2000)
Minimize visual complexity by reducing amount of text and graphics	(Harper, Michailidou, & Stevens, 2009)
Visual cueing	
<ul style="list-style-type: none"> • Use contrasting colors (relative to background), highlighting, arrow pointers, larger fonts, icons to draw attention to key information 	(Roberts, 2009)
<ul style="list-style-type: none"> • Keep color coding consistent (1 color per concept) and to a minimum 	(de Köning, Tabbers, Rickers & Paas, 2007; Harper, Michailidou, & Stevens, 2009)
Images should relate directly to content	(Harper, Michailidou, & Stevens,

2009)

Use of white space

- 50% white space: content (Coursaris & Kripintris (2012))
- 5% white space: content (Lynch & Horton, 2008)

A Need for Visual Accommodations to Enhance Readability

The World Wide Web Consortium (W3C) is an international community of web users whose mission is to establish common standards for the structure and operation of the World Wide Web (<http://www.w3.org/>). One of W3C's functions is to administer the Web Accessibility Initiative (WAI), which formulates guidelines for allowing open and equal access to the online environment. In keeping with the principle of open access, WAI's primary task is to provide uniform standards that include accommodations for web users with disabilities (<http://www.w3.org/>). This includes individuals with physical and visual disabilities as well as individuals with cognitive impairments. Improvements in technologies and visual design standards that increase the usability of web sites, mobile platforms and other e-learning technologies is essential to increase accessibility to approximately 19% of the global population who suffer some degree of visual impairment (Erdogan, 2007), of which approximately one in ten males experience some degree of red-green color blindness (Lynch & Horton, 2008). This section will offer recommendations on improving visual display based on a survey of automated web checking tools that evaluate compliance with Usability and Access (U & A) guidelines, using atypical color response as an example. WAI has produced the Web Content Accessibility Guidelines 2.0 (WCAG 2.0) to help web designers create sites that may be used by individuals with disabilities. Its 12 guidelines are intended to create web pages that are perceivable, operable, understandable, and robust (WCAG2 at a Glance, (www.w3.org/WAI/WCAG20/glance)). The WCAG 2.0 guidelines have informed the development of a set of international web design standards that have been adopted by many countries.

Section 508

The United States has implemented U & A guidelines based on WCAG 2.0 standards, in keeping with the government's commitment to disabled individuals, as expressed in the Americans with Disabilities Act (ADA). In spite of U.S. government regulations for web sites under Section 508 to be accessible for individuals with disabilities, this is not occurring, particularly those managed by the federal government (Jaeger, 2006; Harper, Michailidou, & Stevens, 2009). One study found that 66% of sites are not usable by individuals with disabilities, which is not surprising, as 90% of sites lack features to enhance their usability (Brajnik, 2000, as cited in Vanderdonck & Beirekdar, 2005). Olalere & Lazar (2011) examined 100 federal government sites using both automated and manual evaluation. Only 4% of pages in the sample were free of errors. Most of the problems included images without alt text labels, lack of skip navigation links, poorly labeled tables and forms, or mouse-over actions which lacked a keyboard-only method to achieve the same function. Olalere and Lazar concluded that "having an accessibility policy statement does not impact on actual accessibility for federal home pages (p. 307)." It would appear that the problem with Section 508 is that its mandate is to ensure equal online access to all citizens, yet it currently lacks sufficient monitoring capability; data on federal website compatibility with 508 requirements was last collected in 2001. Furthermore, WCAG forms the basis for most 508 regulations yet was last updated in 2008. New standards that address the enhanced multimedia capabilities of Web 2.0 applications are needed. Frequent updates of web sites also problematize 508 compliance as new content tends to increase the number of 508 violations (Lazar, 2003). As more detailed evaluation strategies for measuring compliance to U & A guidelines are implemented, more sophisticated means to test web pages for accessibility will be required.

Recommendations for Increasing Web Page Readability Using WAI Guidelines.

Section 508 compliance requires that web pages “shall be designed so that all information conveyed with color is also available without color, for example from context or markup” (May & Lake, 2013, p. 407). Yet the slow pace of compliance, as indicated, justifies a reiteration of specific accessibility recommendations—many of the details within the guidelines have yet to be worked out. For example, Table 2 is a checklist of strategies to enhance readability; most of them (as of 2014) do not have forwarding links. Note also that Guideline 3.1 makes only one reference to text color and background, which is highlighted in Table 2. Using dark text on a pastel background is consistent with the recommendations offered by this review. The readability guidelines in Table 2 address a wide range of users, not just those with physical or visual impairments.

Table 2.

WAI guidelines to enhance readability and comprehension.
(<http://www.w3.org/WAI/WCAG20/quickref/#meaning>)

Advisory Techniques for Guideline 3- Make text and content readable and understandable

1. Setting expectations about content in the page from uncontrolled sources (future link)
 2. Providing sign language interpretation for all content (future link)
 3. Using the clearest and simplest language appropriate for the content (future link)
 4. Avoiding centrally aligned text (future link)
 5. Avoiding text that is fully justified (to both left and right margins) in a way that causes poor spacing between words or characters (future link)
 6. Using left-justified text for languages that are written left to right and right-justified text for languages that are written right-to-left (future link)
 7. Limiting text column width (future link)
 8. Avoiding chunks of italic text (future link)
 9. Avoiding overuse of different styles on individual pages and in sites (future link)
 10. Making links visually distinct (future link)
 11. Using images, illustrations, video, audio, or symbols to clarify meaning (future link)
 12. Providing practical examples to clarify content (future link)
 13. Using a light pastel background rather than a white background behind black text (future link)
 14. Avoiding the use of unique interface controls unnecessarily (future link)
 15. Using upper and lower case according to the spelling rules of the text language (future link)
 16. Avoiding unusual foreign words (future link)
 17. Providing sign language versions of information, ideas, and processes that must be understood in order to use the content (future link)
 18. Making any reference to a location in a Web page into a link to that location (future link)
 19. Making references to a heading or title include the full text of the title (future link)
 20. Providing easy-to-read versions of basic information about a set of Web pages, including information about how to contact the Webmaster (future link)
 21. Providing a sign language version of basic information about a set of Web pages, including information about how to contact the Webmaster (future link)
-

Table 3 provides a summary of specific accessibility problems visually impaired users encounter when using the web; only two examples (highlighted) refer to color or contrast. The list is indicative of the range of problems that visually impaired users encounter; color and contrast is only one. Many of the guidelines that follow mandate a text-equivalent interface that allows for manual control of or substitutes for visual elements (size, color, contrast, text-based description of an image, etc.).

Table 3.

Examples of barriers for people with visual disabilities. (<http://www.w3.org/WAI/intro/people-use-web/diversity#visual>)

-
- images, controls, and other structural elements that do not have equivalent text alternatives
 - Text, images, and page layouts that cannot be resized, or that lose information when resized
 - Missing visual and non-visual orientation cues, page structure, and other navigational aids
 - Video content that does not have text or audio alternatives, or an audio-description track
 - Inconsistent, unpredictable, and overly complex navigation mechanisms and page functions
 - Text and images with insufficient contrast between foreground and background color combinations
 - Websites, web browsers, and authoring tools that do not support use of custom color combinations
 - Websites, web browsers, and authoring tools that do not provide full keyboard support
-

WAI's Guideline 2. *Don't rely on color alone* is the most specific guideline with regard to color usage. Checkpoint 2.2 recommends "sufficient contrast when viewed by someone having color deficits" (<http://www.w3.org/TR/2000/WD-AERT-20000426#color>). This set of guidelines, for example, provides suggestions for accommodating colorblind users by using text alternatives to color or by high luminosity contrast ratios to differentiate colors, particularly between red and green, which are impossible for red-green colorblind individuals to differentiate. A specific color brightness algorithm calculation is provided but luminosity contrast ratios are not addressed, which would allow sufficiently high contrast values to be generated that could distinguish between colors. Although the guidelines set standards and offer suggested practices to follow, the most practical method to identify web accessibility issues of any kind, including color and contrast problems, one must turn to specific web accessibility checker online tools.

There are several automated web checkers that specifically examine color usage in web pages. For example, Fujitsu Corporation developed a suite of accessibility-evaluation tools, collectively referred to as Fujitsu Accessibility Assistance to evaluate web page compliance with their own web accessibility guidelines that incorporated W3C and 508 standards (Takamoto & Tosaka, 2005). Three tools within the suite were developed to address readability of web pages and include AccessColor (<http://www.accesskeys.org/tools/color-contrast.html>) to measure brightness and contrast; Accessibility Color Wheel (<http://gmazzocato.altervista.org/colorwheel/wheel.php>), which helps in selecting appropriate foreground-background colors that maximize accessibility in terms of contrast and brightness; the Colorblind Web Page Filter (<http://colorfilter.wickline.org/>) and the associated Color Laboratory (<http://colorlab.wickline.org/colorblind/colorlab/>), which are designed specifically to visualize web pages as color blind users would see them, and the Color Contrast Analyzer (versions 1.0 and 2.0) which include an extension for Mozilla Firefox to analyze foreground/background colors, brightness and contrast luminosity (<http://juicystudio.com/article/color-contrast-analyser-firefox-extension.php>) are other examples. Due to its add-on to Firefox capability, the usability of this application is particularly recommended for instructional designers and web developers.

In spite of a plethora of accessibility guidelines devoted to address the needs of visually impaired web users, W3C and Section 508 currently lack the ability to enforce standards. It is suggested that instructional designers and web developers consult the WAI guidelines to educate themselves on accessibility issues and then refer to the associated recommendations prior to building web sites or other e-learning tools. Selecting appropriate web accessibility checking tools (there are over 20

dealing specifically with visual disabilities) when building and piloting their web pages will yield higher quality design in web sites with the intention of enhance readability and minimizing extraneous cognitive load for all users.

Conclusion and Recommendations

In the realm of e-learning and web design, color and contrast can have a significant impact on readability of on screen text and on associated learner retention by keeping extraneous cognitive load to an absolute minimum. This area of inquiry is particularly relevant to instructional designers and web developers; it can inform design of reusable learning objects and web-based or web-enhanced online courses. The authors recommend appropriate color choices to optimize contrast between text and background (a 3:1 luminance contrast value is ideal), using sans serif fonts, minimizing visual complexity, using white space judiciously, and applying visual cueing sparingly to enhance readability and maximize learning retention by minimizing extraneous cognitive load. In terms of future research, visual impairments such as atypical color response and its relationship to luminance contrast is area in need of additional examination, as the use of contrast (as an alternative visual clue when color cannot be perceived) is not fully understood, nor articulated in current web design practice; the WAI guidelines scarcely mention it. This review has also provided an overview explanation of why web accessibility guidelines promulgated by W3C and Section 508 have received low compliance rates from the web design community and offered suggestions on how to rectify this issue by using a variety of online web accessibility checking tools that can identify color and contrast deficiencies in web pages. Although it is beyond the scope of this paper to address the motivating factors behind this lack of compliance with 508 and WAI accessibility guidelines, it can be surmised that current computer operating systems and web browsers allow for sufficient user-customization for the specific needs of most visually impaired users. The savings in web development and accessibility testing costs, in addition to faster page loading times, due to less code processing, may be a deciding factor.

References

- Clark, R. C., & Mayer, R. E. (2011). *E-learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning*. San Francisco, CA: Pfeiffer.
- Coursaris, C. K., & Kripintris, K. (2012). Web aesthetics and usability: An empirical study of the effects of white space. *International Journal of E-Business Research (IJEER)*, 8(1), 35-53. <http://dx.doi.org/10.4018/jebr.2012010103>
- de Köning, B. B., Tabbers, H. K., Rikers, R. M. J. P., & Paas, F. (2009). Towards a Framework for Attention Cueing in Instructional Animations: Guidelines for Research and Design. *Educational Psychology Review*, 21(2), 113–140. doi:10.1007/s10648-009-9098-7.
- Deubel, P. (2003). An investigation of behaviorist and cognitive approaches to instructional multimedia design. *Journal of Educational Multimedia and hypermedia*, 12(1), 63-90.
- Erdogan, Y. (2007). The effects of gender and visual disability factors on the legibility of web pages. *Journal of Literacy and Technology*, 8(1).
- Geissler, G., Zinkhan, G., & Watson, R. T. (2001). Web Home Page Complexity and Communication Effectiveness. *Journal of the Association for Information Systems*, 2(April), 1–46.
- Hall, R. H., & Hanna, P. (2004). Web Text-Background Color. *Behavior & Information Technology*, 23(3), 183–195. Retrieved from <http://lite.mst.edu/media/research/ctel/documents/LITE-2003-04.pdf>.
- Hanson, V. L., Breezing, J. P., Crane, S., Keats, S., Kjeldsen, R., Richards, J. T., Swart, C, & Trewin, S. (2005). Improving web accessibility through an enhanced open-source browser. *IBM Systems Journal*, 44(3), 573–588. doi:10.1147/sj.443.0573.
- Harper, S., Michailidou, E., & Stevens, R. (2009). Toward a definition of visual complexity as an implicit measure of cognitive load. *ACM Transactions on Applied Perception*, 6(2), 1–18. doi:10.1145/1498700.1498704.

- Hill, A., L. & Scharff, L. V. (1997). *Readability of websites with various foreground/background color combinations, font types, and word styles*. Proceedings of the Eleventh National Conference on Undergraduate Research, Vol. II, 742-746. Retrieved from <http://www.mmeissner.de/AHNCUR.html>.
- Jacko, J.A., Barreto, A.B., Marrnet, G.J., Chu, J.Y.M., Bautsch, H.S., Scott, I.U., & Rosa, R.H., (2000). Low vision: the role of visual acuity in the efficiency of cursor movement. Paper presented at the 4th International ACM Conference on Assistive Technologies, ASSETS, New York: ACM Press, November 2000.
- Lazar, J. (2003). Web Accessibility in the Mid-Atlantic United States : A Study of 50 Home Pages, 1–33. Retrieved from triton.towson.edu/users/jlazar/web_accessibility_in_us.pdf.
- Lin, D. (2003). Effects of contrast ratio and text color on visual performance with TFT_LCD. *International Journal of Industrial Ergonomics*, 31, 65-72.
- Lynch, P. J., & Horton, S. (2008). *Web Style Guide: Basic Design Principles for Creating Web sites* (3rd ed.). Yale University Press.
- May, K. & Lake, S. (2013). *Digital media: Concepts and applications*. Mason, OH: South-western/Cengage Learning.
- Mayer, R. E. (2014). Cognitive theory of multimedia learning. *The Cambridge handbook of multimedia learning*, 31-48. New York, NY: Cambridge University Press.
- Medina, J. (2008). *Brain Rules: 12 Principles for Surviving and Thriving at Work, Home, and School*. Seattle, WA: Pear Press.
- Mogford, R. (n.d.) NASA Ames Research Center Color Usage Research Lab: Using Color in Information Display Graphics. Retrieved from http://colorusage.arc.nasa.gov/design_lum_0.php.
- Murch, G. M. (1987). Color graphics: Blessing or bally-hoo? The visual channel in Baecker, R., M. & Buxton, W. A. S. (Eds.) *Readings in Human-Computer Interaction: A Multidisciplinary Approach*. Burlington, MA: Morgan Kaufmann Publications, 333-341.
- Olalere, A., & Lazar, J. (2011). Accessibility of U.S. federal government home pages: Section 508 compliance and site accessibility statements. *Government Information Quarterly*, 28(3), 303–309. doi:10.1016/j.giq.2011.02.002.
- Papachristos, E., Tselios, N., & Avouris, N. (2005). Inferring relations between color and emotional dimensions of a web site using Bayesian Networks. *In Human-Computer Interaction-INTERACT 2005* (pp. 1075-1078). Berlin, DE: Springer.
- Pett, D., & Wilson, T. (1996). Color research and its application to the design of instructional materials. *Educational Technology Research and Development*, 44, 19–35.
- Roberts, W. E. (2009). The use of cues in multimedia instructions in technology as a way to reduce cognitive load (Doctoral dissertation, North Carolina State University). Retrieved from <http://repository.lib.ncsu.edu/ir/bitstream/1840.16/4434/1/etd.pdf>.
- Misanchuk, E. R., & Schwier, R. A. (1995). The mythology of color in multimedia screen design: art, Science, and connoisseurship. *Canadian Journal of Educational Communication*, 24(1), 3-26.
- Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and instruction*, 4(4), 295-312.
- Tabbers, H. K., Martens, R. L., & van Merriënboer, J. J. (2004). Multimedia instructions and cognitive load theory: Effects of modality and cueing. *British Journal of Educational Psychology*, 74, 71-81.
- Vanderdonckt, J., & Beirekdar, A. (2005). Automated web evaluation by guideline review. *Journal of Web Engineering*, 4(2), 102–117.
- World Wide Web Consortium (2013). Retrieved from <http://www.w3.org>

W3C (2012).



This work is published under a Creative Commons Attribution-Non-Commercial-Share-Alike License

For details please go to: <http://creativecommons.org/licenses/by-nc-sa/3.0/us/>