I, Lingyu Zhu, hereby submit this original work as part of the requirements for the degree of Master of Design in Design.

It is entitled:
Color Contrast for Type on Screen

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Color Contrast for Type on Screen

A thesis submitted to the Graduate School
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Abstract

Black type on a white background is a centuries-old conventional color choice for most of the reading materials, both for print and on screen, because it has the maximum contrast and optimum legibility. However sometimes, designers would like to use different colors on types or backgrounds to present specific themes. And sometimes using colors in different values could show the hierarchy between various texts in the web, newspaper, or signage. However, there are no standards established for visual communication design. Designers cannot find such references when making critical decisions about legibility. Since 2012, with the Apple iPad™ launch, not only young people, but also older people, have accepted the tablet-size device as a preferred tool for reading. A basic problem for older people in reading is the declining perceptual ability. Therefore I believed that there should be a systematic relationship, between word count and color contrast for foreground vs. background, which is legible and readable for readers. And the relationship would be different for older readers from that of young readers. So in this thesis, I did research to find out those relations for the two age groups, and the results could be standards for the other designers to refer to in designing more effective layouts for old readers or young readers.
Acknowledgement

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Chapter 1. Background

1.1. Legibility and Readability

“There are two aspects of a type which are fundamental to its effectiveness … legibility and readability are separate, though connected, aspects of type.”¹ In typography, legibility means the quality of being decipherable and recognizable, which relates to the ability to distinguish one letter from the others. It is more used to describe the typeface design, and it is affected by factors such as x-height, character shapes, stroke contrast, serifs or sans serifs, and weight, while the term readability describes the quality of visual comfort. It can be influenced by line length, leading, justification, typestyle, kerning, tracking, point size, etc. Designers aim to achieve excellence in both.

“If the goal when working with type is to make it more readable, then heeding established legibility guidelines is of utmost important.”² Choosing a legible typeface, which has a relatively big x-height, to be open and well proportioned could be a good start to making sure that the text is legible for the readers. And a suitable type size would improve the recognition of every character. Except for those factors, color is also a crucial variable that needs to be considered. Bigger contrast between the colors used for type and background could make the edge of the stroke clearer, could have the letters deciphered more easily, and could ensure a smooth reading experience.

If legibility is the clear differentiation between every single character, then readability will be the harmonious relationship between the characters, words, lines, and the whole layout, including the color usage. It is something relating to the ease of

² Rob Carter (2002). Digital Color and Type. RotoVision SA. P.14
reading. Sometimes, a big contrast between foreground color and background color could provide a good legibility, but could also lead to eye fatigue after a long reading. A legible color contrast cannot ensure the readability of a text, but a readable text must have a legible color contrast.

1.2. Changing Reading Habits

With the invention of e-readers and tablets such as the Amazon KindleTM and the Apple iPadTM, words printed on paper have been slowly declining. A 2009 Pew Research Survey shows that 55% of readers aged 65+ would miss the printed version of their local newspaper if they were to disappear. In contrast, an average of only 28% of readers under 65 would miss it\(^1\), including Baby Boomers and Gen. Y. These results confirm what newspapers have known for a long time – loyal readers are older, and the younger generation is depending less on getting their news off a printed page.

Increasingly, readers of all ages are accessing their news online from electronic devices such as tablets and e-readers. "Slightly more than half of all tablet owners are Millennials." And "Generation Y tablet owners are more likely than older generations to seek local news on their tablets"\(^2\). Meanwhile, in a study conducted by the Pew Research Center's Internet & American Life Project between December 2011 and January 2012 shows that ownership of electronic devices has been increasing for readers of all ages. The number of tablet owners has nearly doubled from 10 to 19

percent, and the number of e-reader owners jumped from 18 to 29 percent. Specifically amongst Baby Boomers ages 50 to 64, tablet ownership increased from 8 to 15 percent, and from 11 to 19 percent for e-readers\(^1\). And another survey taken by the Pew Research Center in 2013 reports that tablet ownership of adults ages 18-29 increased 14 percentage points from April 2012 to May 2013, while that of adults ages 50-64 increased 18 percentage points\(^2\). Based on those numbers, it can be clearly predicted that tablets and e-readers will become increasingly popular in the future, not only among Gen. Y, but among Baby Boomers as well.

1.3. Study Topic

With the increase in use of tablets and e-readers to access news amongst all age groups, understanding the relationship between typographic color contrast and readability on screen could greatly improve the users' reading experience.

There are some people that have already done researches on similar topics, regarding the effects of type settings, environmental luminance, or electronic devices, on legibility and readability of the type. They have proved that bigger color contrast between type and background could improve both the legibility and readability, but there is still not such a standard for designers to refer to when doing visual communication design.

This study will research the effect of typographic color contrast (between foreground and background) and readability on screen. It will compare the results and levels of tolerance for two distinct age groups – Gen Y. (ages 13 – 33) and Baby Boomers (ages 49 – 67) – representing younger readers and older readers.
Chapter 2. What Is Affecting A Fluent Reading

There are several factors that could affect the legibility and readability of a text on screen. In this thesis, I cannot cover all of them. I will only study the relationship between typographic color contrast and readability.

2.1. Color and Type

Hue, value, and saturation are three important elements to determine a color. Hue is “the purest or brightest form of a color … that have not been mixed with white or black”. Value is “the degree of lightness and darkness of a color”. And saturation is “the intensity or purity of a hue; the colors of the greatest purity are those in the spectrum”\(^1\).

“When color is applied to type, the interplay of hue, value, and saturation must be considered ... The most important thing you can do to achieve optimum legibility when working with color and type is to carefully weigh the three color properties to establish an appropriate contrast between letters and their background.”\(^2\)

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\(^2\) Rob Carter (2002). Digital Color and Type. RotoVision SA. P.32-33
The color wheel (Fig. 2-1) consists of 12 basic hues, including primary hues — red, blue, and green, secondary hues, and tertiary hues. These hues with linear mixtures between adjacent pairs of them are called pure hues. Literally, two complimentary pure hues, which are opposite to each other on the color wheel, can offer plenty of hue contrast. If we pick two such colors and set them as the foreground and the background, however, sometimes it looks illegible. For example, suppose that a magenta text is set on a green background (Fig. 2-2). The edges of the characters appear to be vibrating. That's because the two colors are similar in color value. They are essentially fighting for the readers' attention, which makes it difficult for the eye to recognize the types from the background. Let's look at another example: blue types on a yellow background (Fig. 2-
2). It is more legible than the previous example because blue is darker than yellow in value.

“Of all the contrasts of color, value can be used to enhance legibility most significantly. Value contrasts effectively preserve the shapes and integrity of letters, making them more easily recognizable.”¹ If we change a little bit in the first example, to

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¹ Rob Carter (2002). *Digital Color and Type*. RotoVision SA. P.34
soften the green, and make the magenta darker, the legibility would be improved a lot (Fig. 2-2). In fact, softening the green and darkening the magenta would change their values, meaning they would no longer be considered "pure colors".

My study will examine tolerable value contrasts for more comfortable reading experiences.

2.2. Value of Colors

As Rob Carter said in Digital Color & Type, “value refers to the lightness or darkness of a color. It is a variable that can substantially alter a color’s appearance … it is also an important factor in achieving legibility with type and color.”¹ Most of the reading texts are set as black words on a white background, but for emphasis, or style, sometimes colors are needed.

Achromatic colors with different values constitute the Gray scale, while pure hues with their value changing generate different tints and shades. “A color with added white is called a tint; a color with added black is called a shade.”² Basically, the shades of a pure hue are darker than the tints. However for some colors there are exceptions, because the values of pure hues are different from one another. For example, colors on screen are displayed using different combinations of red, green, and blue (RGB). In RGB mode, every color is encoded by three variables, each representing the amount of red light, green light, and blue light. For achromatic colors, the values of red, green, and

¹ Rob Carter (2002). Digital Color and Type. RotoVision SA. P.22
² Rob Carter (2002). Digital Color and Type. RotoVision SA. P.22
blue are equal. Let’s just name it X. If one color (R, G, B) has the same value with gray (X, X, X) (Fig.2-3), there is a formula that could be used to calculate the value of X.

\[ X = 0.299R + 0.587G + 0.114B \]

“Since pure green is lighter than pure red and pure blue, it has a higher weight. Pure blue is the darkest of the three, so it receives the least weight.”

Generally speaking, the colors that are dark in value normally weigh more than the ones that are light in value.

![Value Calculation for Colors](image)

Fig. 2-3  Value Calculation for Colors

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1 How to Convert RGB to Grayscale. [http://www.had2know.com/technology/rgb-to-gray-scale-converter.html](http://www.had2know.com/technology/rgb-to-gray-scale-converter.html), 06/25/2013
I selected six pure colors from the color wheel (Fig.2-4), and converted the colors from RGB mode to Grayscale mode in Illustrator, so that I got the corresponding grays on the right side. It obviously demonstrated that the red, blue, and violet have relatively dark values, but orange, yellow, and green have lighter values. Since the pure blue is darker than pure green, it is also possible that a tint of blue could have a same value with a shade of green.

![Fig. 2-4 Value of Pure Hues](image)

In Fig.2-5, one is the type with a shade of blue on the background with a tint of green, and another is the type with a shade of green on the background with a tint of blue. The two shades and two tints are at the same level. From the two examples, we can see that the first one appears more legible, because the shade of blue and the tint of green have a bigger value contrast than that between the two pure colors. However in the second example, the shade of green and the tint of blue are similar to each other. The edges of the characters appear to vibrate.
“Generally speaking, pure hues that are normally light in value (yellow, orange, green) make the best tints, while pure hues that are normally dark in value (red, blue, violet) make the most desirable shades.”¹ The example in Fig.2-5 demonstrates Carter’s statement. If designers would like to add color to text or its background, designers should combine shades of colors that are dark in value, and tints of colors that are light in value, to provide the best value contrast and thus increase readability.

In this study, I will only test the effects of both types and backgrounds set in achromatic colors first, to figure out the range of the tolerable value contrast, because it would be easier to control the data and could simplify the test in this way. After that, I will apply the result to the other colors based on the theory of value.

¹ Rob Carter (2002). *Digital Color and Type.* RotoVision SA. P.22
2.3. Legibility and Readability of Achromatic Colors

Black text on a white background is the highest value contrast and thus increases legibility. If I change the text value a little bit, like 85%, it will still be recognizable. If I use 55% gray, it will become even lighter. When applied to only a few characters, the distinctions between the four values are subtle. (Fig. 2-6)

![Achromatic Colors Applied to Characters](image)

If I apply these values to short text blocks (Fig. 2-7), the differences between the four values are more distinct. The lower contrast value of the 55% gray on a white background makes it more difficult to read when applied to longer texts. (Fig.2-8) Even though the readers still can recognize the words, the color would also cause fatigue to their eyes after a long reading.
Because the requirements of readability also depend on how much time people spend on reading, I would like to take reading length as a variable, to study the relationship between the tolerable color contrast for foreground and background, and readability based on different text length.
In traditional typography, text is composed to create a readable, coherent, and visually satisfying whole that works invisibly, without the awareness of the reader. Even distribution of typeset material, with a minimum of distractions and anomalies, is aimed at producing clarity and transparency.

Choice of typeface(s) is the primary aspect of text typography—prose fiction, non-fiction, editorial, educational, religious, scientific, spiritual and commercial writing all have differing characteristics and requirements of appropriate typefaces and fonts. For historic material established text typefaces are frequently chosen according to a scheme of historical genre acquired by a long process of accretion, with considerable overlap between historical periods.

Fig. 2-8  Achromatic Color Applied to Long Texts
Chapter 3. Influence of The Other Factors

Although I will only study the optimal value contrast for readability on screen, based on the variable of reading length, the influence of other factors should not be ignored. So as to get an accurate result, I need to diminish the effects of typeface, font size, and line spacing by selecting a suitable combination.

3.1. Fonts

“Traditionally, a font was one size of one typestyle in a particular typeface. … Today the term font is used more loosely. A font still refers to a specific typeface and typestyle but no longer refers to a particular type size.”¹ To make the words legible, it is a matter of typeface design, type size and also type style.

“The first step in making type legible is to choose text typefaces that are open and well proportioned.”² “There are four main factors that influence typographic proportions … the ratio of stroke width to the height of the character … the contrast between the thickness and thinness of the stroke weight … the proportion of the x-height to the height of the capital letters, ascenders, and descenders … the width of the letterform.”³ These proportions cannot be exactly calculated. The well proportions are optically correct, rather than mathematically. For example, a typeface with a smaller stroke-to-height ratio may work better for a small type size, because it makes the letterforms lighter and clearer; the typefaces with longer ascenders and descenders

² Rob Carter (2002). Digital Color and Type. RotoVision SA. P.14
allow for better recognition at smaller sizes, but conversely, the ones with larger x-height-to-cap-height ratios work better with display types.

Typestyle is a way to increase the diversity of text types, and to show the hierarchy and emphasis on the layout, except for typefaces and type sizes. Typestyle includes Roman, Italic, Oblique, Light, Regular, Bold, Condensed, Extended, and some combinations of them. “Most of these typestyles are simply variations in the weight or width of the letterforms.”¹ Light, Regular, and Bold are different in stroke weight; Condensed and Extended change the widths of letterforms; Oblique refers to a typeface simply slanted to the right, while Italic is a specifically designed slanted style. “Generally speaking, typefaces that are true to the basic letterforms are more legible than typefaces that have been condensed, expanded, embellished, or abstracted.”² When the weight or width of the letterforms has been changed, adjusting the color contrast accordingly could improve the legibility of the text. If the types are condensed to save space, the contrast has to be strengthened; if the types are extended, designers could think about decreasing the contrast and the weight to reduce the typographic color.

3.2. Space

Letterspacing, Wordspacing and Linespacing could have a big influence on legibility and readability of a text. “Consistent letter spacing provides an even typographic 'color', a term referring to the texture and overall lightness or darkness of

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text. Consistent and even color is an attribute that enhances readability.\textsuperscript{1} Proportionally adjusted word spacing could help letters to "flow gracefully and rhythmically into words"\textsuperscript{2}. And "line spacing ensures that the reader is not distracted by lines of type that visually run together"\textsuperscript{3}, and prevent them from struggling to distinguish one line from another one.

If the space were wide, the typographic color would be lighter, while if the space is narrow, the typographic color could be darker. In order to provide a proper and comfortable tone of typographic color, the color usage of types could be relatively lighter or darker.

\begin{flushleft}
\begin{enumerate}
\item Rob Carter (2002). Digital Color and Type. RotoVision SA. P.16
\item Rob Carter (2002). Digital Color and Type. RotoVision SA. P.16
\item Rob Carter (2002). Digital Color and Type. RotoVision SA. P.15
\end{enumerate}
\end{flushleft}
Chapter 4. Methodology

I studied the tolerable value contrast between foreground and background for body texts with different reading length. This study focused on two age groups: one was Gen. Y (ages 15-33), and the other one was Baby Boomer (ages 49-67). Except for the target data -- value contrast, and the variable -- reading length, the other factors were set in a legible and readable condition, in order to reduce the effects on the test.

4.1. Test Conditions

In the test, I only tested people in the two age periods -- 15-33 and 49-67. I interviewed 25 persons for each group, in the places where people are used to reading, such as bookstores, libraries, and coffee bars, because the light and the environments are suitable for reading and thus can have little effect on the legibility and the readability of the types.

Before starting the test, I asked the participants some questions about their reading habits and eye conditions, to make sure that they had some reading experience with Amazon Kindle™ and Apple iPad™, and were sure about their requirements for reading on screen. Someone that rarely did reading with those devices in the past could provide answers which did not exactly reflect their needs. A questionnaire was used to collect all the information and data (Appendices).
4.2. Test Tool

Instead of counting the reading length by word number, I defined it with two categories – short text and long text. Before people start reading a text, they do not calculate how many words it has, or how many paragraphs it contains, they just count them as a short piece – such as an abstract, or a quotation – or a long piece, which occupies several pages. I set 200 words as a divider of short text and long text. With an optimal line length of about 60 characters, 200 words would be about 20 lines with 10 words per line. In order to simulate the layout of a website, I designed the whole page with a title, a subtitle, an abstract, main contents, and a picture on it (Fig.4-2(3)). There were two sliders below, one controlling the color contrast of the short text (Fig.4-2(2)), and the other one controlling the long text (Fig.4-2(3)). The body texts were set in Georgia, which is a readable serif typeface designed for screen, and 4px of the line spacing. It was copied with the contents in four font sizes from 16px to 22px, because optimal legible font size of 12pt in print is equal to 16px on screen, and 22px is the maximum of the font size that can still guarantee the optimal line length for readability (50 -- 75 characters per line)\(^1\). And in order to ensure a readable line length, the texts were set in two columns with 16px and 18px, and in one column with 20px and 22px (Fig.4-2(4)).

4.3. **Test Procedure**

The questionnaires needed to be filled out first, and then the test started. Every participant was asked to select a comfortable font size between the four options on the menu (Fig.4-1). After they had entered the testing page, nothing was viewable on the screen (Fig.4-2(1)). They were notified that they would read a short piece of text with one paragraph, and need to adjust the left slider below to the minimum of the tolerable color contrast for this piece, and finish reading it (Fig.4-2(2)). Then they needed to do the same to the long piece of text and finish reading it as well (Fig.4-2(3)). During the test, the font size they selected, and the value contrasts they preferred for the short piece and the long piece were recorded on paper.
The start of a new chapter
Meet our writing competition winner, Cath Weeks - whose prize was a weekend course at Bloomsbury Publishing - and read her story.

M
ore than 500 readers entered the Writing Masterclass competition we ran in our March issue. The standard of entries was spectacular, and we were inundated with hundreds of beautifully written stories. But one piece captured our attention most, and just left us dying to read more. Cath Weeks, and environmental educator at the Forestry Commission, was announced as our winner. This is her story.

Fig. 4-2 Test Procedure

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Chapter 5. Test Results Analysis

5.1. Test Result

In the test, 25 Baby Boomers, and 27 people from Gen. Y were tested in total. All of them have had experience with reading e-materials on tablets or e-readers before, so that they could correctly know their preference of the color usage on screen for reading. Most of the Baby Boomers were wearing glasses when reading, because they have visual problems of presbyopia that are typical for aging people, while most of the young people were not wearing glasses when reading. People from Gen. Y have better eyesight and could accept relatively smaller font sizes. There are four font sizes in this test, from 16px to 22px. 23 of the 25 Baby Boomers selected to read the content with 20px, and 24 of the 27 people from Gen. Y thought 18px worked best for them.

In order to keep all the settings the same for every test, except the color contrast and reading length, the data of the Baby Boomers who did not select 20px, and the people from Gen. Y who did not select 18px were removed. Finally, four pie charts were generated based on the valid information collected from the tests, which represent the minimum of acceptable value contrasts of the Baby Boomer and the Gen. Y, for short text and long text under specific type settings. (Fig.5-1) In the four charts, the white bold numbers in the middle of every piece refer to the range of value contrasts. Since 5% contrast difference is not so visually obvious, the 5% in the middle were used to represent every 10% range. "25" represents 20%-29%, and "45" represents 40%-49%. The black numbers around every pie mean the percentage of people who could accept the range as a lower contrast limit.
Obviously from the four pie charts, people's acceptance for short texts is wider than that for long texts, in both of the two groups. People can accept about 25% contrast for short texts, but at least 35% or 45% contrast for long texts. "I think reading a short piece would not take much time and tiredness would not come so soon, so I can read it in a light value. A long text has to look comfortable for my eyes, or I don't want to start," one of the participants said. Based on readers' experiences, they are already sure about their preferences for how the layouts look. If anything in the whole page makes them uncomfortable, especially how the types look, they would leave it as soon as possible.

With the type in a comfortable font size -- 20px for Baby Boomers, and 18px for Gen. Y, most of them can accept the contents with a value contrast of 55%, 65%, or 75%, and the higher the contrast, the more people like it. When asked about the reason of reading text in big value contrasts, one old man said, "I would like to read things at least like this (75% contrast), because I have a bad eye sight." As visual problems are common for most of the aging people, and it is not preventable, the darker the words are on a white background, the easier it would be for the elders. "I would like the words to be dark enough on the white background because I think it is easier for me to read. I can read something lighter, but I still prefer the darker words which could make me read faster," a young person mentioned, and some other young people also talked about similar things. Another young man also said, "If I'm reading casually or something interesting, I can accept the type color to be lighter, but for the academic materials, I prefer it to be dark enough, so that I can read efficiently and memorize it better."
Gen. Y, they care more about the readability than the elders. They hope that the reading experience could be efficient, quick, and smooth. Although they could accept something new, something diverse and challenging, they still are loyal to their habits that were formed a long time ago. So what type color would work well for Gen. Y really depends on the purpose of the contents.

Most of the Baby Boomers can accept the value contrasts between 30%-49% of a short piece, and the most popular value contrasts of a short piece for the Gen. Y is from 50% to 69%. Compared to their value contrast acceptance of a long piece, the difference appears bigger for Baby Boomers than that for Gen. Y. When talked about the difference between tolerable value contrasts of a short piece and a long piece, a young lady answered, "Actually I can recognize the lighter words, but if I'm reading, that would slow down my reading speed. I need to stop to see the words more carefully, or I have to try harder to recognize them, or I would easily miss the words. I don't like it even it is a short piece." To the same question, the answers of several old people were that "I can see it clearly word by word, when I am wearing the glasses". Apparently I found that what the young people care about is still the efficiency of reading experience. They would like to read more in a limited time, or spend less time to read something, while the elders would be more patient during the reading, and care more about the legibility of the letters.
Fig. 5-1 Test Result Analysis
5.2. Model

Based on the analysis of the test results above, I am going to build a model for designers to use in order to correctly use color contrast in typography design on screen. Basically, when graphic, or web designers design a text for a website or a magazine, considering color usage, they would normally refer to how long the passage would be, who would be the audience, and how important it should be.

To fulfill those kinds of requirements, I would design a model (Fig.5-2). It is a matrix based on two perpendicular arrows, of which the horizontal one represents the percentage of the people that could accept such contrast, and the vertical one represents the length of the passage. In order to simply calculate the reading length, I would divide it into two categories -- Short piece and Long piece, with about 200 words as a divider. Those four radiant rectangles are just evolved from the four pie charts before. The bold white numbers are the value contrast of the points next to them, and every percentage number under the horizontal arrow is a total value of all the people who would accept the corresponding value contrasts or below them, for the text, as a lower contrast limit.

Designers could decide the audience, and the expected popularity of the text, and find the value contrast from the model. It could also be applied to the other colors, not only for achromatic colors. I would like to design an App later to improve the usability of this model.
Fig. 5-2  Tolerable Value Contrast Model
Chapter 6. The App

In Chapter 5, I used the data got from my test to build a model of the acceptable values vs. the popularity. And right now I am going to design an App to help designers to use the model in designing. The App could be a tool for users to select a proper combination of colors for the text and the background, and view the example before they use it.

The interface of the App is like what in Fig.6-1. There is a page in the middle with the same proportions of the iPad, and some words on it as a placeholder. Before selecting the color, users could set up the Typeface, Font Size and Linespacing by the buttons on the left side. And then they could choose the color for the background and the text. They could set one of those two colors as solid color, and a value scale of a main hue for another one, such as white as the background, and Gray scale for the text. Then the users could decide if the passage is a short piece or a long piece, and the expected audience would be the young group, the elder group or all the people. After all the settings have been settled, the gradient bar below would be generated automatically. This bar presents the acceptable value range of the undefined color, like the color of the text in the example. Users could slide the blue button, and the number below it, which presents the popularity of the value contrast, would change continuously, and so would the white number beside the circle. When users stop sliding, they could tap the white circle, and the color value would be applied to the text. Same with the Gray scale, users could also choose the value scales of the other colors (Fig.6-2), and they can also set the text as a solid color to try different colors for the background (Fig.6-3).
I have suffered from low-level depression most of my life. It would flare up on occasion into something really bad -- I had post-natal depression after having my two children, for example -- and then I'd be on medication or some kind of treatment. But mostly it was not dramatically bad, just a constant dull, tired, joyless, sad feeling. I didn’t realise how bad it actually was until it had gone.

I discovered wild swimming by accident. Swimming in public pools never really appealed, but I live in Dorset near the sea, and one summer, I decided to take advantage of this and do some sea-swimming. I also went kayaking and coasteering, which involved swimming in some quite scary waves, through sea caves and out to little islands. It was all what I would ordinarily have considered cold, uncomfortable and frightening. But it made me feel alive for the first time in years.
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Fig. 6-2  App - Text in Colors
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Chapter 7.  Brightness

Based on the information and data I got from the tests, I figured out the range of tolerance for the legibility and the readability of types. Setting the colors of type and background according to the value range could lead to optimal readability, but exceptions would happen. Except for value, there is another factor that could affect the legibility and readability of type, which is brightness.

Brightness is “the quality or state of having or giving off light”¹. People can see colors, because the objects reflect some of light to their eyes. Different colors consist of different amount of red, green, and blue light, so they also have different brightness. “The most popular Brightness editing algorithm is based on the Arithmetic mean model:

\[
\text{Brightness} = \frac{(R + G + B)}{3}.
\]

This formula explains that the more the total amount of the three lights a color consists of, the brighter it is.

If I rewrite the formula in another way like this:

\[
\text{Brightness} = 0.333R + 0.333G + 0.333B
\]

It looks quite similar to the one used to calculate the color value in the Section 2.2. In other words, normally the colors lighter in value have higher brightness, and the colors darker in value have lower brightness.

If something were too bright, such as the sun, it would be tiring for people’s eyes to focus on it for a long period of time. The same theory applies to the application of color to type – if the color is too bright, it would cause additional strain on the readers’

---

eyes while reading over a long period of time. Generally speaking, the colors that are dark in value normally weigh more than the ones that are light in value. When two colors are put together, the lighter one usually looks more active, while the other looks relatively stable. When people read, their eyes move from word to word. If the type color is brighter than the background, the words will appear to vibrate. As a result, readers’ eyes will have to work harder to focus, leading to increased tiredness.

Previously, I was talking about the brightness representing how much light comes into people’s eyes. There is another way to calculate the brightness of a color.

“Introduced by Alvy Ray Smith, HSV (Hue, Saturation, Value) also known as the HSB (Hue, Saturation, Brightness) model is prevalent in Saturation and Hue editing algorithms:

\[ V = \max(r, g, b). \] \(^1\)

In the HSB model, all the pure hues, their tints and the white color have the highest brightness. This explains why some colors do not have a high brightness level but still put a strain on the reader’s eyes. For example, pure blue has a low brightness and is dark in value, but if it is used on type, the edges of letterforms appear to vibrate – creating a kinetic effect that strains the eyes. This effect also occurs with other pure colors.

If having high value contrast levels between foreground and background is an important factor for legibility, then avoiding the use of very bright or fully saturated colors

is critical to readability. It makes the type easy to capture and not cause tiredness to the readers.

The types in print reflect light, however the types on screen project light. In order to study the colors’ effects on readability on screen, research on colors’ brightness is also a crucial part, which could be the next step to continue the study in the future.
Chapter 8. Conclusion

For legibility and readability, all the factors influence each other very much. When color and type are combined together, ensuring a bigger contrast, and avoiding using bright color on either the text or the background are crucial to a comfortable reading experience. There is a range of tolerance, within which the color setting could provide legible and readable types for readers, and the ranges are different for short texts and long texts, for Baby Boomers and Gen. Y. People’s tolerance for short texts is wider than that for long texts, no matter if they are young or old.

Most of the Baby Boomers can accept at least 40% value contrast for short text, and at least 60% value contrast for long text. They are more concerned about the legibility of the types, so value contrasts above 70% can assure them a better reading experience because of their declining perceptual abilities.

However, Gen. Y cares more about the readability of a text. Most of them can accept at least 50% value contrast for short text, and at least 60% value contrast for long text. Challenging type color on screen could be welcoming for Gen. Y, but for most reading material, especially ones which require them to have a good intention, should be set in an optimum color contrast to guarantee an efficient reading experience.

The Acceptable Value Contrast Model and the Type Color App could provide designers a reference to select highly legible and readable value contrast levels when applying colors to type. The data for the app was taken from tests with people, based on a good design of typeface, font size, and space. Designers could easily find a suitable
color for a text with a specific length for the main audience via this app, which would make their design work much easier.
Appendices

Questionnaire

gender _____ environment ________________

Pre-Test

1. Your age is between:
   ○ 15 -- 25   ○ 26 -- 33   ○ 49 -- 59   ○ 60 -- 67

2. Did you have any surgery for your eyes?
   ○ Yes   ○ No

3. Do you wear glasses when reading?
   ○ All the time   ○ Sometimes   ○ Never
   ○ I need to change glasses

4. How often do you read?
   ○ Everyday   ○ 4 – 6 times / W   ○ 1 – 3 times / W   ○ Rarely

5. How much time of reading did you spend on e-readers in the past?
   ○ 85% -- 100%   ○ 50% -- 84%   ○ 25% -- 49%   ○ 0% -- 24%

6. What do you always read on e-reader
   □ News   □ Websites   □ Novel   □ Magazines
   □ Others  ____________________________________________

Selected Font size _______px

Minimum Acceptable Value

For short piece ___ %      For long piece ___%