VOL 5
FALL/WINTER
2022

Design Behaviors
INTERNATIONAL DESIGN RESEARCH JOURNAL

John T. Drew, MFA
Professor of
Graphic and Interactive Design,
California State University, Fullerton
Executive Director of the
Innovation Center for Design Excellence

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Design with Accessibility in Mind: Gestalt Principles and The Human Visual Pathway

John T. Drew, MFA

Professor of Graphic and Interactive Design, California State University, Fullerton
Executive Director of the Innovation Center for Design Excellence

ABSTRACT

To understand how to create a design that is inclusive to all, including those with visual disabilities, one must first understand how the human visual experience takes place and how the mind interprets these visual impressions. For too long, design educators have taught their students to use their visual expertise to test visibility as a measure of visual success. Unfortunately, this activity excludes 19.5% of humans worldwide, and according to the World Health Organization, by 2050, this number is expected to double. Visually impaired people do not see the same way as a designer with 20/20 vision, naturally or with corrected eyewear. However, design educators still use their students (20/20 vision) as the model for visual legibility and readability success. To prepare for the future, design educators must introduce content that addresses the needs of those with disabilities. You can have a fantastic design, but if 19.5% of the world cannot see it, what is the good in it? The design is inherently exclusive. For these individuals, barriers exist in which they cannot participate, often because visual communication is not designed with accessibility in mind.

This case study demonstrates the ease with which accessible content can be integrated into any project and the theoretical basis of the systems used. The information is multidisciplinary and is intended to provide a clear understanding of the interaction of science and design. Using existing formulas from ophthalmology, color science, physics, physiology, psychology, communication design, and environmental design, a designer can now predict the distance at which typography, color, icons, and logos can be seen for any standardized eyesight, including the visually impaired, legally blind, or 20/20 vision.

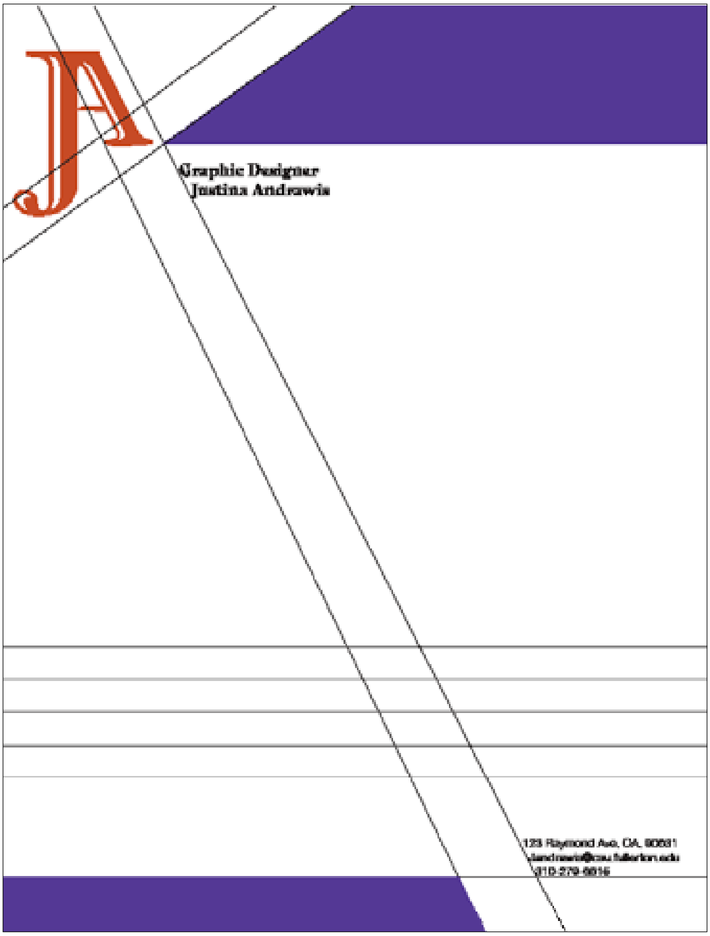
KEYWORDS

Accessibility Design, Color Contrast, Color Science, Viewing Distance

INTRODUCTION

The logotype and stationary system assignment, presented to sophomores in the graphic and interactive design concentration at California State University Fullerton, introduces students to the creative use of typography and basic accessible design principles. To help students understand how to comply with these principles, I first lecture on design and show them the tools they will need to complete this assignment. In many ways, this twofold project is no different from any other logotype and stationary assignment. The only difference is showing the students that color contrast and fonts can be scientifically measured to determine their viewing distance for standardized eyesight (Drew 1997) (Rose 1983). In this case, we are designing the visual distance for a person who has 20/70 vision and is color blind. All other design principles to teach a logotype and stationary system still apply.

Designer: Bryce Verti
Color Ratio: 4.87
C086 M031 Y055 K010
Y-tristimulus Value: 16.207
Color Contrast Differential: 83.793
20/70 Viewing Distance: 6.937’
20/20 Viewing Distance: 23.839’
20/70 Viewing Distance: 2.114 M
20/20 Viewing Distance: 7.266 M



Designer: Justina Andrawis
Color Ratio: 4.74
C016 M084 Y100 K005
Y-tristimulus Value: 17.752
Color Contrast Differential: 82.248
20/70 Viewing Distance: 2.376'
20/20 Viewing Distance: 11.884'
20/70 Viewing Distance: 0.7242 M
20/20 Viewing Distance: 3.622 M

In this example only the logotype is being measured. In more advance classes students will measure all elements to determine distances.

LEARNING GOALS

• Typographic legibility and how it differs from readability (Chapter 3 of Typographic Design: Form and Communication, Innovation Center for Design Excellence: White Paper for App Visual Accessibility pp. 3-34).

• Three-Dimensional Color Theory and how it relates to and differs from subtractive and additive color theories, including understanding both CMYK, RGB, the Y-Tristimulus values, and illuminance values and how they are used in a practical context within the field. (Billmeyer 1981)

• How to measure type for distance.

• How to calculate typographic measurements for standardized eyesight, including normal, visually impaired, and legally blind. (Snellen 1862)

• How to mathematically calculate color contrast for normal and visually impaired eyesight.

• How to mathematically calculate the typographic visual distance for normal, visually impaired, and legally blind audiences.

• Points and picas and how they relate to inches.

• How to determine appropriate fonts for viewing distance and the relationships among font size, actual size, and historical context.

•Some of the principles of gestalt theory (proximity, similarity, closure, figure/ground: visual substitution) and how to use some of the formal processing techniques found within each principle.

Designer: Justina Andrawis
Color Ratio: 8.91
C082 M094 Y100 K000
Y-tristimulus Value: 6.526
Color Contrast Differential: 93.474
20/70 Viewing Distance: 6.1142'
20/20 Viewing Distance: 21.0110'
20/70 Viewing Distance: 1.863608 M
20/20 Viewing Distance: 6.404153 M

At the size the logotype is on this page the above distances are correct.

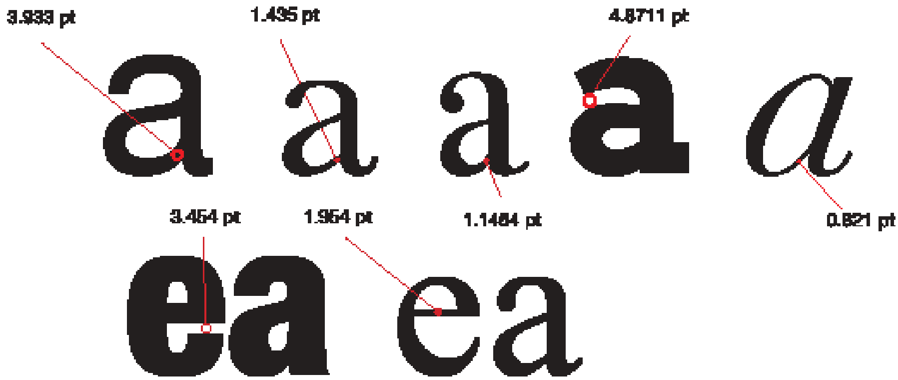
Designer: Justina Andrawis
Color Ratio: 3.65 orange / 8.75 brown
C015 M066 Y092 K003 / C048 M060 Y085 K044
Y-tristimulus Value: 24.548 orange / 7.035 brown
Color Contrast Differential: 75.452 orange / 92.965 brown
20/70 Viewing Distance: 2.797' orange / 1.072 brown
20/20 Viewing Distance: 9.6129' orange / 3.6865'
20/70 Viewing Distance: .8525 M orange / .3267 M brown
20/20 Viewing Distance: 2.93 M orange / 1.123645 M brown

"Figure/Ground: The sum is greater than its parts. The color ratio of 3.65 passes 18pt type. The brown passes all color ratio criteria.

METHODOLOGY

The methodology that governs this assignment is four-fold and is introduced over two weeks. First, I present the gestalt principles of similarity, continuation, closure, proximity, figure/ground, symmetry and order, and common fate and how they relate to the use of type, image, color, grid, composition, and the human visual pathway. Author Mary Ann Dalangin has elegantly described these principles in the online article "7 Gestalts Principles for Visual Perception: Cognitive Psychology for UX," which are listed below for convenience.

• "Similarity: It is human nature to similar group things. In Gestalt, similar elements are visually grouped regardless of their distance from each other. Similar things can be grouped by color, shape, or size."



This diagram is an example of the anatomical parts of a letterform that should be measured for distance.

• "Continuation: The principle of continuity suggests that the human eye follows a path when viewing the lines, regardless of how these lines are drawn. This principle is useful in design when the goal is to guide your usersin a certain direction."

• "Closure: Closure is a Gestalt principle that suggests that your brain will fill in the missing parts of a design or image to create a whole."

• "Proximity: The principle of proximity refers to how elements are grouped by the space between them. If the spaces are not the same, the minds' eyes will not group them."

• "Figure/Ground: The sum is greater than its parts; for example, the elements that make up the mark are sparse but contain enough information so that the viewer's imagination can fill in the rest. The figure/ground principle takes advantage of how the brain perceives negative space between objects and automatically fills in the shape. Visual substitution is also a part of this principle. Visual Substitution: Where one object is replaced for another, or a letterform is replaced with an object of either similar size or shape. Usually, substitution is based on content or context, and it is used when one shape is similar to another in a form counter-form relationship."

• "Symmetry and Order: The principle of symmetry and order, also known as pragnanz, is a German word for 'good figure.' This principle explains that your brain sees ambiguous shapes in the simplest way possible. This principle states that shapes have symmetrical halves, and the closer to symmetrical they are, the more receptive the brain is to them. Thus, in logo design, many companies symmetrically design their logos."

• "Common Fate: This principle explains that people will group things when pointing to or moving in the same direction. This principle is useful in UX design" (Dalangin 2022).

Gestalt principles, first introduced by Max Wertheimer, Kurt Koffka, and Wolfgang Kohler in the 1920s, were designed to demonstrate how humans find meaning and order in the human visual experience. These principles help to describe how humans organize visual information so that meaning can be found and wayfinding can be achieved. (Koffka 1999)

In the second phase, I demonstrate how these gestalt principles are associated with the four types of vision in the visual pathway and the primary visual cortex of the brain: motion, form/silhouette, depth, and color (Duke-Elder 1938). The photoreceptor fields--simple, complex, and hypercomplex (first discovered in 1953 by Kuffler) --demonstrate how these gestalt principles are hardwired in how humans see and interpret the world.

• Simple Fields "contain distinct 'on' and 'off' regions that are parallel rather than concentric to one another, making the position of the stimuli within the receptor field important. Moving stimuli are more effective than stationary ones."

• Complex Fields are "cells with complex fields responding best to a properly oriented moving slit, edges or dark bars. However, stimulus position within the receptor field is not critical (contains no distinct 'on' or 'off' regions). Cells with complex fields receive binocular input from simple cells."

• Hypercomplex Fields "respond best to a moving stimulus with a particular orientation and direction, and the length of the stimulus pattern within the field is critical. Hypercomplex cells received binocular input from many complex cells."

Cones are capable of one more dimension of vision, color. "An important aspect of visual function is the ability to appreciate color. This is, of course, mediated by the retinal cones, and it is now clear that in humans, there are three types of cones, each sensitive to one of the three primary colors. These primaries correspond to the primaries red, green, and blue used by the International Commission on Illumination formed in 1931" (Rose 1983)

The photoreceptive simple fields relate to similarity, continuation, proximity, and common fate. The complex photoreceptive fields relate to symmetry and order, figure/ground, and common fate. The hypercomplex fields relate best to the principles of figure/ground, continuation, similarity, and proximity. Knowing these principles and in what way they relate to how humans make sense of the world in relation to visual acuity is critical in understanding the principles of accessible design for the visually impaired and colorblind, which is discussed in the Third Phase. These principles are a great way to introduce this phase, accessible design, and how the principles of color contrast and measuring type, simple icons, symbols, and graphic bars can be scientifically determined for viewing at a distance, including any standardized eyesight.

According to the Centers for Disease Control and Prevention (CDC), "one in 4.5 adults live with some type of disability (22.5%)." These disabilities are cognitive, visual, auditory, speech, physical, neurological, or situational and exist in digital and built environments. For individuals with disabilities, unintentional barriers are ever-present and create a lack of opportunity in both digital and built environments. The process section of this article demonstrates how to use some of the tools, resources, and principles available to ensure a more accessible future for the visually impaired, color blind, and dyslexic (19.5% of the world's population).

Within accessible design, this project focuses on the visually impaired, color blind, and individuals with dyslexia. One in five designers has some form of dyslexia. These accessible design principles are divided into color contrast, measuring typography for viewing distance in black and white, and color and setting type for individuals with dyslexia. The Americans with Disabilities Act (ADA), the Updated Rehabilitation Act of 2018, and the World-Wide Consortium (Wc3) all have the same standards for color contrast (WebAim 2022). There are many tools and contrast checkers on the web. They are extremely helpful in ensuring that type and color combinations have enough visual contrast. These tools use illuminance values that have been converted to a ratio system (black being one and white being 21), and thus the ratio is 1:21. It does not matter what hue is in the foreground and which is in the background. When measuring an object for distance, use the darker of the two hues (CIE 2005).

There are two ways to measure how well humans see color and color contrast. (1) Illuminance values are used in the digital experience to measure RGB hues. The Worldwide Consortium (WC3) and the 2018 Updated Rehabilitation Act use illuminance ratios (IR) to create a contrast scale, with black and white being a color contrast ratio of 1 to 21 (WebAim 2022). (2) Tristimulus values are used in both the digital experience and built environment, meaning print-based and material-based objects. The Y Tristimulus value represents the relative lightness to the mind's eye, or how efficient the human eye is in seeing color, with black being 0% and white 100% (Paint 2022). Theoretically, illuminance and Y-tristimulus values are the same but use different measuring schemes to demonstrate color contrast. In the human experience, black and white represent maximum color contrast, and all hues fall between black and white, including shades of gray.

Color has a one-to-one relationship to the loss of viewing distance, and the Y-tristimulus is the most accurate way to measure individual hues. This system uses 1/1000s of a nanometer to measure color. When using the Y-tristimulus system, black is 0%, and white is 100% (Drew 1997).

Y-tristimulus values are a one-to-one relationship in the loss of viewing distance (CIE system). For example, a Y-tri of 89% is an 89% loss of viewing distance if the hue is placed on a white background or white type in a color background of 89%. (The Innovation Center for Design Excellence is working on a system to mathematically reconcile the two systems (illuminance values and Y-tristimulus values) to create a better workflow for designers. See www.icde.co (Drew 2022).

When measuring type for distance, use the darkest hue. Under the ADA, 2018 Updated Rehabilitation Act, and the Wc3, the color combination must have the proper contrast. There are many color contrast checkers on the web, including one from the Wc3. Some have better workflow than others. Once this is achieved, measure the darker of the two hues using the Y-tristimulus values. This value is used to help determine the distance at which type, icons, and simple symbols can be seen. In this case, both systems are combined to ensure compliance with the ADA, the 2018 Updated Rehabilitation Act, Wc3, and calculate the viewing distance. However, this working method can also determine the legibility distance for anything designed, whether screen- or print-based. For example, a billboard, broadside, banner, poster, augmented reality, or metaverse. Anything that a human needs to see this system can be used to verify the effectiveness of the design in terms of how far someone can see it, no matter the eyesight.

These principles of measuring color contrast and a one-to-one loss of viewing distance when using color other than black are found in three-dimensional color theory (the source, object, and observer). The source is additive color theory, the object is subtractive color theory, and the observer is the human experience. All three components create three-dimensional color theory. The third component, the observer, can and will change depending on the circumstance (Billmeyer 1981). Thus, scientific standards, such as the ADA, 2018 Updated Rehabilitation Act, Wc3, CIE, and the Visual Acuity System, must be used to ensure compliance. The Visual Acuity System uses the Y-tristimulus of the CIE system to help predict the effects of distance, typographic forms, and color on visual acuity. From an accessible design perspective, we are yet to invent a set of goggles that can make a designer, for example, see in 20/70 vision, create color blindness, induce dyslexia, or all three.

When measuring individual letterforms for a logotype or logo word (logotype is the initials of an entity, and a logo word is when the word(s) are completely spelled out), the thinnest part of the letterform, either the form or counter form, needs to be measured for viewing at a distance. These anatomical parts are the first to evaporate when viewed at a distance. The typeface will either fall apart or collapse in on itself (Drew 1997).

The Fourth Phase of this project introduces students to the grid and how it relates to the principles of gestalt theory, specifically the principles of similarity, continuation, proximity, and symmetry and order. Like fingerprints, each logotype has a unique viewing distance depending on the fonts and colors used. These two elements make the logotype accessible, and the grid should be based on these unique features in the typographic expression.

Although this seems straightforward, students often have difficulty understanding why a grid is necessary for the composition of the design and how the user experience can be enhanced or impaired by its use. Again, the principles of gestalt theory are one of the fastest ways to achieve student comprehension because these principles relate to how humans perceive and understand the world. If we can tap into this reasoning, we can appreciate how gestalt theory, the human visual pathway, grid systems, and accessible design can work together to achieve the goal of a more accessible world.

howie jian

Designer: Howie Jian
Color Ratio: 7.71
C024 M100 Y100 K020
Y-tristimulus Value: 8.926
Color Contrast Differential: 91.074
20/70 Viewing Distance: 3.9839’
20/20 Viewing Distance: 13.690’
20/70 Viewing Distance: 1.214293 M
20/20 Viewing Distance: 4.172712 M

At the size the logotype is on this page the above distances are correct.

PROCESS

Students complete this assignment via the following five steps: 1) sketch out their initials with the letterform intact; 2) crop each letterform in a series of maneuvers that metamorphose the letterform from whole to part using the gestalt principle of closure; 3) use the concept of binary letter opposition, for example, large to small, fat to thin, wide to tall, slanted to vertical, etc.; 4) combine the letterforms into a ligature that references the principle of proximity; 5) substitute symbols or dingbats found in the font that is similar in size or shape to the letterforms that are being replaced (visual substitution is a part of the gestalt principle of figure/ground).

Once the students have identified the potential candidates for the final comprehensives, they are asked to create a grid unique to the anatomical parts of the letterforms used within the top three comps. This process ensures that the

Designer: Timberlynn Mitchell
In this example the principles of proximately and similarity are used. Note the spacing between the letters are the same as the letterforms internal spacing.

principles of proximately and similarity are used to harmonize the anatomical elements and spacing of the logotype. The grid used for the final logotype is also used as the grid for the stationary system in a deconstructionist manner.

Once the students have created the logotype in black and white, they are asked to use color, first as a one-color combination, then one hue on a white background, and then a two-color combination. Black cannot be used as a hue to ensure that students fully understand color contrast and how to measure it for the visually impaired. At this stage, it is much harder for students to achieve the proper contrast using two hues other than black and white. A demo is performed using the contrast checker from ACART Communications (https://contrastchecker.com/). This contrast checker shows if the color combination will pass all accessible design requirements and give the contrast ratio of the two hues.

Students are also asked to measure each hue using the Y-tristimulus of the tristimulus values, which is a much faster process to get readouts of the colors being used and if they have the proper color contrast for the visually impaired. The Classic Digital Color Meter works on Macintosh computers. It is beneficial for predicting the distance at which a logotype can be seen for the visually impaired and for normal vision. If a student does not have a Macintosh computer, the contrast checker listed above will create the best workflow. To determine distance, students without Macintosh computers will need to go to the website provided by ColorMind (http://colormine.org/convert/rgb-to-xyz). Again, to help measure the distance at which the logotype can be seen, use the Y-tristimulus value only. Ignore the X and Z values.

As a side note, the Y-tristimulus can be used to determine color contrast. For 20/20 vision, a color contrast differential (CCD) of 20 between the two hues being measured is a good rule of thumb (Drew 1997). For example, one hue has a Y-tristimulus of 40%, and the other has 60%. The difference between the two is the CCD. How often have students printed work out only to find that the color contrast does not work? It is not legible. You can see it clearly on the screen, but the contrast is not significant enough when the design is printed. Using the Classic Digital Color Meter will prevent this from happening.

Once the hues are measured and recorded, the students are asked to measure their top three logotypes. To determine the proper distance at which the logotype can be seen for 20/20 vision (normal) and 20/70 vision (visually impaired), type measurements must be taken, at 100% of size, from the thinnest part of the letterform, either the form or counter form. If the student uses two fonts, at least two measurements must be taken, one for each font. When calculating the distance, the side-by-side comparison of how far someone with 20/20 vision can see it versus somebody who has 20/70 is quite astonishing. Students should take two measurements: to comprehend the loss of viewing distance for the visually impaired, thus helping them develop empathy.

To measure letterforms, students use the measurement tool in Illustrator after first making sure it is set up to read the measurement in points. Not setting up the tool, so it reads out in points is a common mistake that gives a false reading of the distance. Also, for viewing accuracy, the part of the letterform that is being measured must be zoomed in to at least 5000%. If the letterform is not measured correctly, the distance will not be accurate, and the further the distance intended for viewing, the more inaccurate the measurement will be.

Depending upon the font, the anatomical part to be measured is the crossbar or aperture of the lowercase "e" or the link or aperture of the lowercase "a." However, in a logotype, it is always the thinnest part of the letterform, either the form or counter form and if two fonts are used, two measurements are needed.

When calculating viewing distance, use the darkest of the two hues, meaning the lower of the two Y-tristimulus values. Black is 0% (the lowest), and white is 100% (the highest).

The mathematical equation for viewing distances for both 20/20 and 20/70 vision is as follows:

STEP 1

• The thinnest part of the letterform x 5 equals the viewing distance for 20/20 vision in black and white. The number 5 represents 20/20 vision.

• The thinnest part of the letterform x 1.455 equals the viewing distance for 20/70 vision in black and white. The number 1.455 represents 20/70 vision.

In this example, we will use a 4pt measurement for the letterform and the number 5 for 20/20 vision and 1.455 for 20/70 vision; this will give us a side-by-side comparison of viewing distances.

(4 x 5 = 20' (6m 96), (4 x 1.455 = 5.82' (1m 773.936)

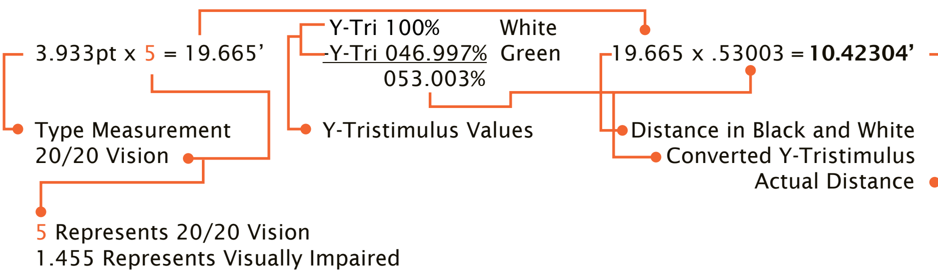
STEP 2

• Convert the darkest hue from white. White (100%) minus the darkest hue's Y-tristimulus value equals the converted value. White has a Y-tristimulus value of 100%. In this example, we will use green as the darkest hue. Green has a Y-tristimulus value of 45%. The converted value would be 55%.

(100% – 45% = 55%)

THE MATHEMATICAL EQUATION FOR VIEWING DISTANCE IN 3 EASY STEPS

Step 1 of the Equation	**Step 2 of the Equatio**	**Step 3 of the Equation**
Type measurement and eyesight in black and white.	Converting the darkest hue from white.	Taking the distance in step 1 times the converted Y-tristimlus in step 2 to achieve the new distance in color.



STEP 3

• Taking the viewing distance in step 1 x, the converted value (.55) equals the new distance in color. For example, in black and white, the viewing distance is 20’ x .55 (converted value) = 11” distance if feet using green.

(20 x .55 = 11’ (3m 352.8), 5.82 x .55 = 3.201’ (0m 975.6648)

Once the students have the 20/20 and 20/70 viewing distances, they place the information under each logotype and hand in the project. The logotypes are presented at three inches. If the logotype is taller than wide, the more elevated part is three inches; if the logotype is wider than tall, the wider part is three inches.

The next step is to put the final logotype on a stationary system, letterhead, #10 envelope, and business card (front and back design). In this step, the size of the logotype at three inches will change to something much smaller, and the students will need to remeasure the logo once they have the final dimensions. Each time the logotype changes size, it will need to be measured. Follow the same process listed above.

If a student is careful and takes accurate notes, they can use the percentage of how far they scale down the logotype as part of the calculation for distance. For example, if the distance is 11' and the logo is scaled to 50% of size, the new distance will be 5.5' if all parts scale down proportionately.

ACCESSIBLE DESIGN PRINCIPLES USED

In this assignment, students are shown how to measure color contrast between type and bzackground for 20/20 vision, visually impaired (20/70), and legally blind (20/200), and to measure typography for viewing at a distance. Accessible design competencies are fully integrated into this typical type one assignment with no additional time needed. Students use the Classic Color Meter or the ColorMind (http://colormine.org/convert/rgb-to-xyz) to measure the Y tristimulus value of each hue. Students are introduced to accessible design competencies for the first time. The color contrast differential (CCD) between two hues must be 40 or greater to meet accessible design standards. For example, yellow-orange has a Y-tristimulus value of 75%, and dark-green is 32.5%, a differential of 42.5. Using a 40 CCD Y-tristimulus meets the color contrast ratio specified by law most of the time. Use visual verification with one of the contrast checkers online to ensure it does. The Classic Color Meter has a great workflow, measuring colors by simply scrolling over the hues. The tool will save time in narrowing down color combinations to input into a contrast checker.

In this font, the measurement of the lowercase "a" link is used to help determine the visual distance for all standardized eyesight, including the visually impaired and legally blind. See figure below. In some cases, the lowercase "e" crossbar should be measured. When measuring a font for viewing distance, use the thinnest part of a letterform within the font, either form or counter form. Once this measurement is taken, use the darkest of the two hues or the lowest Y tristimulus value, with 0 as the lowest and 100 as the highest. (To the human eye, 0 represents black, and 100 represents white.) The Y tristimulus value is a one-to-one relationship in the loss of distance. For example, the Panton Warm Red Y-tristimulus value is 29.126%, a loss of viewing distance of 29.126%.

Link

Below is a chart that represents each eyesight (Snellen 1862):
20/20 (Normal eyesight) = 5
20/40 = 2.5
20/50 = 2.08
20/60 = 1.66
20/70 (Visually impaired) = 1.455
20/80 = 1.25
20/100 = 1
20/200 (Legally blind) = .40

The visually impaired and color deficient, and those with dyslexia represent 19.5% of the total population, increasing the number of end users who can participate in the designed experience. When teaching accessible competencies, I use best practices for accessible design visualization: (1.) Know the intended target distances of your design. This principle is quite often overlooked. For example, a book and iPhone are typically held 18 to 24 inches away from the viewer. For large computer screens, the distance is 24 to 40 inches, monitors the size of 16 inches or smaller are viewed at 24 inches, and desktop use 40 inches. (2.) Measure color for both accessible contrast standards and distance. (3.) Measure the font(s) for distance. (4.) Measure photo color contrast. (5.) Use the principles of photo/illustration minimalism by eliminating unnecessary signifiers. (6.) Set the type for people with dyslexia. These are the "big six" principles for accessible design visualization. For this initial project, I use best practices 1, 2, and 3 above so students do not feel overwhelmed and so they learn three of the six main principles for accessible design visualization (Drew 2022).

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