An Investigation of the Appropriate Level(s) and Ratio of Value Contrast for Partially Sighted Individuals

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Abstract
The present study aimed to investigate the appropriate level of value contrast in built environments, including the ratio of dark value to light value color, to enable people with low vision to distinguish elements more readily from the surroundings. The study included a total of 20 participants from four locations in Texas. Participants received a two-part questionnaire: Part 1 recorded demographic information including age, gender, and visual acuity; Part 2 presented the central questions of the study relating to given images. All of the participants agreed that high value contrast images with at least 60% variance between the dark and light values were very easy to see. Participants also indicated that medium value contrast images with a variance of 30% were recognizable. Most of the participants also indicated a preference for light value to dark value in a built environment.

Keywords
low vision, disabilities, visual impairments, environmental design, interior design

Introduction
Design of the physical environment can enhance quality of life for those with visual impairments. Vision is considered one of the most crucial senses because most daily activities require normal vision. Loss of vision therefore affects people by compromising their independence in carrying out daily routines. Augestad (2017) offers a review of literature related to the visually impaired. According to Augestad, a major element of the self-concept and self-esteem of visually impaired individuals is their level of independence in mobility. Therefore, individuals with low vision are affected psychologically when they experience difficulty independently carrying out activities that are routine for people with normal vision (Douglas et al., 2012). According to Evans et al. (2007), individuals with visual impairments have higher levels of depression than do individuals with normal vision. Giloyan et al. (2015) confirmed that people with different levels of low vision may experience some symptoms of depression. In a study comparing individuals with low vision living in retirement facilities and individuals with low vision living at home, partially sighted individuals in retirement facilities were found to have higher levels of depression (Giloyan et al., 2015).

The loss of sight makes routine activities not only more difficult, but also riskier (Khadka, 2012; Yapici et al., 2019). Activities such as using the stairs, crossing streets, or cooking can result in accident or injury by falling or getting burned. According to Kallstrand-Ericson and Hildingh (2009), 78% of the patients in their research who fell in the course of the study were visually impaired. Manduchi and Kurniawan (2011) note that the occurrence of accidents requiring medical care further decreased participants’ confidence in walking independently.

In consideration of the difficulties that people with visual impairments face, attempts have been made to modify building designs and the physical environments within buildings to make such environments more functional and easier for them to use (Dunn, 1973; Labib et al., 2009). Contrast is a key element in facilitating accomplishment of everyday tasks such as cooking, using the bathroom, and finding one’s way (Brunnstrom et al., 2004; Vilar et al., 2012). The contrast created by placing dark and light values close to each other differentiates objects, making them more readily...
distinguishable for people with visual impairments (Nielson & Taylor, 2011).

Recommended modification of built environments to assist individuals with visual impairments often involves discussion of three types of contrast: tactile contrast which helps visually impaired people use their sense of touch to enhance their perception; luminance (light) and value contrast enable people to benefit from their residual vision. Researchers have focused mainly on luminance to determine the appropriate level of light to enhance well-being and performance of tasks for individuals with visual impairments (Brunnstrom et al., 2004; Martiny et al., 2005). The way in which tactile contrast facilitates the way-finding process for visually impaired people has also been explored by researchers (Arthur & Passini, 1992; Copolillo & Ivanoff, 2011). Although researchers and professionals acknowledge the importance of value contrast for people with low vision in the built environment, there has been relatively little research conducted to assess the actual level/percentage of value contrast and ratio of dark to light value color which facilitates object recognition for visually impaired people. Therefore, the present study aims to answer the following questions:

1. What level/percentage of value contrast improves the ability of people with low vision to recognize physical objects?
2. Do partially sighted people prefer light or dark value contrast?

**Literature Review**

**Value Contrast and Visual Impairment**

Many studies suggest that visual contrast, such as color values in light and dark tones to define door and window frames, baseboards, and furniture, is essential for individuals with low vision in distinguishing ground from background (Kopec, 2012; Lynch, 1960; Nielson & Taylor, 2011; Robinson & Parman, 2010). For instance, switch plates that contrast with wall color or the use of lit switch plates help partially sighted people locate them easily (American Academy of Ophthalmology [AAO], 2019).

Contrast, therefore, is the key to facilitating performance of routine activities for people with visual impairments. Contrast differentiates objects, rendering them easily distinguishable by people with visual impairments. Accordingly, researchers highlight the importance of three types of contrast in recommended modifications for individuals with visual impairments: tactile contrast, luminance, and value contrast. Tactile contrast helps visually impaired people benefit from their other senses; luminance and value contrast, from their residual vision. The current article examines value contrast in its connection to well-being, legibility and performance, and way-finding.

**Value Contrast and Well-Being**

In many countries, the subject of visual impairment has received great attention because of its prevalence and its compromise of the affected individuals’ well-being (Bakker et al., 2019; Brunnstrom et al., 2004; Dibainia et al., 2013; Kaldenberg, 2018; Martiny et al., 2005). Individuals with visual impairments are likely to suffer depression or low self-confidence (Dibainia et al., 2013; Evans et al., 2007; Manduchi & Kurniawan, 2011). Studies conclude that elderly people with visual impairments have a higher rate of depression than the elderly who are sighted, and this depression affects their life negatively and increases mortality risk by 24% to 33% for both genders (Evans et al., 2007; Gu et al., 2013; Ryan, 2014). The well-being of those individuals is impacted by limited accommodation provided for them in their environments or limited access to available resources. Visually impaired individuals are most likely not fully engaged in programs designed to facilitate their activities because of many factors such as rurality, unfamiliarity with the services provided, shortage in equipment and facilities, limited number of service providers and trained staff, or transportation and financial issues (Chiang et al., 2012; Culham et al., 2002; Kaldenberg, 2018; Nia & Markowitz, 2007; O’Connor et al., 2008; Owlesley et al., 2009; Pollard et al., 2003; Ryan, 2014; Ryan et al., 2010; Southall & Wittich, 2012). As an example, the Veterans Affairs Service is a program oriented toward rehabilitation for individuals with visual impairments; however, individuals are reluctant to take advantage of the existing service as it is considered a high-cost program (Ryan, 2014). In such cases, communication between users and service providers should be improved for providers to better understand users’ needs and facilitate accessibility of the services provided (Southall & Wittich, 2012).

One of the easiest ways for a designer or service provider to accommodate individuals with partial loss of sight, with significant impact to their well-being, is to consider color and its appropriate contrast in the built environment, which is a component of universal design. Designers are responsible for improving accommodations for present and future users, incorporating universal design features into the built environment (Spanbroek, 2005). Incidence of falling, which is the major factor in compromising the well-being of the visually impaired, can be minimized by application of universal design. According to AAO (2019), use of color to promote the ability to see important objects or spaces by distinguishing the object from its surroundings will reduce occurrences of falling among partially sighted individuals. Using appropriate contrast in the built environment enables affected individuals to be more independent, which in turn will boost their self-confidence and reduce depression (Augustad, 2017; Dibainia et al., 2013; Evans et al., 2007; Manduchi & Kurniawan, 2011).
Value Contrast, Legibility, and Performance

Researchers and professionals highlight the ways that visually impaired individuals could benefit from their remaining vision. One of these ways is to use colors with different values to improve object recognition and performance of routine activities. A study used video monitors that have a solid background and a movable bar of a different color (gray, green, blue, red, or yellow), to investigate whether the different color values and the movement of objects would attract the individuals’ attention (Cohen-Maitre & Haerich, 2005). According to the study’s findings, the different color values helped participants recognize objects and learn by using their remaining vision, especially if the objects were movable (Cohen-Maitre & Haerich, 2005). Individuals with visual impairments were able to perceive colors and learn the names of the colors, especially when the colors were associated with objects or shapes (Cohen-Maitre & Haerich, 2005).

Another study investigated object recognition on the part of visually impaired individuals, engaging pharmacy students in a medication management activity using a simulated visual impairment (Zagar & Baggary, 2010). The activity enabled students to recognize the challenges that a person with visual impairment might face and to recommend possible solutions to help the affected individuals. Using similar methods, many studies found an association between the size of print and level of impairment with reading speed (Dickinson & Taylor, 2011; Latham et al., 2011). The accuracy and speed of reading increased when the font size was magnified (Latham et al., 2011), or as the level of the visual impairment decreased (Dickinson & Taylor, 2011), or as the value contrast between text and background was enhanced (Gilbert, 2012; Michael, 1965).

Value Contrast and Way Finding

Prior studies that examine accommodations provided for individuals with visual impairments discuss the area of way finding and the importance of facilitating the movement of people from one place to another (Blake et al., 2010; Vilar et al., 2012). One of techniques for facilitation of way finding relies on use of color and value contrast within an environment (Arthur & Passini, 1992). Arthur and Passini (1992) argue that

There is a reliable formula based on the light reflectancy reading in percentages for each of the two colors involved. . . . By subtracting the darker reading from the lighter, dividing the difference by the lighter, and multiplying by 100, we get the “brightness differential” between the colors. (p. 179)

Designers and service providers can use this formula to achieve a high level of contrast in a certain area. An appropriate contrast is generally achieved when the brightness differential is 70% or more (Arthur & Passini, 1992). As the brightness differential increases, the contrast becomes higher and more legible. However, if the brightness differential is less than 70%, then the two colors are not recommended for this purpose (Arthur & Passini, 1992). Awareness of the brightness differential between color values is useful in the design of signage (Gilbert, 2012; Michael, 1965), furniture selection, architectural details (Kopec, 2012; Lynch, 1960; Nielson & Taylor, 2011; Robinson & Parman, 2010), and landmarks (Lynch, 1960), any of which can guide partially sighted individuals while navigating the built environment (Vilar et al., 2012). Awareness of the fact that the number of visually impaired people is increasing and that such impairment is typically associated with a person’s age (Zagar & Baggary, 2010) affirms the need to facilitate way finding for the space users (Vilar et al., 2012).

According to U.S. Census Bureau (2011), one third of the entire visually impaired population in the United States (some 2,727,843 people) are aged 65 years and above, which is a considerable number. With an aging population, this increase of visually impaired people in the United States places visual impairment as one of the top 10 disabilities in the country (Nirmalan et al., 2005).

As people age, they start to experience some decrease in organ function, which will lower a person’s ability to be independent and increase their need for accommodations (Pinheiro & Da Sliva, 2012). One such decrease common among the elderly population is reduction in vision acuity. It occurs because the corneas and lenses of the eye become thicker, more yellowish, and less flexible with age (Pinheiro & Da Sliva, 2012). Pupil size reduces from 7 mm when a person is 20 years old to 4 mm as a person reaches 80 years and older, which reduces the amount of the light that reaches the retina (Pinheiro & Da Sliva, 2012).

As a result, elderly perceive color and color value differently than younger people with normal sight (Pinheiro & Da Sliva, 2012). Age-related vision disability therefore limits a person’s ability to distinguish color “hues” as the normal sighted person does (Nielson & Taylor, 2011; Pinheiro & Da Sliva, 2012). Designers and service providers should understand that when placing a dark brown color, for example, beside or in the center of a light-value purple, elderly people will perceive the light-value color as a darker value—they will see the light purple as a dark one. An understanding of these dynamics will increase the designer’s responsibility in enhancing the value contrast of any close objects even more.

In addition, designers need to pay attention to the color they will use in any environment designed for the elderly population. When people age, it is more difficult for them to distinguish blue, blue-green, and green than to distinguish red and yellow (Pinheiro & Da Sliva, 2012). The reason for that is the yellowing of their eyes, which results in absorption of the short-wavelength colors blue and green (Pinheiro & Da Sliva, 2012).
Method

Participants

The study involved 20 participants in total from four different locations in Texas that are agreed to conduct the study in their place: Texas Tech University (TTU) in Lubbock; the Carillon Life Care Community (CLCC) in Lubbock; the Texas School for the Blind and Visually Impaired (TSBVI) in Austin, and Brookdale Shadow Hills (BSH), a retirement facility in Lubbock (Figure 1). Due to the limited size of the sample, the researcher found that convenience sampling was most appropriate in this situation.

Participants were male or female: 55% of the participants were male ($n = 11$) and 45% of them were female ($n = 9$). Furthermore, participants were 18 years old and above and were visually impaired with visual acuity 20/70 or worse in their better eye; however, their visual acuity could not be worse than 20/400 in their better eye. The participants also had to be able to speak English well enough to understand and answer the questionnaire.

Research Setting

There were no specific settings for the study as it was based on printed images. However, the locations were quiet, such as empty classrooms, conference rooms, and similar enclosed locations to ensure privacy and be conducive to concentration. In addition, all locations had tables, chairs, and good ambient light (fluorescent light).

Research Procedure

Individuals who met the criteria received an email through the Student Disability Services at TTU, the supervision office in CLCC, the supervision office in BSH, and the principal’s office at TSBVI. Those individuals who were willing to participate in the study contacted the researcher or third parties via email to indicate their willingness. Due to the visual impairments of the participants, the researcher met the participants face-to-face and assisted them with the questionnaire by reading the questions to each one of them individually, then writing the answer on the questionnaire. The questionnaire was in two parts: the first part recorded the age, gender, and visual acuity of participants; the second included the central questions related to 12 given images (Figures 2 and 3). The central questions include some questions such as: Please rank these images, from the one in which you can clearly see the difference between the two colors, to the one that is least clear, you will be shown two different images related to the preferred image that you already selected in the previous question, please choose the image(s) that you prefer the most, and so on. The second part of the questionnaire was split into two halves, one of which used images of a living room setting and the other half used images of a bedroom setting. Respondents were required to complete both parts of the questionnaire. The Snellen Fraction Distance Visual Acuity Chart was used to test the visual acuity of participants who did not know their level of visual acuity. The researcher was trained in the use of the...
chart at the Covenant Hospital Ophthalmology Clinic in Lubbock.

The classification of the living room and bedroom images was based on the percentage of the light reflectance value (LRV) of gray scale color (Figure 4). For a high value contrast image, there should be at least 60% variance between the dark and light values. For moderate value contrast, there should be at least 30% variance between the dark and light values. For instance, Moderate Value Contrast Image 1 has a variance of 40%, whereas Moderate Value Contrast Image 2 has a variance of 30%. In terms of low value contrast, the variance between the dark and light values is only 10%. For example, there is 10% variance in both Low Value Contrast Images 1 and 2 (Figures 2 and 3).

Analysis

Due to the limited size of the sample, descriptive statistics were determined to be the best data analysis method in this case. These statistics summarize the essential information obtained from the study sample and the instrument (Trochim, 2006). To summarize the study data, several types of descriptive statistics can be used. It was determined that means, frequencies, and percentages were most suitable for summarizing the current study results.

Results

Demographic Characteristics

Table 1 presents the demographic characteristics of the sample based on their responses to the questionnaire. The average age of all participants \( n = 20 \) was 37.75 years and the average visual acuity of participants was 20/283. Fifty-five percent (55%) of the participants were male and 45% female.

Levels of Value Contrast and Object Recognition

Living room images. Several descriptive statistics were used to demonstrate the relationship between the level of value contrast and participants’ ability to recognize objects. The results indicated a positive relationship between the level of value contrast and ease of object recognition. All of the participants found both High Value Contrast Image 1 and High Value Contrast Image 2, which have between 70% and 90% variance between the dark and light values, very easy to see, where 1 is very easy to see and 5 is very difficult to see.

For moderate value contrast images, which has a variance of 30% to 40% between the dark and light values, the mean of Moderate-Contrast Image 1 was \( m = 2.05 \); 90% of the participants confirmed that Moderate Value Contrast Image 1 was easy to see; 70% of the participants reported that Moderate-Contrast Image 2 was easy to see, with \( m = 1.90 \).

In addition, 50% of the participants agreed that the images that have only 10% variance between the dark and light values—Low Value Contrast Image 1—was very difficult to see, with a mean of \( m = 4.35 \). Low Value Contrast Image 2 also has 10% variance between the dark and light values, and the results were approximately the same as for Low Value Contrast Image 1: 55% of the participants reported Low Value Contrast Image 2 very difficult to see.
with a mean of $m = 4.40$. Table 2 shows the relationship between the value contrast and object recognition for living room images.

**Bedroom images.** The results showed a relationship between the different values of the bedroom images and object recognition, which is similar to the results of the living room images. Almost all participants (90%) reported that High Value Contrast Image 1 was *very easy to see*, with a mean of $m = 1.10$. For High Value Contrast Image 2, 85% of the participants agreed that the objects were *very easy to see*, with a mean of $m = 1.15$.

The mean of Moderate Value Contrast Image 1 was $m = 2.05$: 90% of the participants reported that Moderate Value Contrast Image 1 was *easy to see*. For Moderate Value Contrast Image 2, 75% of the participants reported the image as *easy to see*. The mean of the image recognition was $m = 2.10$.

For poor value contrast images, 60% of the participants agreed that Low Value Contrast Image 1 was *very difficult to see*, with a mean of $m = 4.50$. For Low Value Contrast Image 2, the results were slightly different: 50% of the participants reported Low Value Contrast Image 2 as *very difficult to see*, with a mean of $m = 4.35$. Table 2 provides detailed information about the relationship between the value contrast and object recognition for bedroom images.

### Preferred Ratio of Light to Dark Value

The descriptive statistics indicated that half of the participants (50%) preferred the living room images that have more light value colors than dark value colors. Similarly, more than half of the participants (60%) preferred bedroom images that have more light value colors than dark value colors. The percentages for the preferred ratio of light value to dark value for living room and bedroom images are given in Table 3.

### Discussion and Conclusion

Vision is one of the essential senses that individuals rely on to carry out most daily activities. Consequently, the loss of vision affects people’s independence and thus lowers their self-esteem and self-confidence (Augestad, 2017; Dibainia et al., 2013; Evans et al., 2007; Manduchi & Kurniawan, 2011). Even when accommodations are provided to help them cope with their impairment, relatively few visually impaired individuals benefit from these accommodations or take advantage of existing resources (Ryan, 2014). Reasons include factors such as poor equipment and facilities, limited number of staff, and lack of transportation and financial support (Chiang et al., 2012; Culham et al., 2002; Kaldenberg, 2018; Nia & Markowitz, 2007; O’Connor et al., 2008; Owsley et al., 2009; Pollard et al., 2003; Ryan, 2014; Ryan et al., 2010; Southall & Wittich, 2012).
In the present study, we highlighted the use of value contrast to help individuals with low vision benefit from their remaining vision to improve their daily lives and well-being in general (Giloyan et al., 2015). Some of the current study results were similar to those discussed in the literature. For instance, most of the participants preferred the high level of value contrast with 60% and more variance between two colors and found it helpful in terms of recognizing objects. Similarly, many studies affirm the result that recommends high value contrast for facilitating the recognition of partially sighted users (Cohen-Maitre & Haerich, 2005; Dickinson & Taylor, 2011; Michael, 1965).

### Table 2. Preference for Living Room and Bedroom Images.

| Room type       | Questionnaire item   | Recognition | Percent | M   |
|-----------------|----------------------|-------------|---------|-----|
| Living room     | High Value Contrast 1| Very easy   | 100     | 1.00|
|                 | High Value Contrast 2| Very easy   | 100     | 1.00|
|                 | Moderate Value Contrast 1 | Very easy | 5       | 2.05|
|                 |                      | Easy        | 90      |     |
|                 |                      | Difficult   | 5       |     |
|                 | Moderate Value Contrast 2 | Very easy | 20      | 1.90|
|                 |                      | Easy        | 70      |     |
|                 |                      | Neutral     | 10      |     |
|                 | Low Value Contrast 1  | Neutral     | 15      | 4.35|
|                 |                      | Very easy   | 50      |     |
|                 | Low Value Contrast 2  | Neutral     | 15      | 4.40|
|                 |                      | Difficult   | 30      |     |
|                 |                      | Very difficult | 55   |     |
| Bedroom         | High Value Contrast 1| Very easy   | 90      | 1.10|
|                 | High Value Contrast 2| Very easy   | 85      | 1.15|
|                 | Moderate Value Contrast 1 | Very easy | 5       | 2.05|
|                 |                      | Easy        | 90      |     |
|                 |                      | Difficult   | 5       |     |
|                 | Moderate Value Contrast 2 | Very easy | 10      | 2.10|
|                 |                      | Easy        | 75      |     |
|                 |                      | Neutral     | 10      |     |
|                 |                      | Difficult   | 5       |     |
|                 | Low Value Contrast 1  | Neutral     | 10      | 4.50|
|                 |                      | Difficult   | 30      |     |
|                 |                      | Very easy   | 60      |     |
|                 | Low Value Contrast 2  | Neutral     | 15      | 4.35|
|                 |                      | Difficult   | 35      |     |
|                 |                      | Very difficult | 50 |     |

### Table 3. Preferred Contrast Value for Living Room and Bedroom Images.

| Room type       | Choice                      | Percent |
|-----------------|-----------------------------|---------|
| Living room     | Prefer dark over light      | 15      |
|                 | Prefer light over dark      | 50      |
|                 | Prefer both                 | 35      |
| Bedroom         | Prefer dark over light      | 5       |
|                 | Prefer light over dark      | 60      |
|                 | Prefer both                 | 35      |
Although most studies focus primarily on high value contrast (Arthur & Passini, 1992; Gilbert, 2012), a small body of the literature discusses other levels of value contrast and their effect on visually impaired individuals. Outcomes of the current results, for example, revealed that individuals with low vision can also recognize objects in moderate value contrast starting from 30% variance between colors. One of the few attempts to assess other levels of value contrast was made by Arthur and Passini (1992), who developed a table to show the brightness differential of different color combinations. In addition to high value contrast, researchers recommended a variance of 60% or less between two colors, which is considered a moderate value contrast (Arthur & Passini, 1992). They affirmed that any of these color combinations are suitable and recommended their use for achieving a good value contrast as it helps in way finding (Arthur & Passini, 1992). Such results will encourage designers to apply both high and moderate value contrast rather than limiting their design to high value contrast in designing built environments for users with visual impairments. Incorporation of different levels of value contrast in an environment will enhance variety and be more appealing to users of that environment.

In addition, few studies attempted to define the actual level of value contrast that facilitated object recognition (Arthur & Passini, 1992) or discussed how this information could be used to enhance the built environment for visually impaired people (Vilar et al., 2012). Thus, providing percentages that define each level of value contrast will facilitate application of colors in the spaces. Although this study only used the LRV for the gray scale, the same techniques can be applied to all colors, as each color has its own LRV, making it easy to calculate the LRV variance between any two colors and check the level of contrast.

Several studies discussed the ratio of dark to light values among partially sighted individuals. Some of these studies yielded results that support those of the current study, namely that partially sighted individuals prefer more light values in their environment than dark values (Long, 1995; Michael, 1965). On the contrary, several studies supported the use of more dark values and fewer light values to enhance the object recognition of people with visual impairments (Gilbert, 2012). Any controversy generated by previous studies about the ratio of dark to light value being more useful to people with low vision is not relevant to the design of the built environment, as those studies approached the topic from the perspective of print text and reading. The reason for inclusion of such studies is the lack of research in the environmental design field that highlights the preferred ratio of dark to light value. Thus, designers and service providers may find the results obtained from this study more directly relevant to their field.

**Limitations and Recommendations**

The study focuses on two cities in Texas (Lubbock and Austin). Future studies could be conducted comparing various states in the United States. In a broader context, the findings could be generalizable if the study is conducted on comparative countries. In addition, the sample size of the present study was small due to the relatively small number of visually impaired individuals within the population of the state of Texas.

As mentioned in many studies, partially sighted individuals experience difficulty in finding their way (Blake et al., 2010; Vilar et al., 2012). Due to certain constraints, it was not appropriate to design an actual space, where participants might examine the value contrast more effectively, as the study was conducted in different places and cities, and many participants were above 60 and had severe low vision. Instead, researchers found that conducting the study using digitally manipulated images was more appropriate for the condition of the participants. A similar method was adopted in previous studies, especially for examining areas related to color (Bias et al., 2010; Danovitch & Mills, 2017; Read & Upington, 2009). However, results would be more fruitful if future studies were conducted in actual interiors.

**Author Note**

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