USING VIRTUAL FILTERS TO MEASURE HOW THE ELDERLY PERCEIVE COLOR

MINYOUNG CHUNG[1] and HYUNSOO LEE[2]
[1,2] *Yonsei University, Seoul, Republic of Korea*
[1,2] *{minyoungch|hyunsl}@yonsei.ac.kr*

Abstract. This study was conducted to test the effectiveness of a virtual filter that digitally compensates for age-related changes in color perception. Many elderly people experience declining color perception. Medical studies have been conducted on how elderly people's lenses affect their color perception. However, digital practical method for improving elderly people's color perception need to be developed. Subway map is a good example of many elder's daily experience. To adapt virtual filters to subway maps' colors, standard short-wavelength colors, namely purple and green, were selected for variance independence (VI) because colors with short wavelengths of 400-600 nm on visible light are difficult for elderly people to perceive. Standard color VIs of subway lines and VI transferred to artificial lenses were measured with a spectrophotometer. CIE LAB and RGB; Color value on virtual filter (VD) was analyzed from VI. This virtual filter was developed based on artificial lenses using Dynamo. A visual programming algorithm was developed to adjust the color of a virtual filter through an interface. The results showed that virtual filters can be used to help elderly people detect short-wavelength colors. Therefore, virtual filters should be incorporated into lenses for use by the elderly.

Keywords. Virtual filter; Elderly people's perception; Colors on subway map.

1. Introduction

Color is one of the crucial visual elements of objects that people perceive visually and so is important to mobility. This study was conducted to determine how to change the colors of subway map. Color is defined as the strength of the cognition (Kendel, 2016). The Seoul Metro's subway map is the most widely used public transportation map of transit-oriented development (TOD) in South Korea. Seoul Metro subway map is seen by 7,000,000 passengers every day, 1,000,000 of whom are over 65 years old (Seoul, 2020). The Seoul Metro subway lines are shown in nine colors on its TOD maps with much more complex combinations of colors.

Public transportation such as Seoul metro subway is needed to support perceived color of elders in subway maps. Main color of subway map line 1 dark blue, line 2 green, line 4 blue and line 5 purple is not distinguished on color combination of nine subway lines for elderly people. Green, blue, and purple are

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the colors with the short wavelengths on visible light and are also the colors which people lost the ability to perceive as they age. Thus, for example, blue colors on a black background would appear to be the same color to elderly people. The ability to properly distinguish between colors is a critical part of properly reading maps.

Given the importance of being able to perceive colors in daily life, it is important to understand how aging changes people's abilities to perceive color. However, studies on elderly people's lenses have been largely limited to the medical, architecture, and design fields. Medicals simulated the donors human lens that is similar to artificial lens in some part of visible light. The short part of spectrum through a lens report what elderly people see. Previous studies of lens rarely present on computer. Thus, this study used the Dynamo software to simulate color in an artificial lens. Lens color values were adjusted based on comparative studies of artificial lenses, human eye lenses, and Photoshop filters to simulate the vision of elderly people.

2. Research Question

There have been studies examining how elderly people perceive public interior spaces but not studies with digital application. Artificial lenses are not an effective solution for field application. This study was conducted to determine how elderly people perceive colors by examining how different lenses transmit visible light (Kessel, 2010) into a virtual filter. This study used a virtual filter developed using a visual programming language to manipulate an artificial lens CIE LAB. The validity of how virtual filters represent colors as they are perceived can be confirmed by colorimetry on CIE LAB, RGB and margin of Munsell. The objective of this study was to develop a digitized virtual filter to represent artificial lenses to help elderly people better read maps. The research questions with virtual filter study was conducted to address that affect the way maps colors perceived.

- What is color value transferred artificial lens as VI ?
- What is the color value transferred virtual filters as VD?
- What is differences in color value between artificial lens and virtual filter?

3. Related Information

3.1. MAPS, ACCESSIBILITY AND COLORS

Subway users have a particular need to be able to quickly understand the overall network. Seoul Metro subway map is a representation of public transportation networks on Transit-oriented development (TOD). TOD seeks to create integrated urban spaces that allow more than 20,000,000 people of Korea to easily move between activities, buildings, and public spaces using public transportation.

Distinguishing between lines by portraying them in different colors makes it easier to understand the network layout than if they were portrayed in the same color. Studies have been conducted on the colors used in subway maps. Netzel (2016) found that viewers could locate desired information more quickly using colored maps than greyscale maps (Figure 1 left in color). Lee (2019) found that higher color tones used in Tokyo's subway system's map are more easily perceived by those with visually impaired people than those of Seoul Metro subway map which have lower color tones. Personal mobility is a key determinant of personal independence, the ability to access goods and services, pursuing social and economic opportunities (Capezuti et al., 2014). Therefore, making maps visually accessible to the elderly can help them maintain their independence. Color run through only for normal lens would be more tricky for elderly people to read than normal lens on Netzel's gray map (2016).

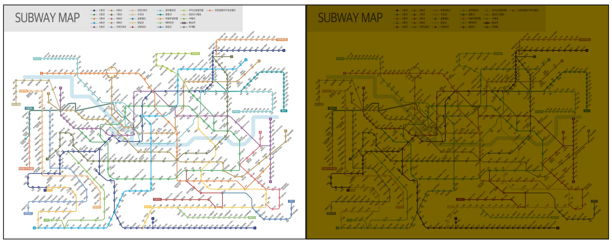


Figure 1. Seoul Metro subway map (left) and when viewed through Y A3 digital lens (Chung,2020).

Visible accessibility of subway map remains a challenge for elderly people. Elderly people might have difficulty identifying destinations on subway lines depicted in yellow. The purpose of this study was to identify the filter that reflects how many elderly people perceive colors to identify a set of colors that would be sufficiently accessible to the elderly and the population at large.

3.2. ELDERLY PEOPLE'S COLOR PERCEPTION ON ARTIFICIAL LENSES

Beginning at around age 50, the internal structure of the lens changes, causing it to harden, which in turn increases the scattering of light. These changes result in a gradual yellowing of vision over time. Various chromatic adaptation mechanisms generally leave people unaware of these gradual changes. Around 20% of people over 80 years old might have marked yellowing of vision (Ishihara, 2001). Nearly 5% of the world's population has cataracts and yellowed vision. This is expected to increase as various populations around the world are aging on average.

Ishihara (2001) studied which colors the elderly confused to simulate their vision. Many elderly people cannot discriminate certain combinations of colors, such as dark blue, green and dark green as above Figure 1. Yoshida (1992) conducted an optical simulation study using YA3 artificial lens (Figure 2), but a yellow filter for this lens is no longer in production. The present study was conducted to create a virtual lens by comparing the results of studies using artificial lenses YA3, Y2 and DG(Yoshida & Hashimoto, 1991; Ishihara, 2001) (e.g. Figure 2).

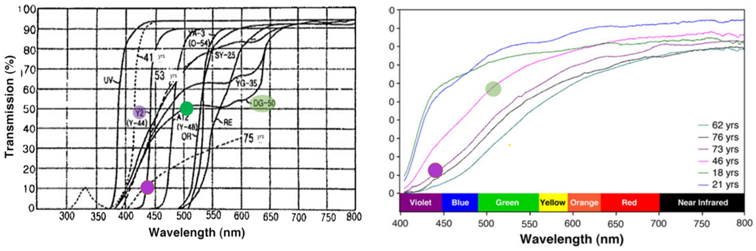


Figure 2. V.I. Reliability on artificial camera lens, (Ishihara, 2001) and on donor's human lens (Kessel, 2010) transmittance of visible spectrum.

3.3. REPRESENTING COLORIMETRY USING VISUAL PROGRAMMING

3.3.1. Colorimetry

Colorimetry is the quantification of how people perceive colors and can be used to predict how an observer will perceive a given color. In 1931, the Commission Internationale de l'Eclairage (CIE) developed a system for measuring color known as the XYZ tristimulus values, which served as the foundation for modern colorimetry. The XYZ values can be used to determine whether two colors match or not. In 1976, the CIELAB color spaces were developed which allowed for uniform CIE values to be used to describe the perceived differences between stimuli under a single set of viewing conditions (CIE, 2020). The L of CIELAB dimension corresponds to perceived lightness, ranging from 0.0 for black to 100.0 for diffuse white. The A of x axis and B of y axis dimensions correlate with the red-green and yellow-blue chroma perceptions, respectively (Figure 3). They can have positive and negative values. Both A and B have values of 0.0 for grayscale stimuli. The L, A, and B dimensions are combined as Cartesian coordinates to form a three-dimensional color space.

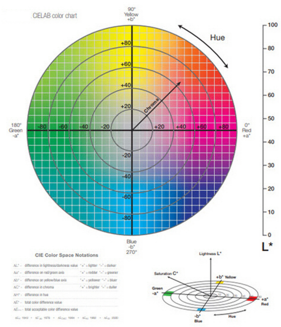


Figure 3. CIE LAB Color space (CIE, 2020).

The color tolerance of similarity for multi-component Munsell and Delta E is a single number representing the distance between two colors. Delta E indicates how color differences are perceived. The term "delta" comes from mathematics, meaning that change in a value. On a typical scale, Delta E will range from 0 to 100. Values of 0-1 indicate differences that are imperceptible by humans while a value of 100 indicates that colors are opposites. It is tempting to determine the Delta E values between red, green, and blue, but the RGB system was developed for convenient use with electronic systems and does not reflect how humans perceive colors. Therefore, Pantone color chips were used because the Seoul Metro subway map's colors are Pantone colors. Subway line's Standard color of CIELAB were measured and their equivalent RGB values were obtained for use with computers.

3.3.2. Programming algorithm using Dynamo

Dynamo is a great application for colors. Colors in Dynamo are created using alpha, red, green and blue inputs where alpha is transparency and red, green, and blue are mixed to generate the whole spectrum of visible color. Dynamo is an open source visual programming platform that was used in this study for adaption on digital field. Data is measurements of variables at various points. When working with abstract data and varying numbers, it can be difficult to determine which factors are causing changes in the data. Therefore, the color of virtual filters can be adjusted.

Coordination and collaboration involves multiple levels of communication where virtual filters are involved in the communication between people regarding values, intents, context, and procedures. The age-related decrease in spectral transmission through the human lens can be modeled by an algorithm that may be useful in designing of intraocular lenses that mimic the characteristics of the human lens and in studies on color vision, psychophysics and melanopsin activation (Kessel, 2010). Although the results of the aforementioned research are often used to predict yellow vision in artificial settings, there have limited on field application investigating how aging affects color perception. Perception of the elderly people is a concern for subways because better visibility would increase elderly people's accessibility.

4. Research methodology

To digitize virtual filters to correct elderly people's perceptions of color, it should be understood how colors are related in artificial lenses (Figure 2), which is possible with spectrophotometers.

4.1. MEASURING THE COLOR VALUES TRANSFERRED ARTIFICIAL LENS

First, the changes in color perceived by elderly people were measured by a spectrophotometer with color from color chips as viewed through an artificial lens DG and Y2 based on Figure 2. DG artificial lens demonstrate 400-550nm and include 500nm that is representative for green. Y2 artificial lens demonstrates a spot of purple 450nm wavelength on visible light.

Pantone color of line 2 is 354C and line 5 is 2583C that are designated by Seoul in 2017. Their colors corresponded to Pantone color chips that were measured by Coloreye-7000a spectrophotometers. Spectrophotometer values were input into an

Excel file where the visual programming algorithm was on run on them (Escalante, 2019). It was possible to get subway map colors RGB on the interface of Dynamo automatically. Spectrophotometer measurements were taken three times on the common application of CIE illuminant D65 using visual field that subtended '2 degrees' standard of central fovea (Fairchild, 2015) and the median value was ultimately input into the Excel file.

Second, Dynamo was used to predict digitized color data to overcome the limitations of filed application using an artificial lens and spectrophotometer. To explore the virtual filter used to perceive the color of subway map, the Seoul Metro subway map was viewed with standard colors based on Pantone color chips that Seoul Metro determined. Seoul Metro subway map colors which were analyzed in this study had the representative short wavelengths of on the map.

4.2. ADJUSTING COLOR VALUES USING A VIRTUAL FILTER

After the color chip values for the Seoul Metro subway map's standard colors were been collected, the virtual filter (VD) was created based on the data transferred by the artificial lens (VI). Color chips transferred by the artificial lens DG and Y2 got the spectrophotometer value. As above transmission of visible light of green through DG lens and dark blue through Y2 lens. Line 2's color chip value of Pantone no. 354C was shown to have a LAB value of (26, -38, 27), an RGB value of (0, 74, 14), and a Munsell value (8.8GY, 2.53, 7.96) when viewed through a DG artificial lens. Line 5's color chip value of 2583C was shown to have a LAB value of (46, 16, 51), an RGB value of (147, 98, 10), and a Munsell H VC value of (9.25YR, 4.43, 8.58) when viewed through a Y2 artificial lens.

The second part of the study examined adaption virtual fitter using visual programming. These values were noted, compared and adapted for the digitization of color change results of the artificial lens to interface with Revit using Dynamo (VI) based on the color range and transparency produced by the algorithm. Code block nodes of red, green and blue were defined by plugging in the appropriate combinations of 0 and 255 (Figure 4) corresponding to color panel on interface (Table 1&2). The lens was set to glazed glass (see bottoms of Figure 5).

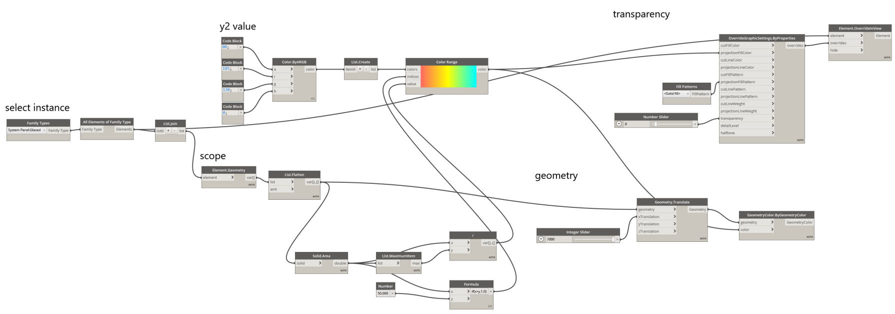


Figure 4. RGB values input into the algorithm of color changing.

The changed value overlaid on the color panel can confirm the color value with an effect similar to the yellowing phenomenon of the lens. Transmitted color matching between artificial lens and virtual lens is the key of finding. This Figure 4 algorithm is explained on below flowchart Figure 5.

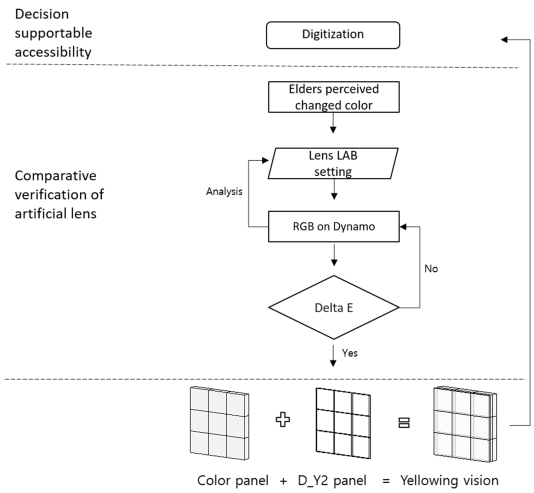


Figure 5. Algorithm flowchart.

The changed value overlaid on the color panel confirmed the color value with an effect similar to the yellowing phenomenon in the human lens. The key finding was that the colors transmitted through the artificial and virtual lenses were the same.

4.3. THE DIFFERENCE COLOR VALUES BETWEEN ARTIFICIAL LENS AND VIRTUAL LENS

To quantify the difference in colors and how elderly people perceived them, the short-wavelength colors on Seoul Metro subway map was examined after being passed through an artificial lens. To digitize the color, color chips were transferred to a virtual filter and Dynamo was used to visualize the colors on the interface where they were then measured using the Adobe Photoshop color sampler. (Table 1) shows the color digitization process.

The result shows the transmitted color on the virtual filter interface, which was measured using color sampler. These results were compared with those produced by the Revit interface which were transmitted through the camera filter. The Delta E 2000 (2020) score was calculated to determine each color chip's position on the two-dimensional CIE LAB map produced by virtual filter applied to the artificial lens. Condition comparison judgment as shown the proposed flowchart Figure 5. The RGB values of colors with Delta E values exceeding 2.0 were adjusted again in Dynamo. Delta E 2.0 over 1.0 is not the same color on human eyes. Virtual lens is limited to adjust exact value for Y2 lens.

Line 2's RGB value was (0, 74, 14) as measured by the artificial lens and (0, 75, 19) as measured by the adjusted virtual lens (e.g. Table 1).

Table 1. Measuring DG virtual filter .

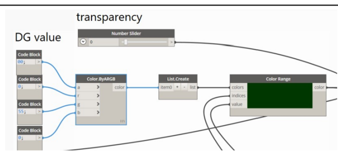
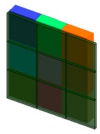
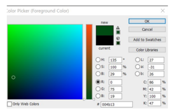
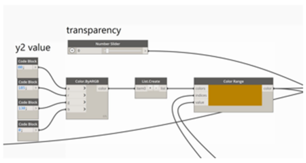
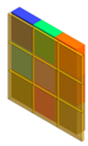
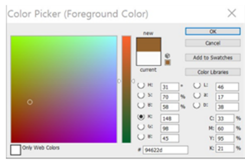
	Spectrophotometers		**Visual programming**	
	LAB	RGB	LAB	RGB
354C	61 –72 37	0 175 75		
DG	-	-		
354C+DG	26 –38 27	0 74 14	27 -31 26	0 75 19
Image				
Delta E	1.8937 < 2			
Margin of Munsell H V/C	H±0.3, V±0.04 C±0.09 <1			

Table 2. measuring Y2 virtual filter.

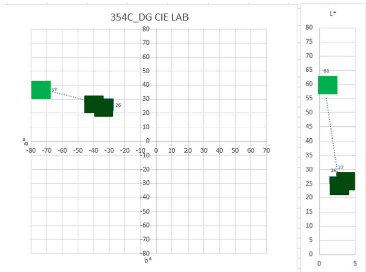
	Spectrophotometers		**Visual programming**	
	LAB	RGB	LAB	RGB
2583C	52 41 -34	170 96 183		
Y2	-	-		185 130 0
2583C+Y2	46 16 51	147 98 10	46 17 38	148 98 45
Image				
Delta E	13.42			
Margin of Munsell H V/C	H±1.81., V±0.04 C±1.65. <2			

4.4. RESULT

The saturation decreased because the variance on color space LAB was reduced (Table 1) when colors are transmitted, getting closer to the central axis on CIE LAB (e.g. Table 3 left). Visible light transmission decrease makes green is near to black. Delta E (Delta E 2000, 2020) of less than 2.0 is perceived same by human eyes.

The purpose of this study was to determine which virtual filter could be used to accurately represent map colors to elderly viewers. The virtual filter identified in this study produced a color for Line 2 with a Delta E 2000 of less than 2. Thus, the virtual filter successfully represented the target color (Tables 1 & 2). The yellowing of the virtual lens accurately simulated how elderly people perceive the colors of subway lines. This virtual lens produced a narrower range of colors than the original colors. Virtual lens based on DG artificial lens (Figure 2 left) can be used for other saturation and tone of purple, blue and green ranges.

Table 3. (V.D.) DG Virtual filter validity on CIE LAB maps.



		R	G	B		L*	a*	b*
02_354C		0	175	75		61	-72	37
DG_02		0	74	14		26	-38	27
D_DG_02		0	75	19		27	-31	26

5. Conclusion

The virtual filter developed in this study accurately represented how elderly people perceive color on maps in day light. The virtual filter was developed in three major steps. First, the virtual filter quantified elderly people's perceptions of colors on subway map as determined by CIE LAB's Delta E measurements. Second, color information discrimination that we can find the same thing with digitized digital color values. Third, the virtual filter simulated the transmission of light through an artificial lens and showed differences in digitization between artificial lens and visual programming interface. Whether the transmission value was valid, the digitally change of the simulated lens and the value of the CIE color space range equal to the human eye colorimetric color were implemented in Line 2. Own RGB value of the virtual filter was different from that of the artificial lens. The RGB value of the simulated lens for Line 5 exceeded the limit of B and so could only be approximately implemented. The simulated Y2 lens was not perfectly valid and the validity of the DG based on reliability was verified.

Therefore, we conclude that colors on digital interface of subway map transfers virtual filter, changed and affects the color perception that are comparable with the artificial lens produced by the short - wavelength transmittance of DG artificial lens. Y2 artificial lens cannot be distinguished by virtual filter for same color transmittance that acquire minus RGB range that is not scope of RGB.

This virtual lens study has boundary in understanding color perception of elderly people. It has limited based on Y2 around 450nm in 10% transmission and DG lens from 400nm to 550 nm in 10 to 50% value of visible light transmittance that is twice clearer view than that of 75years old lens (e.g. figure 2) under D65.

Therefore, the future study will be on Augmented Reality in 360 VR on underground with DG virtual lens.

Interface of this study reflected the reason behind the color change, so it can be used to understand how elderly people perceive colors. Elderly people will not be able to perfectly see every color, but there are other potential combinations that they would be able to perceive more easily.

People should be able to extract information from every color on maps. The appropriate lens to achieve this lies with you even if the color combination is not an easy one. Interface take an open path on what causes the information blindness and what role combinations play in creating distinct colors. It may be that elderly people's reactions to the situation are at the core of the color distinction problem and people cannot control anything other than reacting to being colorblind. Stakeholders must recognize that the perceived unlikeability of many elderly people is the product of social interactions. The results of this study can be used to improve the accessibility of signage in public transportation facilities, such as subways and bus terminals, for all users, including elderly people.

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