Lighting system for elderly to prevent color desaturation due to cataract crystalline lens

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ABSTRACT

A hazy crystalline lens causes great loss of colorfulness in cataract. To prevent the color desaturation in elderly vision, we have proposed a new lighting system named 'color-recovery lighting'. The essence is the relative reduction of the ambient light. It is achieved by the control of two sets of illuminations for object and environment. The idea was implemented as an illumination of a fitting room and its performance was tested colorimetrically and psychophysically using the cataract-simulating goggle. All the results of colorimetric measuremnts, elementary color naming, and categorical color naming showed the significant increase in saturation and proved its efficiency for the elderly color vision.

1. INTRODUCTION

Cataract is one of the most typical age-related diseases in vision as well as presbyopia. In cataract, the crystalline lens becomes yellowish and cloudy. Despite of considerable reduction of transmittance in shorter wavelength, a number of studies have shown a good color-constancy throughout the life span and suggested neural compensation mechanisms. Thus the yellow of lens seems not to be a severe impairment in elderly color perception. On the other hand, lens haziness brings substantial disadvantages in both spatial and color vision. Hazy cataract lens not only reduces the transmittance but also increases the scattering light behind it. This scattered light is superimposed on a retina making blur images and color averaging, and, as a result, causes loss of visual acuity and desaturation of perceived colors.[1,2] We have developed a new lighting system for elderly to prevent this color desaturation and named it 'color-recovery lighting.[3]' Here we report the basic idea of the system, an example of application to a fitting room illumination, and the results of colorimetric and psychophysical performance tests.

2. BASIC DESIGN OF A COLOR-RECOVERY LIGHTING

Main cause of color desaturation in elderly vision is superimposition of scattered light by hazy cataract lens. To prevent the color desaturation of a target whose color is observed, the light coming from its surround must be reduced relative to the light from the target itself. However, in a normal lighting, where only one light source illuminates over an entire room, higher/lower intensity of illuminant results in overall increase/decrease of light and never changes the balance of light from the target and its surround. In a proposed lighting system, two separate lightings were introduced, the one named 'a spot light' illuminating the target exclusively and the other named 'a surround light' for an environment. It's also a good idea to change reflectance for the surround to reduce the scattered light.

Thus in the color-recovery lighting system, three components are indispensable, the spot light, the surround light, and the color-variable wall. For elderly, the intensity of the spot light must be kept relatively high. Though no surround light is desirable to reduce the scattering light, it would make a room very dark and gloomy. Therefore the intensity of the surround light must be set at appropriate level to maintain a room bright enough to provide comfortable environments. These intensity levels should be determined according to an individual room. The color of the backwall should be dark for elderly.

3. IMPLEMENTATION OF THE SYSTEM IN A FITTING ROOM LIGHTING

The idea of color-recovery lighting was implemented as an illumination in a fitting room. Figure 1 shows a perspective and cross sections of the room. In the fitting room, colors of observer’s cloths are observed through the mirror. As the spot light, a luminaire with louvers was installed at the center of the ceiling to illuminates the observer’s cloths exclusively. As the surround light, three luminaires were fixed at the corners on the ceiling and they illuminate the two sidewalls and a backwall respectively. Each luminaire contains three dimmerable 32W fluorescent lamps: one 3000K and two 6700K lamps. The system has two different modes: normal lighting and color-recovery lighting. In the normal mode, the surround light is set at its maximum and the spot light at 60% luminance to the maximum. The backwall is the same white as the sidewalls. In the color-recovery mode, the spot light is increased to the maximum, the surround light down to 40 % and the backwall is covered by a black curtain.

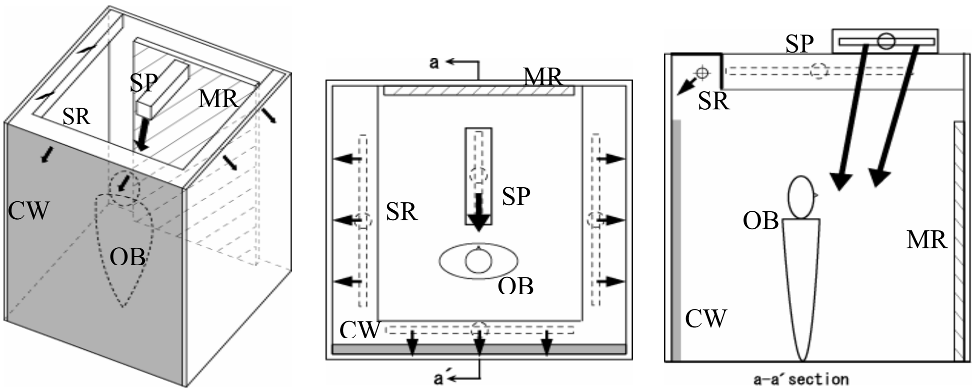

Figure 1: Application of color-recovery lighting to a fitting room. SP, spot light; SR, surround light; CW, variable color wall; OB, observer; MR, mirror.

4. PERFORMANCE TEST

The color-temperature of the lighting was set to 5000K for the experiment by adjusting the relative intensity of 3000K and 6700K lamps. The experimental settings are shown in Figure 2. A color patch of 6cm square, a Munsell paper or a cloth sample, was placed 120 cm from the floor and 100cm from the mirror, facing to the mirror with a 20° slant from the vertical. In the colorimetric evaluation, a colorimeter was set 36 cm above the patch facing toward the mirror. In the

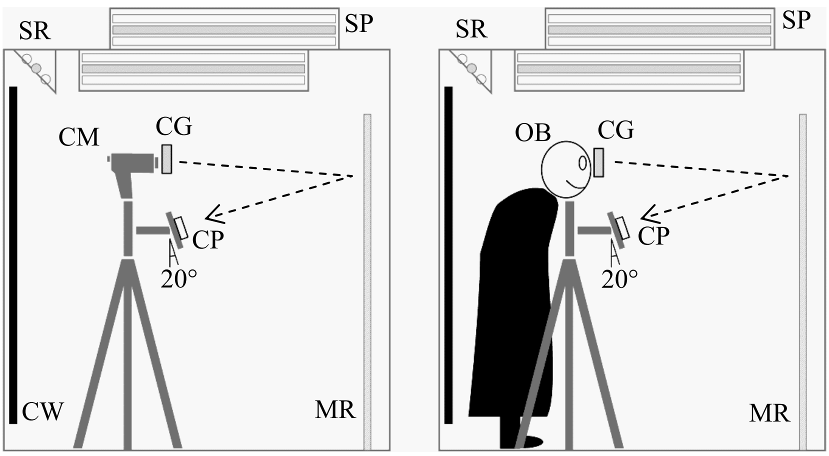

Figure 2: Schematic diagram of experimental settings. Left, colorimetric evaluation; right, psychophysical evaluation. SP, spot light; SR, surround light; CW, variable color wall; MR, mirror; CG, cataract goggle; CM, colorimeter; OB, observer; CP, color patch.

psychophysical evaluation, observer stood behind the patch putting her/his head the same location of the colorimeter. Observers wore a black cloak to avoid the effect of reflection from their cloths. To estimate the effect on elderly vision, a cataract-simulating goggle[2] was put right in front of the colorimeter or the observer's eye. The goggle was originally designed to simulate the vision of slight or moderate cataracts when 40-year-old or younger observers put on. Three conditions were examined; without the goggle in the normal lighting, with the goggle in the normal lighting, and with the goggle in the color-recovery lighting. These conditions simulate the color appearance for young observer, that for elderly observer under normal lighting, that for elderly observer under the color-recovery lighting respectively.

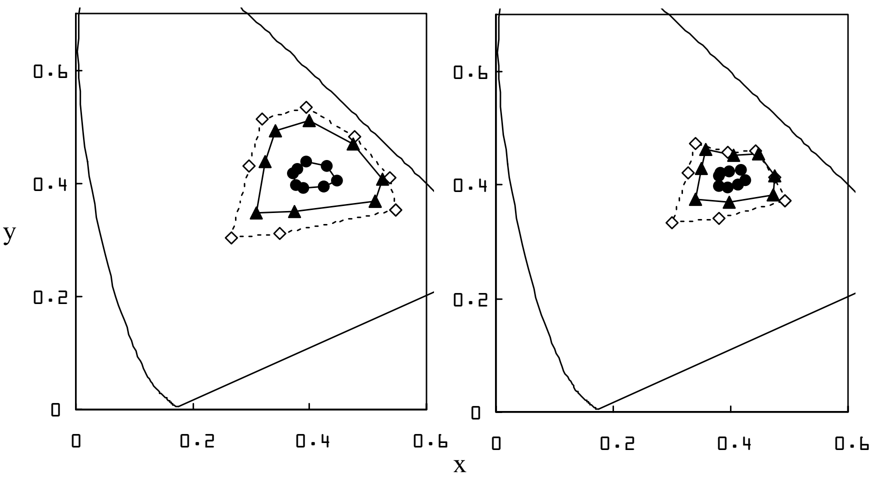

Figure 3: Examples of colorimetric measurements in CIE1931xy. The left chart shows 5R4/12, 5YR7/14, 5Y8/12, 5GY7/10, 2.5G5/10, 5BG6/8, 10B3/10, 2.5P5/10, and the right chart, 5R4/8, 5YR7/6, 5Y8/6, 5GY7/4, 2.5G5/6, 5BG6/4, 10B3/6, 2.5P5/6, 5R4/8. Diamonds, LightN/noGoggle; circles, LightN/withGoggle; triangles, LightCR/withGoggle.

Luminance and CIE1931xy chromaticity were measured from 20 Munsell color patches and 30 cloth samples using Minolta CS-100. As examples, chromaticities of Munsell color patches with higher chroma and with medium chroma are shown separately in Figure 3. Chromaticities distribute around the chromaticity of the illuminant of 5000K in both diagrams. Chromaticities measured through the goggle under the normal lighting, shown by circles, locate far inside of those measured without the goggle, shown by diamonds, showing the color desaturation in simulated elderly under the normal lighting. On the other hand, under the color-recovery lighting, chromaticities, shown by triangles, returned toward the original locations, showing increase in saturation. This color-recovery is less effective for the bluish colors, since the desaturation is enhanced by the larger loss light in the shorter wavelength. The same color-recovery effect and the trend were observed from the other colors.

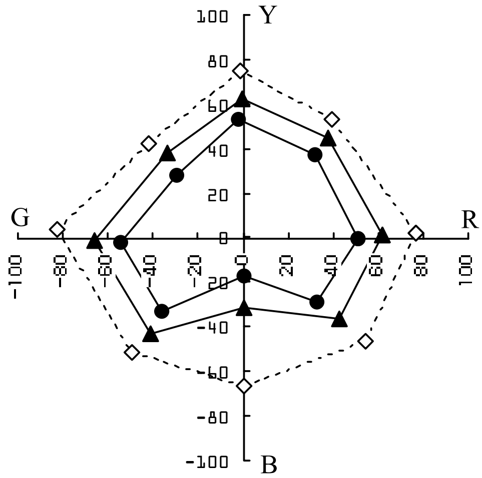

Figure 4: Averaged results of elementary color naming by 4 observers for 5R4/8, 5YR7/6, 5Y8/6, 5GY7/4, 2.5G5/6, 5BG6/4, 10B3/6, 2.5P5/6, and 5R4/8.
Diamonds, LightN/noGoggle;
circles, LightN/withGoggle;
triangles, LightCR/withGoggle.

In the psychophysical evaluation, both 'elementary' and 'categorical' color namings were done. As targets of color naming, 8 Munsell color patches with medium chroma and 7 cloth samples were selected from those used in the colorimetric evaluation. Three-male and one-female observers participated in the experiments. All observers are color normal checked by Ishihara plate and their age ranged from 26 through 52 years old. Each observer repeated both the color namings 10 times against 15 samples under the same 3 conditions described above.

In the elementary color naming, color appearance was evaluated by assigning percentage to perceived portion of whitness, blackness, and chromaticness. Then chromaticness was divided into four primary hues, such as red, green, yellow, and blue. Averaged result across observers is shown in Figure 4. Note that the evaluated color samples were the same as shown on the right of Figure 3. The radius represents the percentage for chromaticness and the angle represents hue. Though the perceived hue showed no shift throughout conditions, the variation among the conditions showed the same trend as in Figure 3. Under the normal lighting, perceived saturation dropped when observed through the cataract goggle. But once the color-recovery lighting was put into effect, the perceived saturation goes up. The color-recovery was the least efficient for 10B3/6, likewise in the colorimetric evaluation. These cataractous desaturation and color-recovery by the proposed lighting system were not so strong as expected from the colorimetric evaluation or Figure 3.

In categorical color naming observers assigned the most appropriate color term from the 14 terms, such as black, gray, white, red, green, blue, yellow, orange, brown, pink, purple, olive, beige, and navy. Part of results are shown in Figure 5. Without the goggle in the normal lighting, 10B3/6 was assigned 'blue' 34 times out of 40 (4 observers x 10 sessions). Through the goggle, the same patch received just 20 responses of 'blue' and, 10 responses of 'navy' and 'black' each, showing the misidentification of color due to color-desaturation. Under the color-recovery lighting, 'blue' responses increased and those of 'black' and 'navy' decreased. The other samples, 'Leather#5', 'Linen#17', and 'Cotton#23', are normally called 'olive,' 'blue,' or 'brown' but misidentified as 'black' or 'gray' by the elderly under the normal lighting. The color-recovery lighting does not eradicate the color-misidentification but considerably reduces its possibility, by half at least.

All the results proved the efficiency of the proposed system. Above all, the color-misidentification, shown in Figure 5, likely happens more often with moderate colors than with vivid colors and such colors are in flood in our everyday lives. Furthermore the color-misidentification may cause more serious problems in communicating colors. Thus, the proposed lighting system is thought very beneficial in practical situations.

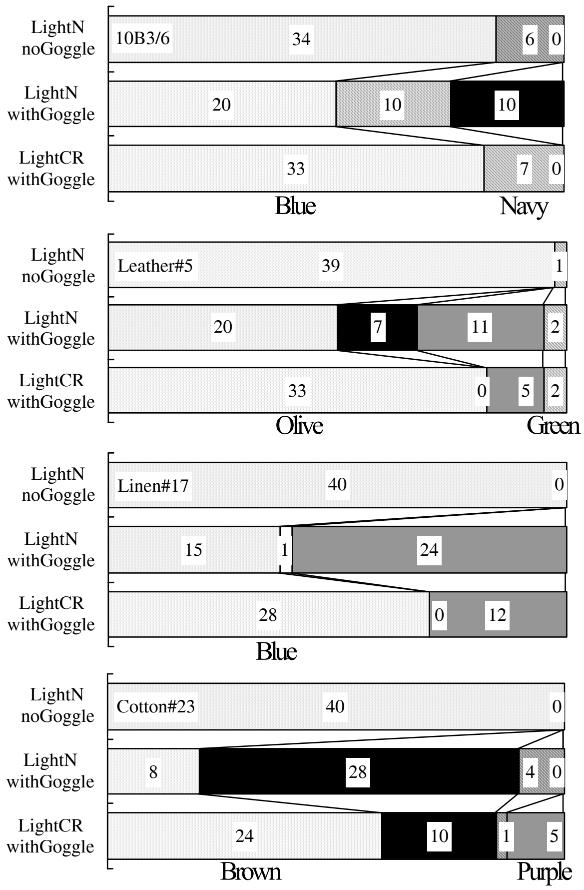

Figure 5: Examples from the results of categorical color naming. Numbers represent total color responses out of 40 (4 obs. x 10 trials). Black bars, 'black' responces; gray bars, 'gray'; white bars, 'white'; other bars are labelled.

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