Haze estimation of crystalline lens by spatial resolution as a function of light scattering intensity

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ABSTRACT

Cataract is one of the most typical age-related eye diseases. As the cataract progresses, the crystalline lens becomes hazier and such lens causes light scattering within the eye, resulting in decreases in the visual ability such as color vision and spatial resolution. In this study, we measured spatial resolution for pseudo-cataract young subjects wearing foggy filters. Subjects observed a grating through an integrating hemisphere inside which LEDs (inducing further scattering as glare) were attached. We manipulated the light intensity from LEDs (i.e., level of glare) and the haze factor of the filter. The results showed that, irrespective of the haze factor, the spatial resolution decreased as the level of glare increased. However, the rate of the decrease changed with the haze factor; it was larger as the haze factor increased. From the analyses of spatial resolution obtained, we propose a new method for estimating the haze of the crystalline lens.

INTRODUCTION

In Japan, most elderly people, particularly over the age of 80, suffer from cataract. Cataract is the most prevalent age-related eye disease in which the crystalline lens becomes hazy. It is well known that cataract causes light scattering within the eye, resulting in impairments in various visual abilities such as color vision and spatial resolution.[1] Given the growing population of elderly people and the importance of healthy life for elderly people, it is essential to assess the haze level of their lens (i.e., the progress in cataract) quantitatively and, on the basis of it, to provide them with appropriate visual environments. In the present study, we propose the method for estimating of the haze of crystalline lens by measuring spatial resolution for pseudo-cataract young subjects wearing foggy filters.

METHODS

Six young subjects ranging from 21 to 23 years of age participated in the present experiment (4 males and 2 females; mean age of 22.3). All stimuli were presented on 17 inch in CRT monitor, controlled by a personal computer which also controlled the experimental timing and recording from a keyboard. The stimuli were viewed monocularly using the right eye from a distance of 135.5 cm. In front of the participant's eye, an integrating hemisphere was located. Figure 1 illustrates the integrating hemisphere. In this, a foggy filter, a scattering filter, and LEDs (as a glare source inducing further scattering within the eye) were arranged. Four foggy filters with different haze value (i.e., amount of haze) were used; 0 (we refered to filter 1), 5.27 (filter 2), 9.03 (filter 3) and 13.46% (filter 4). The scatter intensity from the LEDs was either 100lx, 500lx, 1000lx or 2000lx.

Figure 2 is an illustration of examples of the stimulus display used for the measurement of spatial resolution. In the display, a sine wave grating and four black rectanglars were presented on a gray background. The grating was inclined either 0, -45, or 45 degree from vertical and served as a test stimulus. The grating had various frequencies in a range of 0.9-30 cpd and always had a fixed number of stripes, independently of its frequency. Therefore, the size of the grating changed depending on the frequency (from 0.9 to 30 cpd). The contrast of grating was either 0.1, 0.3, 0.5 or 0.7. Each rectangular subtended 0.4×0.8 deg and served as a frame to keep a fixation on the center of the display.

The experiment was conducted in a dark booth. Each participant sat on a chair while viewing the display through the integrating hemisphere. After dark adaptation for 5 min, the participants practiced the task for several trials until they were familiarized with the task, followed by an experimental session. In the present study, to measure the spatial resolution, we determined a threshold for the width (spatial frequency) of the grating by using a up-down method. At the beginning of each trial, the rectanglars was presented and then the grating was presented for 5 ms. The participant's task was to report the orientation of grating. When the subject responded correctly the orientation of grating, the width of stripes for the next trial was reduced (spatial frequency increased) by 6.25% of the current trial. When the subject responded incorrectly, the width for the next trial was increased. After 2 reversals of the up-down staircase, width adjustment was reduced to 50%. When 9 reversals were completed, the trial was stopped and the threshold was calculated by averaging the width of the last four reversals. There were 12 blocks of 16 trials. The order of conditions, i.e., scatter intensities, haze values of filter, and gtating's contrasts, were randomized across the subjects.

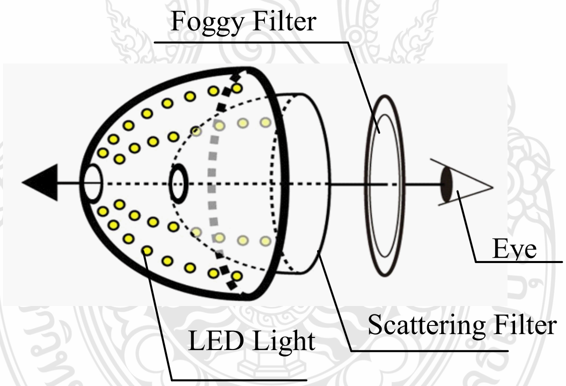

Figure1. Light scattering was configured LED light and scattering filter. There were the device of light scattering and foggy filter in front of the subject's eye.

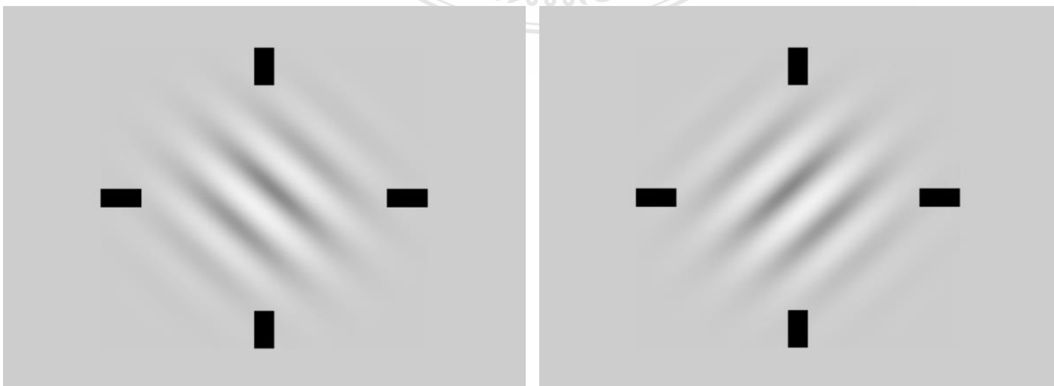

Figure2. The stimulus of gratings (Left inclined -45° and right inclined 45° as the condition of contrast 0.7)

RESULTS

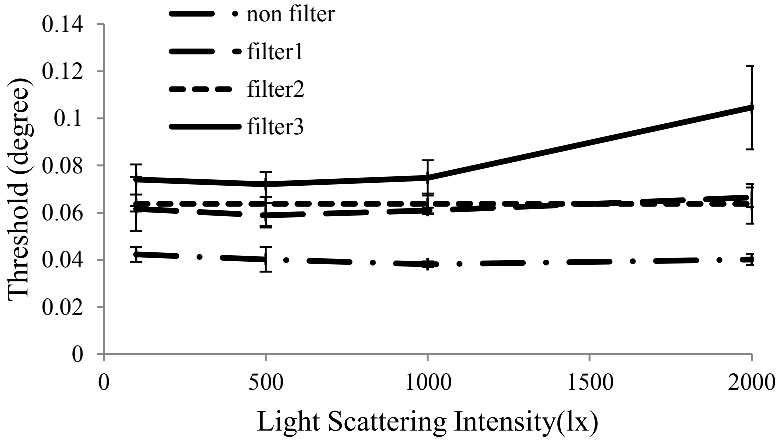

Figure3. The change of thresholds with increasing light scattering intensity as condition of contrast 0.1 (Subject KY)

Figure3 shows the change of threshold with increasing light scattering intensity. It is the result of subject KY when the condition of contrast was 0.1. Light scattering intensity was plotted on the vertical axis and thresholds on the horizontal axis. This data is the averages of the three trials. The result shows that thresholds decreased with increasing light scattering intensity. Additionally, thresholds also increased with increasing haze value of filters. The peak threshold was 2000lx for light scattering intensity. The similar results were appeared in another condition of contrast and other subjects.

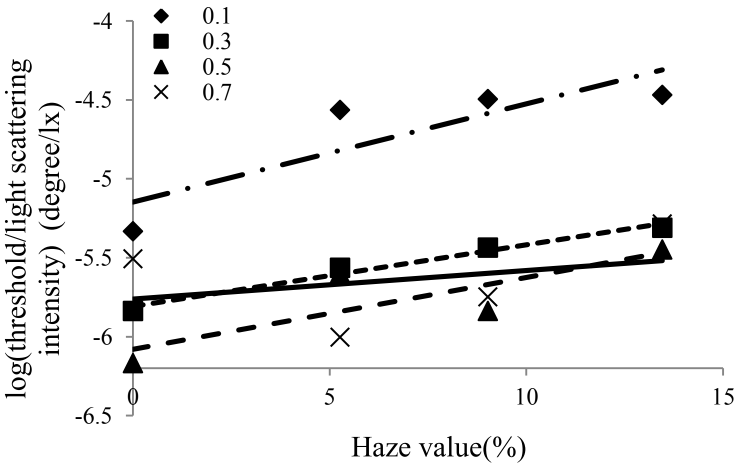

Figure4. The change of slope for haze values is plotted. The slope was obtained by dividing the threshold by light scattering intensity.

Figure4 shows the change of slope which was obtained by dividing the threshold by light scattering intensity for haze values in each condition of contrast. Haze value was plotted on the vertical axis and the slope which was logarithmic on the horizontal axis. Four points each of the conditions of contrasts were approximated by straight lines. The result was presented as the mean of all subjects. All values of the slope increase with increasing haze values.

DISCUSSION

We found the spatial resolution decreased with increasing light scattering intensity. Additionally, this decrease rate became higher with increasing haze values of filters. According to Figure4, the condition of contrast 0.3 was highest determination coefficient in all conditions of contrast. Therefore, we got the following of formula which could estimate the haze value of the crystalline lens. The haze value of crystalline lens can estimate by substituting the threshold and light scattering intensity.

$$\text{Haze value}[\%] = 5.8082 + \frac{\log\left(\frac{\Delta \mathrm{T}}{\Delta \mathrm{E}}\right)[\text{degree/lx}]}{0.039}$$

T; Thresholds, E; Light scattering intensity

CONCLUSION

The spatial resolution was influenced by the degree of haze and the intensity of light scattering in this experiment. Additionally, we produced the function which could estimate the haze value of the crystalline lens. By using this function (above formula), it is possible to know how much progresses has cataract each patient. Therefore, we suggest the present method as a new method for estimating the haze of the crystalline lens.

REFERENCES

1. N. Ohnaka (2011). *i-Perception: Haze estimation of crystalline lens by contrast sensitivity as a function of scattering light intensity.* 2(4), 305