Development of senile miosis simulator adapting to variable illumination in colour environments

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ABSTRACT

We propose a new simulator of elderly colour vision for young observers under variable illuminance levels. The goggle-type simulator has an illuminance sensor to measure the lighting level of environment and automatically changes the luminous transmittance of optical filters as a function of the illuminance level in real time. To determine the transmittance function of the filter, we measured pupil area of the young and the elderly under several illuminace levels (from 0.03 to 4850 lx). Based on the obtained characteristics on the pupil area, we revealed transmittance formulae for the filter simulating the retinal illuminance of the elderly for young observers. In addition, we developed a goggle-type simulator using an Electro-Chromic Devices (ECD). The ECD can be controlled with an electrical circuit to realize the transmittance formulation as a function of the sensor-output, simulating the decreasie of the retinal illuminance by senile miosis.

1. INTRODUCTION

In order to improve the design of products used by the elderly, several methods have been proposed to simulate colour vision of the elderly [1-5]. However, no previous study considered the change of illuminance, though colour appearance and colour discrimination depend on the illuminance of the surroundings. Perception of colours varies with changes in retinal illuminance[6]. Tritanlike defects in the elderly, and the young at lower illuminance levels, was reported[7].

The pupil size becomes smaller with aging[8]. This constricting of pupil is called senile miosis. It is suggested that senile miosis causes the changes of elderly colour vision, because it decreases retinal illuminance. Therefore, to simulate elderly colour vision in consideration of senile miosis in real colour environment, we propose a new simulator which senses the illuminance of environment and changes the luminous transmittance of optical filters as a function of the illuminance level in real time. The basic concept of the optical simulating senile moisis is shown in Figure 1. The optical device in the filters is a type of Electro-Chromic Device (ECD). First, to estimate the reduction of retinal illuminance in the elderly, we measured actual pupil size of young and elderly subjects at several illuminance levels. Next, we derived a transmittance formulae of the filter simulating the retinal illuminance of the elderly as a function of illuminance derived from the experimental results. Finally, we developed a prototype of the goggle-type simulator using the filters and a control circuit.

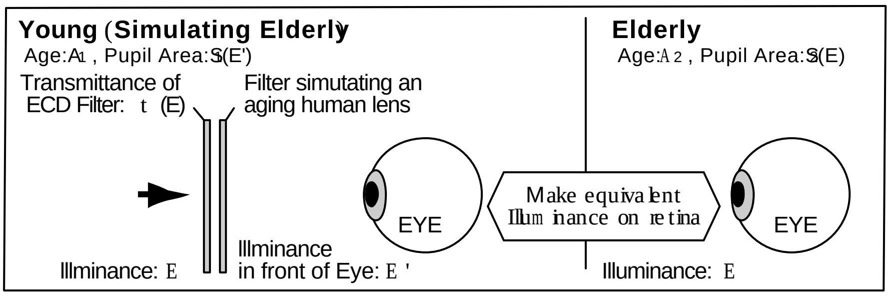

Figure 1: Basic concept of optical simulation of senile miosis

2. METHOD

We measured pupil area for young subjects (4 males and 4 females, average age 21.8yrs., S.D. 0.89yrs.) and elderly subjects (4 males and 4 females, average age 67.1yrs., S.D. 0.83yrs.) at six illuminance levels (Table.1). An electronic pupilary measuring instrument (IRISCORDER C7364, Hamamatsu Photonics K.K.) was used. The young subjects put on the goggle of this instrument (viewing field: 24° in height and 32° in width) and looked at the cross-shaped fixation point on the large surface light source in front of the subjects. The light source was consisted of a diffuser and fluorescent lamps (Matsushita E.W. FHF32EX-N-H, 5000K). The visual distance between the subject and the light source was 50cm. The intensity of the incident light on the subject's eyes was changed by attaching ND filters on the goggle. Table 1 shows the illuminance and luminance levels of the light on the inside of the goggle. These levels were firstly changed in 1^{st} to 6^{th} condition order as increasing the illuminance, and then changed in 6^{th} to 1^{st} condition order as decreasing the illuminance. Pupil area was measured for 300s in each condition. The data were adopted and averaged in late 200s.

Table 1 : Experimental conditions

Cond. No.	illuminance (lx)	luminance (cd/m^2)
1	4850	19000
2	372	1400
3	19.6	85
4	1.6	6.2
5	0.16	0.58
6	0.03	0.07

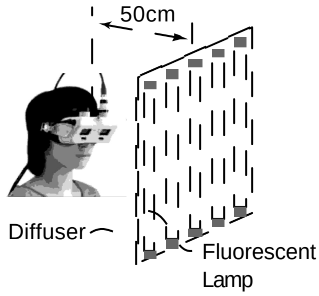

Figure.2: Experimental setup

3. RESULTS and ANALYSIS

Figure 3 shows the mean of pupil area for young and elderly subjects in each condision as a function of log illuminance. Error bars show S.D. Lines in Figure 3 were fitted with the following function

$$S(x) = k + l\tanh(mx + n) \qquad (1),$$

where x=log(E), $S(x)$ represents pupil area, E represents illuminance level, and k, l, m, n represent the regression coefficients. The Eq.(1) corresponds to S_1 and S_2 in Figure 1.

When senile miosis is simulated using the optical filter, it might be assumed that the transmittance of the filter is the ratio of the pupil area of the elderly to the young. However, wearing the filter decreased the illuminance in front of eyes and the pupil area became larger. Therefore, we should consider the effect of decreasing illuminance by the filter on pupil area.

Figure 4 shows schematic diagrams which illustrate retinal illuminance in mind the effect of changing pupil area by the filter. In Figure 4, given equivalence of retinal illuminance between the elderly and the young with filters, an equality expression for retinal illuminance can be defined as

$$ELeS_2(x) = ELet(x)S_1(x') \qquad (2)$$

$$\text{where } x' = \log\{Et(x)(Le/Ly)\} \qquad (3),$$

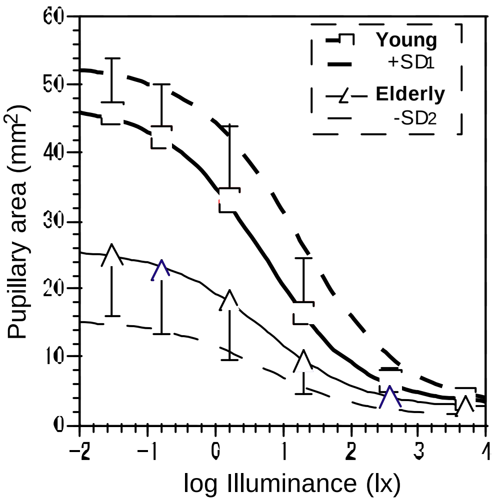

Figure 3: Pupil area as a function of illuminance. SD_1 and SD_2 represent standard deviations of young and elderly subjects, respectively.

Table2: Coefficients of regression curve Eq.(1).

	k	l	m	n
Young	25.32	-21.91	0.712	-0.498
Young+SD_1	28.59	-25.13	0.767	-0.827
Elderly	14.05	-11.59	0.702	-0.505
Elderly-SD_2	9.911	-8.012	0.608	-0.052

and Le/Ly is the luminous transmittance of the filter simulating an aging human lens[4,9] and its value is 0.758. The transmittance function $t(x)$ cannot be derivable by solving Eqs.(2) and (3), because $t(x)$ is an implicit function. Therefore we numerically calculated $t(x)$ as a function of illuminance level x using a computer. Figure 5 shows the results calculated within x = -2 to 4 every 0.5 not only from the average of both subject categories, but also the average of plus S.D. for the young and the average minus S.D. for the elderly.

In order to design the transmittance function of the ECD filter simulating senile miosis, we fit the calculated $t(x)$ with Eq.(4). The formula of Eq.(4) is rewrote Eq.(3) as a $t(x)$ expression and the term S_1 include $t(x)$ and $\log(Le/Ly)$ is replaced the derivative of S_1. Differentiating Eq.(1), $dS_1(x)/dx$ is shown in Eq.(5). Fitting curves are shown in Figure 5 as dashed lines. Coefficients of regression p, q and determination coefficient R^2 are shown in Table 3.

$$t(x) = S_2(x)/\{S_1(x) + p(dS_1(x+q)/dx)\} \quad (4)$$

$$dS_1(x)/dx = kl(1 - \tanh(mx+n)^2) \quad (5)$$

Additionally, we fit the obtained $t(x)$ with a six order polynomial equation, because there was a little gaps between the calculated value and Eq.(4). The thick solid line in Figure 5 is the regression curve t_{mean} of calculated data from the mean of pupil area. t_{mean} was described as

$$t_{mean} = -3.30\times10^{-5}x^6 - 1.14\times10^{-3}x^5 + 4.61\times10^{-3}x^4 + 1.45\times10^{-2}x^3 - 2.06\times10^{-2}x^2 - 7.20\times10^{-2}x + 0.485 \quad (6)$$

On the other hand, a thin solid line in Figure 5 shows the regression curve t_{SD} of calculated from the mean plus S.D. for the young and the mean minus S.D. for the elderly. t_{SD} was described as

$$t_{SD} = 3.13\times10^{-4}x^6 - 1.19\times10^{-3}x^5 + 2.47\times10^{-3}x^4 + 2.75\times10^{-4}x^3 - 4.37\times10^{-3}x^2 - 7.28\times10^{-2}x + 0.202 \quad (7)$$

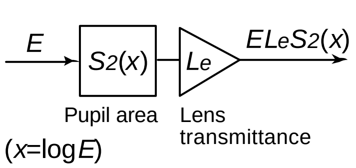

Figure 4(a): The factors related retinal illuminance of the elderly

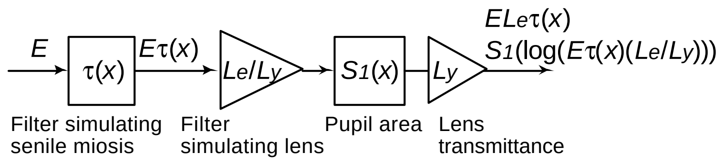

Figure 4(b): The factors related retinal illuminance of the young with filters simulating senile miosis and the aging lens.

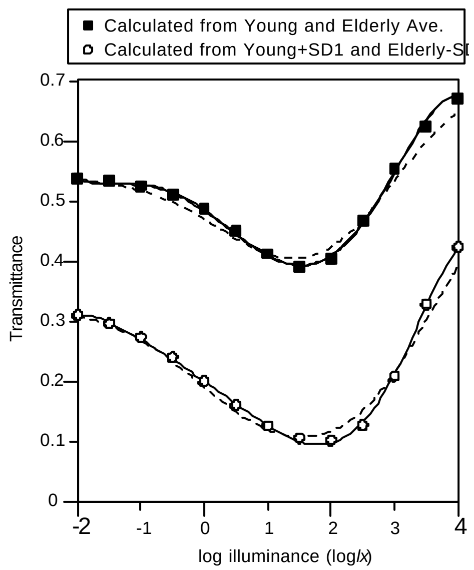

Table3: Coefficients of regression curve Eq.(4) and determination coefficient R^2

Eq .No.		Line in Fig.5	p	q	R^2
4	(mean)	— — — (dashed)	-0.506	-0.107	0.969
4	(mean±SD)	- - - - - (dashed)	-0.983	-0.233	0.977
6	(mean)	thick solid line	-	-	0.997
7	(mean±SD)	thin solid line	-	-	0.999

Figure 5: Transmittance functions of the filters simulating senile miosis. Filled Squares show the results calculated from the mean of both subject categories, and Open dots show the results calculated from the mean of plus S.D. for the young and the average minus S.D. for the elderly according to Eqs.(2) (3). Dashed lines show the calculated result of Eq(4), the thick and thin solid line show the calculated results from Eq.(6) and Eq.(7), respectively.

4. PROTOTYPE

We developed a prototype goggle which simulates senile miosis using the transmittance function shown in Fig.5. The transmittance characteristic was realized to change the applied voltage to the ECD filter. We made the ECD filters which have characteristic according to Eq.(6). Figure 6 is a picture of the prototype. The Illuminance of environment was sensed by a photo-diode placed on the middle of the goggle. The ECD filters were controlled by a microcontroller which was programmed so as to apply the voltage to set the transmittance character in Eq.(6) the based on sensing illuminance. The actual transmittance of the ECD filter and Eq.(6) as the desired value are shown in Figure 7. The control circuit was driven a battery and easily small enough to fit inside the breast pocket small. In addition, the goggle could hold the filters simulating an aging human lens on top of ECD filters. Therefore, we can simulate both senile miosis and the elderly yellowing lens at the same time.

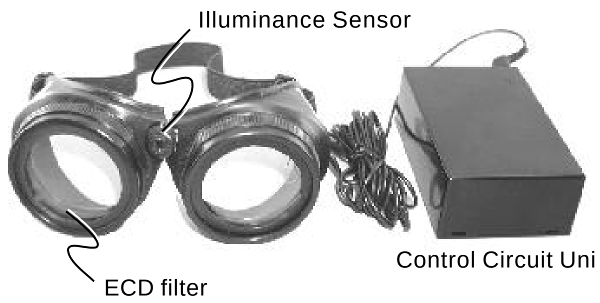

Figure 6: Prototype set of the simulator

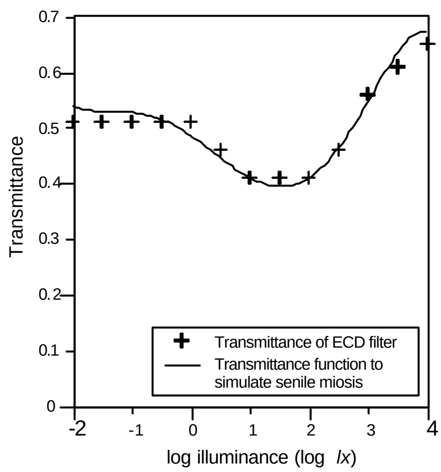

Figure 7: Measured transmittance of an ECD filter in the prototype (+). Solid line was calculated from Eq(6) as the desired function.

4. CONCLUSIONS

In order to simulate the elderly colour vision in consideration of miosis causes under different illuminance, we proposed a new simulator which senses illuminance of environment and changes the luminous transmittance of optical filters as a function of the illuminance level in real time. To determine the transmittance of the filter, we measured the pupil area of the young and the elderly. Based on obtained characteristics of pupil area from the experiment, we revealed transmittance functions to simulating the retinal illuminance of the elderly, and developed a goggle-type simulator with the ECD filters.

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