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The effects of photochromatic lenses on pupillary response to light

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Abstract

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Introduction

The Corning Glass Company estimates that one out of every five eyewear consumers in this country will purchase photochromatic lenses.[1] Many of these consumers are not first time wearers, but have worn photochromatic lenses in the past. Kavner, the author of Total Vision, feels that once a person begins to wear this type of lens, it is difficult to go without them and also constant wear of these lenses is not good because they may take over the adaptive response to light which the eyes would normally handle by themselves.[2]

Today's photochromatic lenses such as Photogray Extra and Photobrown Extra by Corning are virtually clear indoors having approximately 87% transmittance and turns to a true sunglass outdoors to approximately 22% transmittance.[10] These lenses, therefore, act to control the amount of retinal illuminance. Since the receptors for the pupillary light reflex are found in the retina along with the receptors for vision, a decrease in retinal illuminance as when wearing photochromatic lenses outdoors, will cause the pupil to contract less than it would in bright sunlight.

The purpose of this study was to examine the possibility of an adaptive response to wearing photochromatic lenses. There are two possible adaptive responses that may occur with a decrease in retinal illuminance. One possibility is that the retina may become more light sensitive as it does in dark adaptation.[9] With an increase in retinal sensitivity a greater pupillary contraction should occur when the eyes are exposed to bright light. The second possible adaptive response may be a decrease in muscle tone that would lead to a decrease in pupillary constriction to bright light. Kavner feels that wearing photochromatic lenses is like using crutches to walk around with. The legs become weaker the longer the crutches are used. The same will happen to the eyes with constant wear of photochromatic lenses.(2) Here we would expect the pupillary sphincter muscle to become weak and show a diminished capacity to constrict fully when exposed to bright light. It is our hypothesis that the latter adaptive response occurs.

We compared the pupillary response of subjects who wear photochromatic lenses to those who wear clear glass lenses. Pupillary response was determined by the percent change in pupil area from dark to light ambient conditions. There have been no previous studies that show any effects of photochromatic lenses on pupillary response.

Method

Two groups of subjects were chosen: 1) an experimental group of photochromatic lens wearers of over two years and 2) a control group of clear glass lens wearers of over two years. Sixteen subjects were selected from optometry students and patients at the Pacific University School of Optomtry Clinic. The ages of the subjects ranged from 15 to 55 years old. None were experiencing any visual difficulties and all had good ocular health at the time of testing. The subjects were either low myopes or myopic astigmats. Refractive errors ranged from -.50 to -5.50 diopters. Seven subjects had dark irides and nine subjects had light irides. Subjects were matched for iris color, refractive error and age, respectively.

Pictures of each subject's right eye were taken in both dark adapted and light adapted conditions. A ruler was placed approximately in the corneal plane of the subject's right eye for use as a calibration standard. The subject's eyes were dark adapted for thirty seconds before the picture of the right eye was taken. This was followed by a rest period of one minute in normal room illumination. Next, a light was shown in the subject's eye for thirty seconds and another picture was taken. Light incident at the eye was one-hundred foot candles (approx. 1100 lux) of illuminance. The camera was positioned directly along the eye's line of sight. The left eye fixated a 20/400 Snellen letter. All pictures were taken without spectacle correction worn. A 35 mm Nikon F camera with a Braun 2000 Variocomputer flash system was used to take the pictures. The flash was held about 45° off axis of the camera and was farther away from the subject than the camera.

Pupil size was measured by projecting the negatives onto a screen and measuring the horizontal diameter. Actual diameter was calculated by refering to the photographed mm scale.

Results

Table 1 shows the results of the data collected. As mentioned earlier, each of the subjects in the photochromatic group was matched with a subject in the clear lens group according to iris color, refractive error, and age in that order. Analyses by a related sample t-test for differences between the percent of pupil area change from dark to light conditions for each group was found to be statistically insignificant at the 0.05 level. (Refer to the Appendix for computation of 't') Figure 1 compares the mean pupil size of dark and light adapted eyes of the two groups.

TABLE 1

Results of pupillary change for matched pairs between Group I (photochromatic lens wearer) and Group II (clear lens wearer).

PAIRS	1	2	3	4	5	6	7	8
Group I Subjects	BH	AA	PK	EG	RP	BP	JW	SP
Iris Color	brown	blue	brown	brown	brown	blue	blue	brown
Refractive Error (diopters)	-1.25	-.50	-2.00	-2.25	-3.00	-3.00	-2.25	-2.25
Pupil Diameter in Dark (mm)	7.0	6.7	7.6	5.1	7.8	5.0	5.0	8.0
Pupil Diameter in Light(mm)	4.5	3.4	3.6	2.9	4.3	2.9	2.7	3.5
% Change in Area (%)	58.5	74.25	77.56	67.65	69.61	67.34	70.85	80.27
Group II Subjects	JH	LJ	WL	JC	JP	MH	SB	AL
Iris Color	green	green	brown	brown	brown	blue	blue	brown
Refractive Error (diopters)	-2.00	-1.00	-5.50	-5.00	-.50	-2.00	-3.00	-.75
Pupil Diameter in Dark (mm)	6.0	6.5	7.0	6.5	7.5	8.0	8.0	5.3
Pupil Diameter in Light (mm)	3.5	4.0	4.2	4.0	4.0	4.2	4.8	3.5
% Change in Area (%)	64.91	60.98	64.0	60.98	70.69	72.45	63.99	55.04

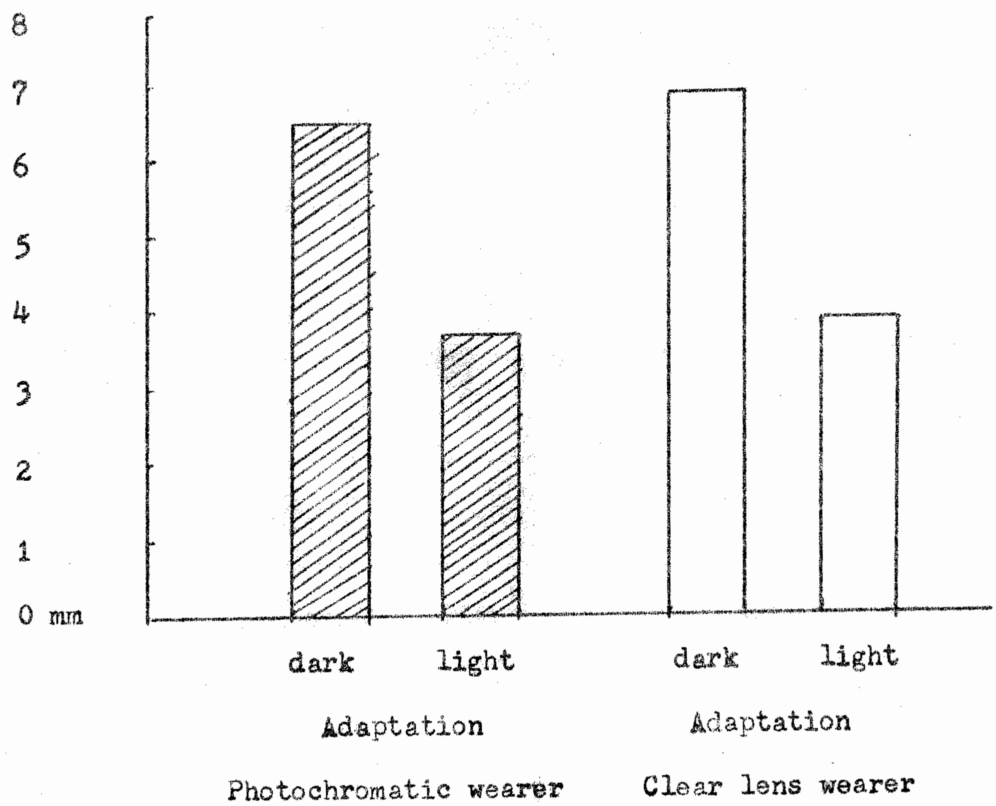

Figure 1: Mean pupillary size of dark and light adapted eyes of photochromatic and clear lens wearers.

Discussion

There are numerous variables that may affect the size of the pupil. A dark iris will usually have a smaller pupil than a light iris.(3) Myopes have larger pupils than hyperopes.(4) Miosis of the pupil occurs with age due to atrophy of the dilator muscle fibers, loss of retinal receptors responsible for pupillary neural pathways, and decrease of retinal illuminance due to changes in ocular media of the aged. (5) Ophthalmic lenses of different powers have been shown to either increase or decrease the amount of light entering the eye. A plus lens converges light while a minus lens spreads light beyond the area of the pupil.(6) To control these variables, the subjects from the photochromatic group were matched with those wearing clear lenses.

There are other variables that may also affect pupil size. Lowenstein and Loewenfeld (1951) found the pupillary behavior of the dark adapted eye differs completely from the pupillary behavior of the light adapted eye.(7) The pupils are large and quiet in the dark. When the eyes are exposed to a constant light stimulus, the pupil contracts, then redilates partially and begins to oscillate producing pupillary unrest or hippus. They found the size of the pupil may vary anywhere from 0.5 mm to 2.0 mm. The rate of oscillation may be as fast as two per second in bright light and slowly diminishes when the light level is reduced. To increase the reliability of our data it may have been necessary to take several pictures and take an average pupil size.

In this study we did not screen the subjects for anxiety or emotional stability. This psychological aspect of a subject may have a great bearing on the pupil size during dark and light adaptation. Part of the pupillary reflex involves the parasympathetic reflex arc which is influenced by higher brain centers. Lowenstein and Loewenfeld (1962) studied the pupillary responses of subjects in various emotional states.(8) A subject who is experiencing discomfort, pain or noise, or when exciting thoughts or emotions are elicited the pupils become larger than when the subject is calm. This occurs because the pupillary reflex to light is inhibited and subsequent premature redilation may appear. On the other hand, a tired subject may show relatively small pupils in darkness and the light reflex may be slightly inhibited. In tense, hyperexcitable subjects the pupil is large when dark adapted and the light reflex is less extensive than in calm subjects. In hyperfatigable subjects, the pupil is usually smaller in darkness and the light reflex lightly depressed. Many of our subjects were patients at Pacific University Optometric Clinic and had an eye examination just prior to participating in our research. The eye exam may have induced fatigue and thus altered the normal pupillary response.

Lowenstein and Loewenfeld (1959) have found that a bright environment will reduce retinal sensitivity and since retinal and pupillary response coincides, the pupillary response will also be reduced.(9) They found both retinal rods and cones furnish afferent impulses for the pupillary reflex to light. The cones, however, were more effective than rods in producing an extensive and prolonged pupillary response. According to this, if a person shields his eyes from bright light as when wearing photochromatic lenses, there should be less reduction in retinal sensitivity when compared to a person wearing clear lenses. If the eyes of both individuals are exposed to bright illumination there sould be a greater response of the cone system in the photochromatic individual resulting in a more extensive pupillary response which is contrary to our hypothesis. From Figure 1 there was no evidence of either greater or lesser pupillary response from wearing photochromatic lenses.

Conclusion

In this study we tried to demonstrate the possibility that subjects wearing photochromatic lenses may have a reduced pupillary response to light as compared to those subjects who wear clear glass lenses. Analysis of the data collected revealed no significance. There was no indication that wearing photochromatic lenses either decreases or increases pupillary response to light. Because of the small number of subjects used in this study and not being able to adequately control all of the variables that influence pupillary reflex, we can not assess whether or not further investigation will result in more conclusive findings.

Appendix

Computation of t-Ratio for related samples, comparing percent change in pupil area from dark to light adaptation.

Pairs	Group I	Group II	D	D^2
1	69.61	55.04	14.57	212.28
2	77.56	64.0	13.56	183.87
3	80.27	70.69	9.58	91.78
4	67.65	60.98	6.67	44.49
5	70.85	63.99	6.86	47.06
6	67.34	72.45	-5.11	26.11
7	58.5	64.91	-6.41	41.09
8	74.25	60.98	11.27	127.01
	$\Sigma X_1 = 566.03$	$\Sigma X_2 = 513.04$	$\Sigma D = 50.99$	$\Sigma D^2 = 773.69$

$$S_{\bar{D}} = \sqrt{\frac{\Sigma d^2}{N(N-1)}}$$

$$\Sigma d^2 = \Sigma D^2 - \frac{(\Sigma D)^2}{N}$$

$$\Sigma d^2 = 773.69 - \frac{(50.99)^2}{8} = 448.69$$

$$S_{\bar{D}} = \sqrt{\frac{\Sigma d^2}{N(N-1)}} = \sqrt{\frac{448.69}{8(8-1)}} = 2.83$$

$$t = \frac{\bar{D} - 0}{S_{\bar{D}}} = \frac{6.37}{2.83} = 2.25$$

$$df = 8 - 1 = 7$$

With a value of 2.25 and 7 df, t of 2.365 is required for significance at the .05 level. We, therefore, cannot reject the null hypothesis and cannot assert that wearing photochromatic lenses results in diminished pupillary response to bright light.

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