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Abstract

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EFFECTS OF COMMERCIALLY AVAILABLE COLORED LENSES ON COLOR PERCEPTION IN A NORMAL POPULATION

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ABSTRACT

Effects upon color perception were studied using the Corning Medical Optics CPF lenses and the Younger Optics PLS lenses. Measurements were obtained using the Farnsworth 15-hue (D-15) color test. Color perception errors associated with the respective lenses were statistically analyzed. Comparisons of these individual lens errors were then made among all the lenses included in the study. All the lenses significantly altered color perception in some or all of the visible spectrum. In all cases, the Corning CPF lenses had either equal or lesser effects upon color perception errors than did the Younger PLS lenses.

KEY WORDS: Color perception, Corning CPF lenses, Younger PLS lenses, Farnsworth (D-15) test, filters, absorptive lenses.

INTRODUCTION

Color filter and tinted lenses occupy a significant place in the prescription lens market. Whether they are used for cosmetic or therapeutic reasons, the induced secondary effects upon vision should be known by each practitioner prescribing them. Studies concerning a wide variety of visual effects secondary to tinted lenses include spectral transmittance[1], prevention of ocular disorders[2], contrast sensitivity[3], reaction time to spatial frequencies[4], and night driving[5]. The scope of the present study is limited to color perception effects induced by colored lenses. Research articles written concerning color filter effects upon color perception include the effects of chromatic adaptation on color discrimination and color appearance[6], the limited improvement of color deficient vision with color filters[7],and the effects of colored filters on color perception when viewing traffic lights[8]. Two series of recently developed, therapeutically oriented lenses, the Corning Medical Optics CPF lenses and the Younger Optics PLS lenses, will be evaluated in this paper.

The Corning Photochromatic Filter (CPF) lenses[9] are photochromic lenses with special absorption characteristics. The three different lenses in the series, (511nm, 527nm, and 550nm), absorb virtually all visible and ultraviolet (UV) light energy shorter than the designated cutoff wavelengths. The Younger Protective Lens Series (PLS) lenses[10] are made from a hard resin CR-39 material with UV and blue filtering properties as an integral component of the lens material. They are designed to filter UV and blue light below their designated cutoff wavelengths of 530nm, 540nm, and 550nm. Both lens series are relatively new on the market; consequently, little research is available regarding them, especially in the area of color perception.

Studies involving the CPF 550 lens generally have addressed issues other than color. Research involving enlarged field of view[11], effects on vision of cataract patients[12], and preferences of retinitis pigmentosa patients concerning red photochromic lenses[13] are samples of these studies. Another study included testimonials of three light sensitive patients who were therapeutically treated with the CPF 511, 527, and 550 lenses[14]. Two studies did include incidental comments regarding color perception effects secondary to the use of the CPF 550 lens. Morrissette, et al.[15], reported there was difficulty in distinguishing colors among users of the CPF 550 lens. However, when asked about appearance of color changes while watching color television, users of the CPF 550 lens reported changes were for the better or at least the same. There were no reports of worse effects. Lynch, et al.[16], found that color normal individuals passed the City University color test while wearing the CPF 550 lenses but did have a 50% error rate in color naming tasks with the incorrect responses corresponding to the reds, greens, and blues.

This study was designed to investigate the effects upon a normal observer's color perception ability when using these special filtering lenses. Potential differential effects of the lenses upon the color spectrum will be analyzed in the study. If there are effects, which part of the spectrum, (blues, greens, yellows, reds), will be affected most? Possible similarities and differences between the respective lenses will also be investigated.

METHODS

Forty-two subjects (84 eyes) were evaluated, 31 males and 11 females. Subject age ranged from 21 to 33 years old. With habitual correction in place, all subjects had monocular near visual acuities of 20/20 or better. All subjects, including those wearing tinted contact or spectacle lenses, were tested monocularly for normal color perception using the Farnsworth D-15 color confusion test[17] and the Criticolor lamp[18]. One subject (male) was omitted from the study because of anomalous color perception. The remaining 41 subjects (82 eyes) were color normal, and exhibited no errors while performing the D-15 test.

After reviewing all the different types of color vision tests, we chose the Farnsworth D-15 test because it is generally accepted as the best test for color confusion testing. As Linksz states in his book, An Essay on Color Vision, "No other color vision test, even including the anomaloscope, [better] reveals this particular characteristic [color confusion] of the color defective. It's ability to demonstrate the pattern of actual color confusion is, in fact, the outstanding feature of the Farnsworth (D-15) test, and that it accomplishes this with such a small number of samples ... is even more remarkable" [19].

The test consists of 16 color tiles affixed in holder caps. The color spectrum ranging from blue to purple is divided into 16 equivalent intervals. The parametric interval between cap colors that Farnsworth selected when developing the test, was based on one psychophysical unit, each unit being six J.E.N.D.'s (just easily noticeable differences)[17]. Each increment is represented by a different color tile. The first tile/cap in the blue end of the spectrum is permanently affixed to the test tray, which is a long box lined with black felt. The remaining 15 movable caps are mixed by the tester and the subject is then told to arrange the caps in their proper color sequence, beginning with the cap closest in color to the fixed cap and continuing through the color spectrum. The instruction set is standardized to insure that each subject receives the same information. No help is given to the subject while he/she is arranging the caps. After completing the arranging of the caps, the subject is asked if he/she wishes to make any changes. Once the subject is satisfied that the arrangement is correct, a record is made of the order in which the caps are placed.

For scoring purposes, the 15 movable caps are numbered 1-15 in order of spectrum chromaticity from blue (1) to red/purple (15). The caps are then scored by summing the absolute difference between a given cap and adjacent caps, one on each side (as in the Farnsworth 100-hue test)[17]. For example, if caps 1, 2, and 3 were placed in proper order, the score for cap #2 would be: (2-1) + (3-2) = 2. If caps 2, 3, and 4 were placed in a confused order, say 3, 2, 4, then the score for cap #2 would be: (3-2) + (4-2) = 3. Thus, each cap, if placed in proper order, is given a score of 2; if out of order, the score is higher. The cap position scores are then totalled. A score of 30 results if no effect on color perception is observed. In this study, the cap in position 1 was scored by labeling the affixed reference cap as "0". The cap in position 15 was scored as if a cap "16" was correctly placed at that end. This gave the test subject the benefit of any doubt in ordering these end caps, so that all 15 cap positions could be included for statistical analysis.

Based on the D-15 test, color perception was tested monocularly through the Corning CPF and Younger PLS colored lenses. The photochromaticity of the Corning lenses was held constant by using the Criticolor lamp as the only light source during testing. Each lens was randomly placed before the subject to eliminate systematic error related to testing order. The companion eye was then similarly tested.

RESULTS

One way repeated measures analysis of variance (ANOVA) was utilized for all data. The Newman-Keuls post hoc test was used to analyze group differences when a significant f-ratio was derived from ANOVA. Statistical significance was measured at the .01 and .05 levels. Individual lens error scores were evaluated. Comparisons were then made between lenses according to error score.

Analysis of Total Error Score. The data were evaluated in terms of total error scores across the full color spectrum, and for differences in error scores within specific parts of the spectrum. The total error score for each lens is shown in table 1 and is represented graphically in figure 1. The higher error scores indicate a greater effect upon color distortion. The largest error score occurred in the PLS 540 lens at 5031 with a mean of 61.4 (SD=11). The lowest error score was seen in the CPF 527 lens at 2750 with a mean of 33.5 (SD=5.5). ANOVA analysis showed that the lens error totals were significantly different from each other (f-ratio= 198.51, $p<.01$). When each lens was compared to the baseline, all were seen to significantly alter color perception ($p<.01$, CPF 527 $p<.05$). An analysis comparing lens scores indicated that the Younger lenses did not differ from each other in affecting color perception, which indicated a relatively homogeneous group. The CPF 511 lens, on the other hand, differed significantly from both the CPF 527 and CPF 550 lenses in affecting color perception ($p<.01$). This indicates that the CPF 511 lens, with its higher error score, alters color perception more than the CPF 527 and CPF 550 lenses. The differences between the CPF 527 and CPF 550 lenses were insignificant. Each Younger lens error score was significantly higher than any of the Corning lens scores ($p<.01$).

Subgroup Error Scores. To determine the effect of each lens upon specific parts of the color spectrum, the cap error scores were separated into color subgroups A, B, and C. The sum of cap scores in positions 1-5 (blues and greens) constituted subgroup A; caps in positions 6-10 (yellows), and 11-15 (reds and red/purples) became subgroups B and C respectively. These cap color subgroups are based on Linksz's report on the color groups of the D-15 test caps[19]. The error score of each subgroup by lens is shown in table 2 and represented graphically in figure 2. These subgroup error scores were then analyzed within each individual lens and then all respective subgroups were combined and analyzed across all the lenses.

Analysis of Individual Lens Subgroup Error Scores. Each lens was individually analyzed, comparing its subgroup error scores to determine if the scores of any one subgroup differed from the scores of the other two subgroups or from the baseline error score. Statistical analysis showed that each subgroup of each lens differed significantly from the baseline error score ($p<.01$). For the CPF 511 lens, the differences between subgroups A, B, and C were insignificant. The same was true for the CPF 550 and PLS 550 lenses. This suggests that for these lenses each subgroup was affected similarly in terms of perceived color. The CPF 527 and PLS 540 lenses both affected subgroups A and C significantly more than subgroup B (PLS 540 $<.01$, CPF 527 $p<.05$). The PLS 530 lens had its greatest effect upon subgroup A ($p<.01$).

Analysis of Lens Subgroup Error Scores Comparisons. Changes in color perception upon a given subgroup across all the lenses were then evaluated (Table 3). All lenses significantly affected subgroup A, (blues and greens), ($p<.01$, CPF 527 $p<.05$). However, the CPF 527 and CPF 550 lens error scores were significantly lower than the other lenses ($p<.01$). Also, in this region of the spectrum, each Younger lens gave significantly more errors than the Corning lenses ($p<.01$).

In subgroup B, (the yellow region of the spectrum), only the CPF 527 lens showed no significant effect on altering color perception. All other lenses distorted the colors in this region ($p<.01$, CPF 550 $p<.05$). Both the CPF 527 and CPF 550 lenses scored significantly less yellow color errors than the other lenses ($p<.01$). Differences in scores between the CPF 511 and all three Younger lenses were insignificant.

In subgroup C (reds and red/purples), neither the CPF 527 lens nor the CPF 550 lens affected this color group significantly. All other lenses significantly distorted the colors in this region ($p<.01$). Again the Younger lenses performed significantly poorer than the Corning lenses ($p<.01$) as was seen in the blues and blue/greens (Subgroup A). Among the Younger lenses, the PLS 540 lens showed greater color errors than the PLS 530 or 550 lenses ($p<.05$).

Interestingly, for each color subgroup, the CPF 511 lens, as well as the Younger lenses, scored significantly more errors than the CPF 527 and CPF 550 lenses. The CPF 527 and CPF 550 lenses were not significantly different in any of the three subgroups, suggesting that they have approximately equal effects across the color spectrum.

Analysis of Lens Error Score Comparisons Between Lenses of Similar Spectral Transmitance. The final statistical comparison was made between similar Corning and Younger lenses. The CPF 527 and PLS 530 lenses were compared, as were the CPF 550 and PLS 550 lenses. Analysis of their total error scores showed that both Corning lenses had less effect on color perception than their Younger counterparts ($p<.01$ in each case). Moreover, for each subgroup, A, B, and C, each Corning lens had a significantly lower error score than the subgroup error scores of the Younger lens to which it was compared ($p<.01$ in each analysis).

DISCUSSION

This study was developed to determine what effects the Corning CPF and Younger PLS lenses had on color perception. Based on the reports of both manufacturers, we expected the colors blue and green to be most affected[9,10]. Our results indicated that each lens signficantly altered color perception. Unexpectedly, not only were the blues significantly affected by each lens, but all other color groups as well. Interestingly, for the CPF 511 and 550 lenses as well as the PLS 550 lenses, the color groups blue, yellow, and red were similarly affected. For the CPF 527 and PLS 540 lenses, the reds and blues were more affected than were the yellows. Only for the PLS 530 lens were the blues significantly more affected than the other colors. In none of the lenses were the yellows significantly more affected than the reds or blues. It appears, therefore, that the yellows are least affected by the lenses studied.

The changes in color perception of the blues are probably due to attenuation of cap colors outside of the lens transmission spectrum. This subtractive effect of the lenses makes given cap color groups appear similar, resulting in blue color confusion. This confusion is seen in the mispositioning of the caps and a high error score. The high red error scores of all the lenses studied cannot be easily explained. Theoretically, the lenses filter only blue and blue-green light, leaving the reds unaffected. Undoubtedly other factors are involved which have yet to be isolated and studied.

Over all, the CPF 527 lens showed the best performance. Though comparisons of individual color subgroups of the CPF 527 and 550 lenses showed no differences, the CPF 527 lens had significantly less color errors when compared to the baseline than the other lenses. The reasons for the better performance of the CPF 527 lens are in need of further study.

Comparisons of the Corning and Younger lenses showed that the Younger lenses performed consistently poorer than the Corning lenses, both in total errors and in color subgroup errors. Differences in materials and transmission characteristics may account for some of the differences between the two manufacturers.

CONCLUSION

Practitioners commonly use special color absorptive lenses for either therapeutic, preventive, and/or increased comfort regimens for their patients. In our study involving six of those lenses, the CPF 511, CPF 527, and CPF 550 lenses from Corning Medical Optics, and the PLS 530, PLS 540, and PLS 550 lenses from Younger Optics, we attempted to derive some useful generalizations to aid the practioner in prescribing these lenses and in counseling those patients using the lenses with regard to color perception effects.

Significant effects upon color perception, based upon the Farnsworth 15-hue (D-15) color confusion test, resulted when subjects were tested using the above lenses. The magnitude and scope of the effects varied depending on the lens used. In general, the Corning CPF lenses affected color perception less than did the Younger PLS lenses. Patients will experience less altered color perception in the yellow range of the spectrum while using any of the six lenses in contrast to the significant changes on either end of the spectrum. Proper counseling of patients with regard to induced color perception anomalies while using these lenses is essential for patient safety within their respective environmental demands.

TABLE 1

TOTAL ERROR SCORE BY LENS

	C 511	C 527	C 550	Y 530	Y 540	Y 550	BASELINE
TOTAL	4440	2750	2867	4933	5031	4938	2460
MEAN	54.15	33.54	34.96	60.16	61.35	60.22	30
SD	15.35	5.46	7.9	11.23	10.99	14.18	0
RANGE	30-85	30-54	30-90	44-90	41-102	30-109	-

f(df(6))=198.51 (p<.01)

TABLE 2

CAP COLOR GROUPS

		1-5 blues & greens	6-10 yellows	11-15 reds & purples	BASELINE	
C511	TOTAL	1525	1492	1421	820	F(3,79)=76.26, p<.01
	MEAN	18.6	18.22	17.33	10	
	SD	4.94	7.73	5.28	0	
	RANGE	10-29	10-40	10-29	-	
C527	TOTAL	932	881	937	820	F(3,79)=15.11, p<.01
	MEAN	11.37	10.74	11.43	10	
	SD	2.39	1.75	2.43	0	
	RANGE	10-29	10-20	10-19	-	
C550	TOTAL	975	978	914	820	F(3,79)=11.15, p<.01
	MEAN	11.89	11.93	11.15	10	
	SD	4.55	2.38	2.68	0	
	RANGE	10-47	10-19	10-26	-	
Y530	TOTAL	1864	1487	1582	820	F(3,79)=105.45, p<.01
	MEAN	22.73	18.13	19.29	10	
	SD	4.2	6.56	6.22	0	
	RANGE	10-31	10-42	10-35	-	
Y540	TOTAL	1821	1480	1730	820	F(3,79)=140.18, p<.01
	MEAN	22.21	18.05	21.1	10	
	SD	4.06	5.21	6.32	0	
	RANGE	10-33	10-32	10-54	-	
Y550	TOTAL	1742	1604	1592	820	F(3,79)=78.11, p<.01
	MEAN	21.24	19.56	19.41	10	
	SD	5.35	8.11	6.15	0	
	RANGE	10-34	10-56	10-37	-	

TABLE 3

LENSES

		C511	C527	C550	Y530	Y540	Y550	BASELINE
SUBGROUP A	total error score	1525	932	975	1864	1821	1742	820

F(6,79)=194.62, p<.01

		C511	C527	C550	Y530	Y540	Y550	BASELINE
SUBGROUP B	total error score	1494	881	978	1487	1480	1604	820

F(6,79)=56.21, p<.01

		C511	C527	C550	Y530	Y540	Y550	BASELINE
SUBGROUP C	total error score	1421	937	914	1582	1730	1592	820

F(6,79)=94.59, p<.01

LEGEND

SUBGROUP A=caps 1-5 (blue/green)
SUBGROUP B=caps 6-10 (yellows)
SUBGROUP C=caps 11-15 (red/red-purples)

FIGURE 1

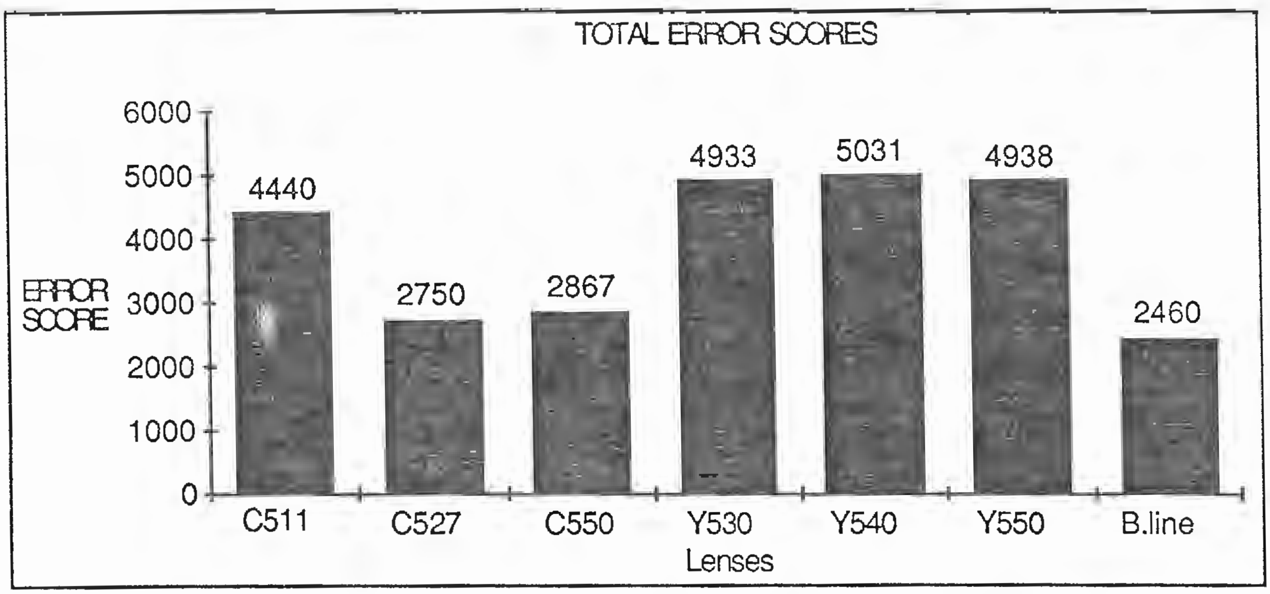
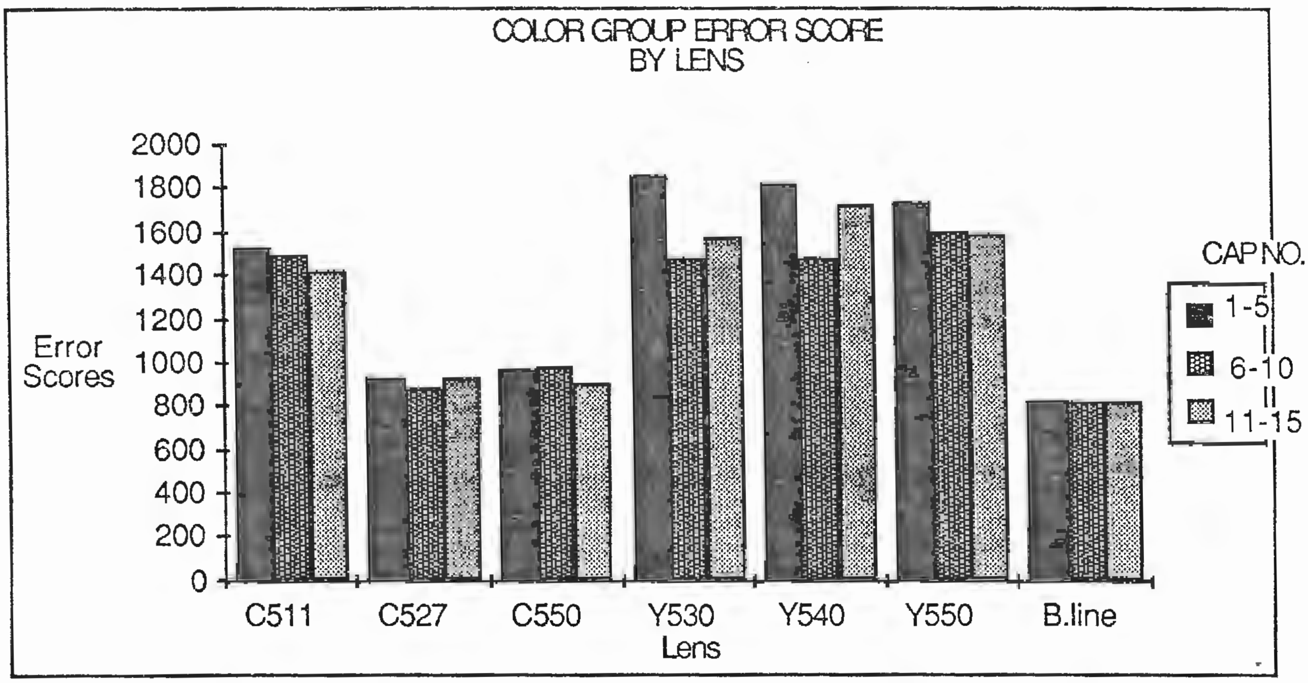

TOTAL ERROR SCORES
6000
5000
4000
3000
2000
1000
0
ERROR SCORE
4440
2750
2867
4933
5031
4938
2460
C511
C527
C550
Y530
Y540
Y550
B.line
Lenses

FIGURE 2


COLOR GROUP ERROR SCORE
BY LENS
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Error
Scores
C511
C527
C550
Y530
Y540
Y550
B.line
Lens
CAP NO.
1-5
6-10
11-15

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