EFFECTS OF CPF LENSES ON COLOR DISCRIMINATION, VISUAL ACUITY AND CONTRAST SENSITIVITY IN NORMAL INDIVIDUALS

Senior Project
by
Robert J. Slezak

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INTRODUCTION

CPF lenses are photochromatic cut-off filters which were developed by Dow Corning for opthalmic use. The prototype lens, the CPF 550, was originally developed for use by individuals with retinitis pigmentosa. Presently there are three CPF lenses on the market: the CPF 550, the CPF 527 and the CPF 511. The number of each lens indicates the point, in namometers, below which no spectral transmission occurs; that is, the CPF 527 transmits light above 527nm but blocks light below 527nm including ultra-violet light.

As stated, the CPF 550 was developed for the management of the retinitis pigmentosa patient. Now with the development of the CPF 511 and the CPF 527 the scope of therapeutic use of CPF lenses has increased. At present CPF lenses have been advocated in the management of many ocular disorders including macular degeneration, diabetic retinopathy, cataract, aphakia, pseudophakia, corneal dystrophy, optic atrophy, albanism, aniridia and glaucoma. The proposed usefulness of the CPF lenses in managing these disorders lies in the physical characteristics of the lenses themselves. These characteristics are: 1) the ability to lighten and darken in response to changing light conditions, thereby effectively modulating the intensity of light entering the eye and 2) the ability to selectively absorb light energy, thus preventing the shorter visible wavelengths and ultra-violet light from also entering the eye.

The aforementioned properties of the CPF lenses are proposed to be particularly valuable in the management of retinal disorders (5). Research has shown that visible light can cause retinal damage (1)(3). This damage may be either thermal (immediate) or photic (delayed) in nature. It is therefore proposed that existing retinal pathologies may advance more quickly when not protected from the "destructive" effects of ambient light, particularly the short visible and U-V light which carry relatively higher energy. This fact is particularly important to aphakes and pseudophakes who have lost significant

protection from short visible and U-V radiation with the extraction of their natural lens. Ocular conditions which enhance photophobia and sensitivity to glare such as aniridia, albanism, corneal dystrophies and cataracts are purported to be managed well with CPF lenses since these lenses do decrease the intensity of a light or glare source as well as eliminate the shorter wavelengths which are scattered to a greater extent by the ocular media.

Based upon the above arguments CPF lenses are now used extensively in managing many low vision patients. Research on the use of the CPF lenses in low vision patients has concentrated primarily on the CPF 550. Very little data has been gathered on the CPF 511 and the CPF 527 to date. Upon review of the literature several effects of the CPF 550 lens are apparent: 1) CPF 550 lenses improve visual acuity, both subjectively and objectively, under natural lighting and under glare conditions (2)(4)(6)(7). 2) CPF 550 lenses increase eye comfort (2). 3) they decrease dark adaptation time (4)(6). 4) they increase depth perception (6). 5) they decrease color discrimination abilities (4)(6), and finally, 6) CPF do not show a significant improvement in contrast sensitivity (4).

Based upon the previously stated literature findings it was decided to investigate three areas with CPF lenses, namely, visual acuity, color discrimination ability and contrast sensitivity. It is believed that this study will further validate literature findings in these areas, as well as extend these findings to the CPF 511 and CPF 527. Additionally, the study will establish normative data for the CPF lenses which will serve as a data base for further investigation of low vision patients with these lenses.

PROCEDURES

CPF lenses were investigated in three areas: visual acuity, color discrimination ability and contrast sensitivity. A total of six subjects were tested in each of the above areas. Subjects were free from any ocular pathology and had visual acuities of 20/15 O.U. best corrected as measured with a reduced

snellen chart. In each area of investigation subjects were tested under four conditions: 1) without CPF lenses (control), 2) with the CPF 511, 3) with the CPF 527, and 4) with the CPF 550. Subjects were tested under binocular conditions and the order of presentation of CPF lenses and the control was always random. All results were compared to the control and analyzed by the Wilcoxon Ranked Sign Test for statistical significance.

Color Discrimination Ability

Color discrimination ability was assessed by using the Farnsworth-Munsell 100-Hue Test. Standard testing prodedures were used including illuminant C. Results of the 100-Hue test for each individual subject were used to compile a mean graph for each of the four testing conditions. Color discrimination ability was further analyzed by computing mean error scores. A total error score as well as error scores for each tray of color caps used in the test were computed for each of the four testing conditions.

Visual Acuity

Visual acuity was measured with a psychometric slide series using the Landolt C. Visual acuities for each subject were recorded from which mean acuities for each of the four testing conditions were computed.

Contrast Sensitivity

Contrast sensitivity was evaluated with both stationary and moving gratings. In both cases threshold values were determined by increasing the contrast on the video monitor until the gratings were first visible. All settings were made going from non-seeing to seeing. Contrast sensitivity values for each subject and frequency were recorded. The mean values for each frequency were calculated and these values were used to plot the CSF for each of the four testing conditions.

Stationary Gratings - Test Conditions
Instrument - Optronix Series 200 Vision Tester
Frequencies (c/d) - .5, 1, 3, 6, 11.4, 22.8
Test distance - 3 m
Ambient lighting - moderate incandescent

Moving Gratings - Test Conditions
Instrument - Cadwell CTS 5000
Velocity - 10 degrees/second
Frequencies (c/d) - .78, 1.56, 2.08, 3.12, 4.16, 8.32, 12.4
Test distance - 60 inches
Ambient lighting - moderate incandescent

RESULTS and DISCUSSION

Color Discrimination Ability

As earlier mentioned, color discrimination ability was analyzed using the Farnsworth-Munsell 100-Hue Test. Objective assessment of the test was accomplished by two methods: 1) drawing standard 100-Hue graphs using mean values and 2) calculating mean error scores for both the entire test and for each individual tray of color caps.

The analysis of color discrimination ability by standard methods is summarized in Charts 1-4. By comparing each of the graphs of the CPF lenses to the control (no lenses) it is easily seen that CPF lenses do have a marked effect upon color vision. This effect is not expressed as a typical tritan or deutan defect but appears as a defect across the visible spectrum or as a combination of both a deutan and tritan anomaly. This decrease in color vision may be related to the spectral cutoff properties of the CPF lenses and the spectral sensitivity of the blue, green and red cones. Since all CPF lenses stop transmission of short visible light they effectively eliminate a blue cone response and should produce a tritan defect. However, the spectral cutoff point of each of the lenses is high enough to influence the green cone response as well, with the CPF 550 having the greatest impact. Thus a progressive tritan-deutan color defect should be expected as one moves from the CPF 511 to the CPF 550. This progressive defect is apparent when comparing the graph of the CPF 511 lens (Chart 2) which suggests a vertical axis indicating a tritan defect, to the graph of the CPF 550 (Chart 4) which exhibits no particular orientation.

Error scores for the 100-Hue test are summarized in Fig. 1-5. Inspection reveals a significant difference in error scores in each graph when comparing the

control to any of the CPF lenses. This difference is statistically significant down to the .001 confidence level. Fig. 2-5 show that the decrease in color discrimination ability is not confined to any specific wavelengths or trays of color caps. Also to be noted is the fact that on each graph of error scores the error score of the CPF 527 is less than the CPF 511 or CPF 550. This suggests that the CPF 527 decreases color discrimination ability the least when comparing the three CPF lenses.

Visual Acuity

Results of the psychometric testing of visual acuity using CPF lenses are summarized in Fig. 6. Although the graph shows that each of the CPF lenses decreases visual acuity the decreases are not statistically significant.

Contrast Sensitivity

Stationary Gratings: Results of contrast sensitivity with stationary gratings are summarized in Fig. 7. All the CPF lenses exhibit the typical umbrella-shaped curve of the CSF. The graph of each CPF lens appears to mirror the curve of the control until the higher frequencies are reached, at which point the CSF decreases. Statistical analysis of the CSF at each frequency tested reveals that at frequencies 11.4 c/d and 22.8 c/d the CSF of all CPF lenses is significantly different from that of the control. Since the higher frequencies of the CSF are related to visual acuity it appears that for normal individuals under the described testing conditions CPF lenses may actually decrease acuity.

Moving Gratings: Results of contrast sensitivity with moving gratings are summarized in Fig. 8. Unlike the curve of the CSF with stationary gratings the curve of the CSF with moving gratings does not show the typical umbrella shape. However, the graphs of all three CPF lenses do again appear to mirror the graph of the control until the higher frequencies are reached. Statistical analysis reveals a significant difference in contrast sensitivity at frequencies 4.16 c/d and 8.32 c/d for all three CPF lenses when they are compared to the control. It

is interesting to note that at the highest tested frequency, 11.4 c/d, no significant difference was found with any of the CPF lenses. Since the shape of the CSF with moving gratings is so drastically different from the normal CSF no inferences about the results should be made until further study is done in this area.

CONCLUSION

The results of this study reinforce the findings of other investigators that the CPF 550 significantly affects color vision (4)(6). The study also found that the decrease in color discrimination ability to be true for the CPF 511 and the CPF 527. Of the CPF lenses the CPF 527 seemed to have the least detrimental effect and the CPF 550 the most. This information should be of value to the low vision practitioner, particularly in his selection of the appropriate lens for use as a low vision aid and in his advising of the low vision patient in regard to potential color vision problems associated with the use of these lenses.

Unlike previously published information it was found that CPF lenses do not increase visual acuity (4)(6)(7). It should be noted, however, that in this study low vision patients were not tested and testing conditions were not the same as the natural environment of the low vision patient. It is therefore prudent to reserve judgment until further investigation is completed in this area.

Contrast sensitivity is influenced by CPF lenses. These lenses decrease the CSF at higher frequencies which indicates that CPF lenses may actually decrease visual acuity. This information is contrary to reports which state that CPF lenses cause no change in the CSF and that CPF lenses do subjectively increase contrast (4)(6). It should be noted, however, that in both these studies low vision patients were tested. Additionally, the testing conditions used in this investigation are very much different from the color-filled natural environment of the low vision patient upon which their subjective response of increased contrast perception with the CPF 550 was made.

In closing, this study has reevaluated existing information on the CPF 550 and established new information on the effects of the CPF 511 and CPF 527 on various aspects of visual performance. Additionally, the study has provided normative data on all CPF lenses presently in use. It is hoped that the results of this study promote further inquiry into the use of CPF lenses with the eventual outcome of being able to more fully meet the needs of the low vision patient.

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Chart 1: A graph of the Farnsworth-Munsell 100-Hue Test-
no lenses (control)

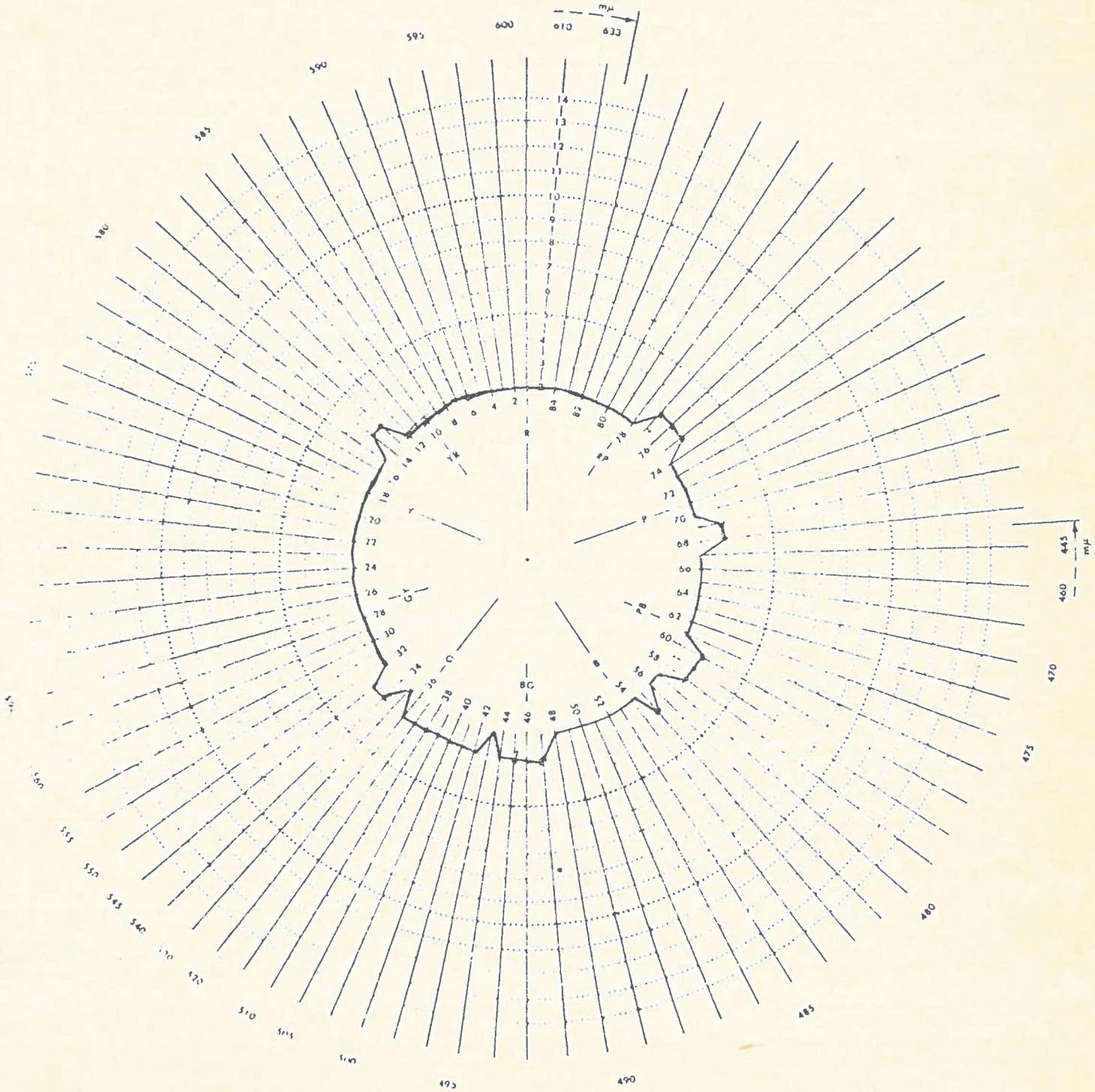


Chart 2: A graph of the Farnsworth-Munsell 100-Hue Test-
CPF 511 lenses

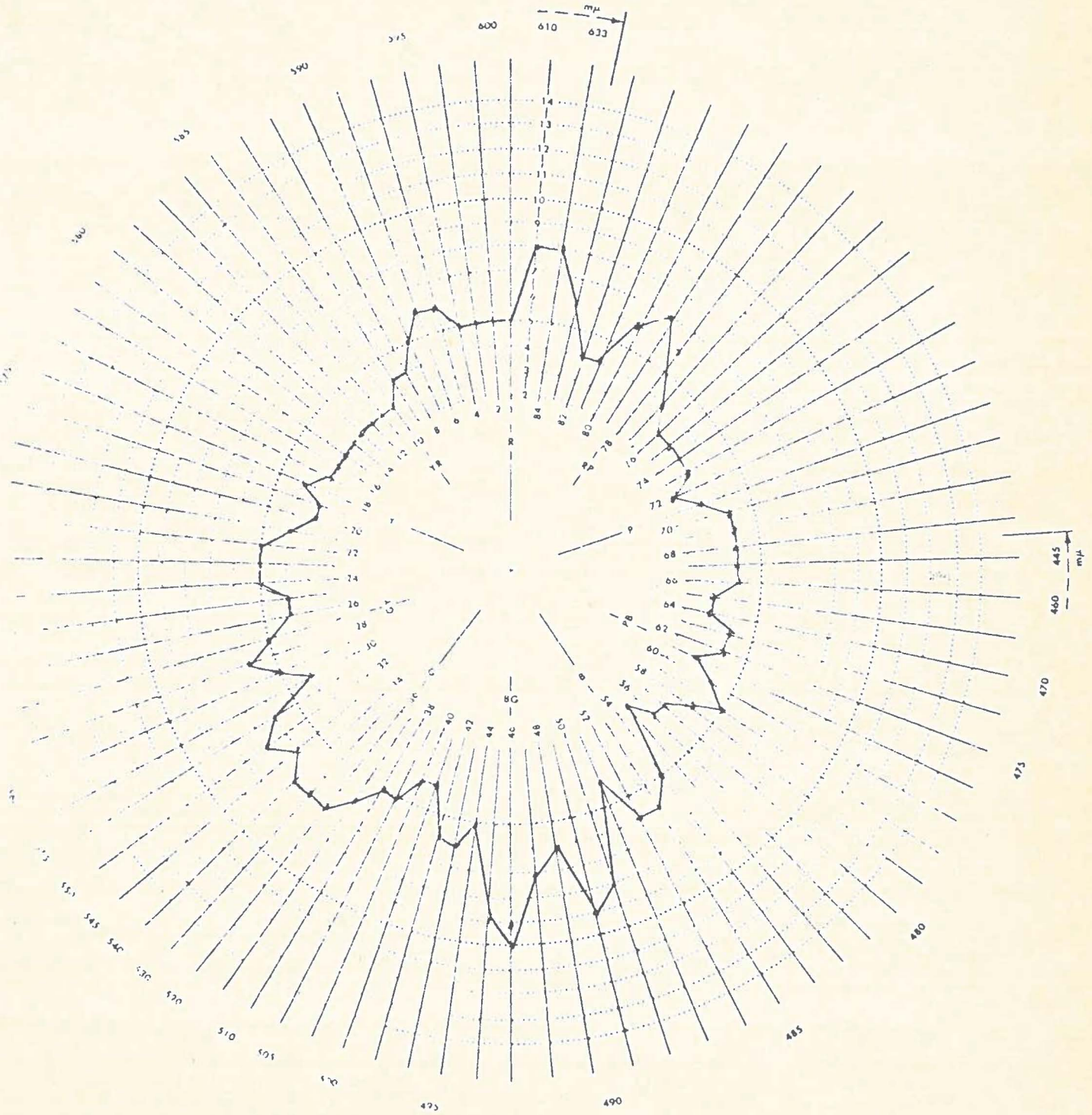


Chart 3: A graph of the Farnsworth-Munsell 100-Hue Test-
CPF 527 lenses

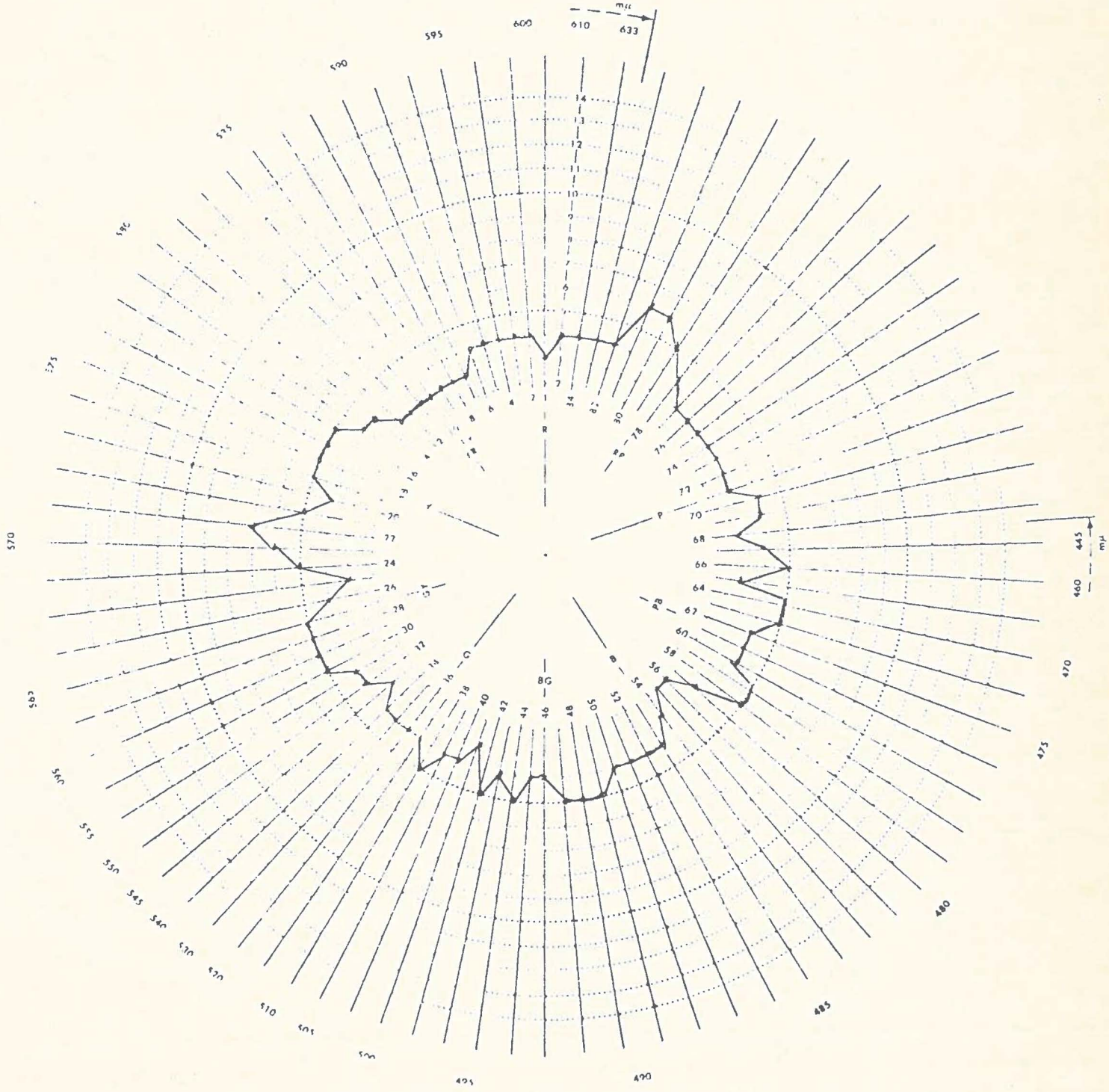
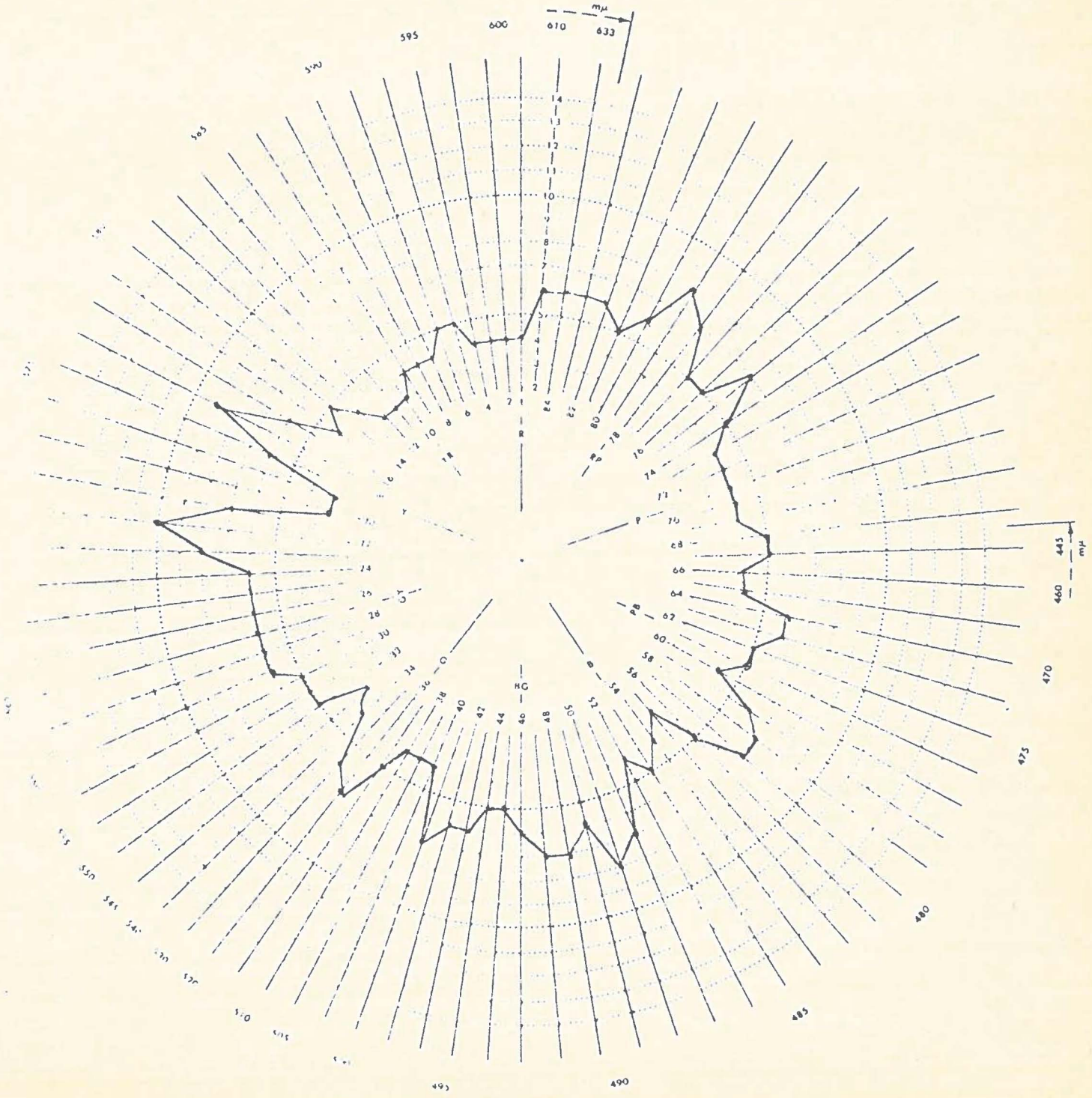


Chart 4: A graph of the Farnsworth-Munsell 100-Hue Test-
CPF 550 lenses



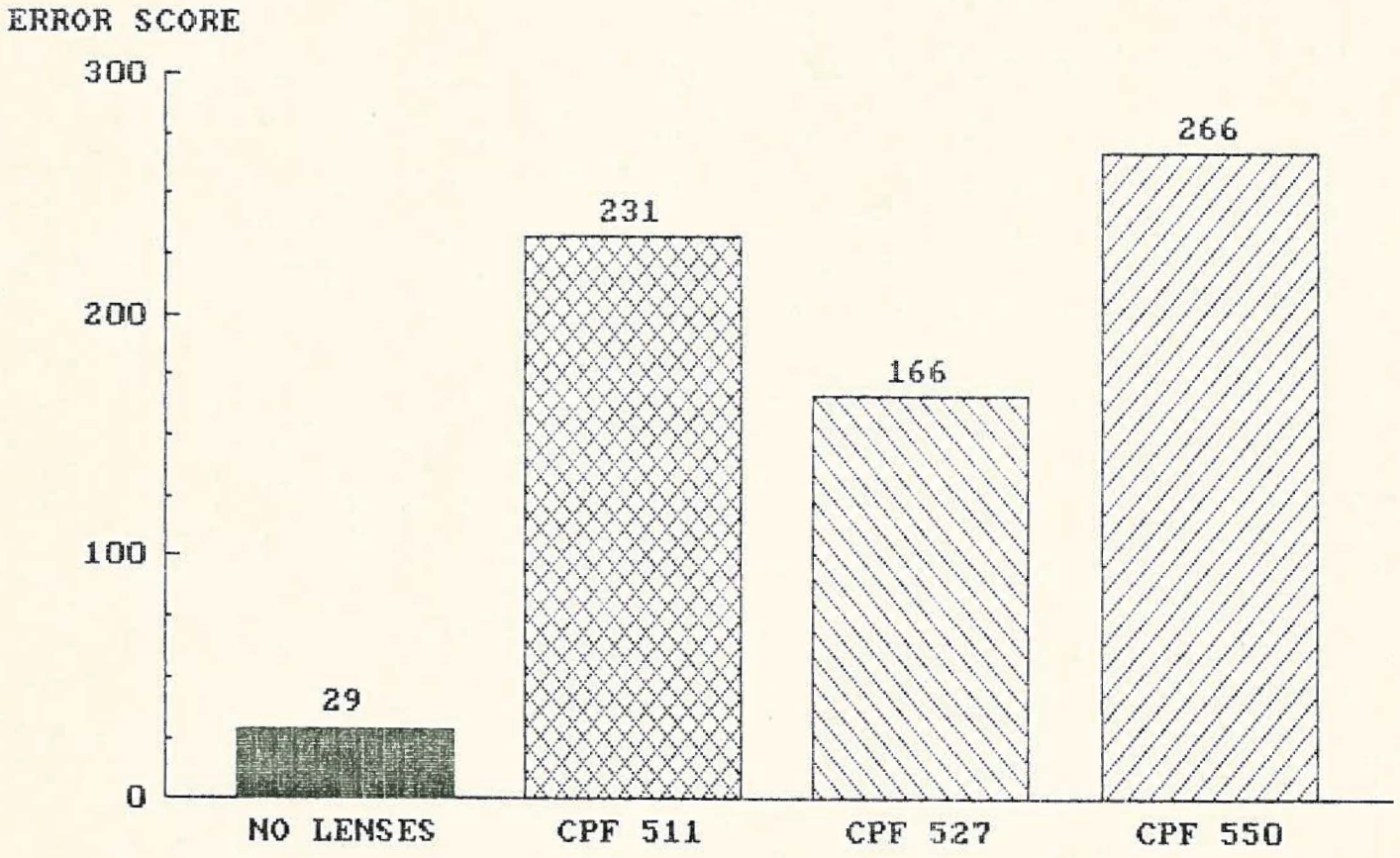


Fig. 1 A comparison of the total error scores for the Farnsworth-Munsell 100-Hue Test

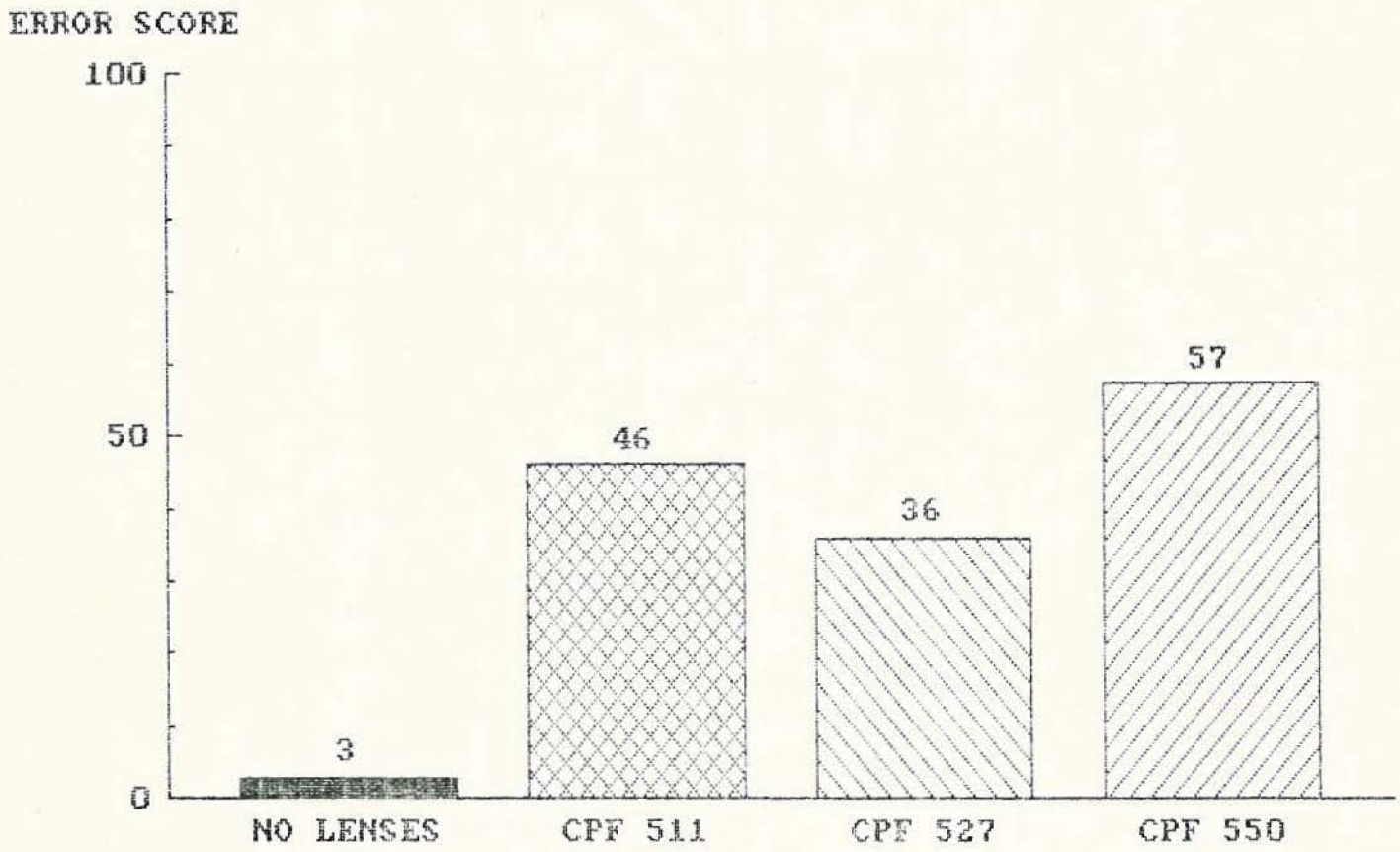


Fig. 2 A comparison of the error scores for the values 85-21 (572-610nm) of the Farnsworth-Munsell 100-Hue Test

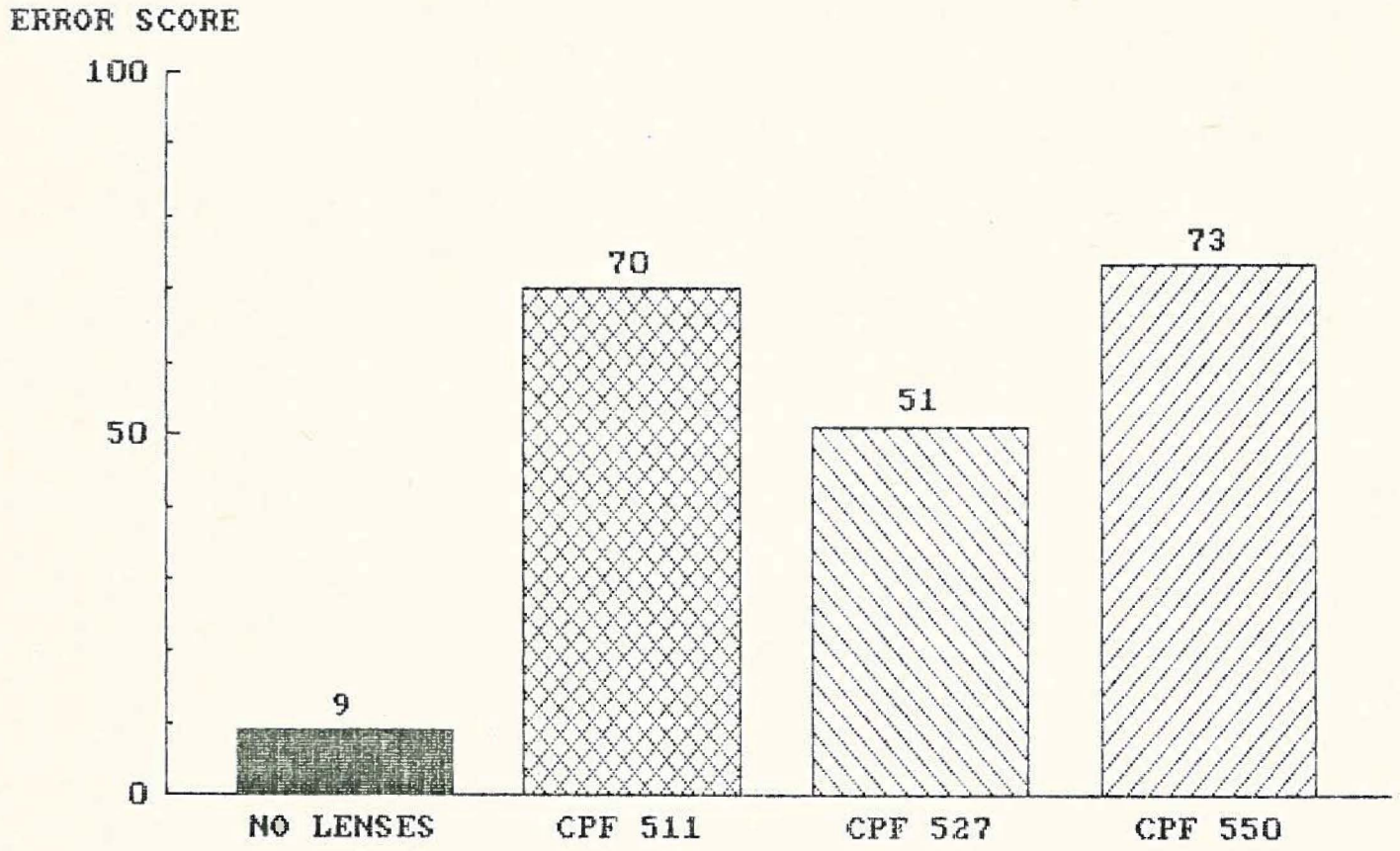


Fig. 3 A comparison of the error scores for values 22-42 (571-498) of the Farnsworth-Munsell 100-Hue Test

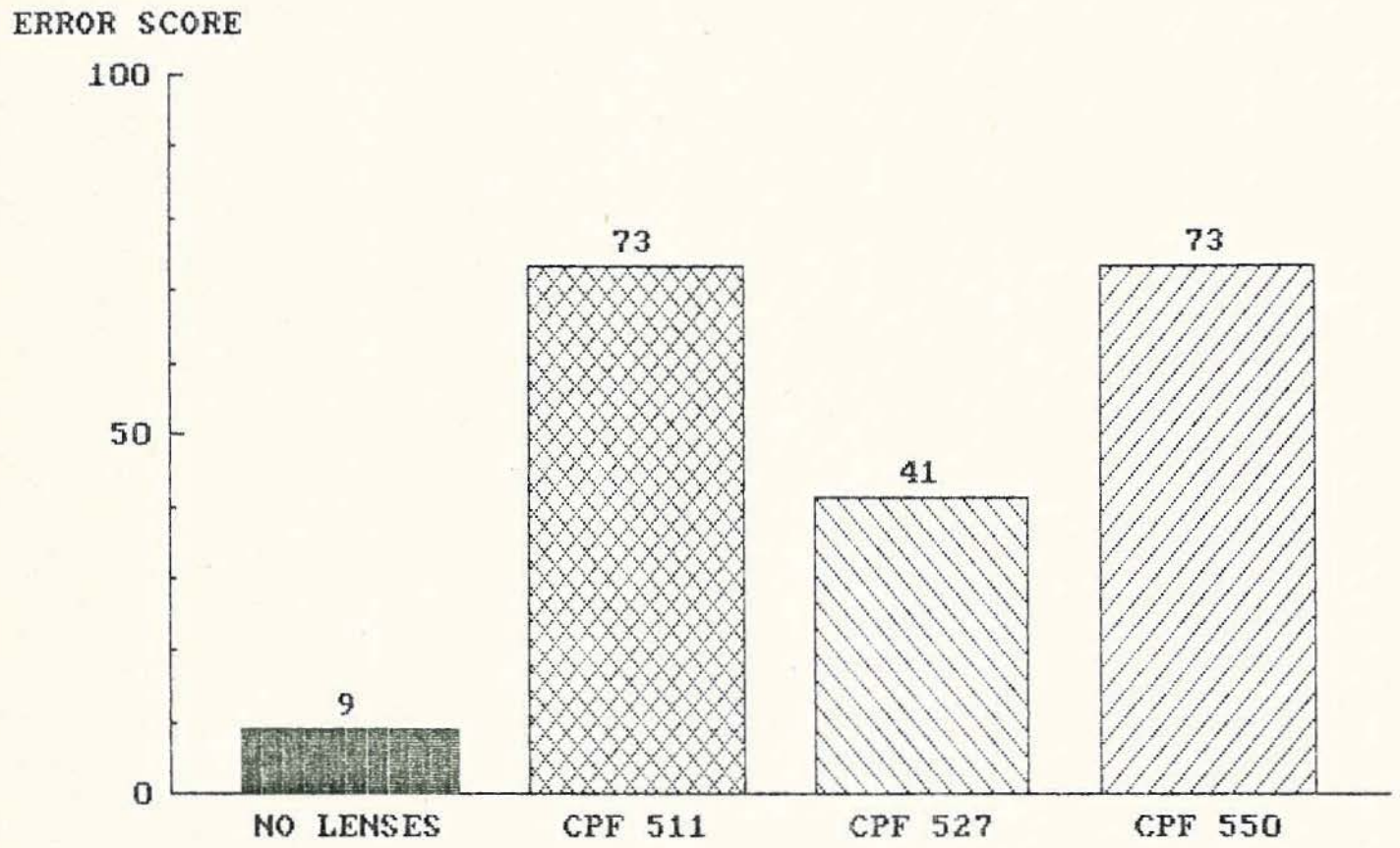


Fig. 4 A comparison of the error scores for values 43-63 (497-472) of the Farnsworth-Munsell 100-Hue Test

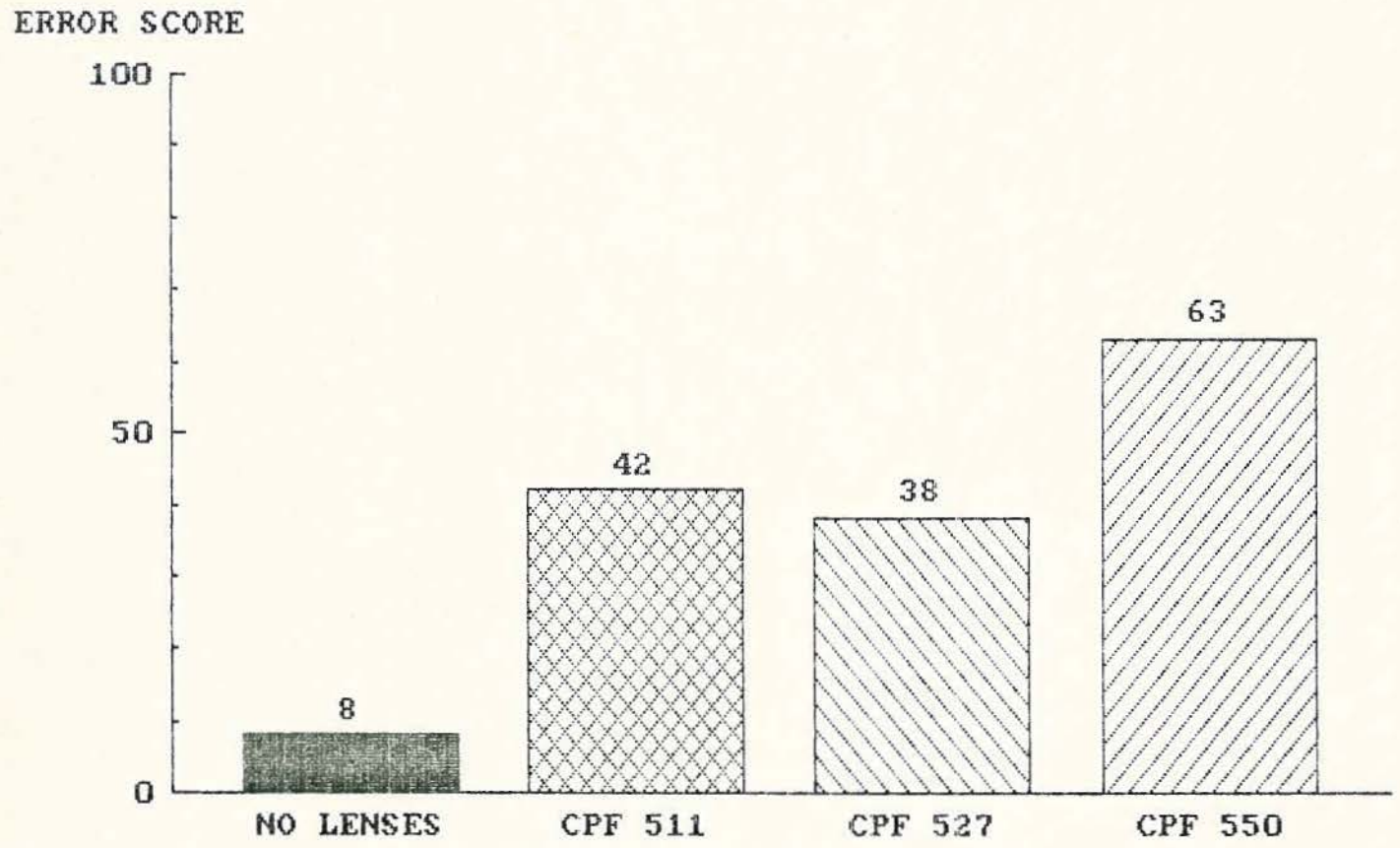


Fig. 5 A comparison of the error scores for values 64-84 of the Farnsworth-Munsell 100-Hue Test

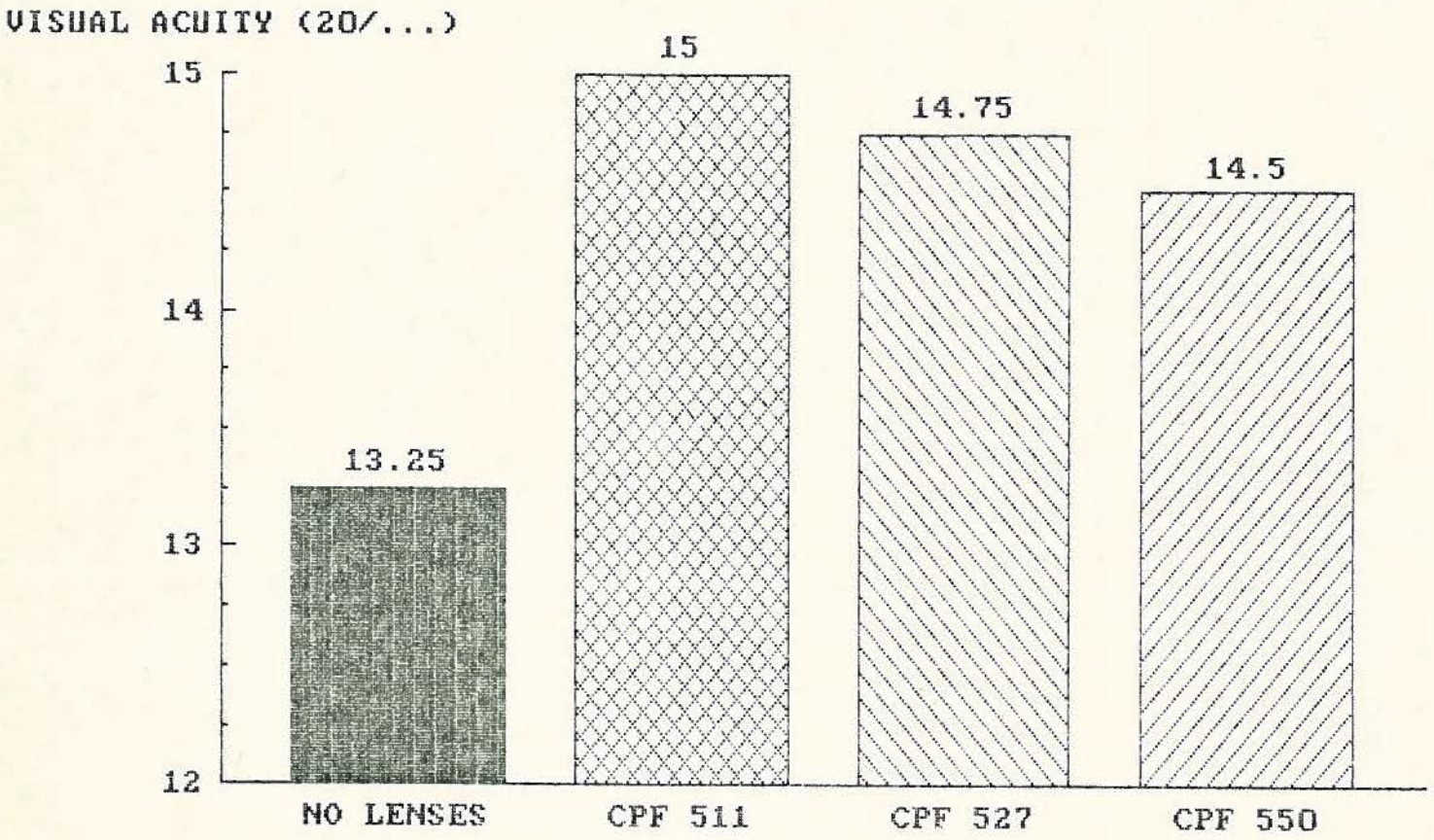


Fig. 6 Psychometric visual acuity with CPF lenses

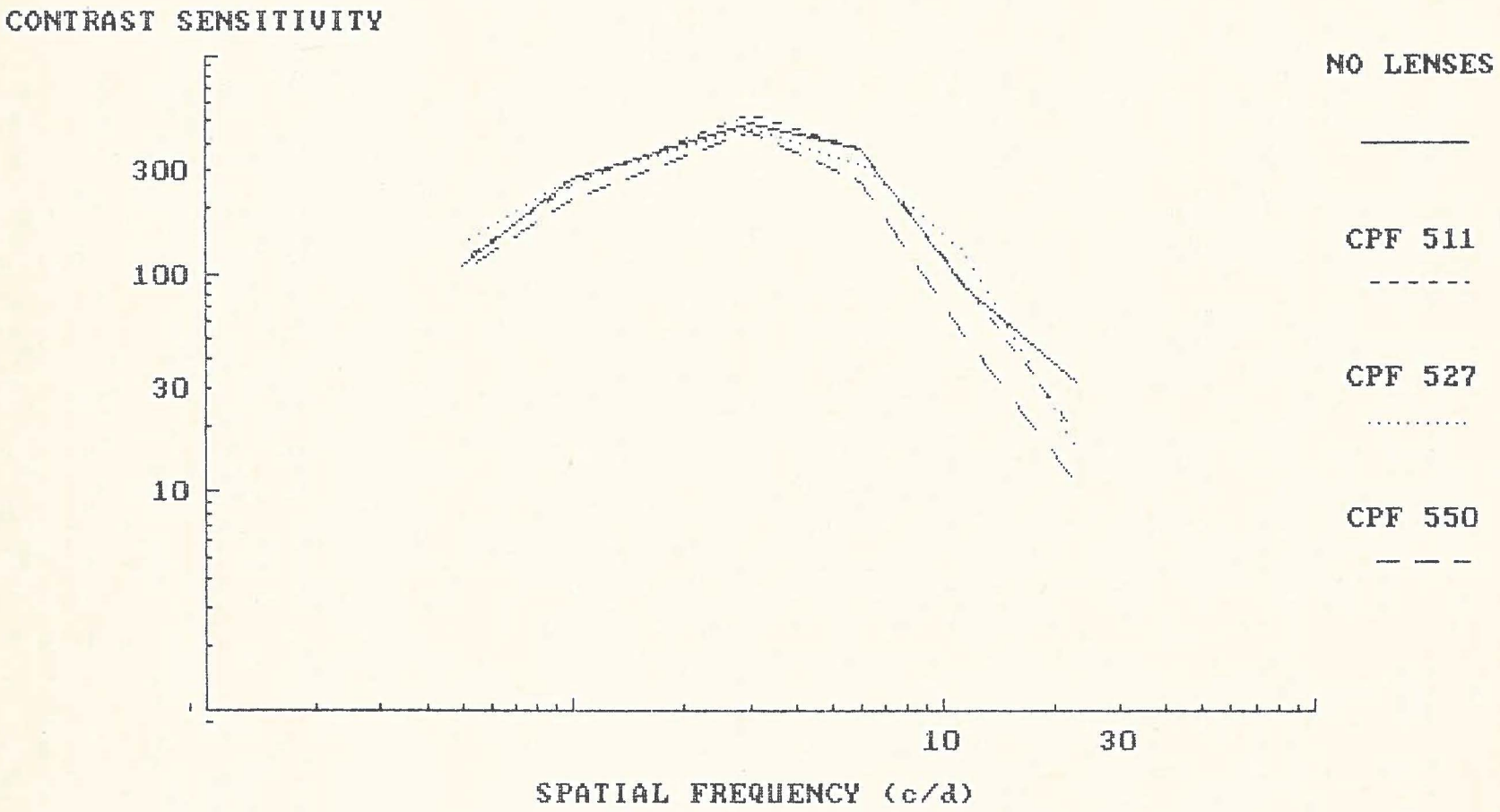


Fig. 7 Contrast Sensitivity with CPF lenses:
Stionary Gratings

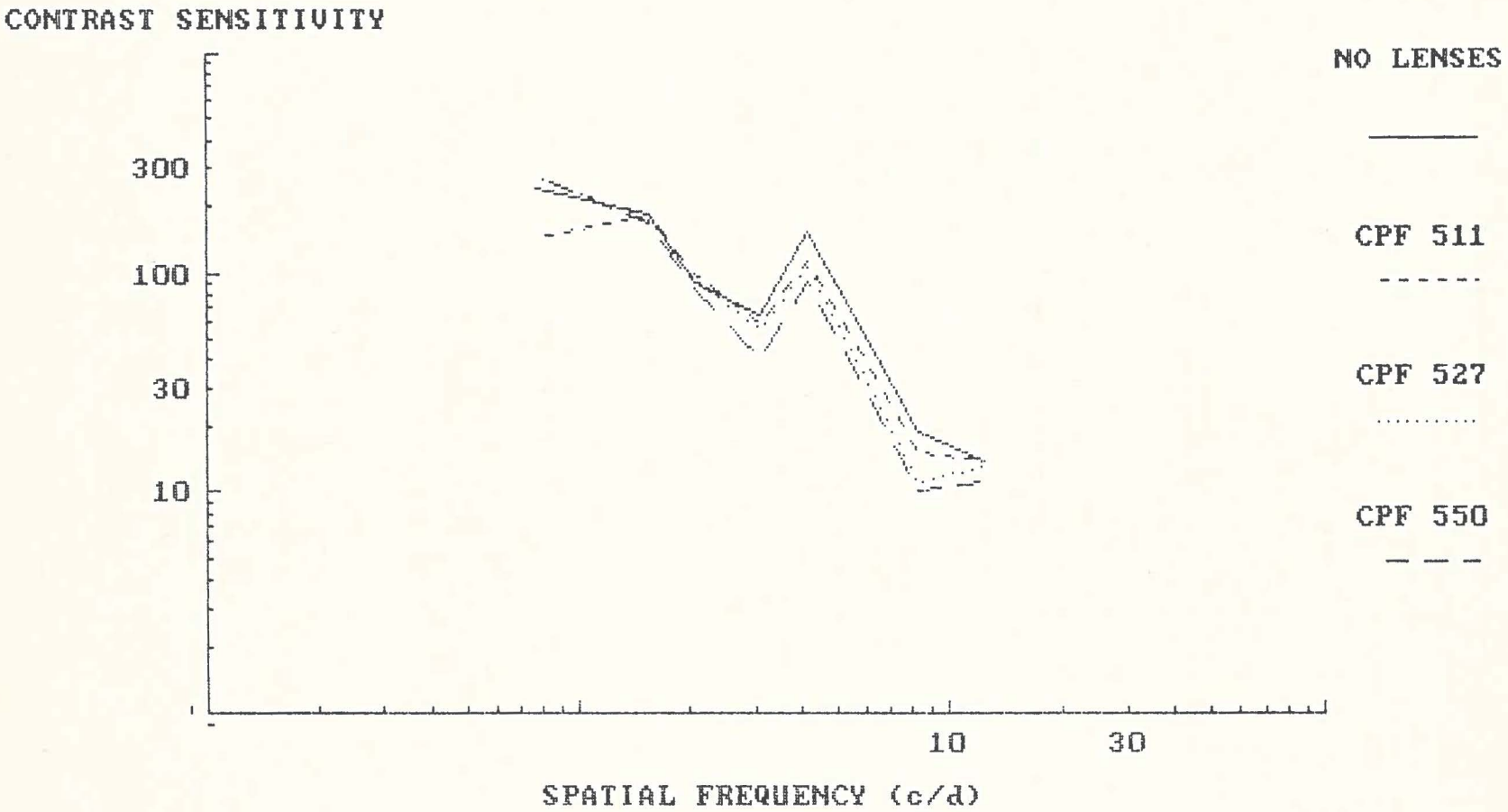


Fig. 8 Contrast Sensitivity with CPF lenses:
Moving Gratings (10 degrees/sec)