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An investigation into the effects of axis orientation on the binocular cross cylinder

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Abstract
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An Investigation into the Effects of Axis Orientation on the Binocular Cross Cylinder

by

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S.R.B.

G.H.I.

INTRODUCTION

The cross cylinder lens has long been used in clinical and research-oriented applications. Its use was either for the subjective determination of the magnitude and direction of the cylindircal component of a spectacle correction or for the analysis of accommodative performance, particularly with regard to the changes in accommodation in monocular versus binocular conditions. The theory that surrounds the latter use assumes that since a true focus cannot be placed on the retina the accommodation will relax an amount free of convergence or an amount equal to the excess demand, if any, on accommodation. The relation would place both foci behind the retina and the addition of plus lenses would then restore the circle of least confusion on the retina, marking the critical measuring point. It is with this latter use that we concerned ourselves.

Throughout our somewhat abbreviated clinical experience there has been some discussions among students as to the 'correct' or 'best' technique to use in the performance of the associated cross cylinder test (Optometric Extension Program #14B). The factor that was questioned related to target orientation. Generally, two different ones were used by the various students-- one with the cross-grid lines at 90° and 180°, and the second with the lines at 45° and 135°. Proponents of each group seemed to get satisfactory results with their respective target orientations and had rather definite dislike for the one they had chosen not to use. Our examination of the literature indicated that no studies spoke directly to this question. It was this in mind that we instigated our investigation, attempting to discover any quantitative or qualitative differences in response to cross-grid targets at three different orientations, namely, 45^{o} - 135^{o} , 67.5^{o} - 157.5^{o} , and 90^{o} - 180^{o} . The 67.5^{o} - 157.5^{o} target orientation was used to determine whether there was a systematic variation in the cross cylinder findings as the cross-grid lines were rotated from the oblique position toward the vertical- horizontal configuration.

PROCEDURE

Thirty-eight male students and one female student from the college of optometry were used in this study. The instrument used was the Bausch and Lomb Green's refractor, using a cross cylinder magnitude of $\pm$ .50 diopters. All testing was done at forty centimeters with the refractor adjusted according to the near-point inter-pupillary distance. Illumination was controlled and constant at eight footcandles, as measured at the target plane by the General Electric type 213 footcandle meter.

Prior to the cross cylinder investigation that we were undertaking each subject was examined for the presence of any astigmatism and/or anisometropia. The Pratt near-cylinder test was utilized in making the astigmatism determination as follows.

The control lens was the recovery lens of a monocular relative negative accommodation test. The subject was presented a 90° - 180° cross grid test chart and asked which, if either, group of lines appeared darker or more distinct. The minus cylinder axis was placed parallel to the darkest line and cylinder was added until both sets of lines appeared equally dark. A 45° - 135° cross-grid chart was then presented with the subject again responding as to whether either group of lines was darker or more distinct. If so, the minus cylinder axis was rotated until both sets appeared equally dark. The 90° - 180° chart was again presented to verify the amount of cylinder present. If one group appeared darker the cylinder magnitude was either increased or decreased to create equality. This procedure was contined until both sets of lines in each chart were subjectively equal. This was repeated for both eyes. The cylindrical correction was then noted, and left in the phoropter for the second phase of preliminary testing.

Anisometropia was determined, or measured, through the use of monocular cross cylinder tests at forty centimeters using grids of lines in the 90° - 180° direction as well as the 45° 135° orientation. Determinations were made first using an (increased) plus pre-set with red (minus) axis at 90° and then with the red axis at 180°. This was then repeated using the 45° - 135° chart with the red axis at each position. Thus, there were four measurements for each eye using a plus pre-set, followed by four determinations for each eye using a minus pre-set. These eight pairs of findings were then compared to one another to note the magnitude and direction of any anisometropia present. (Plus pre-set red axis 90° was compared for left and right eyes; plus pre-set red axis 180° for left and right eyes, etc.) Thus, eight separate pairs of findings were utilized in determining the presence, amount and direction of any anisometropia. The average anisometropia was then combined with the cylindrical prescription determined above as a control for the binocular (associated) cross cylinder testing that was the purpose of our investigation.

Prior to the binocular testing the subject fixated a reduced Snellen test chart with the previously determined cylinder and anisometropia in place and the spheres at the negative relative accommodation recovery level.

The three different target orientations used were presented to the various subjects in random order to eliminate any systematic error that might arise on the basis of presentation order. In this segment of the testing, as in the preliminary portion, both plus and minus lens presets were used, with the plus being used first in all cases. It was theorized that this precedure would allow or promote less flucuation in accommodation than would a procedure in which the sequence alternated from plus pre-sets to minus pre-sets, to plus, etc. Therefore, the plus pre-sets for axes 45° - 135° , 67.5°- 157.5° , and 90° - 180° , with the red axis in each meridian, were run prior to the minus pre-set group. The dioptric value of the reversal point for each of the twelve conditions (see recording form-figure #1) was recorded and a statistical analysis performed. The results of that analysis, and the discussion of the implications of the results, follows.

DATA

As previously stated, the original purpose of the project was to determine if there is any significant difference in cross cylinder findings taken at axes 90°-180°, 45° - 135°, and 67.5° 157.5°. The data obtained at these axes was compared employing several statistical evaluations.

Since the data was obtained and recorded in plus and minus pre-set form, it was decided to analyze the plus and minus pre-set data separately. The two sets of data were then collated in order that an analysis of the combined data could be ascertained.

A mean and standard deviation was computed for each axis pair in both the plus and minus pre-set data as well as the combined data. An analysis of variance was then computed between each possible set of axis pairs in the plus pre-set, minus pre-set, and combined data. There were three axis pairs in each pre-set and three in the combined data. This made a total of nine correlation coefficients. The correlation coefficients, however, only tells if the scores are consistantly predictable from each other (how close do they lie to the line representing their trend.) The correlation coefficient does not reveal if the scores are similar to each other in magnitude.

To determine dimilarity in magnitude, an F ratio was performed on the data. This ratio compares the data from an individual sample with the data from the combined sample. This F ratio was determined for the plus and minus pre-set data as well as the combined data.

Plus Preset Data

Subject Number	Red Axis at: 90	180	45	135	67	157
1	1.75	1.75	1.50	1.75	1.75	1.75
2	2.00	2.00	1.75	1.75	2.00	1.75
3	2.50	2.75	2.50	2.00	2.50	2.50
4	2.00	2.50	2.75	2.25	2.00	1.75
5	-2.25	-2.00	-2.25	-2.25	-2.25	-2.00
6	2.00	1.75	1.50	1.25	2.00	1.50
7	-3.50	-3.50	-3.50	-3.25	-3.50	-3.50
8	1.00	1.00	1.00	1.00	1.00	0.75
9	1.25	1.00	1.00	1.00	1.25	1.00
10	-2.50	-3.00	-3.00	-3.50	-3.25	-3.50
11	0.00	0.00	-0.25	-0.25	0.25	-0.50
12	-1.00	-0.75	-1.00	-1.00	-1.00	-1.00
13	1.50	1.50	1.50	1.25	1.25	1.00
14	2.00	2.00	2.00	2.00	2.00	2.00
15	2.00	1.75	1.50	1.75	2.00	1.75
16	-1.00	-1.00	-0.75	-0.50	-0.75	-0.75
17	2.00	2.25	2.25	2.00	2.00	2.00
18	1.50	1.50	1.00	1.25	1.50	1.25
19	1.25	1.25	1.25	1.25	0.50	1.25
20	0.00	0.25	0.00	0.00	0.25	0.00
21	1.75	1.75	1.50	1.50	1.75	1.75
22	-5.50	-4.75	-5.50	-5.50	-4.75	-4.75
23	-5.50	-5.00	-5.25	-5.00	-5.25	-5.25
24	-1.00	-0.50	-0.50	-0.25	0.00	0.00
25	2.00	2.00	2.00	2.00	2.00	1.75
26	-2.00	-1.75	-1.75	-1.50	-1.25	-1.50
27	1.75	2.00	1.75	1.75	2.25	2.00
28	0.75	0.50	0.75	0.50	0.75	0.50
29	2.00	2.00	1.75	2.00	1.75	2.00
30	1.00	1.00	1.00	1.25	1.25	1.25
31	0.25	0.25	0.50	0.50	0.50	0.50
32	-0.25	0.00	-0.25	0.00	-0.25	-0.25
33	1.00	1.00	0.75	0.75	1.00	0.75
34	0.25	0.00	0.00	0.00	0.00	-0.25
35	0.25	-0.25	-0.25	0.00	-0.25	-0.25
36	0.00	0.25	0.25	0.00	0.00	0.00
37	-2.50	-2.50	-2.50	-2.50	-2.25	-2.50
38	-0.25	-0.25	-0.25	-0.25	0.00	-0.25
39	1.75	2.00	2.25	2.25	2.50	2.25

Minus Preset Data

Subject Number	Red Axis at: 90	180	45	135	67	157
1	1.75	1.75	1.25	1.75	2.00	1.75
2	1.50	2.25	2.00	1.75	2.25	1.75
3	2.25	2.25	2.50	2.25	2.75	2.75
4	2.00	2.00	2.25	2.25	2.00	1.75
5	-2.25	-2.50	-2.25	-2.25	-2.00	-2.00
6	2.00	1.50	1.50	1.50	2.00	1.50
7	-3.75	-3.75	-4.00	-3.75	-3.75	-3.50
8	0.50	0.50	0.50	0.50	1.00	1.25
9	1.00	0.75	1.25	1.00	1.25	1.00
10	-4.25	-4.00	-5.25	-4.75	-3.75	-4.25
11	-0.75	-0.50	-0.75	-0.50	-0.50	-0.50
12	-1.50	-1.00	-1.00	-1.00	-0.75	-1.25
13	0.50	0.25	0.75	0.50	1.00	0.75
14	2.25	2.25	2.25	2.50	2.25	2.00
15	1.75	2.00	2.00	1.75	2.00	2.00
16	-1.50	-1.50	-1.25	-1.25	-1.00	-1.00
17	2.25	2.25	2.25	2.25	2.25	2.25
18	0.50	0.75	0.25	0.50	0.75	0.50
19	0.50	0.25	0.25	0.75	0.75	0.75
20	0.25	0.50	0.75	0.50	0.50	0.50
21	1.50	1.50	1.75	1.50	1.75	2.00
22	-4.25	-5.00	-5.00	-4.50	-4.75	-4.75
23	-6.25	-6.00	-5.50	-5.50	-5.25	-5.25
24	-0.50	-0.50	-0.50	-0.25	-0.25	0.00
25	1.75	2.00	1.75	2.00	1.75	1.75
26	-2.00	-2.00	-2.00	-2.00	-1.75	-1.75
27	1.50	1.75	1.75	1.75	2.00	2.00
28	0.50	0.75	0.75	0.50	0.75	0.75
29	1.25	2.00	1.75	1.50	1.75	2.00
30	1.25	1.50	1.25	1.25	1.50	1.25
31	0.00	0.25	0.25	0.25	0.75	0.75
32	-0.75	-0.50	-0.25	0.00	-0.25	0.00
33	1.00	1.25	0.75	1.25	1.25	1.25
34	-0.25	-0.50	-0.25	0.00	0.00	0.00
35	-0.75	-0.50	-0.25	-0.50	-0.25	0.00
36	0.25	-0.25	-0.25	-0.25	0.00	0.25
37	-3.00	-3.25	-3.00	-3.00	-2.50	-2.75
38	-0.25	-0.25	-0.25	-0.25	0.00	0.00
39	1.50	1.75	2.00	1.75	2.25	2.50

CALCULATED DATA

PLUS PRE-SET

AXIS	90-180	45-135	67-157
MEAN	.246795	.169872	.230769
STD. DEV.	1.98799	1.96344	1.94893

CORRELATION COEFFICIENTS

90-180/45-135	90-180/67-157	45-135/67-157
.978157	.974270	.977741

F RATIO .33210

MINUS PRE-SET

AXIS	90-180	45-135	67-157
MEAN	-.0320513	.0192388	.227564
STD. DEV.	2.08362	2.09117	2.02628

CORRELATION COEFFICIENTS

90-180/45-135	90-180/67-157	45-135/67-157
.974979	.975899	.977754

F RATIO .345068

Calculated Data

Combined Plus and Minus Preset

Axis	90-180	45-135	67-157
Mean	.107372	.0945513	.229167
Std. Deviation	2.03460	2.02312	1.98156

Correlation Coefficients

90-180/45-135	90-180/67-157	45-135/67-157
.982328	.979174	.983365

F Ratio

.212460

ANALYSES OF DATA

For each set of data a mean and standard deviation were calculated. These are fairly common statistics, therefore, no explanation will be made other than to encourage the reader to examine this data and be cognizant of the small range of the means and the consistancy of the standard deviations. It might be of interest, however, to note the slightly larger standard deviation of the minus pre-set data. Although beyond the scope of this paper, it is conjectured by the authors that this might be due to the fluctuation of the accommodative system when pre-set with minus lenses. This might lead to more variation in response and hence the greater standard deviation.

The correlation coefficients between sets of data indicate a high correlation. Although a perfect correlation (1.0 is perfect), is extremely rare, especially in a biological system, .97 and above are indicative of excellant correlation.

As stated in the introduction, it is our contention that there is no significant difference among a large population when cross cylinder measurements are made at differing axes. Of course, individual difference will be noted with certain subjects, but no significant difference should be noted when using a large population.

In order to understand the data more fully, a short explanation of the F test is necessary. According to Edwards,[1] the null hypothesis that is being tested is that the samples are random samples drawn from the same population with a mean $\overline{X}$. Forthurmore, if this is true, the mean square among samples estimates the same variance as the mean square within samples. Therefore, in order for there to be a significant difference, the ratio of the mean square among samples to the mean square within the sample must be greater than one. If the ratio is less than one, it can be assumed that the within and among samples do indeed arise from the same population. An examination of the data shows that all three F ratios are less than one.

Hence, the statistics indicate that not only does the data agree well among different pre-sets, it agrees well within pre-sets. There is a negligible (according to the previously explained statistical procedure) difference among the individual findings themselves. The null hypothesis, then, states that there is no significant difference between the 'within' and 'among' sets of data.

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[1]Allen L. Edwards, Statistical Methods (New York, Holt, Rinehart and Winston, Inc., Second Edition, 1967), pp. 264-65.

CONCLUSIONS

It is our conclusion, then, that the null hypothesis must be accepted. Therefore, the authors believe that there is no statistical significance as determined by the F ratio among cross cylinder measurements performed at differing axes.

The experimenters caution, however, that this results is obtained from a large population of subjects. Many subjects subjectively reported that they had more difficulty in making a response when the target was oriented at the 90°- 180° position than when it was oriented at either of the two oblique positions.

There have been numerous explanations concerning this phenomenon. Some have held that because humans live in an essentially vertical-horizontal world they become relatively sensitive to objects oriented in this manner as compared to objects oriented in oblique meridians. That is to say that the distinction between a vertical form and a horizontal form is more readily apparent than the distinction between two forms oriented at varying oblique positions. On this basis, then, we might suspect an unconscious biasing in either the vertical or horizontal directions.

Others have argued that since the great majority of astigmatism present in humans is either at axis 90° or axis 180° people have become less critical of their differences. Whatever the reasons, it was the authors' experience in performing this experiment and has been their experience in examining clinical patients that a sizable portion respond with less hesitation and greater sureness when the target is not oriented in the vertical-horizontal meridians.

DATA SHEET

Name________________ Date____ Age___ PD______

#21 monocular

OD________
OS________

Near Cylinder

OD____________
OS____________

#14A with cyl.

OD_____________
OS_____________

#14A (Plus pre-set)

Red 45	OD________	
	OS________	
Red 135	OD________	
	OS________	
Red 90	OD________	
	OS________	
Red 180	OD________	
	OS________	

#14B (Plus pre-set)

Red 90__________
Red 180__________
Red 45__________
Red 135__________
Red 67__________
Red 157__________

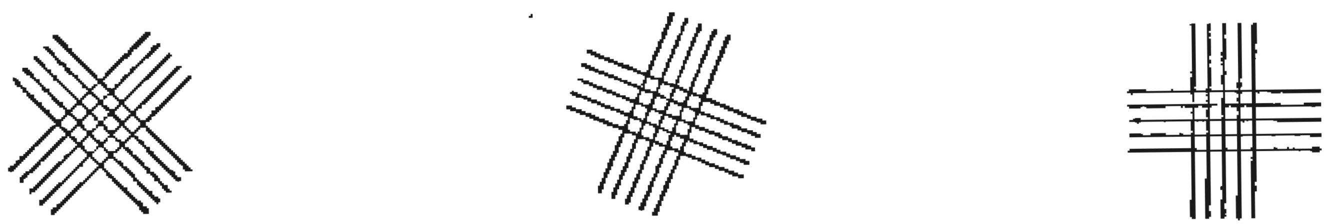
#14A (Minus Pre-set)

Red 45	OD_______	
	OS_______	
Red 135	OD_______	
	OS_______	
Red 90	OD_______	
	OS_______	
Red 180	OD_______	
	OS_______	

#14B (Minus Pre-set)

Red 90___________
Red 180___________
Red 45___________
Red 135___________
Red 67___________
Red 157___________

FIGURE #1



45°- 135° 67.5°- 157.5° 90° - 180°

FIGURE #2. Target orientations used in the study

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