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Richard Erenstone
Pacific University

James C. Fornes
Pacific University

John P. O'Connor
Pacific University

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OBJECTIVE:

Classically the cross-cylinder test has been used in Optometry to determine the posture of the accommodative system under various stimulus conditions. It is our purpose in this experiment to determine the relationship, in terms of accommodative posture, between the cross-cylinder test done at various real distances and the cross-cylinder test using prism to simulate the distance. It is felt that this relationship would be useful in the design of a clinically relevant and economically sound system of analysis.

METHOD:

The test of accommodative posture as determined with cross-cylinders was done in the standard way using plus .50 combined a minus 1.00 cross-cylinder as found on the Green's refractor. The axes were oriented in the 45^{o}, 135^{o} position and the standard P.U. near point cross grid target with the same axes was used for all 40cm tests. In order that a constant angular subtense of this image be maintained on the retina this target was reproduced photographically so as to subtend the same visual angle at all other test distances. This set of cross grid targets was obtained with the help of the Learning Resources Center at Pacific University. Targets were made for each of the following distances; 4M, 1M, 66.66cm, 40cm, 27.4cm. Illumination was held at a constant 20fc during all the tests,as measured with a G.E. light meter on the target surface. For the simulated distance findings, the amount of prism necessary to demand a convergence posture equal to each of the above distances was calculated and corrected for the vertex distance in the refractor. These data are found in Table #1.

Distance	Prism
27.4cm.	8.0 pd BO
40.0cm.	0 pd.
66.6cm.	7 pd. BI
1.00m.	10 pd BI
4.00m.	14 pd. BI

Table #1

The testing routine was as follows. Each subject was measured for the correct Pd. and seated behind the refractor without his R_x. The monocular to blurout and recovery was done which was followed by a determination of the astigmatic correction at 40cm. using the near cylinder technique. This was followed by a standard # 14A finding. The plus blurout and the #14A were used as a determination of the anisometropia. Following the #14A , the 4m. target was presented and the cross-cylinders were introduced before each eye. The subjects was then asked to tell which lines appeared " blackest and most distinct" , and plus was reduced to reversal. The amount of sphere less .25 diopters was recorded as the accommodative posture preset plus. The cross-cylinder was flipped and minus 1.50D below the plus preset posture was placed in the refractor and again the subject was asked which lines were the " blackest and most distinct ". Minus lenses were now reduced to reversal and this was recorded as minus preset.

The refractor lenses were now set at the #14A level plus one diopter, and the one meter target was presented. The cross-cylinder was again flipped and the sequence was begun and followed for each test distance. The results are found in the data section of this paper.

The simulated distance tests were done in similar manner as described above with the following exceptions. The target was always at 40 cm, distance and prism values from table #1 were introduced in the following sequence. In this case we began with a 14 BI plus preset and did all plus presets first and then did the minus preset 8BO and then did all minus preset findings. The cross-cylinder was flipped after each reversal. The results of this testing are found in the data section.

The test sequence was done with 22 subjects. All subjects were Optometry students, and all were considered to have normal binocular vision. The subjects ranged in age from 22 years to 30 years of age. The results were analyzed using the correlation coefficient and the T-test for related samples.

STATISTICS:

The data were analyzed in the following manner:

1. The plus and minus preset values were averaged for each subject for each distance under each condition. (see below)

2. The prism average was corrected to the dioptric vergence of the real distance plane of regard by adding or subtracting the calc ulated constant difference between 40 cm and the distance being simulated.

3. Using the plus preset at 4 m finding as a base line, the average distance finding and finding corrected prism finding were subtracted

from this value to give a "residue". These residual values were used in the statistical analysis.

Example:

J.B. - +4 m = +1.00 D

	+preset	-preset	average	corrected	residue
Distance = 26"	+1.75	+1.25	+1.50	-	,+.50
Prism = 7 BI	+2.75	+2.25	+2.50	+1.50	+.50

We investigated two questions with the statistics. First, how close was the average prism finding to the average distance finding for each distance with respect to their standard deviations. We took as our null hypothesis that there is no variation between real distance findings and prism simulated distance findings other than that which is due to sample selection and random variation. The confidence interval was established at .01. The following results were found:

Distance	t	Null Hypothesis	Difference Between Means
4 M	3.65	rejected	0.34 D
1 M	0.30	accepted	0.02 D
66.6 cm	0.40	accepted	0.03 D
40.0 cm	-3.11	rejected	0.22 D
27.4 cm	-1.61	accepted	0.16 D

These results indicate no significant difference between the real and simulated findings at 1 meter, 66,67 cm, and 27.4 cm. A significant difference is indicated at 40 cm and 4 meters. These differences will be discussed in the conclusion. A comparrison of the means of the residues has been illustrated in graphical form. (see figure 1).

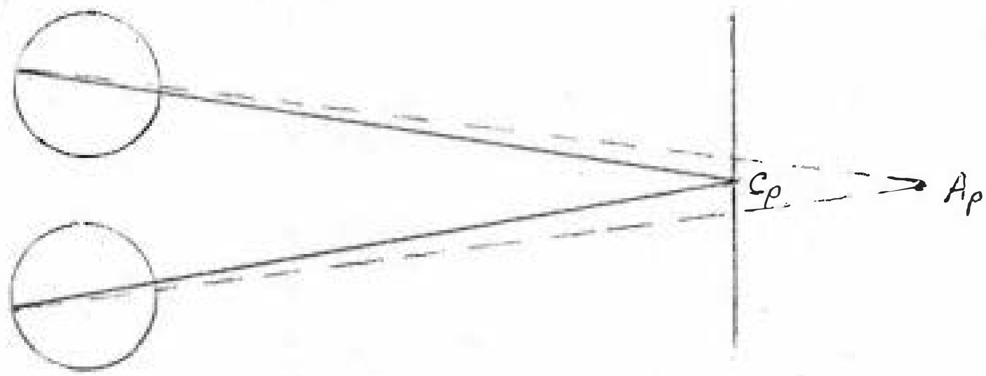
The second question was how well can the real distance finding be predicted from the prism findings or vice versa. For this, we again used the residue values referred to above. The product moment correlation coefficient was employed for this.

Distance	Correlation Coefficient
4 m	-0.13
1 m	-0.19
66.6 cm	0.38
40.0 cm	0.78
27.4 cm	0.80

The correlation coefficient reveals that you cannot make an exact prediction of a real distance from a simulated distance or vice versa with much success. This information is of almost no value, however, in light of the findings on the t-test. That test shows that for most distances, the difference between the real and simulated distance is insignificant. In light of this fact, the correlation coefficient for distances of 1 m, 66.67 cm, and 27.4 cm tells a value X cannot be well predicted by knowin a value Y, even though there is no significant difference between X and Y! Obviously, the value placed on this statistic should be minimal.

DISCUSSION AND CONCLUSION:

In order to discuss the results obtained in a logical manner, it is necessary to describe the difference between the two sets of findings in terms of testing techniques, physiological, and psychological variables. The real distance paradigm, a physiologic situation exists under the standard cross cylinder testing conditions in which the convergence posture(Cp) is assumed to be equal to the convergence stimulus(Cs) , which is in turn equal to the binocular vergence(Bv) as defined in meter angles or prism diopters. Also, the accommodative posture(Ap)(defined as the physical plane in space that is optically conjugate with the retina) is located at some distance from the plane of regard, the location being governed by a number of variables including the dioptric vergence(Dv) at the spectacle plane, the target characteristics, testing conditions, illumination, and the interaction between accommodation and convergence.(Figure 2)



It should be noted that in all the testing conditions described, the Cp is the independent variable and is assumed to be equal in all cases to the Cs and/or Bv. In the real distance paradigm, therefore, the Bv was varied by changing the physical location of the target, all other variables (target size, illumination, testing conditions, etc.) being held constant. In the simulated distance paradigm, the postural characteristics of the convergence system of each real distance was mimicked by the use of prism, the difference between the two methods therefore being that the physical location of the target was maintained at 40cm (i.e., the Dv is held constant in the latter approach).(Figure #3)

The Ap was then measured relative to the 40.0cm crossgrid plane. On the basis of the physiologic interaction between accommodation and convergence, it was proposed that this induced alteration in the Cp by the use of prism would affect the accommodative system such that the optical conjugacy of the eye would be postured in the same physical plane in space as it would when the convergence system was viewing a target at the real distance that the prisms had simulated.

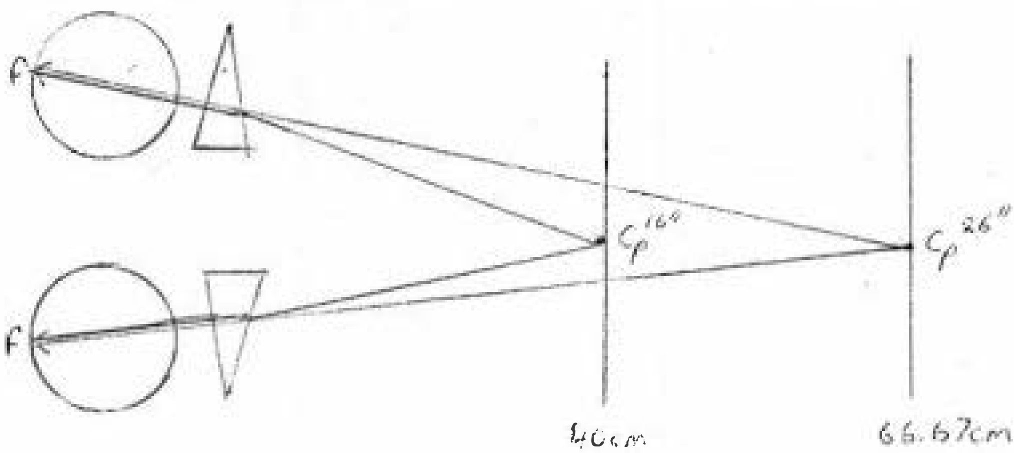


Figure #3- simulation of Cp for 66.67cm testing distance with actual physical target location at 40.0cm.

As a illustrated example, if a subject views a target at one meter the Bv is one meter angle (MA), and the Cp is at one MA (under conditions of single binocular vision). If a target is located at 40.0cm the Bv is 2.5 MAs and the Cp is 2.5 MAs . Now, if under the latter conditions 1.5 meter angles of BI prism is placed before the eyes (corrected for effectivity and neglecting fixation disparity and heterophoria), the eyes will diverge out by that magnitude and position themselves in the same angular orientation that would be present when viewing a target located at one meter. Since convergence and accommodation are physiologically related activities, the change in physical orientation of the eyes(and thus the change in neuralogical activity occuring in the extra ocular musculature) will produce a change in the physical optical conjugacy of the accommodative system (as a function of the effects the neurological activity of the extra-ocular musculature on the amount and direction of neurological activity in the ciliary and pupilomotor system as they relate to accommodative posture).

The results obtained in comparing these two methods of evaluating the postural characteristics of the visual system were positive. In terms of statistical analysis, the t-test for related samples showed that the null hypothesis was valid at the .01 confidence level for the 1m,66.67cm, and the 27.4cm distances. The t magnitude for the 40.0cm finding was of such a value that the null hypothesis was rejected for that distance in spite of the fact that the onle difference between the two paradigms at the 40.0cm distance was the preset conditions. This phenomenon demonstrates the effect of presets on accommodative behavior. In the real distance paradigm, the 40.0cm finding was taken from a distance (plus or less accommodation) preset, i.e. the accommodative system was moving from a stimulus of lesser magnitude to a stimulus of greater magnitude. In the prism simulation paradigm, the plus preset finding was taken in a similar manner (i.e. preset by lesser stimulation), whereas the minus preset finding was taken from the direction of greater stimulation (27.4cm simulation and minus lens preset). This difference in technique is responsible the observed varience in the two findings. The consequent statistical rejection is reduced in significance, however,by the fact that the mean difference between the two sets of data for this distance was 0.22 D which is within the standard error of measurement for cross-cylinder testing at 40.0cm as established in the Pacific University clinical norms. It must be pointed out here that the smallest unit interval available for measurement of optical units with a standard refractor is 0.12 D. A mean difference of 0.22 D therefore, is less than two units of difference between the two methods of measurement. Consequently, the clinical value of the simulated distance paradigm is not negated by the statistical rejection of the null hypothesis for this one condition. The 4m distance t-value also rejected the null hypothesis at the .o1 confidence level, showing a mean difference of 0.34 D for the two paradigms. On inspection of the raw data, however, it becomes evident that a significant skewedness occurs in the minus preset prism condition which is primarily responsible for the statistical rejection. If only the plus preset prism data is compared to the mean real distance data, a more comparable relationship exists, indicating clinically that only the plus preset prism finding can be relied upon for most individuals under these conditions.

The product-moment correlation coefficient was also employed to evaluate how well the real distance finding can be predicted from the prism simulation data. The results of this statistic indicated that the 40.0 cm and 27.4cm findings showed a moderately high correlation with their real distance counterparts (.76 and .80 successively), whereas the other data showed very low correlation, indicating that an exact prediction of the real distance Ap cannot be made from the prism simulation Ap. The authors failed to take into account the observation noted above in evaluating this statistic, ie., the interval employed was such that the difference between .24D and .25D was considered one unit interval. A more relavent magnitude of .12D per unit interval would provide a data scatter profile of greater clinical significance than the units employed.

The authors suspect three variables as being causitive factors in the differences manifested in the two sets of data. The first of these is the factor of fixation disparity. As was stated previously, it was assumed that the Cp was equal to the Bv for each distance. As is discussed in Ogle's work on convergence, this assumption is not necessarily true, but rather that a certain amount of disparity exists between the lines of sight under binocular fusion conditions such that Cp does not equal Bv. Ogle's data further shows that the magnitude of fixation disparity for any given distance may vary markedly (1 - 5 seconds of arc) by the introduction of prism or sphere lenses, the magnitude of the disparity being related to the power of the lens in place. The effect of this physiological observation is that at any given real distance, the magnitude and direction of fixation disparity may differ markedly from the amount exhibited with some quantity of prism in place intended to simulate the same distance. Since the magnitude of convergence response will effect the magnitude of accommodative response, the fact that the fixation disparity under the two conditions is different will induce a difference in the accommodative response and therefore the Ap as measured by the two methods.

The second variable is the magnitude and direction of heterophoria as it relates to the prism simulation. For example, if the subject exhibits an eso posture at 40.0 cm, it is necessary for this subject to diverge his lines of sight to the plane of regard in order to obtain fusion, with the resultant effect that the Ap is moved further from the plane of regard than the orthophoric individual under the same conditions. Now, if the prescribed amount of prism to simulate 27.4 cm is placed before such an individual, the amount of divergence necessary to maintain fusion of the 40.0 cm target is reduced, and the Ap moves closer to the 40.0 cm plane. Comparing this situation to the real distance test at 27.4 cm, a different set of postural relationships exists, the subject again being required to diverge his lines of sight to obtain binocularity, and thus causing the Ap to move further from the plane of regard than might exist in the prism simulation. The reverse situation exists for the exophoric subject, the amount of relative convergence varying with the prism employed as compared to the real distance con ditions.

The third variable is that of proximal convergence, a phenomenon noted commonly in stereoscopic observations. The effect here is that the magnitude of convergence response as measured by phoric behavior is different for real and simulated conditions, the convergence tending to increase in magnitude in the positive direction. The reason commonly cited for thsi observation is that the subject is aware that a given target is near him even though sufficient amounts of prism are in place to render his lines of sight parallel.

On the basis of the above observations, it can be concluded that accommodative behavior at various distances as measured by cross-cylinder responses can be evaluated accurately enough for clinical purposes by the use of prism simulation, but the clinician must be aware of the variables affecting the observed responses as possible sources of error. Lastly, the minus preset simulation at 4 meters is an unreliable finding and should not be employed as a measure of a given individual's visual system.

Means of the "Residue"

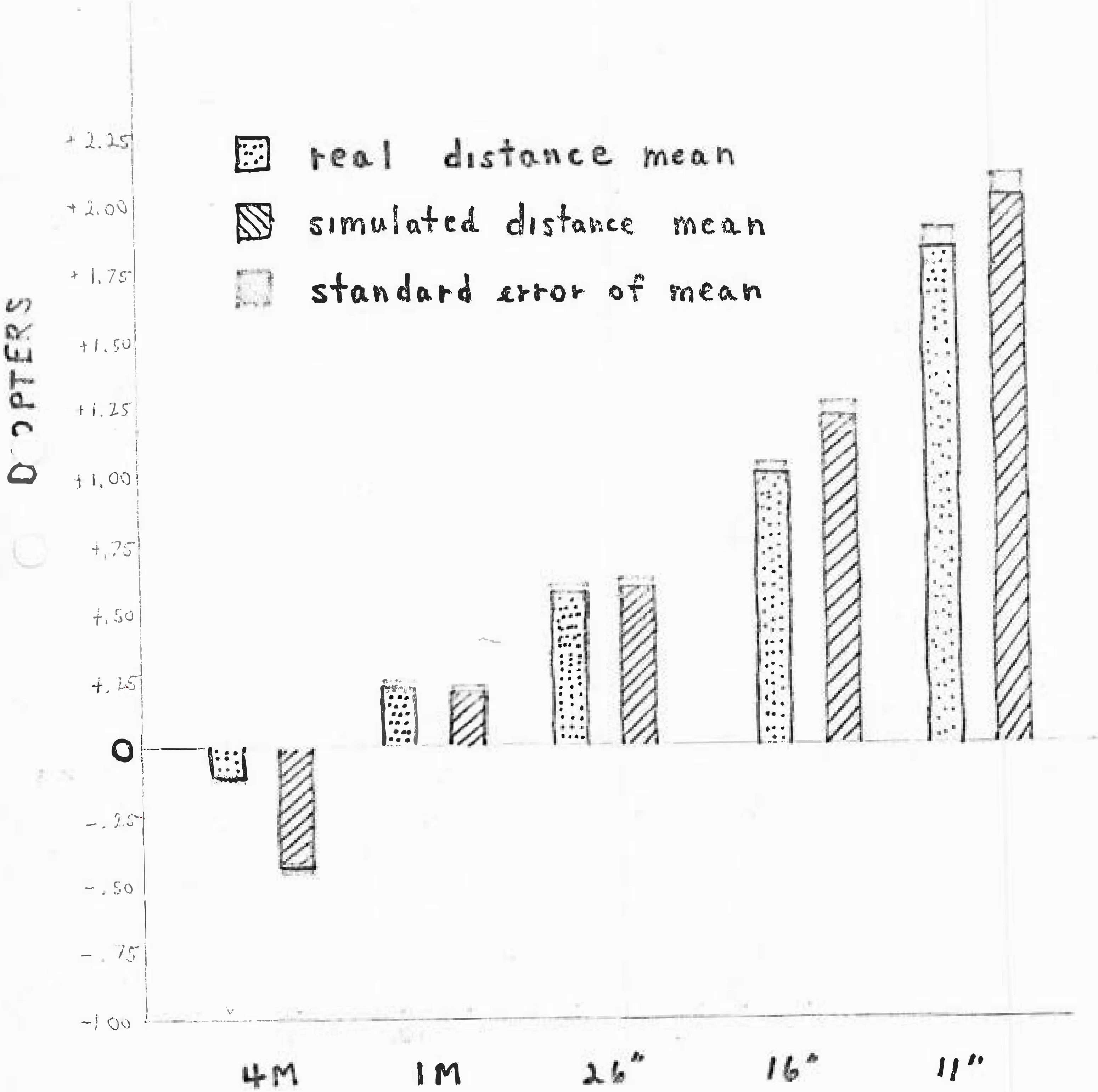
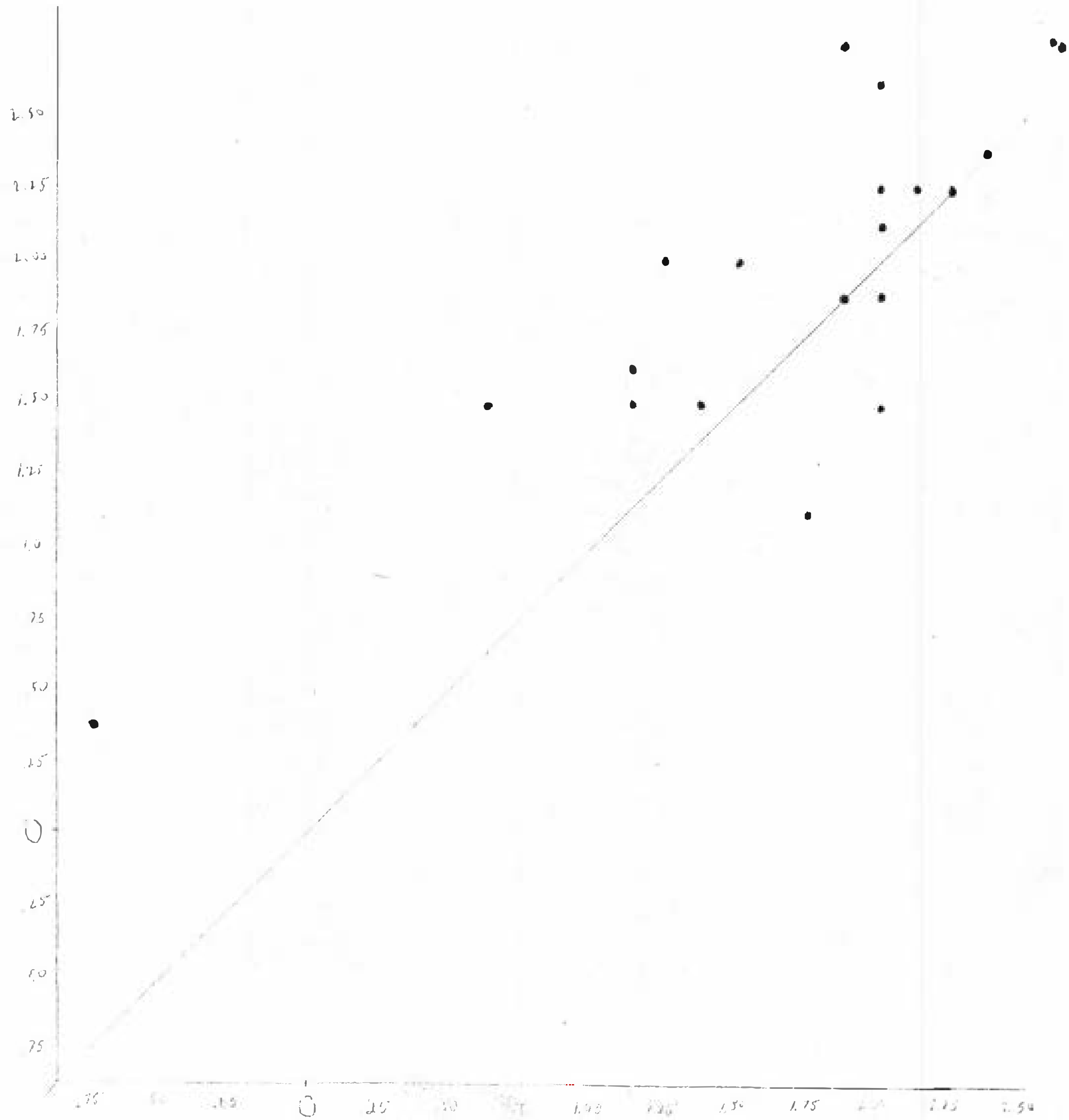


Figure 1

Scatter Diagram

11°

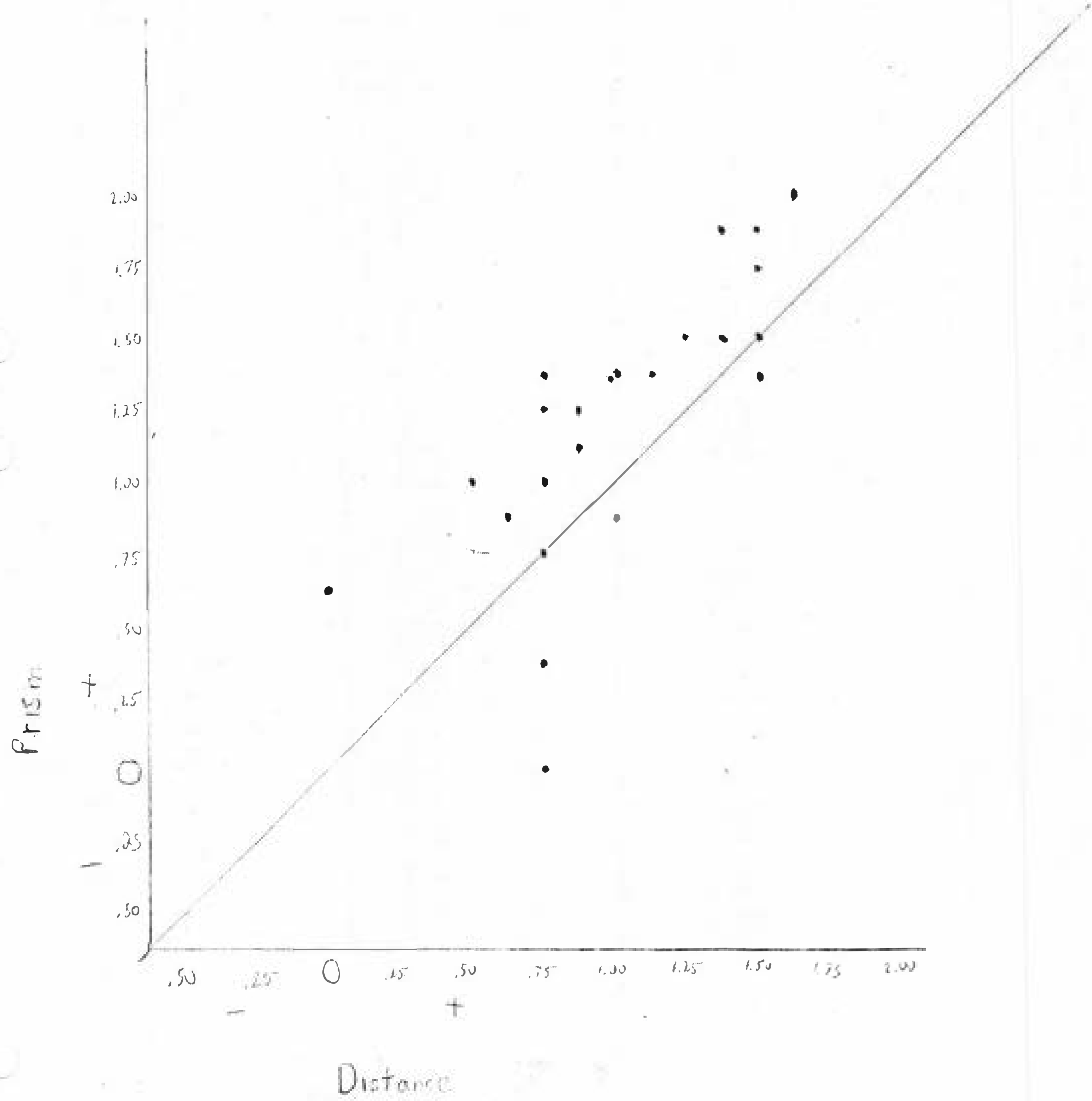
Correlation Coefficient = .804446



Scatter Diagram

16"

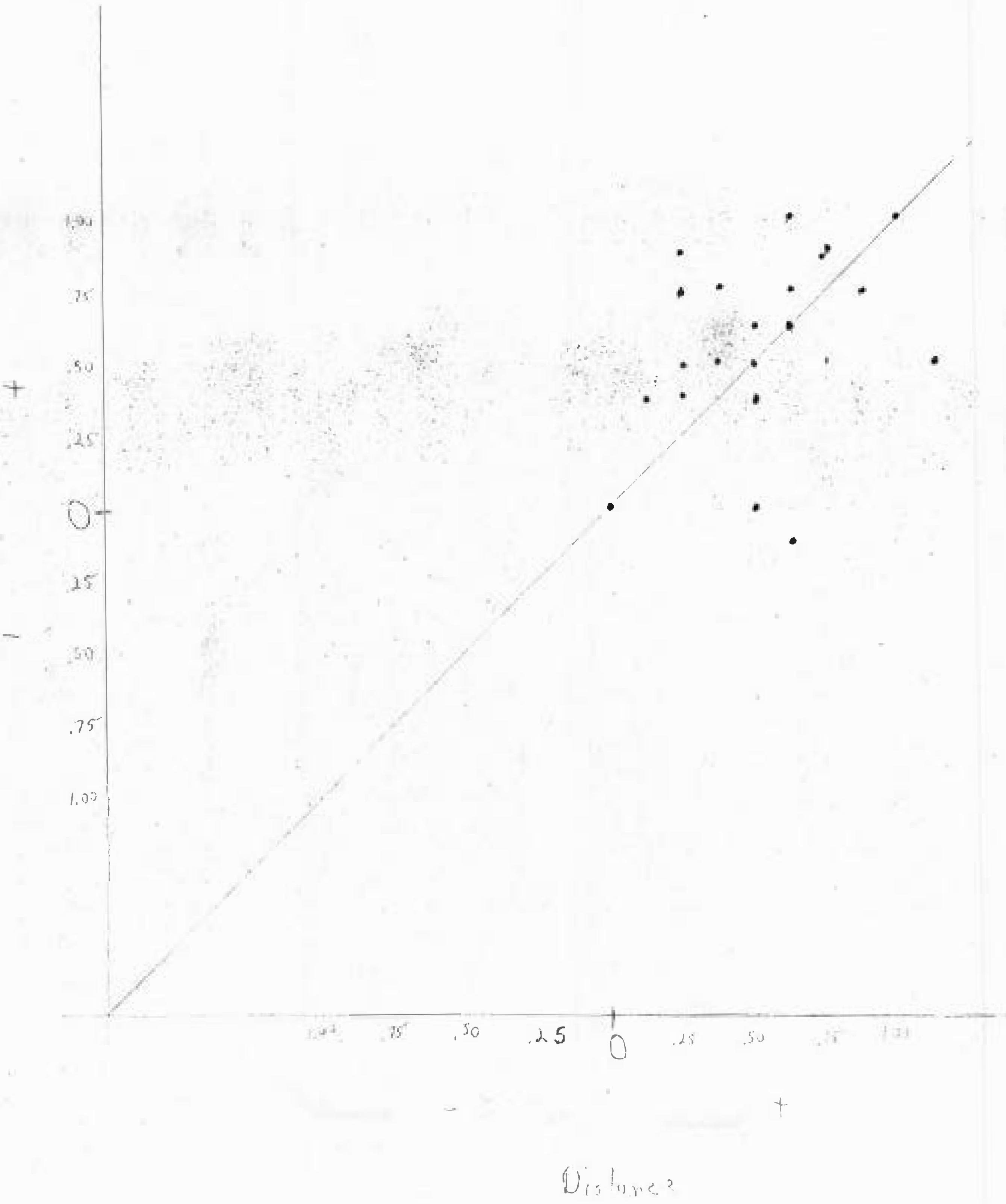
Correlation Coefficient = .830961



Scatter Diagram

26"

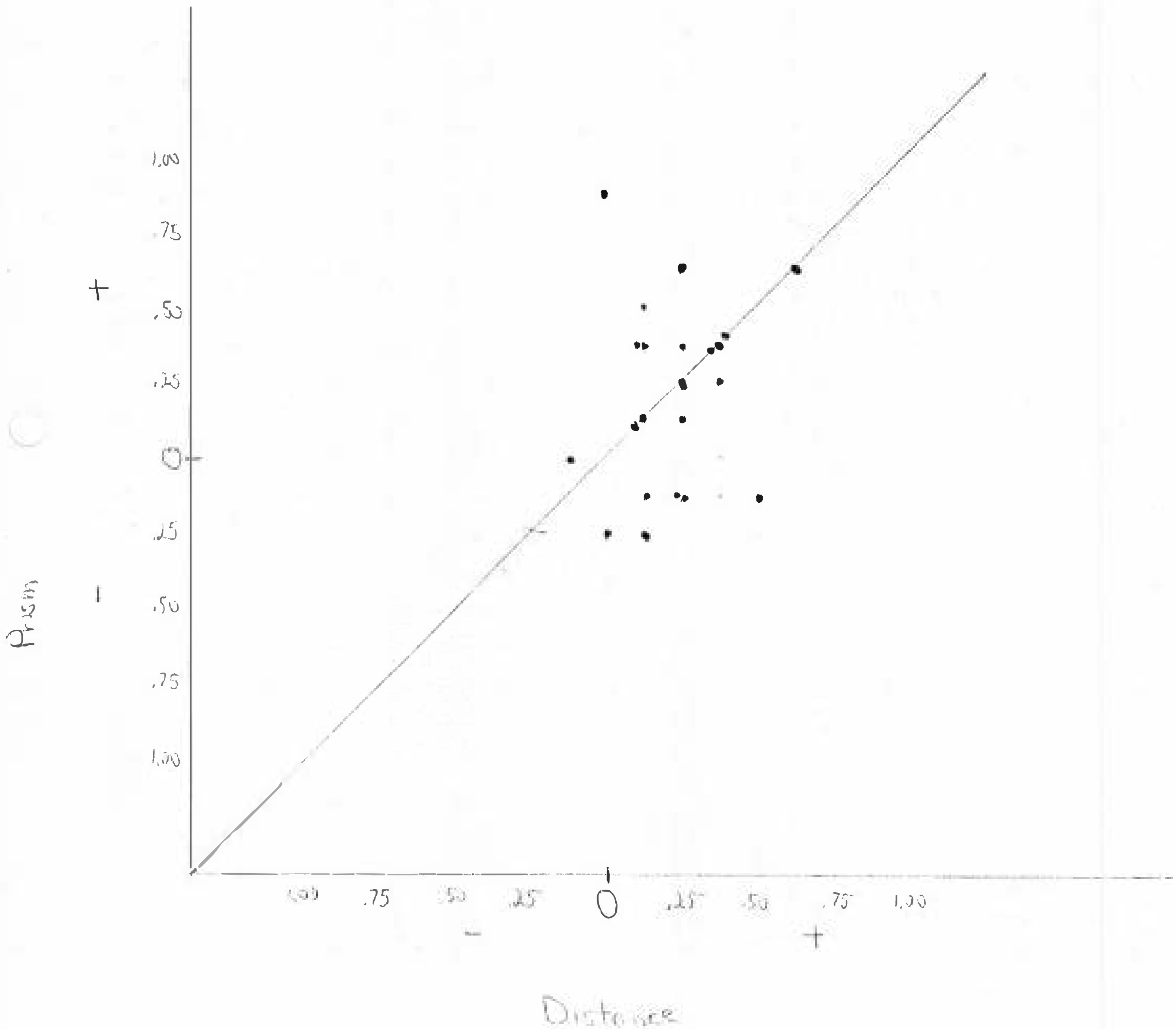
Correlation Coefficient = .378358



Scatter Diagram

1 meter

Correlation Coefficient = .188617



Scatter Diagram

4 Meters

Correlation Coefficient = -.134315