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Comparison of the Kaplan and Nagel anomaloscopes

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Abstract

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COMPARISON OF THE
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COMPARISON OF THE KAPLAN AND NAGEL ANOMALOSCOPES

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BY

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COMPARISON OF THE KAPLAN AND NAGEL ANOMALOSCOPES

INTRODUCTION:

An anomaloscope is an instrument used to assess color vision by mixing red and green test lights in various proportions to match a standard yellow light. These matching characteristics describe the subject's color sense. These colored lights may be obtained by colored filters or by suitably masking the spectral output from a diffracting source.

There are only two readily available anomaloscopes marketed world wide today: the Pickford-Nicholson and Nagel instruments from Great Britain and Germany, respectively. While each of these anomaloscopes have been shown to be accurate and reliable [1,2], they are both quite expensive which preclude their use in many clinics.

It is therefore the purpose of this thesis to compare the Kaplan anomaloscope to the Nagel.

APPARATUS:

The Kaplan-Anomaloscope used in this test is the model LS-1 from Scientific Instrumentation Co. and is of the filter type. The light source is a single 15 watt lamp with red and green vinyl strips and a Kodak Wratten #15 filter for the test and standard colors. The round viewscreen is divided vertically into two equal fields. The left side represents the red/green (R/G) mixture and the right side represents the yellow standard [3]. Knobs on each end of the instrument control the R/G and yellow standard, respectively. The control dials on the anomaloscope

have an arbitrary scale with a range of "0-100". The actual usable range for the R/G is "0-90" where 0 = 100% green light in the mixture and where 90 = 100% red. The yellow scale is also useful from "0-90" where 0 = lowest brightness [4].

The Nagel anomaloscope employed in this study was the model II . This instrument is a spectral device using prisms as described previously. The round view aperture is divided equally in the horizontal plane. The bottom half is the R/G field and the top is the yellow standard field. The R/G and yellow level control knobs are on the left and right sides of the stand, respectively. Each of the dial plates has a range from "0-100". The actual useful R/G range is approximately "3-75" where 3 = 100% green and 75 = 100% red. The useful yellow range is approximately "0-50" where 0 = lowest brightness level [5].

METHOD:

Prior to any comparisons, normative studies were performed for both instruments. This consisted of testing on each device a random sample of "normals" and as many "abnormals" that were available.

For this procedure the Kaplan-Anomaloscope was viewed binocularly at a distance of approximately 20 inches. With the 1" aperture in place, the viewscreen subtended an angle of 3^{o} at the retina. The ambient room illumination was adjusted to the low level used during visual field testing. The subjects were tested with habitual Rx's in place provided they were clear or of a light blue tint. This condition was constant for both instruments.

The Nagel testing was performed with the subject viewing the screen monocularly with the eye of his choice. The room illumination was dim and the aperture was adjusted to allow image subtense of 2^{o} 10". Habitual Rx's were worn as described above.

The testing techniques for both anomaloscopes were similar to that described in the Willis, Farnsworth investigation [6]. It consisted of having the subjects fixate the viewports which had previously been adjusted to the approximate "normal" match point. The subject then described the quality of this setting in terms of hue and brightness. If slight differences between screen halves were apparent, the subject adjusted the yellow control [7] to match the two screen fields. The R/G control was changed [8] when necessary if a difference in hue persisted. A "match point" was eventually attained using the above method.

The "match range" was investigated using this match point as a starting place. This range was determined by the examiner changing the R/G setting slightly in the green direction and asking the subject if he could maintain a hue/brightness match by readjusting the yellow level. This was continued until a point of non-acceptance was attained and the subject could no longer obtain a match. This procedure was then repeated by moving the R/G setting into the red direction. Thus, the two limiting match points defined the "match range". The "mid match point" is defined as the locus bisecting the match range. It is these two findings; match range and mid match point, that are used as the comparative data in this study.

The data collected from both anomaloscopes were used to separate the subjects into one of seven possible classes: normals, moderate deutans and protans, severe deutans and protans, deuteranopes, and protanopes. The data from each of the above classes was then analyzed (when N was sufficient) to give the means and sigma (σ) of the mid match points and average match ranges for each instrument.

Investigations were then performed between each respective class from the two anomaloscopes to determine correlations and regressions.

RESULTS:

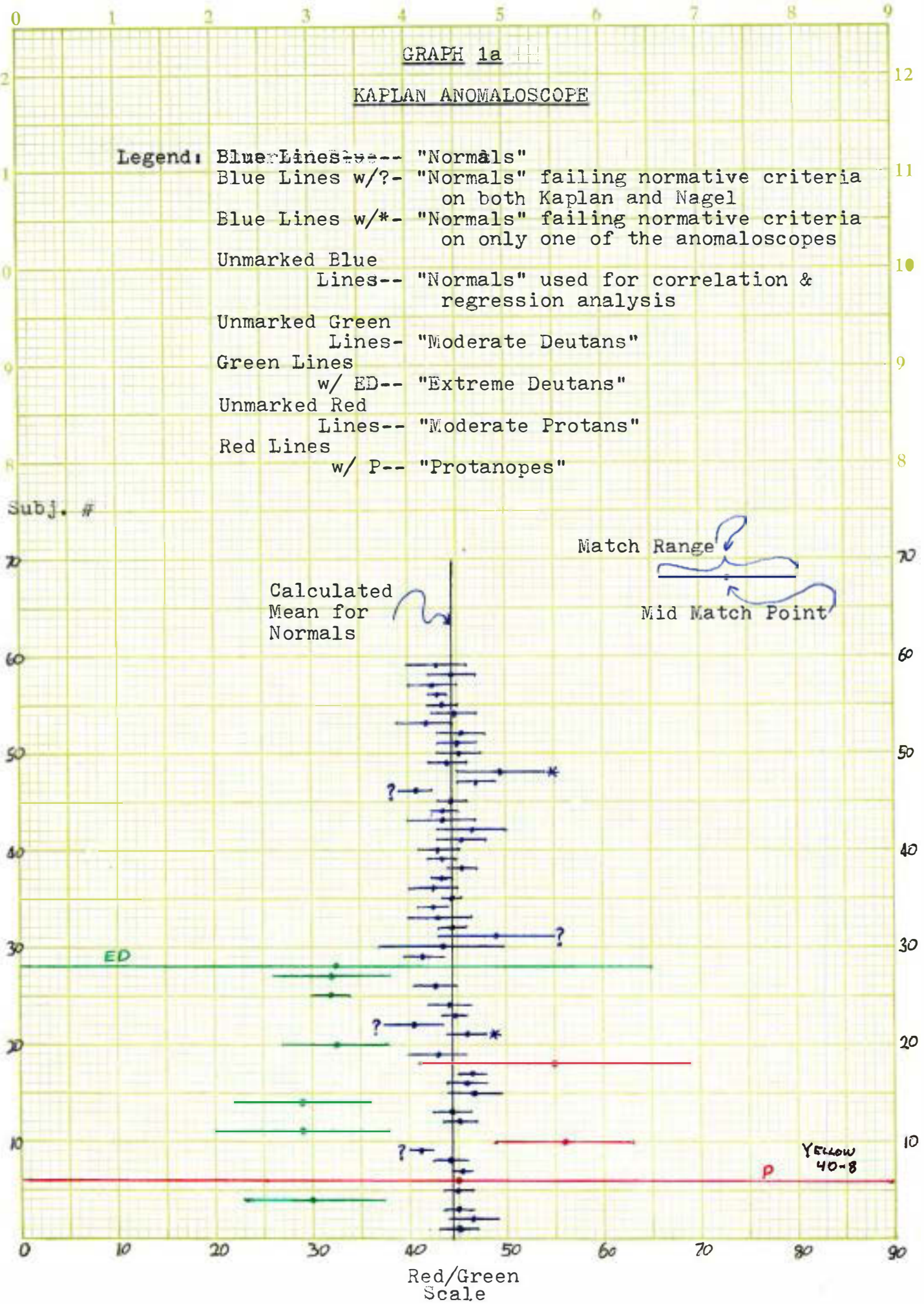
A total of 59 subjects were tested on each anomaloscope and classified as follows: Normals, N=49; Moderate deutans, N=6; Severe deutans, N=1; Moderate protans, N=2; Protanopes, N=1. [9.] All findings were plotted on a Kaplan and Nagel graph, respectively, with match range and mid match point as parameters, see Graph 1a.&b.

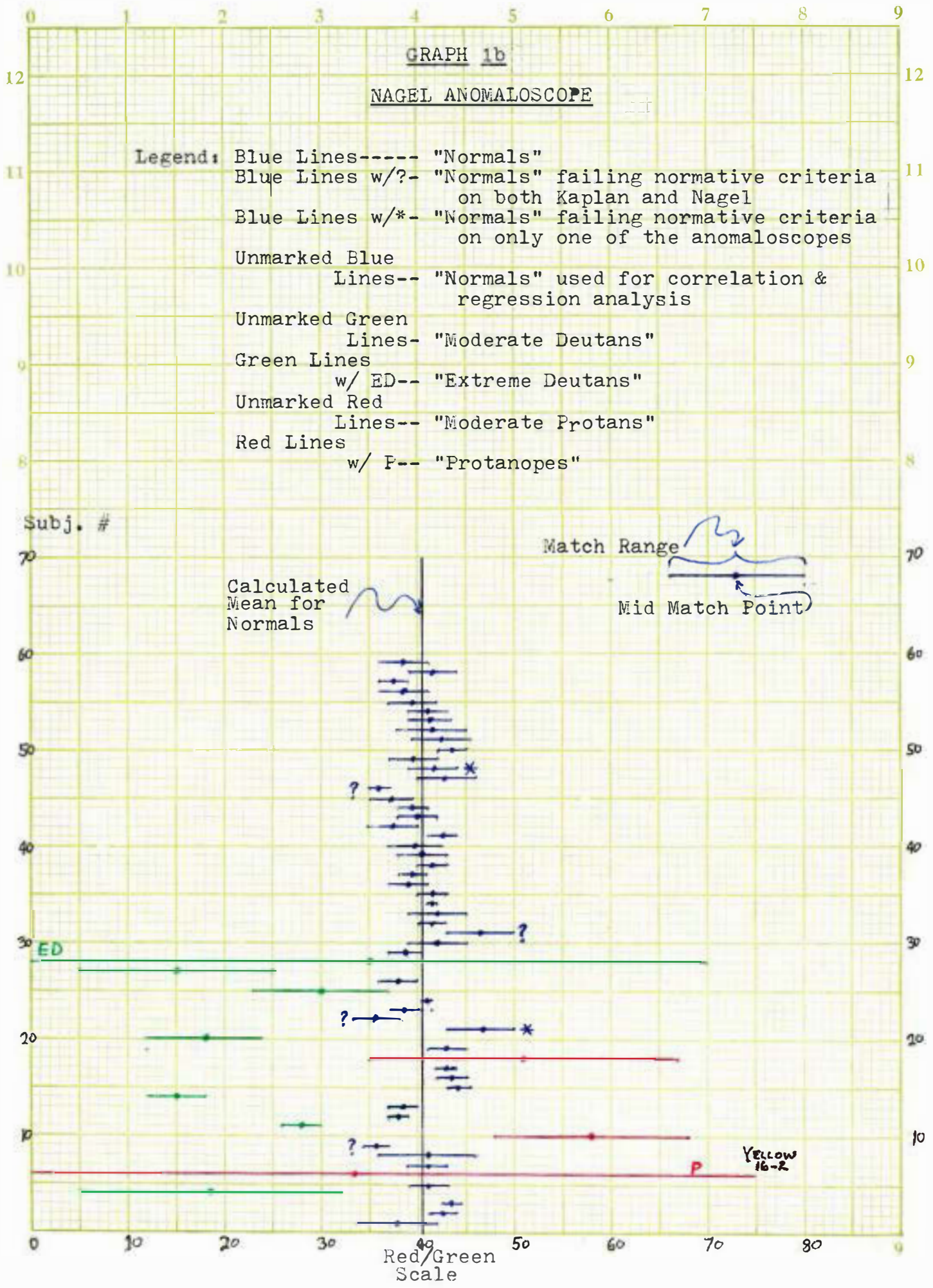
Normals:

The data used for the initial normative studies were selected from the above "normal" class (N=49) by the following criteria: All findings (mid match points) with in ±4.0 units of the "estimated" mean. [10, 11.] This method yielded N=44 for each anomaloscope. [12.] For the purpose of this thesis, the 5 findings not qualifing for the normative analysis (49-44=5) were considered dubious &/or of very mild anomals. [13.]

The mean and sigma for mid match point and the average match ranges are shown in Table 1. [14.]

The population for the correlation and regression study consisted of all subjects that had mid-match point findings


GRAPH 1a
KAPLAN ANOMALOSCOPE
Legend:
Blue Lines-- "Normals"
Blue Lines w/?- "Normals" failing normative criteria on both Kaplan and Nagel
Blue Lines w/*- "Normals" failing normative criteria on only one of the anomaloscopes
Unmarked Blue Lines-- "Normals" used for correlation & regression analysis
Unmarked Green Lines- "Moderate Deutans"
Green Lines w/ ED-- "Extreme Deutans"
Unmarked Red Lines-- "Moderate Protans"
Red Lines w/ P-- "Protanopes"
Subj. #
Match Range
Mid Match Point
Calculated Mean for Normals
ED
P
YELLOW 40-8
Red/Green Scale


GRAPH 1b
NAGEL ANOMALOSCOPE
Legend: Blue Lines----- "Normals"
Blue Lines w/?- "Normals" failing normative criteria on both Kaplan and Nagel
Blue Lines w/*- "Normals" failing normative criteria on only one of the anomaloscopes
Unmarked Blue Lines-- "Normals" used for correlation & regression analysis
Unmarked Green Lines- "Moderate Deutans"
Green Lines w/ ED-- "Extreme Deutans"
Unmarked Red Lines-- "Moderate Protans"
Red Lines w/ P-- "Protanopes"
Subj. #
Match Range
Mid Match Point
Calculated Mean for Normals
ED
P
YELLOW 16-2
Red/Green Scale

NORMALS

Anomaloscope	Mid Match Point		Average Match Range
	Mean	Sigma	
Kaplan	44.5	1.35	4.17
Nagel	40.5	2.11	4.23

TABLE 1

that adhered to the "normative criteria" for both the Kaplan and Nagel instruments. This reduced the number from N=44 to N=41. [15] Correlations and regressions were then found with the aid of a correlation table; [16, 17].

$r = .46$

$X = .657Y + 11.23$

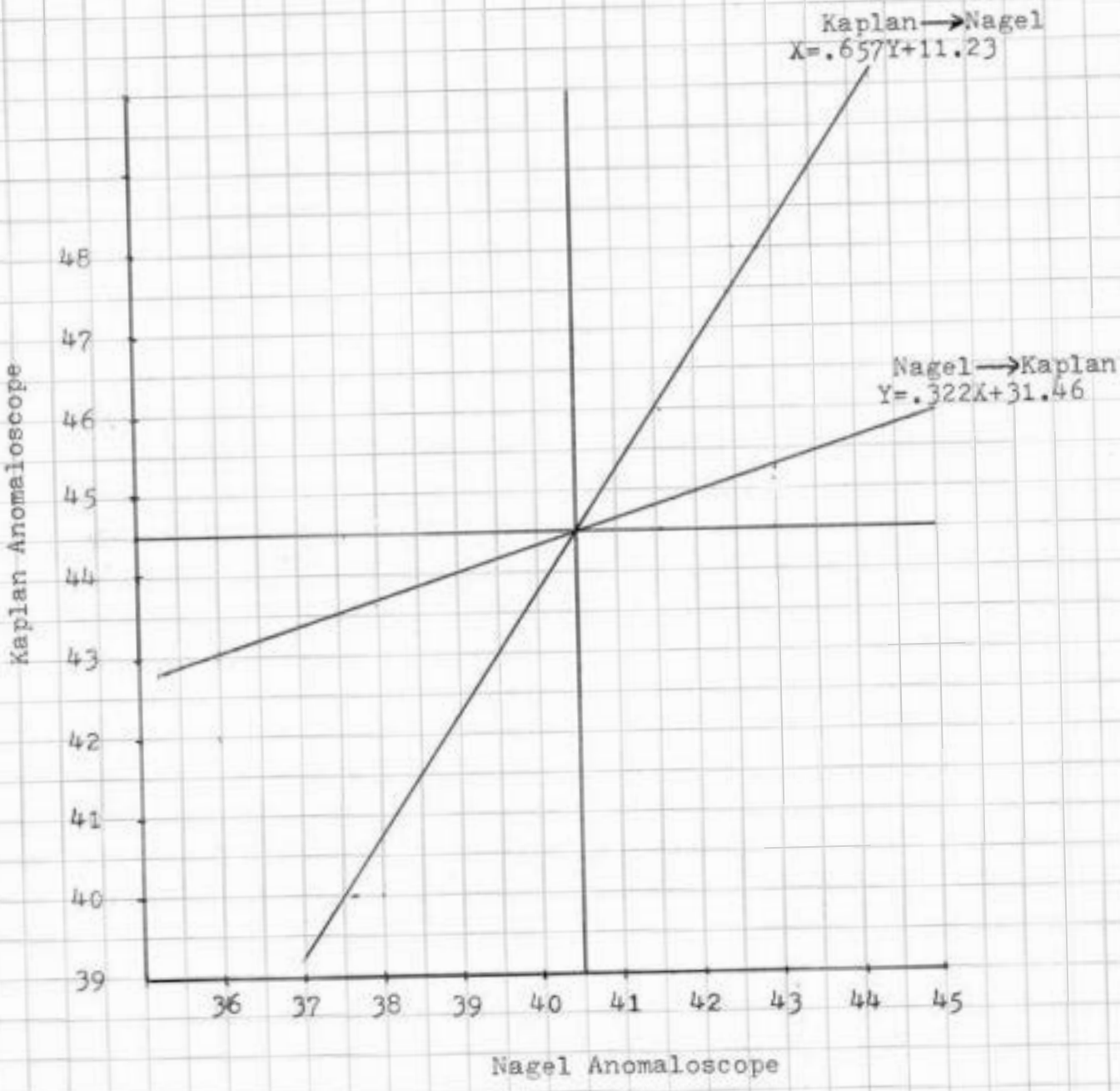
$Y = .322X + 31.46$

where; X=Nagel value
Y=Kaplan value.

The regression lines are represented on Graph 2.

GRAPH 2

REGRESSIONS
NORMALS



Anomals:

Statistical analysis was performed on only the anomalous classes for which N was sufficient. This included only the "moderate deutans" where N=6. The other classes; severe deutans (N=1), moderate protans (N=2), and protanopes (N=1), will be described here only in terms of raw numerical findings and will be discussed later as individual cases.

Moderate Deutans: [18.]

The means and sigmas for the midmatch points and the average match range for both Kaplan and Nagel anomaloscopes are shown in Table 2. [19.]

MODERATE DEUTANS

Anomaloscope	Mid Match Point		Average Match Range
	Mean	Sigma	
Kaplan	30.75	1.54	12.25
Nagel	20.75	6.01	13.83

TABLE 2

Correlations and regressions for this class were determined with the aid of a correlation table: [20]

$r=-.009$
$X=21.83-.04Y$
$Y=30.8-.002X.$
where X=Nagel values
Y=Kaplan values

Severe Deutans:

There was one subject in this study that met the requirements of this class.[21] Subject #28, displayed much difficulty when attempting to match the screen halves in the red end of both the Kaplan and Nagel devices. His findings are shown in Table 3.

Moderate Protans:

Subjects #10 and 18 were the two placed in this category. Both subjects displayed great ease when attempting to subjectively match the screen halves on both anomaloscopes. Their findings are shown in Table 3.

Protanopes:

Subject #6, was the only one placed in this class. He made extremely quick matching responses across the entire R/G ranges by turning the yellow level down as he entered the red end of the scale.[22] His findings are shown in Table 3.

SEVERE DEUTANS, MODERATE PROTANS, PROTANOPES

Subject # & Class	Anomaloscope			
	Kaplan		Nagel	
	Match Range	Mid Match Point	Match Range	Mid Match Point
Severe Deutan #28	0-65	32.5	0-70	35
Moderate Protan #10	49-63	56	48-68	58
#18	41-69	55	35-67	51
Protanope #6	0-90	45	0-75	37.5

TABLE 3

DISCUSSION: Normals

The data for normals show a moderate correlation, r=.46, between the Kaplan and Nagel anomaloscopes. This finding is consistant with the correlation (r=.56) with the Susumi, Rosenstein, 1976, data in their Comparative Evaluation of Anomaloscopes: Pickford-Nicholson and Nagel. [23]. Since the P-N and Kaplan anomaloscopes operate on the same filter principle, the Susumi, Rosenstein finding adds credence to the correlation value found in this study.

The regression analysis gives a slightly more usable relationship when estimating the Nagel finding from the known Kaplan finding than vice versa, see Graph 2.

Imperical comparisons of the 5 "normal" subjects on each anomaloscope that were disqualified from the initial normative study [24], show 4 of these subjects, #9, 22, 31, 46, to be common to both anomaloscopes. That is to say that these subjects showed matching responses on both anomaloscopes that were skewed in the same direction and by the same relative amount. The remaining 5th subject on each anomaloscope were disqualified from the normative study because they failed to meet the normative criteria on only one of the instruments. Subject #21 failed only on the Nagel and subject #48 failed only on the Kaplan device. However, the"passing" findings for these subjects on the other anomaloscope were skewed in the same direction as the corresponding "failing" finding but to a lesser degree.

This strongly suggests that each anomaloscope was, in fact, measuring real pyschophysiological deviations from the norm rather than dubious or spurious responses.

DISCUSSION cont.

Moderate Deutans:

The data from this class show a correlation of essentially "0", r= -.009. The regression formulas reflect this in the equations given previously.

These findings are consistant with those found between the Pickford-Nicholson and Nagel devices in the Susumi, Rosenstein report. This complete lack of correlation may be due to a general decrease in sensitivity and discrimination ability associated with broad pass-band light in the filtered instruments as compared to the more pure spectral light of the Nagel device. As a result, estimation of the Nagel finding is impossible when the Kaplan finding is known and vice versa.

While the correlation between this class was nil, it is very important to note that all moderate deutans in this study were diagnosed as such on both instuments. In other words, a moderate deutan on the Nagel would be similarly diagnosed on the Kaplan anomaloscope.

Severe Deutans:

Data indicate that the severe deutan, subject #28, showed very similar matching characteristics on each anomaloscope. The matching ranges obtained from the Kaplan and Nagel extended from "0" (100% green) to well into the red end of the spectrum. Subject #28 reported much difficulty when making the required subjective matches. Niether the Kaplan nor Nagel instruments represented an easy task.

The striking similariy of the findings on both anomaloscopes indicates a usefulness of both insruments to detect such an

extreme color anomal.

Moderate Protans:

The two subjects, #10, 18, in this class showed very similar matching characteristics on each instrument. Subject #10 gave a relatively shorter range and a more skewed mid match point on both devices than subject #18. This consistancy between anomaloscopes indicates a usefulness in distinguishing between moderate and more severe proanomals. There were no "mis-diagnosis" between the Kaplan and Nagel devices.

Protanopes:

Only one subject, #6, was placed in this classs. The Kaplan and Nagel anomaloscopes both described subject #6 as an actual dichromat according to the criteria of a complete match across the entire scale with a concurrent dimming of the yellow in the red end of the spectrum. 25.

Subjective matching was quick and precise with none of the subjective difficulty experienced by the other severe anomals.

The findings of subject #6 indicate agreement between the two anomaloscopes when diagnosing this protanope.

CONCLUSION:

1. A moderate correlation of r=.46 exists between the Kaplan and Nagel anomaloscopes for normal subjects.
2. It is more useful to estimate Nagel findings from known Kaplan findings than vice versa to a small degree.
3. Subjects diagnosed as normal on one device will be similarly diagnosed on the other.
4. No correlation exists between the anomaloscopes for moderate deutans and it is impossible to estimate the findings on one instrument when the finding on the other is known.
5. A moderate deutan will be diagnosed as such on both the Kaplan and Nagel anomaloscopes.
6. This investigation indicates the usefulness of the Kaplan anomaloscope for diagnosing: severe deutans, moderate protans and protanopes.
7. This investigation suggests a general and consistant compatibility of the Kaplan and Nagel anomaloscopes for use in the clinic environment.

I would like to extend sincere appreciation to Dr. Oscar Richards, Pacific University, College of Optometry, for his guidance and direction without which this paper would not be possible.

REFERENCES

1. Willis M.P. and Farnsworth, D. (1952) Comparative evaluation of anomaloscopes. U.S. Naval Med Res. Lab (No. 190) 9. p.80
2. Lakowski R. (1971) Calibration, validation and population norms for the Pickford-Nicholson anomaloscope. Br. J. Physiol. Op. 26. 166-182.
3. Kaplan G. (1976) Operator's Manual for Kaplan Anomaloscope Model LS-1. For complete physical description, see:
4. Ibid
5. See #1, for complete physical description of the Nagel.
6. See #1, Pp. 36-39. "Testing techniques"
7. The tested subject controlled only the yellow level, the examinor controlled the R/G.
8. Ibid
9. Pickford R. and Lakowski R. The Pickford-Nicholson Anomaloscope. Br. J. Physiol Optics, Vol. 17, pp 139-40. 1960.
10. ±4.0 units was chosen since previous investigations (Dr. Oscar Richards, Pacific Univ.) has given an average sigma of 2.0 units. It was therefore decided to consider findings with in ±2sigma of the "estimated mean" (see below) as "normal". This criteria was arbitralily applied to the Kaplan anomaloscope.
11. "Estimated average (mean)" is the imperically derived mean by "eyeballing" the data graph.
12. See: Legend, Graph 1.
13. Ibid
14. For calculations, see Appendix.
15. See # 12.
16. Freund J. Modern Elementary Statistics, 3rd. Ed. Prentice-Hall, 1967, p 375.
17. See #14.
18. See #12.
19. See #14.
20. Ibid
21. See #12.
22. See #9..
23. Susumi M. and Rosenstein D. (1976) Comparative Evaluation of Anomaloscopes: Pickford-Nicholson & Nagel. Unpublished thesis, Pacific University College of Optometry, 1976.
24. See: Results; Normals, p 4 of this report.
25. See #9.

APPENDIX

CALCULATIONS

Kaplan Anomaloscope

Normals: Mid Match Point; Mean=44.5

$N=44$, $\Sigma y=1955.5$

$$\frac{1955.5}{44} \cong 44.44 = 44.5$$

* Sigma of Mid Match Point; Sigma= ± 1.35

$N=44$, $\Sigma(y-\bar{y})^2=80.38$

$$\sqrt{\frac{80.38}{44}} \cong 1.351 = 1.35$$

Average Match Range; Avg.=4.17

$N=44$, Σ Match Range=183.5

$$\frac{183.5}{44} = 4.17$$

Nagel Anomaloscope

Mid Match Point; Mean=40.5

$N=44$, $\Sigma x=1782$

$$\frac{1782}{44} = 40.5$$

Sigma of Mid Match Point; Sigma= ± 2.11

$N=44$, $\Sigma(x-\bar{x})^2=195.44$

$$\sqrt{\frac{195.55}{44}} \cong 2.107 = 2.11$$

Average Match Range; Avg.=4.23

$N=44$, Σ Match Range=186.0

$$\frac{186.0}{44} = 4.23$$

* Standard Deviation: variance of the Mid Match Point around the calculated Mean.

NORMALS - CORRELATION TABLE

NORMALS

Y \ X	37	37.25	37.5	37.75	38	38.25	38.5	38.75	39	39.25	39.5	39.75	40	40.25	40.5	40.75	41	41.25	41.5	41.75	42	42.25	42.5	42.75	43	43.25	43.5	43.75	44	44.25	44.5
↑																															
47.25																															
47																									/					/	
46.75																															
46.5			/																					/	/						
46.25																															
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45				/													/						/				/				
44.75							/										/														
44.5		/					/												4												
44.25																/	/														
44													/																		
43.75											/																				
43.5											2		/		/						/										
43.25																					/										
43					/		/						/																		
42.75					/																										
42.5	/								/										/												
42.25																															
42																															
41.75																		/													
41.5								/																							
41.25																															

Y	Fy	y	yFy	y²Fy	(y+1)²Fy	Tx	yTx
↑	0	12	0	0	0	0	0
47.25	0	11	0	0	0	0	0
47	2	10	20	200	242	25	250
46.75	0	9	0	0	0	0	0
46.5	3	8	24	192	243	7	56
46.25	0	7	0	0	0	0	0
46	1	6	6	36	49	12	72
45.75	0	5	0	0	0	0	0
45.5	2	4	8	32	50	6	24
45.25	2	3	6	18	32	2	6
45	4	2	8	16	36	11	22
44.75	2	1	2	2	8	-6	-6
44.5	6	0	0	0	6	-5	0
44.25	2	-1	-2	2	0	3	-3
44	1	-2	-2	4	1	-2	4
43.75	1	-3	-3	9	4	-4	12
43.5	5	-4	-20	80	45	-4	16
43.25	1	-5	-5	25	16	6	-30
43	3	-6	-18	108	75	-20	120
42.75	1	-7	-7	49	36	-10	70
42.5	3	-8	-24	192	147	-16	128
42.25	0	-9	0	0	0	0	0
42	0	-10	0	0	0	0	0
41.75	1	-11	-11	121	100	3	-33
41.5	1	-12	-12	144	121	-7	84
41.25	0	-13	0	0	0	0	0
	Σ41		Σ30	Σ1230	Σ1211		Σ792

Fx	1	1	1	1	3	0	3	1	1	0	3	0	3	0	1	1	4	1	6	0	2	0	1	1	2	0	3	0	0	1	0
x	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
xFx	-14	-13	-12	-11	-30	0	-24	-7	-6	0	-12	0	-6	0	0	1	8	3	24	0	12	0	8	9	20	0	36	0	0	15	0
x²Fx	196	169	144	121	300	0	192	49	36	0	48	0	12	0	0	1	16	9	96	0	72	0	64	81	200	0	432	0	0	225	0
(x+1)²Fx	169	144	121	100	243	0	147	36	25	0	27	0	3	0	1	4	36	16	150	0	98	0	81	100	242	0	507	0	0	256	0
Ty	-8	0	8	2	-10	0	-5	-12	-8	0	-11	0	-12	0	-4	-1	6	-11	-4	0	-9	0	2	8	18	0	11	0	0	10	0
xTy	112	0	-96	-22	100	0	40	84	48	0	44	0	24	0	0	-1	12	-33	-16	0	-54	0	16	72	180	0	132	0	0	150	0

.24 (1593) 99.5

Σ41 · Σ1 · Σ2463 · Σ2506 · Σ792

41		
2	ΣxFx	
2463	x²Fx	
2506	Σ(x+1)²Fx	

Checks:

Fy	41
yFy	-60
y²Fy	1230
Σ	1211

$b_x = .0244$, $b_y = -.732$, $\bar X = 40.5$, $\bar Y = 44.5$, $\sigma_X = 1.93$, $\sigma_Y = 1.35$

σ_x = , S.E.x = , S.E.y = , S.E.Y = ; $\frac{1-r^2}{\sqrt{N-1}}$ = ; σ_r = ; t =

x = y. y = X. X = Y. Y = X.

$r = \frac{792/41}{(1.42)(1.35)} = .46$

$\bar X = X_0 + bx$. $\sigma_X = W_X\sigma_x$. W_X = group interval of X. $\Sigma xy = \Sigma xT_y = \Sigma yT_x$. $N = \Sigma F_X = \Sigma F_Y$. $b_x = \frac{\Sigma xF_x}{N}$. $\sigma_x = \sqrt{\frac{\Sigma x^2F_x}{N} - b_x^2}$.

$r = \frac{\Sigma xy - Nb_xb_y}{N\sigma_x\sigma_y}$. $x = r\frac{\sigma_x}{\sigma_y}y$. $S.E._x = \sigma_x\sqrt{1-r^2}$. $\sigma_r = \frac{1-r^2}{\sqrt{N-1}}$. $n = N-2$.

$t = \frac{r}{\sqrt{1-r^2}}\sqrt{N-2}$. $S.E._X = W_X S.E._x$. $X = \bar X + r\frac{\sigma_X}{\sigma_Y}(Y - \bar Y)$. (Similarly for y and Y).

$Y = .322X + 31.96$ $X = .657Y + 11.23$

$r = \frac{\Sigma xT_y - b_xb_y}{\sigma_x\sigma_y} = .46$

CALCULATIONS cont.

Moderate Deutans:

Kaplan Anomaloscope

Mean Mid Match Point; Mean=30.75

$N=6, \Sigma y=184.5$

$$\frac{184.5}{6} = 30.75$$

Sigma Mid Match Point; Sigma= 1.54

$N=6, \Sigma(y-\bar{y})^2=14.14$

$$\sqrt{\frac{14.14}{6}} \cong 1.535 = 1.54$$

Average Match Range; Avg.=12.25

$N=6, \sum$Match Range=73.5

$$\frac{73.5}{6} = 12.25$$

Nagel Anomaloscope

Mean Mid Match Point; Mean=20.75

$N=6, \sum x=124.5$

$$\frac{124.5}{6} = 20.75$$

Sigma Mid Match Point; Sigma=6.01

$N=6, \sum(x-\bar{x})^2=216.88$

$$\sqrt{\frac{216.88}{6}} = 6.01$$

Average Match Range; Avg.=13.83

$N=6, \sum$Match Range=83

$$\frac{83}{6} = 13.83$$

DEVIANS (Anomals)

DEVIAN CORRELATION TABLE

Y \ X	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5	23	23.5	24	24.5	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	Fy	y	yFy	y^2Fy	$(y+1)^2Fy$	Tx	yTx
32.5							/																									1	1.75	1.75	3.06		-2.75	-0.91
32	/																												/			2	1.5	3	4.5		3.50	5.25
31.5																																0		0			0	
31																																0		0			0	
30.5																																0	0	0			0	
30								/																								1	-.75	-.75	.56		-2.25	1.69
29.5																																0		0			0	
29	/																										/					2	-1.75	-3.5	6.12		1.50	-2.62
																																Σ 6		Σ .50	Σ 14.25	Σ	0	Σ -.49

32.25 (margin beside 31)

	15	18	18.5	21	28	29
Fx	2	1	1	0	1	1
x	-5.75	-2.75	-2.25	0	7.25	8.25
xFx	-11.5	-2.75	-2.25		7.25	8.25
x^2Fx	66.13	7.56	5.06		52.6	68.06
$(x+1)^2Fx$						
Ty	-.25	1.75	-.75		-3.75	1.5
xTy	1.44	-4.81	1.69		-27.18	12.38

Σ 6		
	6	Fx
Σ 0	0	ΣxFx
Σ 216.9	216.9	x^2Fx
	222.95	
Σ -.49		

Fy	6
ΣyFy	1
y^2Fy	14.25

Σ 21.25 — checks

$b_x = 0$
$b_y = .08$
$\bar{X} = 20.75$
$\bar{Y} = 30.75$
$\sigma_X = 6.01$
$\sigma_Y = 1.54$

$\bar{X} = X_0 + b_x$. $\sigma_X = W_X \sigma_x$. W_X = group interval of X. $\Sigma xy = \Sigma x T_y = \Sigma y T_x$. $N = \Sigma F_X = \Sigma F_Y$. $b_x = \frac{\Sigma x F_x}{N}$. $\sigma_x = \sqrt{\frac{\Sigma x^2 F_x}{N} - b_x^2}$.

$r = \frac{\Sigma xy - N b_x b_y}{N \sigma_x \sigma_y}$. $x = r\frac{\sigma_x}{\sigma_y} y$. $S.E._x = \sigma_x \sqrt{1-r^2}$. $\sigma_r = \frac{1-r^2}{\sqrt{N-1}}$. $n = N-2$.

$t = \frac{r}{\sqrt{1-r^2}} \sqrt{N-2}$. $S.E._X = W_X S.E._x$. $X = \bar{X} + r\frac{\sigma_X}{\sigma_Y}(Y - \bar{Y})$. (Similarly for y and Y).

SEx = $\sqrt{1-r^2}$ =
SEX = σ_r =
SEy =   t =
SEY =
x = y. y = x.
X = Y. Y = X.

$r = \frac{-.49 / 6}{(6.01)(1.54)} = -.009$

X = 21.83 - .04Y

Y = 30.8 - .002X

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