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Testing the simultaneous influence of three variables on the displacement in the Poggendorff figure

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Abstract

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TESTING THE SIMULTANEOUS INFLUENCE OF THREE VARIABLES ON THE DISPLACEMENT IN THE POGGENDORFF FIGURE

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POGGENDORFF FIGURE

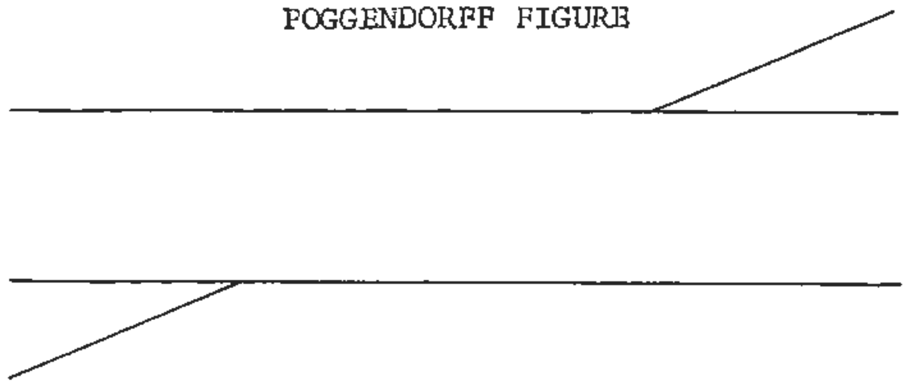


Figure 1

Whenever a line is interrupted by two parallel lines, a displacement is seen.

2. THE STATISTICAL APPROACH

The statistical treatment followed Fisher's analysis of variance. Thus it was possible to test the influence of three variables simultaneously. These variables are the angle, the length of line, and the subject.

THE EXPERIMENT

1. THE PROBLEM

To test the main effects and interactions of the three variables, subjects, lengths of angle side, angles, on the displacement in the Poggendorff figure.

2. THE MATERIAL

Instead of an apparatus that would allow an adjustment like Burmester's, a number of drawings were used. (1)

The parallel lines were horizontal, and the distance between the parallels was kept constant at 40 mm. Four angles were used: A_1 20°, A_2 40°, A_3 60°, A_4 80°.

The length of the crossing oblique line showed the following proportions to the distance between the parallels: B_1 ½, B_2 1, B_3 1½, B_4 2. The line did not extend beyond the lower parallel but was drawn only on the lower side as is illustrated in Figure 2.

FIGURE 2

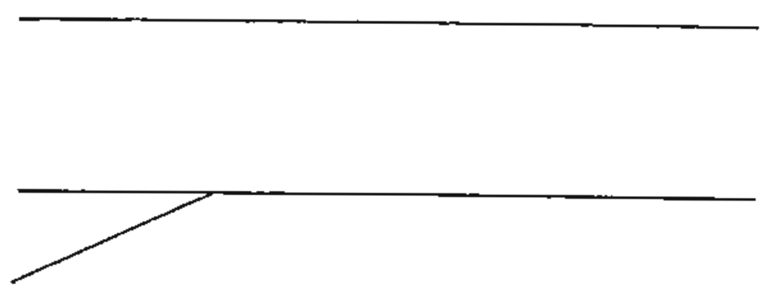


Illustration of figures used in this experiment.

3. THE PROCEDURE

The procedure follows that given by Forni. Thus each subject observed each design five times. The sequence and order of the sixteen designs were randomized for each observer for each repetition.

4. THE INSTRUCTIONS

The observer was instructed to mark the upper parallel where the oblique line would cross if it were extended.

5. THE SUBJECTS

Five observers who had no knowledge of the displacement volunteered as subjects. There were three women and two men, four undergraduates and one graduate.

6. THE STATISTICAL METHOD

A three dimensional design was used, i.e., treatment (A) by treatment (B) by subject (S) according to Lindquist (2, p. 237).

From the beginning it was decided to use the five percent level of significance.

7. THE DATA

The four Tables (I-IV) contain the mean displacements for the four angles for each length for each subject. Thus Table I shows the values obtained for angle 20^{o}, Table II the values obtained for angle 40^{o}, etc. Each cell within each table represents the mean displacement for five observations. Thus in Table I 16.24 is the mean displacement of five observations for length 20 mm. at angle 20^{o} for subject one. The sums of each stimulus situation are also shown and these values are squared.

Table IV contains three minus values. This means that the subject placed the crossing point to the right of the objective point of crossing.

TABLE I

VARIABLE A_1 FOR ALL SUBJECTS FOR ALL LENGTHS (B)

	B_1	B_2	B_3	B_4
S_1	16.24	26.28	21.62	32.20
S_2	26.78	38.06	37.04	39.46
S_3	46.90	35.08	55.14	40.84
S_4	25.34	22.48	28.48	25.30
S_5	48.92	48.18	46.18	39.20
X	164.18	170.08	188.46	177.00
$\Sigma(X^2)$	6203.91	6131.60	7823.43	6363.28

S= subjects B_1 = 20 mm. B_2 = 40 mm. B_3 = 60 mm. B_4 = 80 mm. A_1 = angle 20^{o} Each value is based on the mean of five observations.

TABLE II

VARIABLE A_2 FOR ALL SUBJECTS FOR ALL LENGTHS (B)

	B_1	B_2	B_3	B_4
S_1	9.64	8.54	3.98	6.78
S_2	9.96	8.12	7.90	7.22
S_3	16.54	13.84	13.16	13.50
S_4	4.08	4.58	5.42	6.44
S_5	13.58	13.74	17.78	14.98
ΣX	53.80	48.82	48.24	48.92
$\Sigma(X^2)$	666.75	531.55	596.94	546.08

S = subjects B_1 = 20 mm. B_2 = 40 mm. B_3 = 60 mm.
B_4 = 80 mm. A_2 = angle 40^o
Each value is based on the mean of five observations.

TABLE III

VARIABLE A_3 FOR ALL SUBJECTS FOR ALL LENGTHS (B)

	B_1	B_2	B_3	B_4
S_1	5.32	3.10	2.52	2.30
S_2	5.96	4.42	6.02	6.62
S_3	5.90	7.68	8.92	5.00
S_4	3.76	3.62	3.78	3.88
S_5	8.48	9.12	8.68	6.88
ΣX	29.42	27.94	29.92	24.68
$\Sigma(X^2)$	184.68	184.40	211.79	136.49

S = subjects B_1 = 20 mm. B_2 = 40 mm. B_3 = 60 mm.
B_4 = 80 mm. A_3 = angle 60^o
Each value is based on the mean of five observations.

TABLE IV

VARIABLE A_4 FOR ALL SUBJECTS FOR ALL LENGTHS (B)

	B_1	B_2	B_3	B_4
S_1	0.64	0.70	0.04	0.84
S_2	1.18	0.68	1.46	1.38
S_3	0.54	-0.76	0.48	-1.72
S_4	0.12	-0.08	1.34	1.22
S_5	1.46	1.42	0.66	2.06
ΣX	3.94	1.96	3.98	3.78
$\Sigma(X^2)$	4.23	3.55	4.59	11.30

S = subjects B_1 = 20 mm. B_2 = 40 mm. B_3 = 60 mm.
B_4 = 80 mm. A_4 = angle 80°
Each value is based on the mean of five observations.

Table V shows the sums of all columns from Tables I thru IV and the squares of these sums for each subject. Thus 140.74 is the sum of the displacements for all stimulus situations for subject one and the square of the sum is 19,802.50.

TABLE V

SUMS FOR ALL SUBJECTS FOR ALL A FOR ALL B

	X	$(X)^2$
S_1	140.74	19802.50
S_2	202.26	40909.00
S_3	261.04	68143.00
S_4	139.76	19533.50
S_5	281.32	79140.00
	1025.12	227528.00

S = subjects X = sums of columns from Tables I - IV

On the basis of Table V the sums of the squares ~~was~~ were calculated and found to be 16,631.48.

The ss of the three main effects A, B, and S, can be calculated from the margins of Tables VI and VII. The ss of two of these main effects, B and S, can be determined from Table VI. It is necessary to utilize either Table VII or Table VIII in calculating the remaining main effect A. Thus it is not necessary to have three tables for finding the ss for all three main effects.

All three Tables, VI, VII, and VIII, are essential for calculating the ss for the interactions AB, AS, and BS. The ss for the interaction BS can be calculated from the individual cells in Table VI. Likewise, from the individual cells in Tables VII and VIII can be calculated the ss for the interactions AB and AS respectively.

TABLE VI

SUMS OVER ALL A

	B_1	B_2	B_3	B_4	ΣX_s
S_1	31.84	38.62	28.16	42.12	140.74
S_2	43.88	51.28	52.42	54.68	202.26
S_3	69.88	55.84	77.70	57.62	261.04
S_4	33.30	30.60	39.02	36.84	139.76
S_5	72.44	72.46	73.30	63.12	281.32
ΣX_B	251.34	248.80	270.60	254.38	1025.12

S = subjects   B = Length   n per cell = 4

TABLE VII

SUMS OVER ALL S

	A_1	A_2	A_3	A_4	ΣX_B
B_1	164.18	53.80	29.42	3.94	251.34
B_2	170.08	48.82	27.94	1.96	248.80
B_3	188.46	48.24	29.92	3.98	270.60
B_4	177.00	48.92	24.68	3.78	254.38
ΣX_A	699.72	199.78	111.96	13.66	1025.12

B = length   A = angle   n per cell = 5

TABLE VIII

SUMS OVER ALL B

	A_1	A_2	A_3	A_4	ΣX_S
S_1	96.34	28.94	13.24	2.22	140.74
S_2	141.34	33.20	23.02	4.70	202.26
S_3	177.96	57.04	27.50	-1.46	261.04
S_4	101.60	20.52	15.04	2.60	139.76
S_5	182.48	60.08	33.16	5.60	281.32
ΣX_A	699.72	199.78	111.96	13.66	1025.12

S = subjects A = angle n per cell = 4

The ss of the triple interaction ABS is obtained by taking the difference of the sums of the sums of the squares of A, B, S, AB, AS, BS, and the total sums of the squares. All of the ss are found in Table IX.

8. THE RESULTS

Table IX shows the source (A, B, S, etc.), degrees of freedom, sums of the squares, the mean squares, and the F values. The mean squares are found by dividing the ss by the degrees of freedom for each source. The F values for the main effects are determined by dividing the ms of each main effect by the ms of the corresponding two-factor interaction. Thus the F value of main effect A is found by dividing the ms of A by the ms of interaction AS.

The F value for each two-factor interation is found by dividing the ms of each two-factor interaction by the ms of the triple interaction.

TABLE IX

SUMMARY TABLE

Source	df	ss	ms	F
A	3	13974.71	4658.24	58.12
B	3	16.46	5.48	.47
S	4	1086.90	271.72	
AB	9	60.25	6.69	.61
AS	12	961.56	80.13	7.35
BS	12	138.74	11.56	1.06
ABS	36	392.86	10.91	
	79	16631.48		

df = degrees of freedom   ss = sums of the squares
ms = mean squares   F = F value

MAIN EFFECT

The F value for the angles (A) is significant at better than the 5% level. Thus the observed displacement differs significantly for different angles. The length of the lines is not a significant factor in the displacement. It is assumed that there are subject differences on almost any criterion scale, therefore it is unnecessary to find the F value for S.

THE INTERACTION

The interaction AS is significant at better than the 5% level. That is, the effect of the angle is not the same for each subject. Interactions BS and AB are not significant at the 5% level. That is, the individual differences are not affected by the length of the lines and the effect of the angles is independent of the lengths of the lines.

9. THE DISCUSSION

This experiment was done to test the influence of the angle size and the lengths of the crossing lines and to determine if there was a significant interaction between the two.

INFLUENCE OF LENGTH

Burmester found a significant difference in the lengths of the crossing lines, but at the time of his experiment the fact that practice influences the illusion was not known. (3) In this experiment, the sixteen designs were randomized for each repetition for each subject. In this way any practice effect would affect the different stimulus situations in the same way.

BURMESTER'S COEFFICIENT

It was assumed by Burmester that the observed displacement was in agreement with the formula d = c u cot a. His coefficient c was calculated with the method of least squares from the observed and the calculated means and found to be 0.158 for the unit distance between the parallels. Burmester was the only observer, but he assumed that the coefficient would vary from subject to subject.

The coefficients for the five observers of this experiment were also found by the method of least squares. They are listed in Table XI. In general these coefficients are higher than Burmester's and those found by Forni. The figures used in this experiment were the reverse of those used by Forni. That is, the diagonal was located on the bottom parallel and the subject marked on the top parallel. This difference in orientation may have some effect on the coefficient. This would have to be testedin another experiment using both orientations for each subject.

Again following Burmester the observed and calculated means were compared for each subject at each angle. The observed values in Table XI are taken from Table VIII. The calculated and observed values show considerable agreement.

The analysis of variance tests only whether the levels of a variable lead to significantly differing results. A study of Table VIII shows that the subjects follow a definite order. Subject 5 gives greater displacement than subject 3. Subject 2 follows next, and the two remaining subjects, subject 1 and subject 4, agree rather closely. The graph, figure III, illustrates these results.

Table VIII shows also a definite trend in regard to the different angles. It has already been pointed out in the discussion of Table XI that there is not only a trend, but a functional relation between the angle size and the displacement and that the displacement varies as the cotangent of the angle. Beyond this functional relation between angle and displacement the graph illustrates clearly the importance of the coefficient c. If we rank the coefficients from the highest to the lowest as 1, 2, 3, 4.5, 4.5, the rank gives the position on the figure. It is of interest to notice how closely the lines of mean displacement compare with the respective coefficients.

Table X

COEFFECIENTS BASED ON TABLE VIII

	C
S_1	.206
S_2	.296
S_3	.383
S_4	.209
S_5	.397

S=subject C=coefficient

Table XI

COMPARISON OF THE OBSERVED AND CALCULATED MEANS

	A_1		A_2		A_3		A_4	
	O	C	O	C	O	C	O	C
S_1	2.41	2.26	.72	.98	.33	.48	.06	.15
S_2	3.53	3.27	.83	1.41	.58	.68	.12	.21
S_3	4.45	4.23	1.43	1.82	.69	.89	.04	.27
S_4	2.54	2.30	.51	.99	.38	.48	.07	.15
S_5	4.56	4.37	1.50	1.89	.83	.92	.14	.28

A_1= angle 20° A_2= angle 40° A_3=angle 60° A_4= angle 80°

S = subject O = observed displacement

C = calculated displacement

10 THE LIMITATIONS

In the present experiment only four variations of the angle were used, 20°, 40°, 60°, 80° and four variations in the length of the angle side were used, 20, 40, 60, and 80 mm. The distance between the parallels was kept constant at 40 mm. Only one position of the Poggendorff figure was used with the parallel lines lying in the horizontal position and the oblique line being at the bottom of the design.

11. THE SUGGESTIONS

It is suggested that further experimentation be carried on in the field of optical illusions to gain new insights into the problem of how people react differentially to varying visual stimuli. The effects of refractive variables could be tested by having subjects observe with and without the refractive errors being corrected. Also, the head tilt could be rigidly controlled by use of a head rest.

Eventually, if the necessary experimentation is done, the responses to illusions may be related to present optometric methods of testing. In this way optometry may some day gain new valuable methods of testing and / or training.

THE SUMMARY

Tested in this experiment were the main effects and interactions of the three variables, subject, length of angle side, and angle on the displacement in the Poggendorff figure.

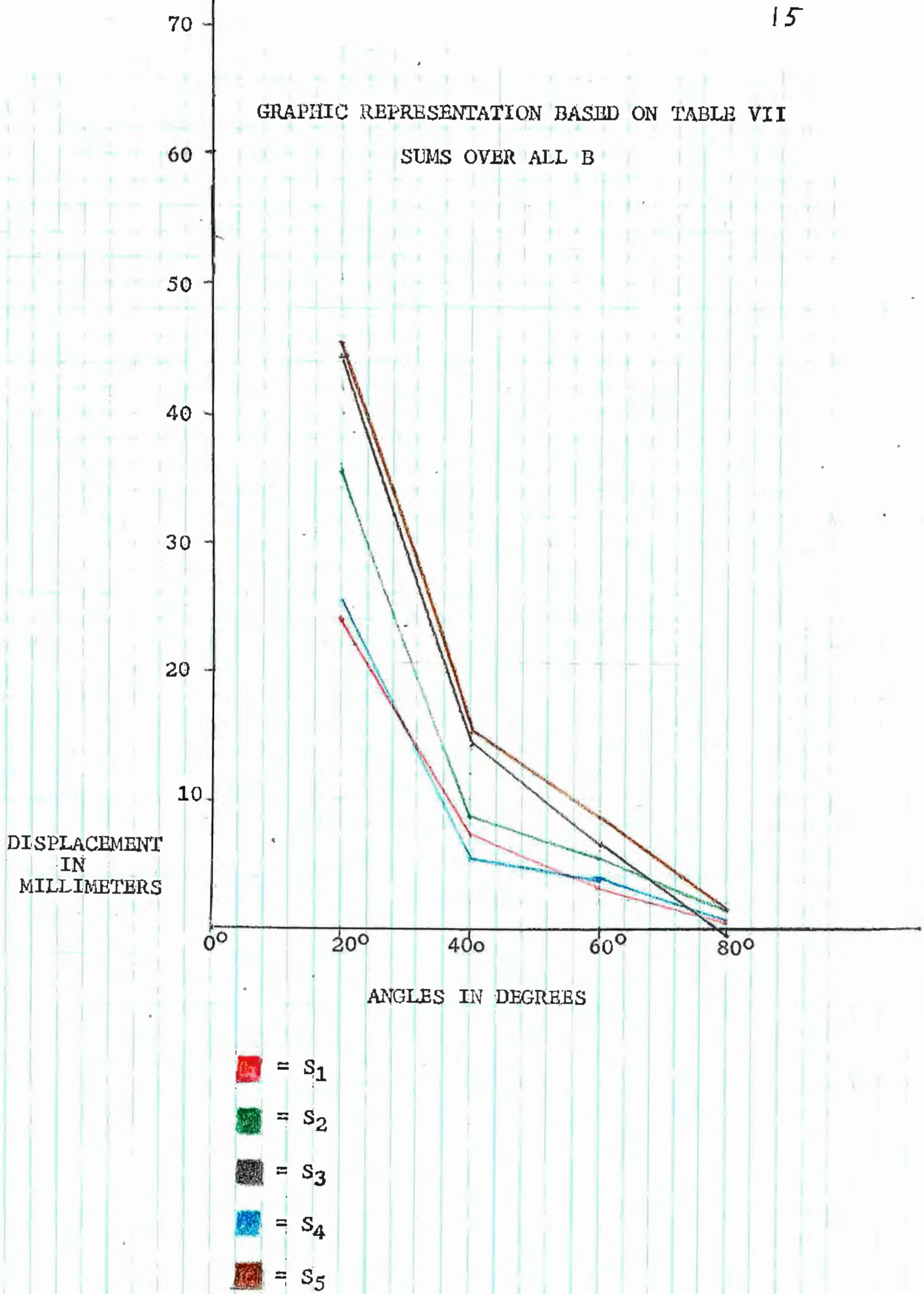
A number of drawings were used (see figure II). The observer was instructed to mark the upper parallel where the oblique line would cross if it were extended.

A three dimensional statistical design was used, i.e., treatment (A) by treatment (B) by subject (S). From the beginning it was decided to use the five percent level of significance.

It was found that there were two variables significant at better than the 5% level, the angles and the interaction between the subject and the angles. The lengths of the lines were not found to be significant at the 5% level.

This experiment supports Burmester's assumption that the displacement varies as the cotangent of the angle. Individual differences were noticed.

Fig. III


GRAPHIC REPRESENTATION BASED ON TABLE VII
SUMS OVER ALL B
70
60
50
40
30
20
10
DISPLACEMENT IN MILLIMETERS
0°
20°
40°
60°
80°
ANGLES IN DEGREES
= S_1
= S_2
= S_3
= S_4
= S_5

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