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The motor-visual effects of apertures on a 20/20 acuity field at a 40 cm viewing distance

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Abstract

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by

Philip D. Goicoechea

Willis S. Muncey

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APPROVED

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Chairman

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P.D.G.
W.S.M.

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INTRODUCTION

INTRODUCTION

In the prescribing of ophthalmic lenses the practitioner must consider two groups of findings. Those which are relative to the patient's "far point" and those which are relative to his "near point." It is the contention of the experimentors that the latter group of findings is of paramount importance. Since the nearer the required task is to the patient, the more the interplay is developed between the accommodative and convergence facilities. The coupled involvement of these two systems can cause or resolve a myriad of problems and we feel that a more thorough investigation of aperture effects on light reduction and its consequential effects on the accommodative and convergence systems both as isolated entities as well as coupled components of a compound system, should prove to be valuable information for the inquisitive optometrist.

As far as we know our study is unique in that we not only determined the convergence response of the patient to plus and minus lenses but we also evaluated the accommodative response and posture while using a foveal discriminatory criteria, rather than a peripheral evaluation.

Our clinical evaluation consisted of 20 subjects between the ages of twenty and thirty. Among which 90% were males and 10% were females. All of the patients were found to have more than the "normal" (O.E.P.) amount of accommodative facility available, (5.0 Diopters). On each subject we conducted 40 accommodative and 40 convergence evaluations. The results of these measurements were statistically evaluated using standard "t" test procedures, and the compiled results were graphed for convenience of observation.

PROCEDURE

PROCEDURE

The equipment used in this study was:

1. A standard B. and L. stand and chair with a greens phoropter;

2. Two point source illuminators which provided 40fc of illumination on each side of the near point target;

3. A near point target of our own design - designed only for this particular experiment (study). See drawing at the end of this section, page 7.

The subject's habitual far point Rx was determined and a near cylinder evaluation was made using Dr. Pratt's technique. If the near cylinder varied from the far cylinder by more than 1/4 Diopter then the near cylinder was used in the testing. Also, the subject's normal 14A and 15A were determined through this Rx. Standard testing charts were then removed and the special target was introduced at the same distance (40cm), such that now, with the subject's 14A in place, the right eye sees the 20/20 block of letters and the subject's left eye sees the cross target.

With each subject we performed a standard sequence of tests which was repeated under four different conditions for each patient. The sequence is as follows:

1. 14A + 1.00
2. 14A + 0.00
3. 14A - 1.00
4. 14A - 2.00
5. 14A - 3.00
6. 14A - 3.00
7. 14A - 2.00
8. 14A - 1.00
9. 14A + 0.00
10. 14A + 1.00

The different condition controls were placed before the right eye only and they are as follows:

Condition # 1

a neutral density filter of .6

Condition # 2

a vertical slit of .75mm width

Condition # 3

a horizontal slit of .75mm width

Condition # 4

a pinhole of 1.0mm diameter

At this point it should be understood that the conditional controls and the sequence lenses were used and altered only before the right eye, while cross cylinder measurements were made before the left eye only. That is, the right eye through the lenses and controls constantly viewed a block of standard 20/20 Snellen letters, while the left eye viewed constantly a lined cross (refer to drawing). The constant lenses before the left eye include enough lateral prism to align these two targets, one directly below the other, and a

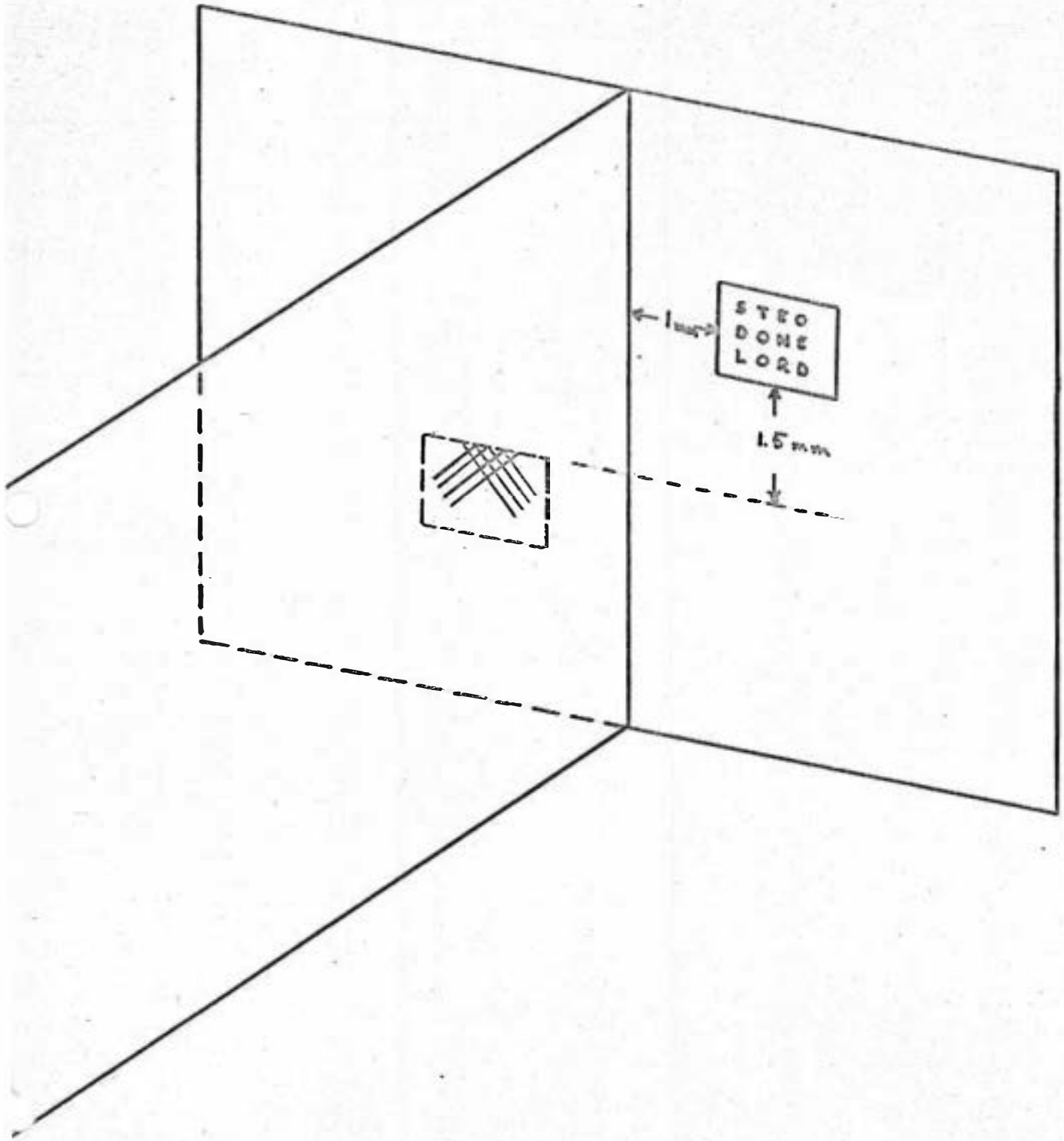
Jackson Cross Cylinder with the axis represented by the red dot at 135 degrees and the axis represented by the white dot at 45 degrees. All measurements were made before the left eye even though our conditions were binocular and the particular procedure per patient is as follows:

Assuming that we have already determined the refractive status of the patient (sphere and cylinder) as well as the 14A and 15A, we then begin with the 14A + 1.00 and the neutral density filter (log filter) placed before the right eye and 14A + 1.00, the Jackson Cross Cylinder and the variable lateral prism unit all before the left eye. The patient is instructed to "call out" the letters he sees before his right eye and to keep these letters clear at all times. We then introduce enough lateral prism to align the two field blocks while the patient maintains fixation on the 20/20 letters. Once alignment has been accomplished, the patient is instructed to glance rapidly down at the lined cross and back to the letters (which should have remained clear) and to then indicate verbally which of the line groups appeared "blacker." After each response the lens value was changed in 1/4 diopter steps until an equal response was elicited or until the response was bracketed (1/4 diopter change produced a reversal of response). When a 1/4 of a diopter lens change caused the response to change from right to left,

the value recorded was the intermediate one-eighth. When a 1/2 of a diopter lens change was necessary to produce a change, the intermediate 1/4 was recorded. When the patient responded "equal," this value was recorded. In each instance, before a value was recorded, four reversals were elicited and the final median value was considered to be between the last two reversals.

This procedure was then repeated totally for step 2 of the afore mentioned sequence until the ten steps had been completed. Then condition # 2 was introduced and the ten steps, in sequence, were repeated. This procedure was repeated for conditions # 3 and # 4 as well, such that we obtained 40 accommodative and 40 convergence measurement findings for each of the 20 patients. Thus providing us with a data base of 1600 findings.

NEAR POINT TARGET - 40 cm



DATA

AND

CALCULATIONS

DATA AND CALCULATIONS

Data was obtained on 20 individuals using the previously described procedure. The Original Data is shown in the Appendix. From this data the following calculations were performed to obtain a statistical evaluation of the data.

A. Accommodation Response

The accommodative response was determined for each subject by first averaging the two accommodative findings that were obtained under each viewing and stimulus condition. This average value was subtracted from the 14A value under each viewing condition to obtain the net accommodative response. A plus value indicates an accommodative response less than 14A, and a minus value indicates that the accommodative response made was greater than 14A.

1. EXAMPLE of accommodative response calculations:

Subject No: I — Log Filter

	Data	Average	Net
14A + 1.00	+2.25/+1.75	+2.00	+.25
14A	+1.87/+1.62	+1.75	0
14A - 1.00	+1.50/+1.62	+1.56	-.18

14A - 2.00	+1.37/+0.50	+0.94	-.81
14A - 3.00	+0.75/+1.00	+0.87	-.87

The average and net values for each viewing and stimulus condition are shown in the Appendix (Average Accommodative and Convergence Findings and Net Accommodative and Convergence Responses).

B. Convergence Response

The convergence response was determined for each subject by first averaging the two convergence findings that were obtained under each viewing and stimulus condition. This average value was then reduced by 1/7 or approximately 85% of its original value to account for the distance between the center of rotations of the eyes and the Risley Prisms on the phoropter.

Once the effective prism value was determined this value was corrected for the subject's inter-pupillary distance at the 40cm distance. This value was subtracted from the 15A value under each viewing condition to obtain the net convergence response. A plus value indicating exophoria above 15A, and minus indicating esophoria above 15A. The following table is the correction factors that were used for each

interpupillary distance.

Interpupillary Distance	Correction Factor
55-56	+3.5
57-58	+4.0
59-60	+4.5
61-62-63	+5.0
64-65	+5.5

1. EXAMPLE of convergence response calculations:

Subject No: I

Pd: 60

Correction Factor: +4.5

	Log Filter Data	Average	85%	Net
14A + 1.00	-2/-6	-4.0	-3.5	+2.5
14A	-6/-8	-7.0	-6.0	0.0
14A - 1.00	-7/-10	-8.5	-7.0	-1.0
14A - 2.00	-8/-12	-10.0	-8.5	-2.5
14A - 3.00	-11/-11	-11.0	-9.0	-3.0

The average and net values for each viewing and stimulus condition are shown in the Appendix (Average Accommodative and Convergence Findings and Net Accommodative and Convergence Responses).

C. Mean, Variance, Standard Deviation, Standard Error of the Mean

Shown below is how the mean, variance, standard deviation and standard error of the mean were calculated for the log filter viewing conditions and with a 14A - 1.00D stimulus. The means, variance, standard deviation, and standard error of the means for both the accommodative and convergence responses are shown in the Appendix (Table I: Mean, Variance, Standard Deviation, and Standard Error of the Mean for both Accommodative and Convergence Responses for all viewing and stimulus conditions).

1. EXAMPLE of mean, variance, standard deviation, and standard error of the mean calculations:

   Viewing Conditions = Log Filter

   Stimulus Conditions = 14A + 1.00

   Subject No: I

(refer to example A at the end of the DATA section)

D. t test

Shown below is how the t test was calculated for the various accommodative responses at the Log Filter viewing condition and the 14A + 1.00 stimulus condition. The results of the t test for both the accommodative and convergence

responses for all viewing and stimulus conditions are shown in the Appendix (Table II: t test values for both Accommodative and Convergence Responses).

1. EXAMPLE of t test calculations:

   4 viewing and stimulus conditions

   t.95 = 1.73 n = 20

   Confidence Interval = $\pm 1.73 \geq H_1 - H_2 \geq -1.73$

(refer to example A at the end of the DATA section)

E. Frequency Distribution Graphs

Graph 1 (Appendix) is a frequency distribution graph of the net accommodative responses and the number of subjects making a certain accommodative response. There are a total of 20 graphs, one for each viewing and stimulus condition.

Graph 2 (Appendix) is a frequency distribution graph of the net convergence responses and the number of subjects making a certain convergence response. There are a total of 20 graphs, one for each viewing and stimulus condition.

F. Graphs of the Mean Accommodative and Convergence Responses

Graphs 3 and 4 are graphs of the mean accommodative and convergence responses respectively

and the stimulus that was used. In each case the response is plotted on the vertical axis, and the stimulus is plotted on the horizontal axis.

G. Graphs of the Mean Accommodative and Convergence Responses as Per Cents of the Log Filter

Graphs 5 and 6 are graphs of the mean accommodative and convergence responses respectively as percentages of the response made during the log filter viewing condition and stimulus conditions. The percentages of the log filter in each case was determined by dividing the mean response made during each viewing and stimulus condition by the mean of the log filter under each viewing and stimulus condition and multiplying by 100.

The percentage values are shown in the Appendix (Table III: Viewing and stimulus conditions as percentages of the log filter viewing and stimulus condition).

EXAMPLE A

	ACCOMMODATION		CONVERGENCE	
	X	X^2	X	X^2
1	+ .25	.06	+ 2.5	6.25
2	+ .18	.03	+ 3.0	9.0
3	+ .25	.06	0.0	0.0
4	+ .50	.25	+ 2.5	6.25
5	+ .37	.13	+ 1.5	2.25
6	+ .43	.18	+ 1.0	1.0
7	+ .50	.25	+ 4.0	16.00
8	+ .25	.06	+ .50	.25
9	+ .37	.13	+ 2.0	4.00
10	0.00	0.00	+ 1.5	2.25
11	+ .06	.003	+ 3.0	9.0
12	+ .43	.18	+ 2.0	4.0
13	+ .25	.06	0.0	0.0
14	+ .25	.06	+ .5	.25
15	+ .50	.25	+ 6.0	36.00
16	- .12	.01	- .5	.25
17	+ .62	.39	+ 4.0	16.00
18	- .12	.01	- 1.0	1.0
19	+ .31	.09	+ 2.5	6.25
20	- .06	.003	0.0	0.0
	ΣX = + 4.24		ΣX = +35.00	
	M = + .21		M = + 1.75	
	ΣX^2 = 2.38		ΣX^2 = 1.20	

VARIANCE: $= \dfrac{\Sigma X^2 - \dfrac{(\Sigma X)^2}{n}}{n-1}$

$\sigma^2 = \dfrac{2.38 - .90}{19}$ $\qquad$ $\dfrac{120 - 61.25}{19}$

$\sigma^2 =$ .08 $\qquad$ 3.09

STD. DEV.: $= \sqrt{\sigma^2}$

$= \sqrt{.08}$ $\qquad$ $\sqrt{3.09}$

$\sigma =$ .28 $\qquad$ 1.76

STD. ERROR OF THE MEAN: $= \sigma / \sqrt{n}$

= .28 / 4.47 $\qquad$ 1.76 / 4.47

$\sigma_m =$ .06 $\qquad$ .39

EXAMPLE B

VIEWING CONDITIONS (LOG FILTER)	STIMULUS CONDITIONS (14A+1.00)
$\overline{X}_1$ = + 1.00	$\overline{X}_1$ = Log Filter
$\overline{X}_2$ = - 1.00	$\overline{X}_2$ = Vert. Slit
$\overline{X}_3$ = - 2.00	$\overline{X}_3$ = Hori. Slit
$\overline{X}_4$ = - 3.00	$\overline{X}_4$ = Pinhole

$$t_1 = \frac{\overline{X}_1 - \overline{X}_2}{\overline{X}_{\sigma_{m_1 m_2}}}$$

For each of the "t" calculations, the subscripts found in the numerator for the $\overline{X}$'s are the same as those found in the denominator for the $\overline{X}_{\sigma_m}$'s (note above) Where; t_1 uses 1&2; t_2 uses 1 & 3; t_3 uses 1 & 4; t_4 uses 2 & 3; t_5 uses 2 & 4; t_6 uses 3 & 4; Such that:

t_1 = + 9.43	t_1 = + 1.00
t_2 = +12.11	t_2 = + .40
t_3 = +11.30	t_3 = + 2.18
t_4 = + 4.60	t_4 = - .50
t_5 = + 5.63	t_5 = + 1.77
t_6 = + 1.45	t_6 = + 2.50

The underlined values, for this example, are those values which demonstrate a significant difference. (note the confidence interval for this example in subsection D of the DATA and CALCULATIONS section.

DISCUSSION

AND

CONCLUSION

DISCUSSION AND CONCLUSIONS

At the outset of our investigation we proposed two hypotheses: H_1 and H_2. Where H_1 states that the accommodative and convergence responses under the three aperature conditions (Vertical Slit - V.S.; Horizontal Slit - H.S.; Pinhole - P.H.) are significantly different than those responses found with the reduced illumination only (Log Filter - L.F.). H_2 is the anti-thesis of this and summarily states that under the above varied conditions no significant difference will be found. Through the "t" testing procedure the 95% confidence interval was determined to be: + 1.73 H_1 - H_2 - 1.73. Thus, any value that lies outside of this interval can be said to have a significant difference from the Log Filter findings.

You will note from the Frequency Distribution Graphs for both the accommodation and the convergence, that these two facilities are statistically responding very similarly. That is to say, that as an increase in minus lenses are introduced the grouping of both the accommodative and convergence findings become more dispersed. In other words, the responses in both systems under all viewing conditions show that at the + 1.00 and - 1.00 diopter stimulus levels

that all responses are relatively evenly grouped around the mean response in each case with only slight variability, as shown by the Standard Deviation Scores (note Tables I-A and I-B).

However, at the - 2.00 and - 3.00 diopter stimulus levels there is definitely a larger variability from the mean value (note Tables I-A and I-B) and this is again consistent for both the accommodative and convergence responses. Also, the graphs of the Mean Accommodative and Convergence Responses compared to their own stimulus levels (Graphs # 3 and 4) demonstrate this pattern. The Accommodative graph (# 3) shows a pronounced significant difference for the - 2.00 and - 3.00 diopter levels under all the viewing conditions. However, with the + 1.00 and - 1.00 diopter levels this significant difference is limited to only one of the comparative aperatures (accommodative = pinhole and convergence = horizontal slit at the + 1.00 level and the vertical slit at the - 1.00 diopter level).

In summarizing our study we find that neither of our original hypotheses holds absolutely true and consistent for all viewing and stimulus conditions but that each applies on a conditional basis and must be evaluated for each of the tested conditions on this basis.

APPENDIX

TABLES

I

II

III

TABLE I-A

	LOG FILTER		VERTICAL SLIT	
	ACC	CON	ACC	CON
14A+1.00				
ΣX	4.24	35.00	3.35	23.00
ΣX^2	2.38	126.00	1.06	64.50
M	.21	1.75	.17	1.15
σ^2	.08	3.09	.03	2.00
σ	.28	1.76	.17	1.42
σ_M	.06	.39	.04	.31
14A-1.00				
ΣX	- 8.43	- 48.00	- 5.57	- 29.00
ΣX^2	5.75	174.00	2.46	83.00
M	- .42	- 2.40	- .27	- 1.45
σ^2	.12	3.09	.05	2.15
σ	.34	1.76	.22	1.47
σ_M	.08	.39	.05	.32
14A-2.00				
ΣX	- 17.57	- 104.00	- 10.29	- 69.00
ΣX^2	21.04	707.00	8.56	389.50
M	- .88	- 5.20	- .51	- 3.45
σ^2	.29	8.74	.17	7.97
σ	.54	2.95	.42	2.82
σ_M	.12	.65	.09	.63
14A-3.00				
ΣX	- 21.75	- 142.00	- 11.99	- 96.50
ΣX^2	34.69	1469.00	12.57	757.25
M	- 1.09	- 7.10	- .60	- 4.82
σ^2	.58	24.25	.28	15.34
σ	.76	4.92	.53	3.92
σ_M	.17	1.10	.12	.87

Tables I-A and I-B show the mean, variance, standard deviation and standard error of the mean for both accommodative and convergence responses for all viewing and stimulus conditions.

TABLE I-B

	HORIZONTAL SLIT		PINHOLE	
	ACC	CON	ACC	CON
14A+1.00				
ΣX	3.97	21.50	1.97	24.00
ΣX^2	1.52	69.75	.86	56.00
M	.19	1.07	.09	1.20
σ^2	.04	2.33	.04	1.43
σ	.20	1.52	.20	1.20
σ_m	.04	.34	.04	.26
14A-1.00				
ΣX	- 5.45	- 35.50	- 4.32	- 35.00
ΣX^2	2.31	106.50	1.52	122.00
M	- .27	- 1.77	- .22	- 1.75
σ^2	.05	2.17	.03	3.19
σ	.22	1.47	.17	1.79
σ_m	.05	.32	.14	.40
14A-2.00				
ΣX	- 12.58	- 78.00	- 9.09	- 62.50
ΣX^2	13.46	576.50	6.50	332.75
M	- .63	- 3.90	- .45	- 3.12
σ^2	.29	13.61	.12	7.00
σ	.54	3.69	.34	2.64
σ_m	.12	.82	.08	.59
14A-3.00				
ΣX	- 11.36	- 99.50	- 13.70	- 98.00
ΣX^2	26.03	847.50	14.34	855.75
M	- .87	- 4.97	- .69	- 4.90
σ^2	.58	18.55	.26	19.76
σ	.76	4.31	.51	4.44
σ_m	.17	.96	.12	.99

TABLE II-A

	t_1		t_2		t_3	
	ACC	CON	ACC	CON	ACC	CON
L.F.	+ 9.43	+10.64	+12.11	+13.37	+11.30	+11.80
V.S.	+ 9.78	+ 8.13	+10.46	+ 9.79	+ 9.62	+10.12
H.S.	+ 10.22	+ 8.61	+10.25	+ 8.57	+10.09	+ 9.29
P.H.	+ 6.89	+ 8.94	+ 8.31	+10.05	+ 9.18	+ 9.68

TABLE II-B

	t_4		t_5		t_6	
	ACC	CON	ACC	CON	ACC	CON
L.F.	+ 4.60	+ 5.38	+ 5.63	+ 6.27	+ 1.45	+ 2.16
V.S.	+ 3.42	+ 4.17	+ 3.88	+ 5.62	+ 1.86	+ 1.82
H.S.	+ 4.23	+ 3.74	+ 5.45	+ 5.00	+ 1.65	+ 6.82
P.H.	+ 3.83	- 2.74	+ 5.88	- 4.50	+ 2.40	- 2.25

TABLES II-A and II-B represent the t test values for both accommodative and convergence responses under the viewing conditions. Where : n=20, $t_{95} = 1.73$

$t_1 = +1 : -1$ $\quad$ $t_4 = -1 : -2$

$t_2 = +1 : -2$ $\quad$ $t_5 = -1 : -3$

$t_3 = +1 : -3$ $\quad$ $t_6 = -2 : -3$

Confidence Interval = +1.73 $H_1 - H_2$ -1.73

TABLE II-C

	t_1		t_2		t_3	
	ACC	CON	ACC	CON	ACC	CON
+1.00	+ 1.00	+ 1.89	+ .40	+ 1.84	+ 2.18	+ 1.62
-1.00	- 2.30	- 2.64	- 2.30	- 1.75	- 3.33	- 1.62
-2.00	- 3.52	- 2.73	- 2.08	- 1.76	- 4.30	- 3.35
-3.00	- 3.37	- 2.30	- 1.29	- 2.07	- 2.75	- 2.10

TABLE II-D

	t_4		t_5		t_6	
	ACC	CON	ACC	CON	ACC	CON
+1.00	- .50	+ .24	+ 1.77	+ .17	+ 2.50	+ .43
-1.00	0.00	+ 1.00	- 1.11	+ .83	- 1.11	- .05
-2.00	+ 1.14	+ .62	- .71	- .54	- 1.80	- 1.10
-3.00	+ 1.86	+ .16	0.00	+ .09	- 1.24	- .07

TABLES II-C and II-D represent the t test values for both accommodative and convergence responses under the stimulus conditions. Where n = 20; t_{95} = 1.73

t_1 = L.F. : V.S. t_4 = V.S. : H.S.

t_2 = L.F. : H.S. t_5 = V.S. : P.H.

t_3 = L.F. : P.H. t_6 = H.S. : P.H.

Confidence Interval = +1.73 $H_1 - H_2$ -1.73

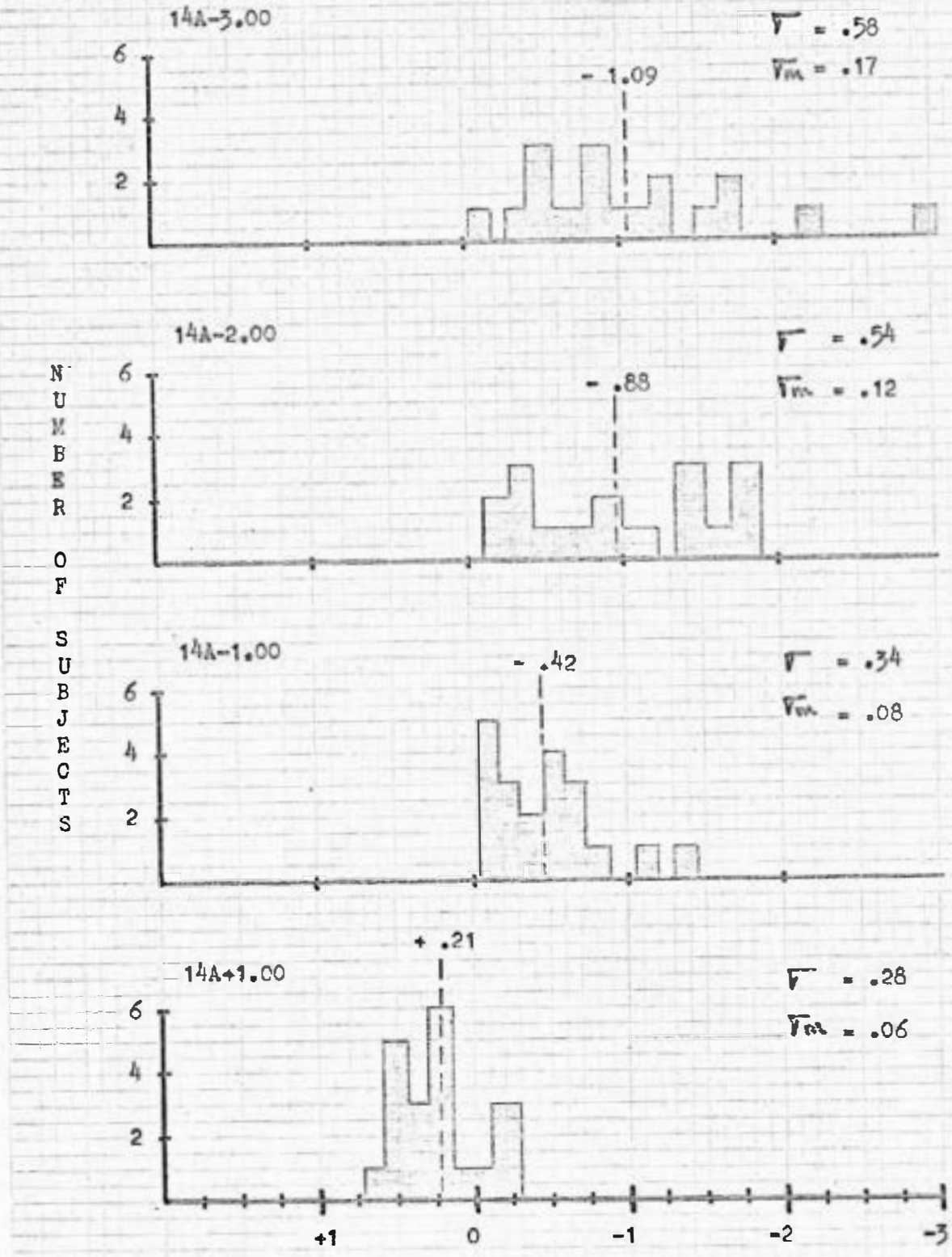
TABLE III

	V.S.		H.S.		P.H.	
	ACC	CON	ACC	CON	ACC	CON
+1.00	80	65	90	61	42	68
-1.00	64	60	64	73	52	62
-2.00	57	65	71	75	51	60
-3.00	55	67	79	70	63	69

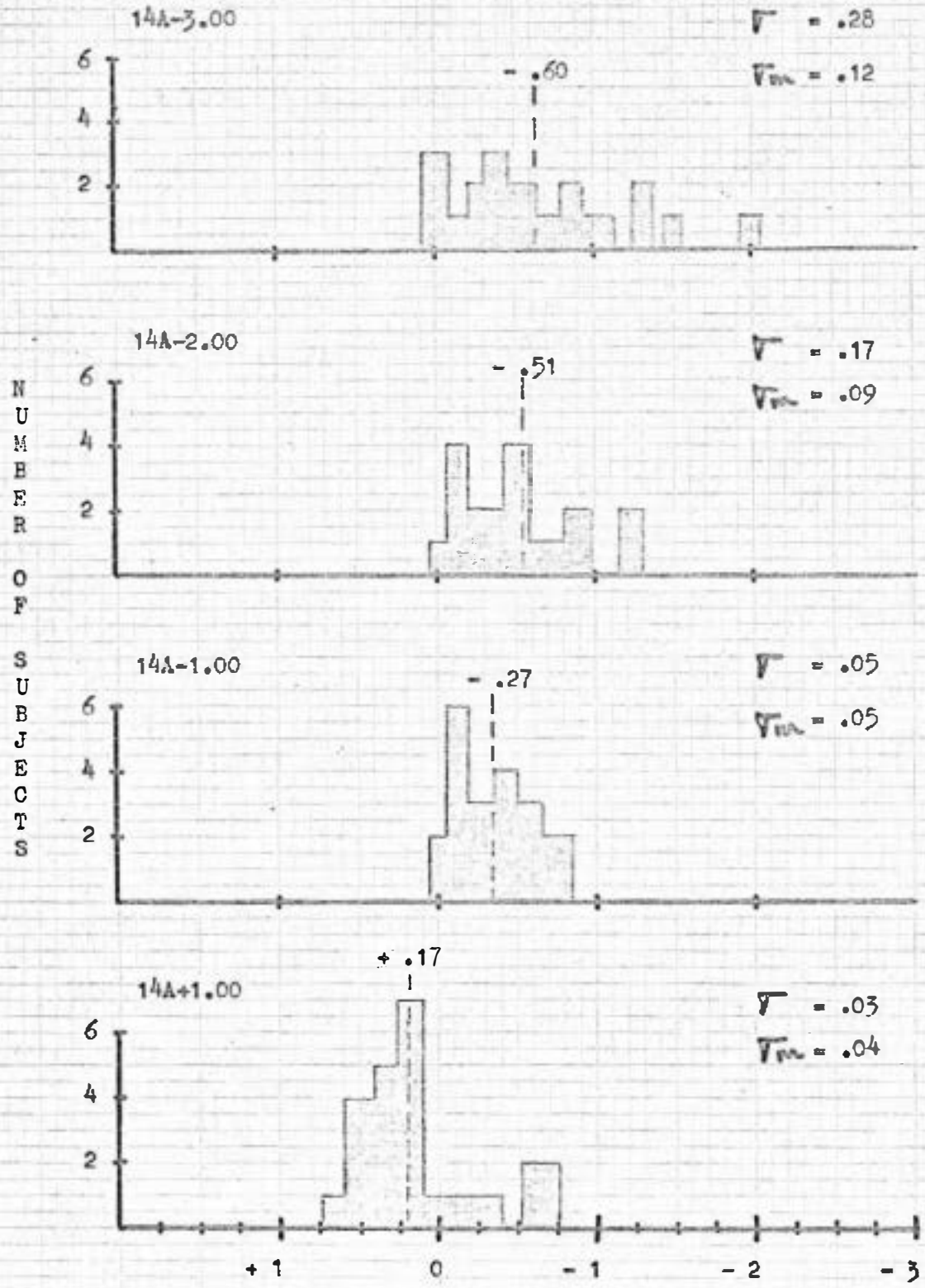
TABLE III represents the viewing and stimulus conditions as percentages of the log filter viewing and stimulus conditions.

GRAPH I

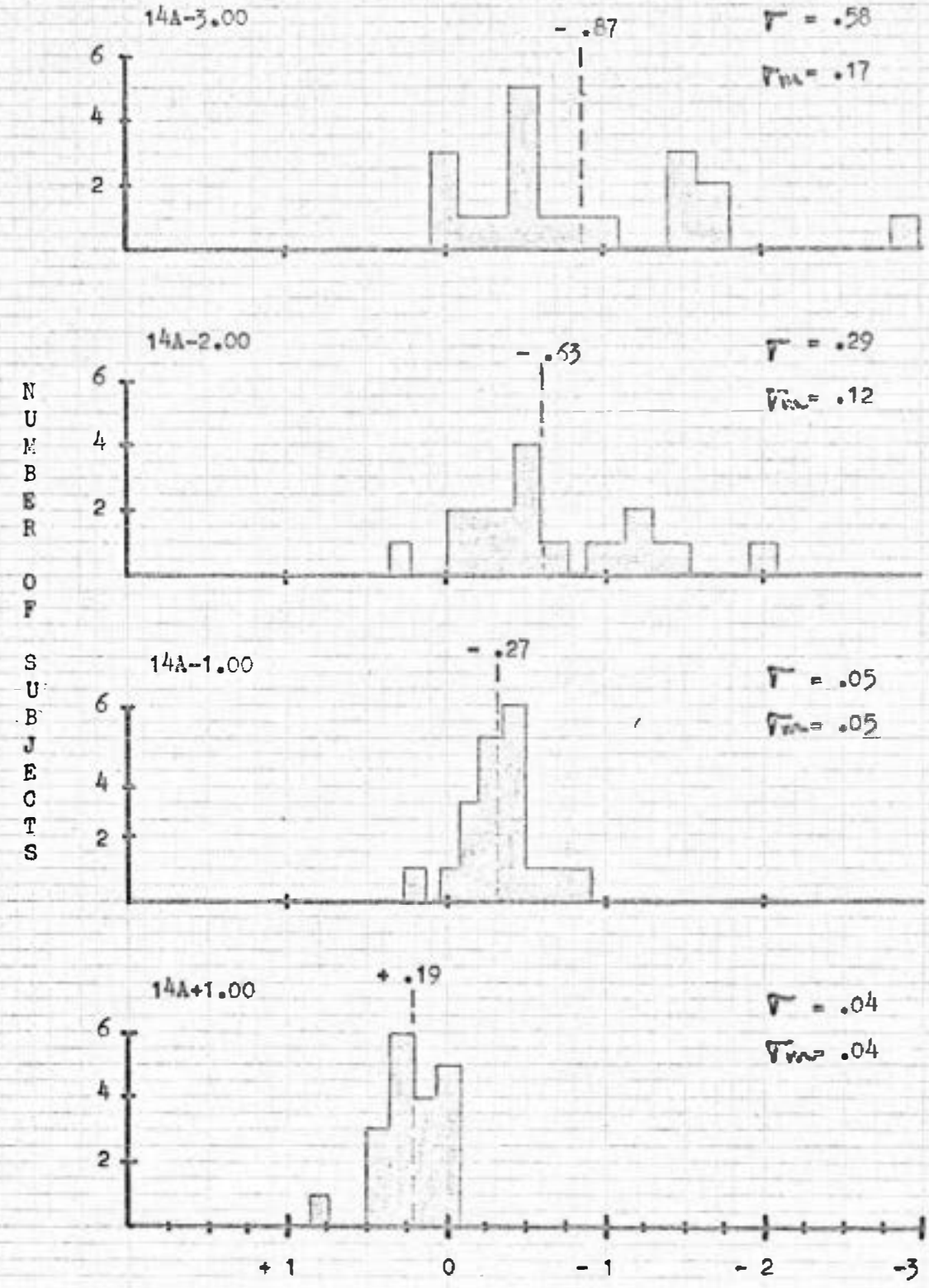
ACCOMMODATIVE RESPONSE FREQUENCY DISTRIBUTION GRAPHS



ACCOMMODATIVE RESPONSE - LOG FILTER

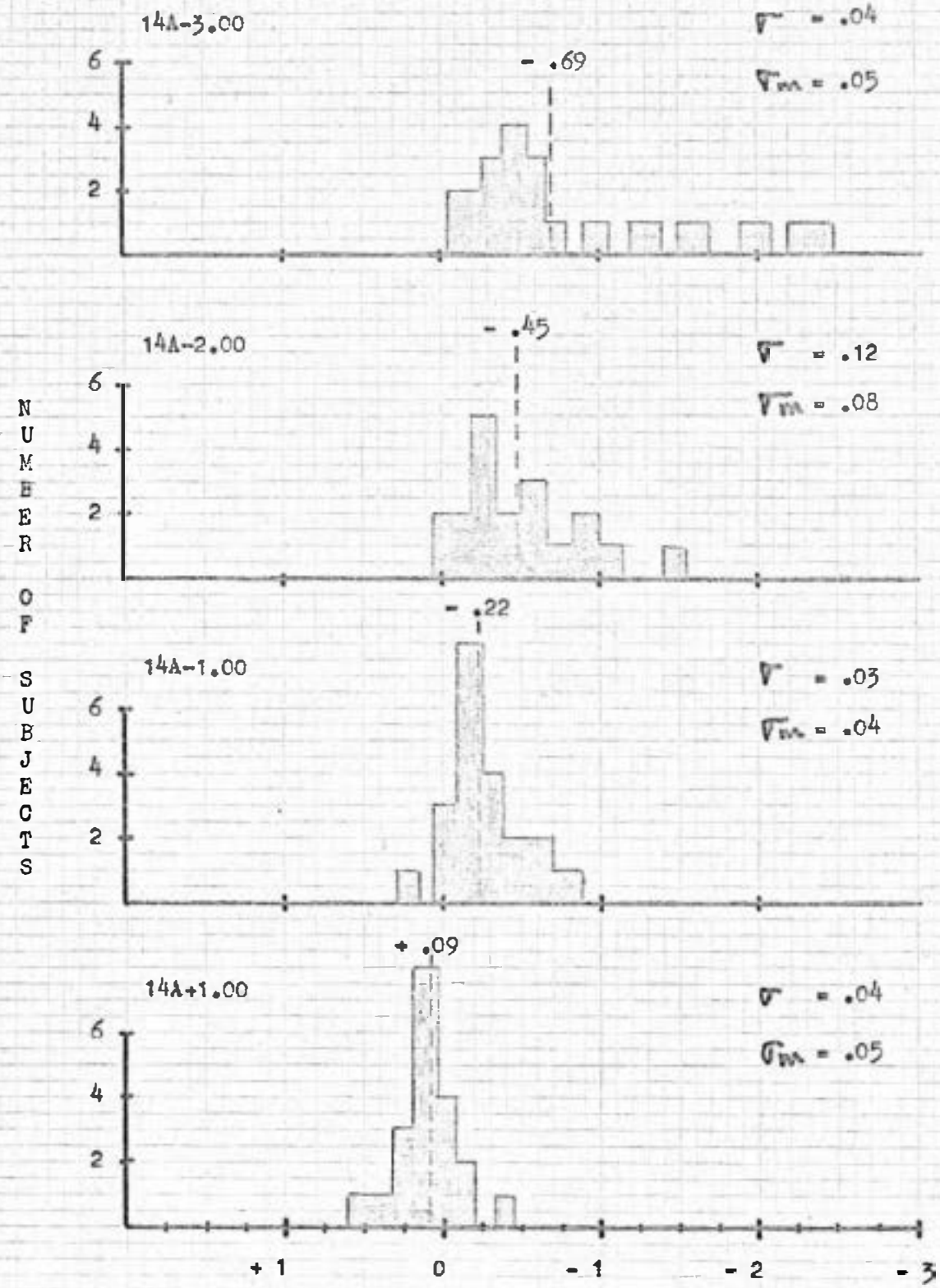


VERTICAL SLIT

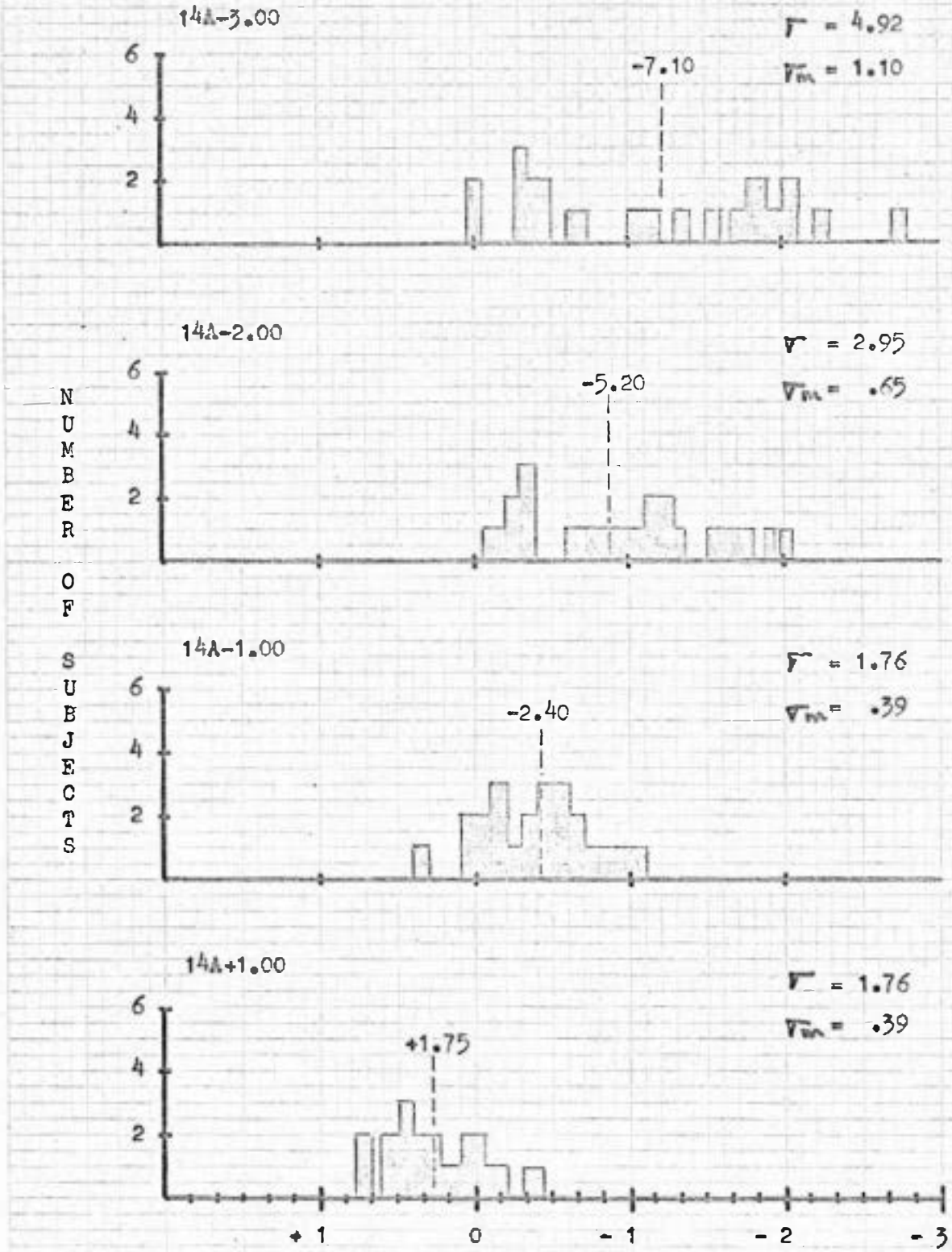


ACCOMMODATIVE RESPONSE

HORIZONTAL SLIT


14A-3.00
- .69
σ = .04
σm = .05
14A-2.00
- .45
σ = .12
σm = .08
- .22
14A-1.00
σ = .03
σm = .04
+ .09
14A+1.00
σ = .04
σm = .05
6
4
2
NUMBER OF SUBJECTS
+ 1
0
- 1
- 2
- 3
ACCOMMODATIVE RESPONSE

PINHOLE



CONVERGENCE RESPONSE (1MA = 6^{Δ})

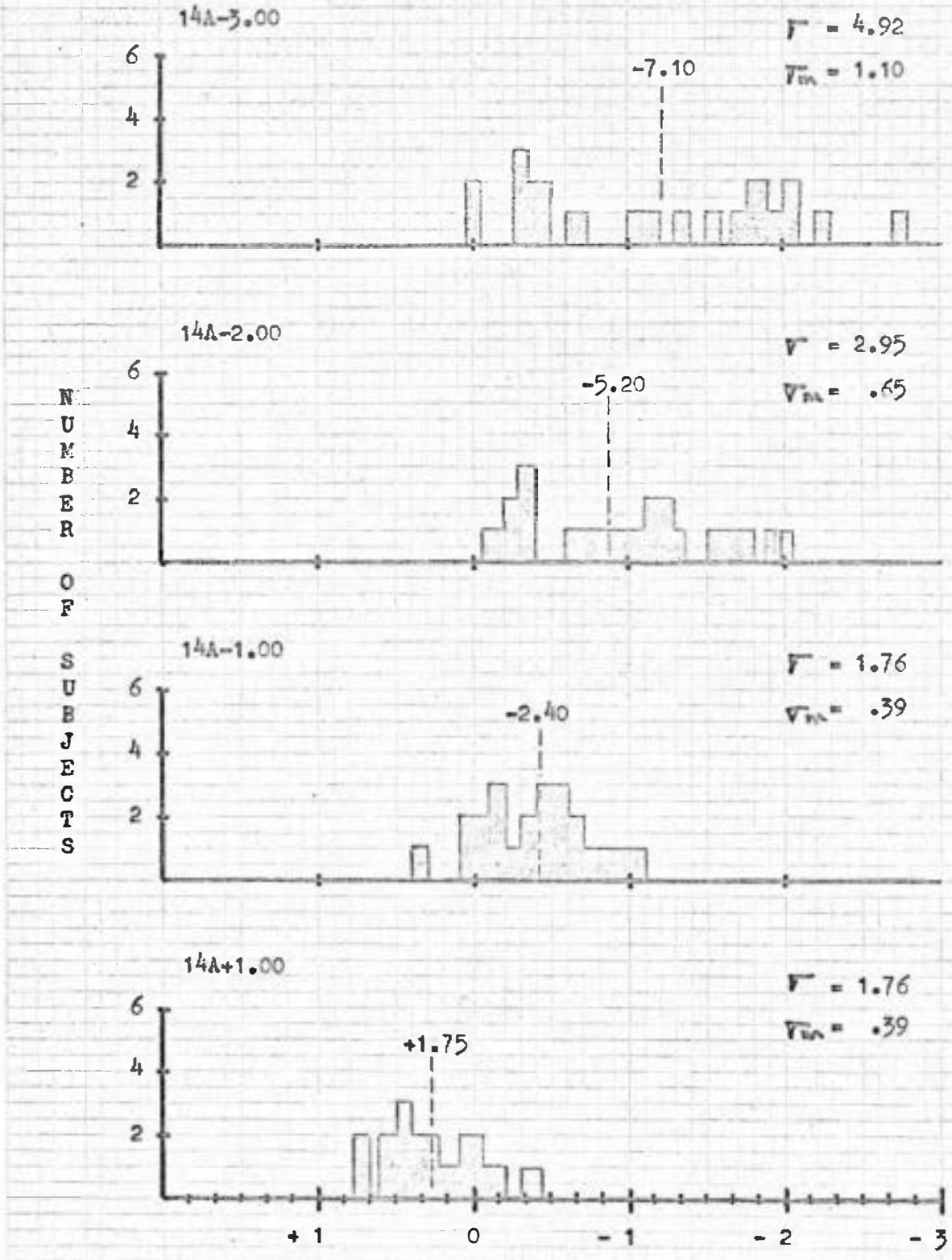
LOG FILTER

GRAPH 2

CONVERGENCE RESPONSE

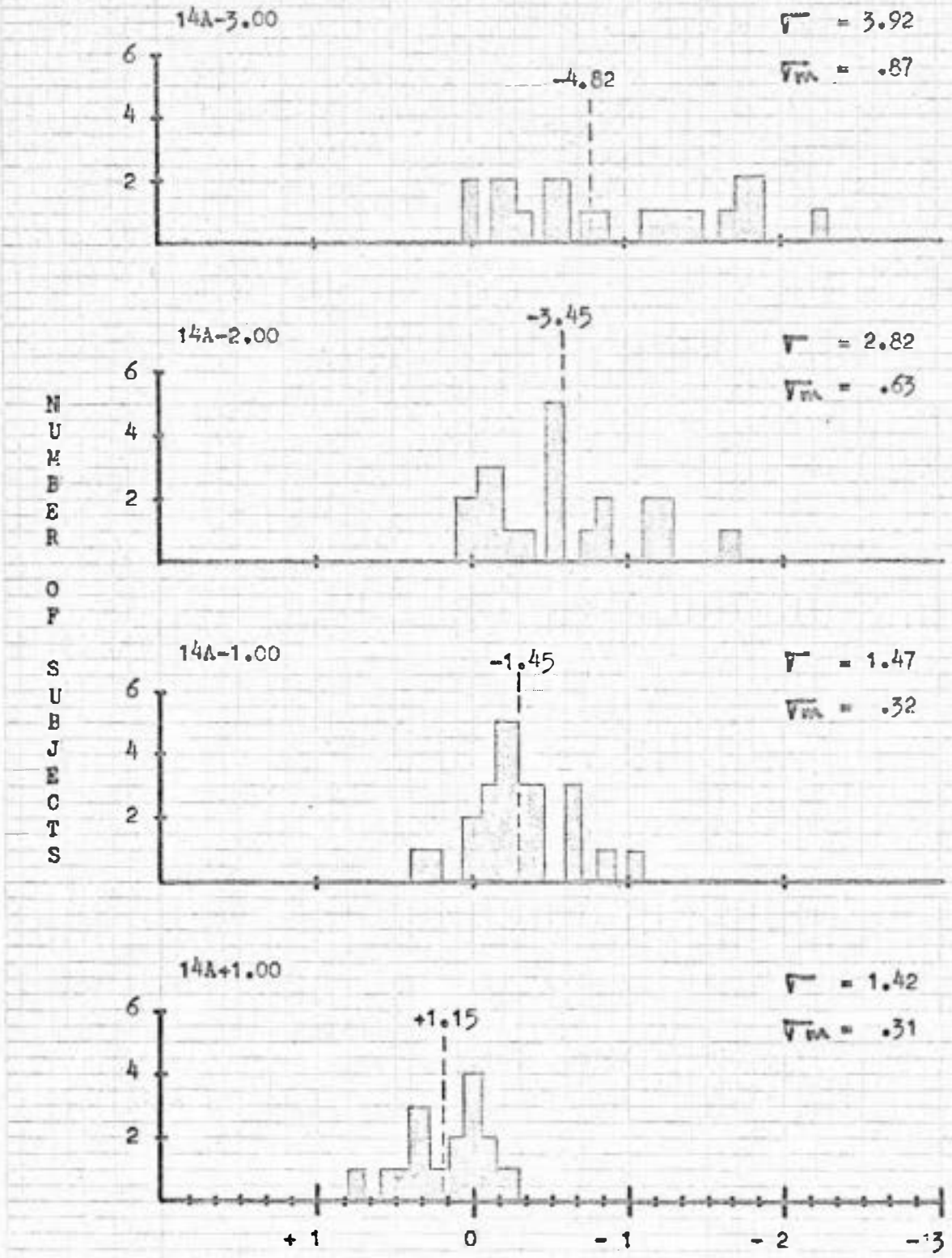
FREQUENCY DISTRIBUTION

GRAPHS



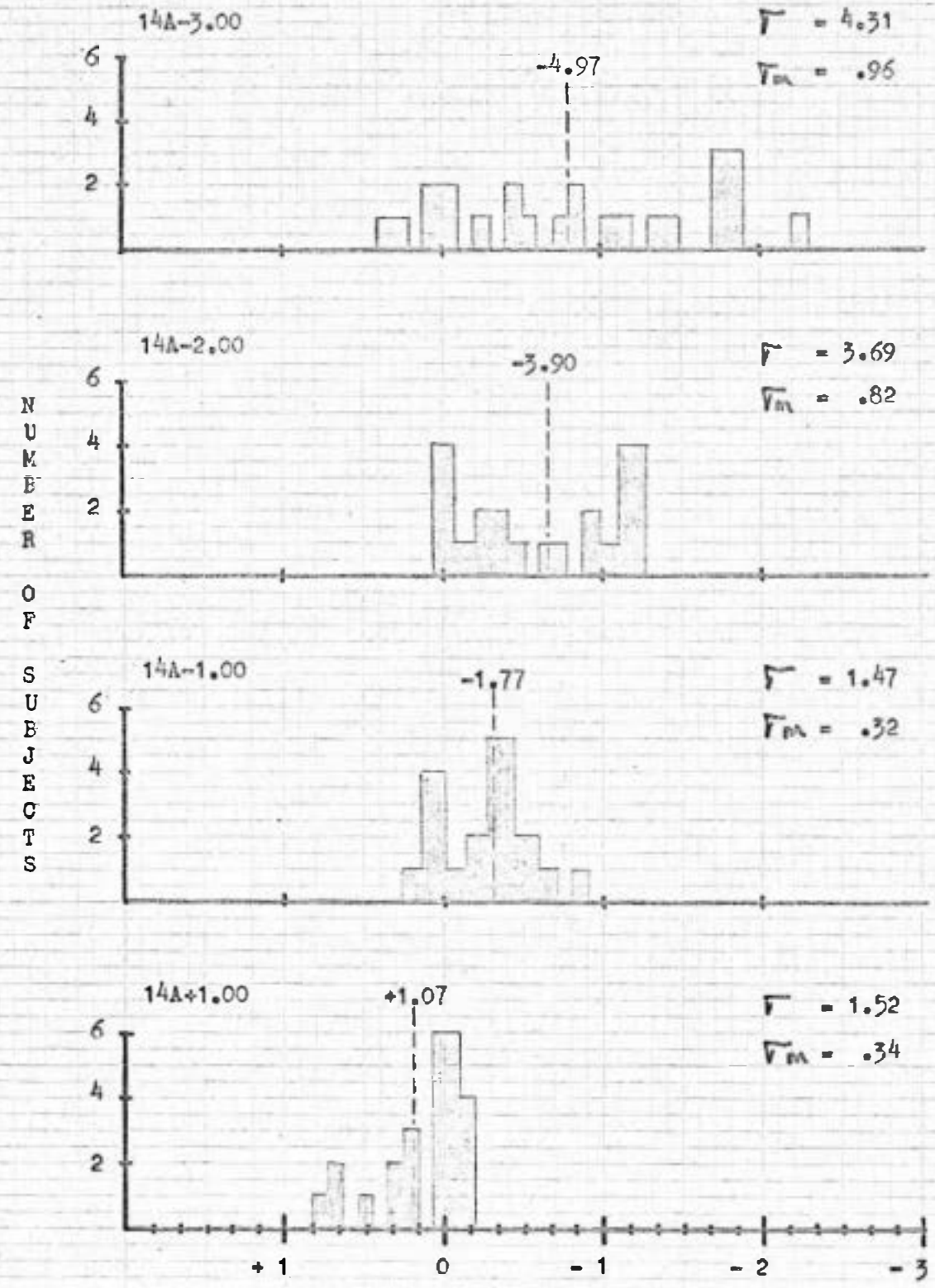
CONVERGENCE RESPONSE (1MA = 6^{4})

LOG FILTER



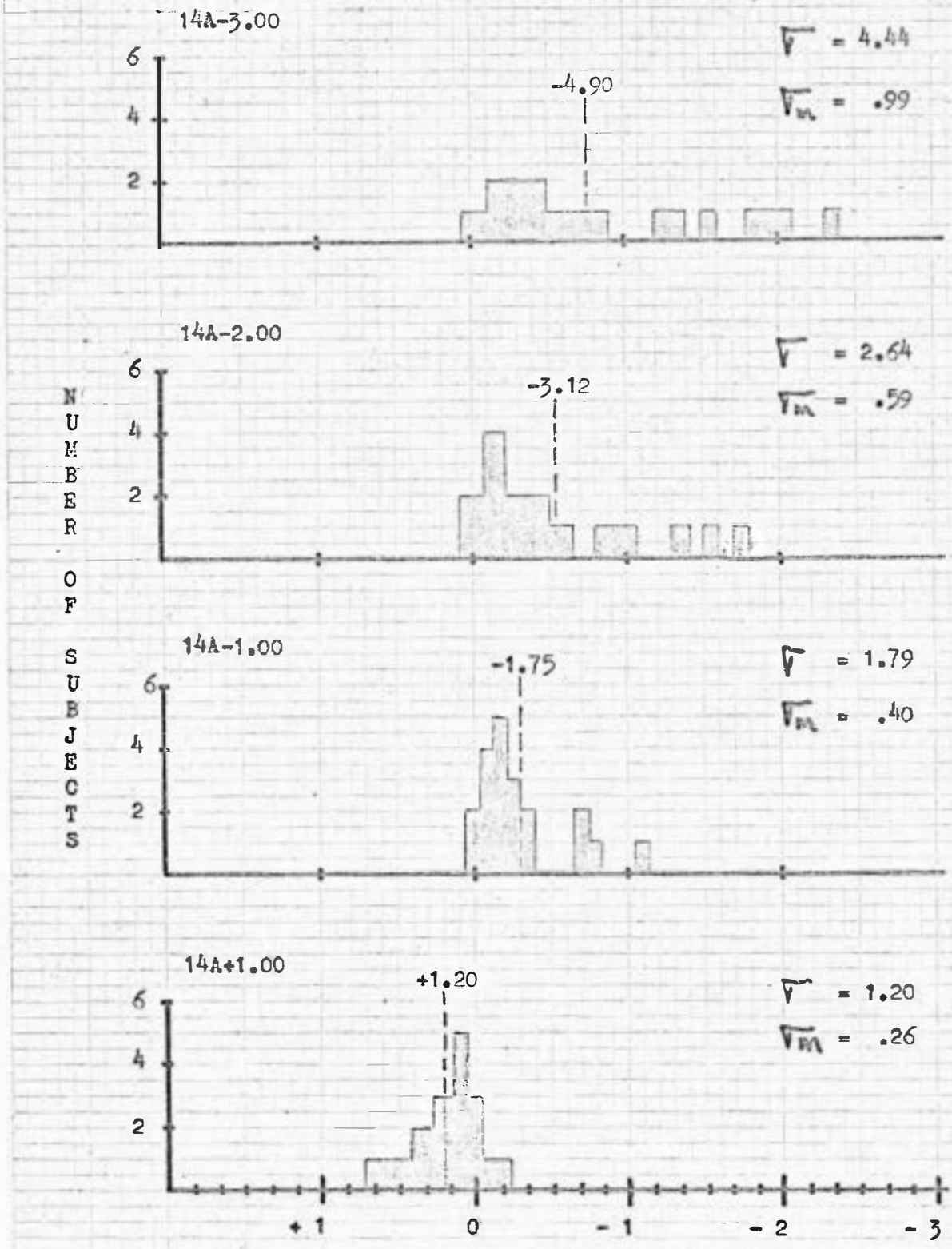
CONVERGENCE RESPONSE (1MA = 5°)

VERTICAL SLIT



CONVERGENCE RESPONSE (1MA = 6$^{\Delta}$)

HORIZONTAL SLIT



CONVERGENCE RESPONSE (1MA = 6Δ)

PINHOLE

MEAN

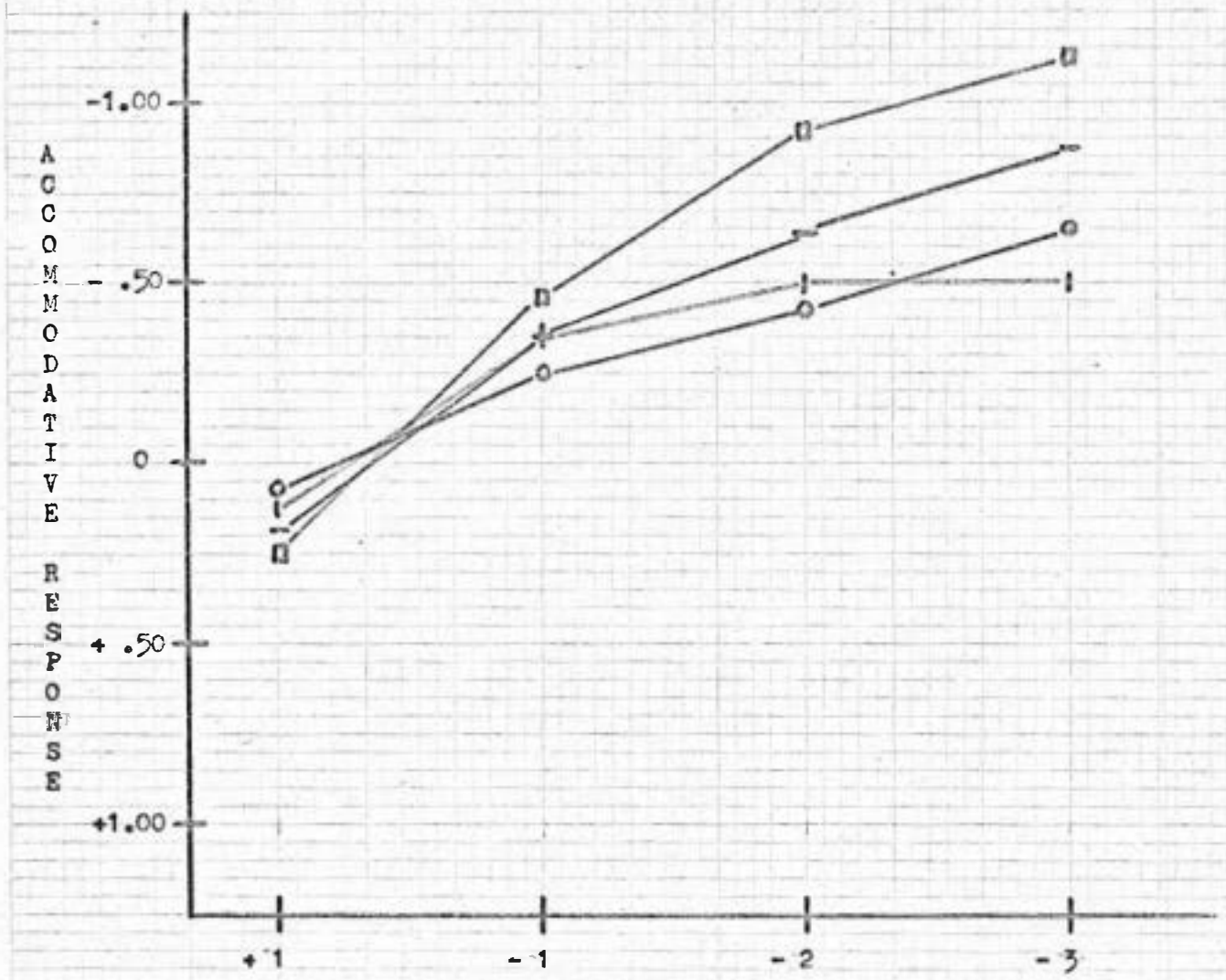
RESPONSE-RESPONSE

RESPONSE-STIMULUS

GRAPHS

GRAPH 3

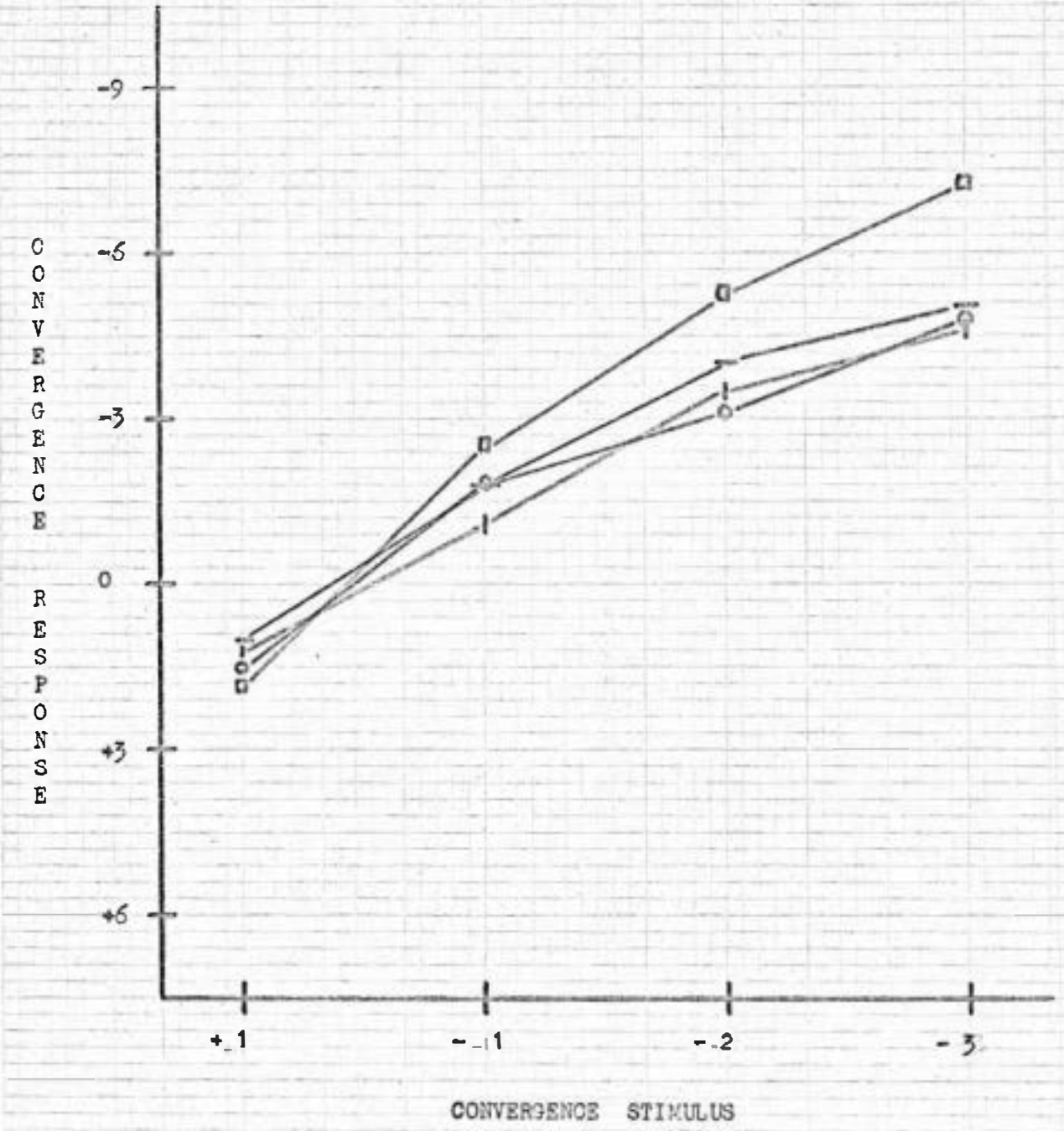
A Graph of the Mean Accommodative Response and Stimulus



□ = Log Filter
| = Vertical Slit
— = Horizontal Slit
O = Pinhole

GRAPH 4

A Graph of the Mean Convergence Response and Stimulus



□ = Log Filter

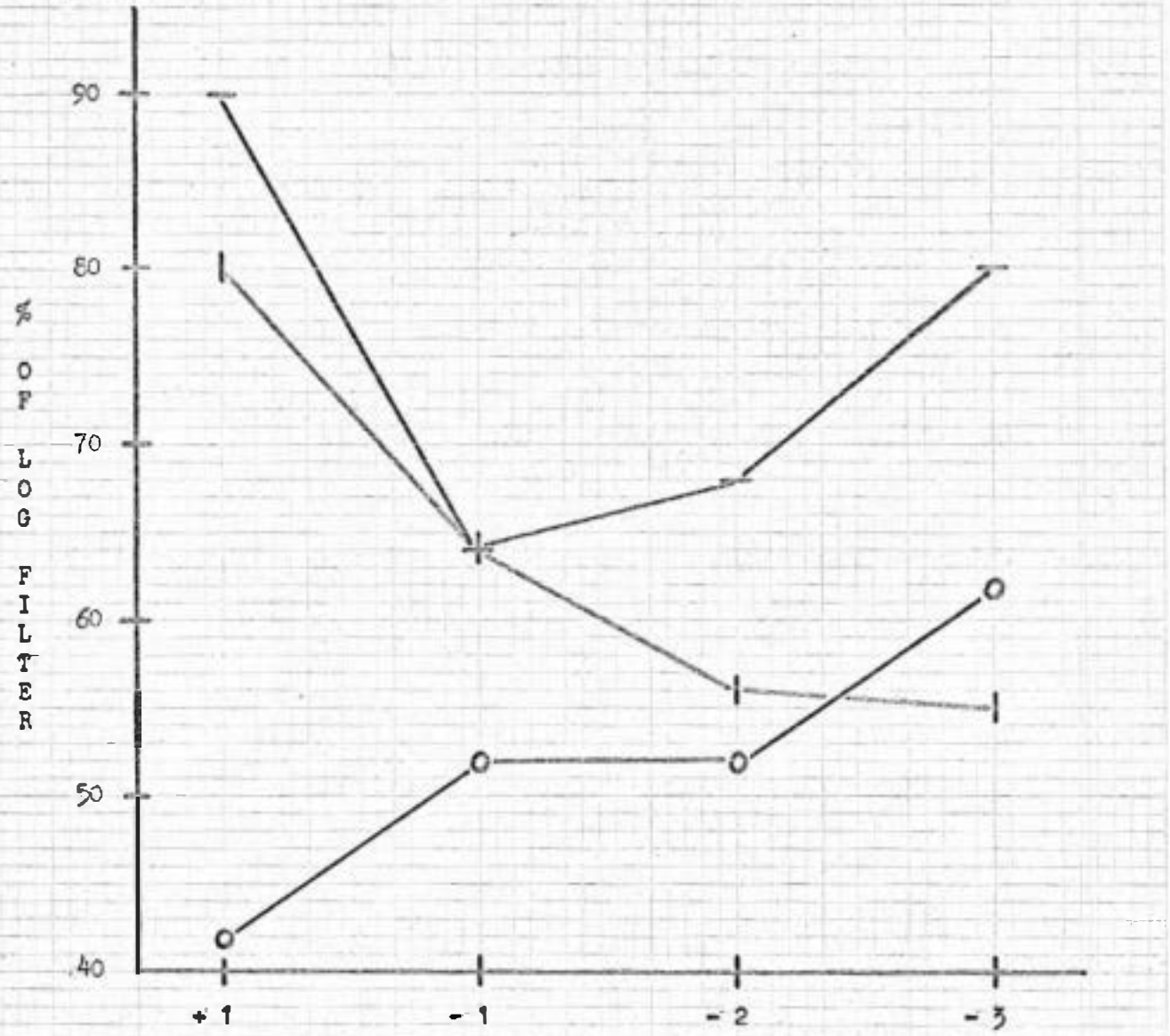
| = Vertical Slit

— = Horizontal Slit

○ = Pinhole

GRAPH 5

The Mean Accommodative Response as a Percentage of the Mean Accommodative Response made during the Log Filter Viewing Conditions.



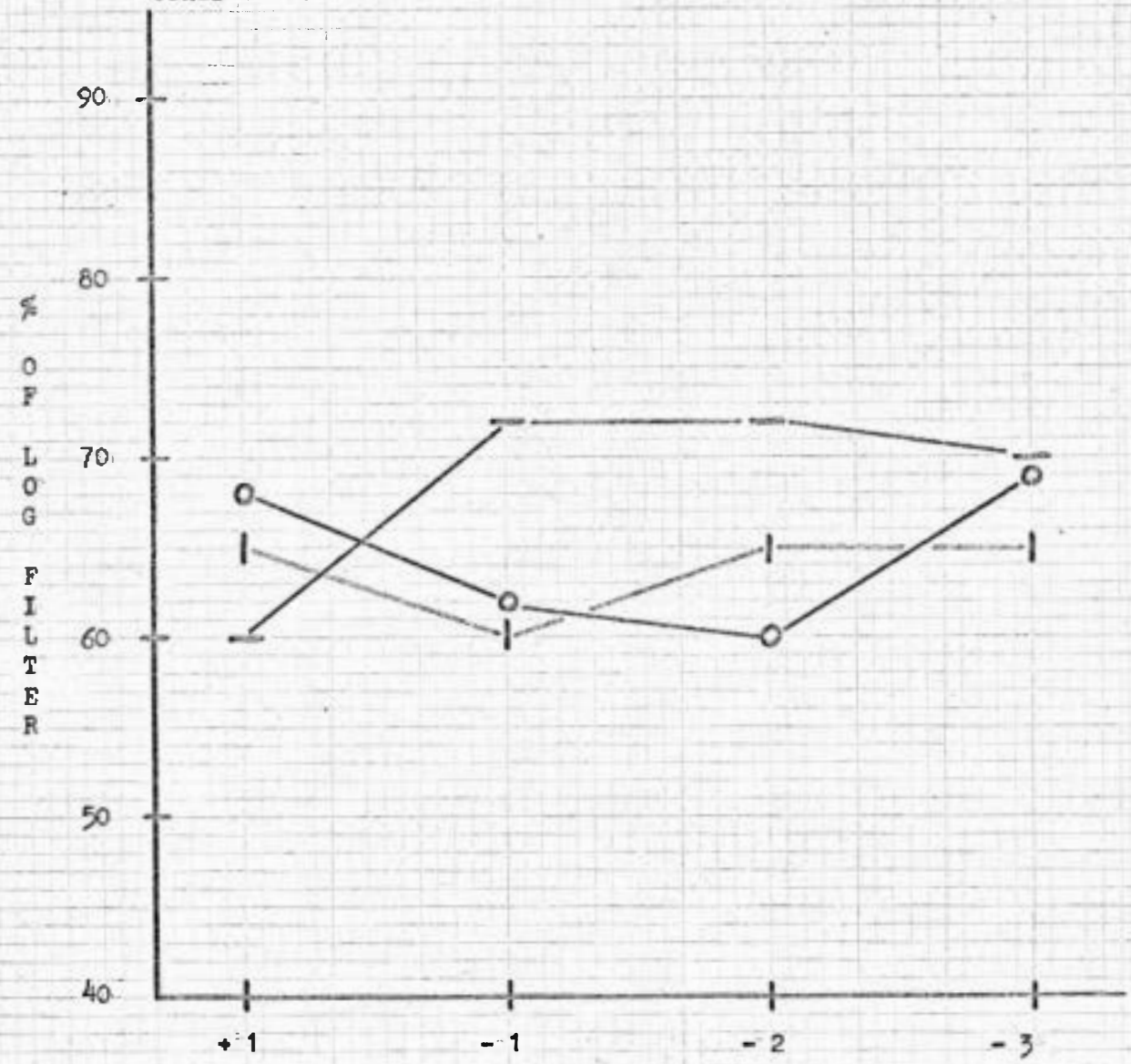
| = Vertical Slit

— = Horizontal Slit

O = Pinhole

GRAPH 6.

The Mean Convergence Response as a Percentage of the Mean Convergence Response made during the Log Filter Viewing Conditions.



| = Vertical Slit

— = Horizontal Slit

O = Pinhole