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BASE OUT VISUAL TRAINING AND PROXIMAL CONVERGENCE

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I. INTRODUCTION

Proximal convergence, variously referred to as "directional complement and psychic complement"[1] has been investigated by several persons. Maddox[2] originally identified proximal convergence assuming it to be a reflex part of accommodative convergence. Fry[3] described proximal convergence as a separate convergence reflex which is stimulated by the awareness of nearness. He listed tonic convergence, accommodative convergence, fusional convergence, and proximal convergence as being the four components of convergence. Morgan[4] postulated that proximal convergence was a learned part of fusional convergence which with time may become a conditioned response to any near target. Hofstetter[5] found a positive correlation between positive fusional convergence and proximal effects and stated that proximal convergence may actually be the facilitator of positive fusional convergence. He further stated that individuals having little accommodative convergence are likely to have greater proximal convergence. Alpern[6] found marked individual differences in the change in phoria with test distance when accommodation was held constant. He reported evidence for positive, negative, and zero proximal convergence. Ogle[7] reported that factors other than accommodative convergence affect the fusionfree convergence when test objects are viewed at various distances. These factors are not present when test distance is held constant and these have been termed psychic awareness of near. Ogle also found that in 16% of the cases, a negative proximal effect was present, which he attributed to faulty distance localization. Neumueller[8] noted that knowledge of spatial proximity gives rise to proximal convergence and therefore, makes stereoscope phoria measurements invalid. Ittleson and Ames[9] studied the effects of apparent distance by changing target size. They found that convergence shifted in the direction of the apparent distance. Morgan[10] also suggested that in individuals having small proximal effects, it may be harder to train base out ranges. Knoll[11] proposed that individuals demonstrating negative proximal effects may be poor cases for base out training and good cases for base in training. Flom[12] suggested that changes in the AC/A ratio with orthoptics are genuine and not due to proximal convergence, however, no specific calculations of proximal convergence were provided to substantiate that conclusion.

Base out visual training can be prescribed with the intention of increasing the positive fusional reserve of an individual until it is sufficient to meet the demands of exophoria.[13] "This form of training is usually a very effective method of treating convergence insufficiency.... and often requires only a small number of training sessions to increase the base out zone sufficiently enough to solve the patient's problem."[14] It has been suggested by Morgan[15] that proximal convergence is a learned function and not simply a reflex. If proximal convergence is learned, it should also be affected by vision training. Therefore, it is possible that when base out is trained, what one may actually be training is a person's awareness of nearness. It is the intent of this research to measure the effects of base out vision training on proximal convergence and to determine it's role in the fusional convergence scheme.

II. METHODS

Subjects. Ten subjects were selected from a population of students ranging in age from 20 - 26. Those having visual acuities of less than 20/20 each eye and those with ocular motility problems precluding single binocular vision were excluded from the study. Subject 3 exhibited restricted base out ranges and was symptomatic. Subjects 1, 2, and 7 also demonstrated low base out ranges under some conditions but were asymptomatic. All other subjects exhibited adequate base out ranges prior to training. All subjects exhibited adequate base in ranges. Nine of ten subjects exhibited an AC/A of between 2/1 and 4/1. However, subject 3 exhibited an AC/A of less than 1/1.

Test Conditions. The following tests and procedures were used during both pre and post training examinations.

1. Interpupillary distances: Far and near pds were taken using the standard pd rule technique. The far pd measurement was used for all 6 m tests and the near pd for all near test distances.
2. Illumination: For distance testing, an illumination of 10 to 15 footcandles was used. For near testing, a near point light was used in addition to the 10 to 15 footcandle room illumination.
3. Equipment: The equipment consisted of an AO Ultramatic phoropter with Risley rotary prisms and an AO projector.

4. Targets: A vertical row of Snellen acuity letters subtending 5 minutes of arc at 6 m was used at the 6 m test distance. Vertical rows of Snellen acuity letters subtending 4 minutes of arc at .50 m, 5 minutes of arc at .40 m, and 6.1 minutes of arc at .33 m were used at their respective test distances.
5. Control lenses: The 7A lens, or maximum plus to best visual acuity, was used as the basic starting lens for all test conditions. The 6 m phoria and prism vergences were taken through the 7A lens and the 7A - 1.00D lens. The .50 m phorias and prism vergences were taken through +2.00D over 7A, +1.50D over 7A, +1.00D over 7A, and 7A. The .40 m phorias and prism vergences were taken through 7A. The .33 m phorias and prism vergences were taken through +3.00D over 7A, +2.00D over 7A, +1.00D over 7A, and 7A. All lens values were placed in the phoropter lens banks.
6. Phoric conditions: Heterophorias were taken using the vertical rows of letters at 6 m, .50 m, .40 m, and .33 m test distances. Dissociation was accomplished by 15 prism diopters base in OD and 6 prism diopters base up OS. Five findings were taken under each test condition and the mean was calculated for use in statistical analysis. One test consisted of the average of BI to alignment and BO to alignment. To preclude phoria drift over time, binocular vision was restored for a

period of 10 seconds after each measurement.

7. Phoria instructions:
   1. After dissociation, the question was asked, "How many rows of letters are there?" (two)
   2. "Is the top row of letters to the right or the left of the bottom row?" (right)
   3. "If the top row of letters is moved to the left, will the targets pass by each other or will they hit?" (If necessary, the vertical prism was increased so that the targets would not hit.)
   4. "I am going to move the lines relative to each other <u>Keep the letters in the bottom clear and say now</u> when the top line is directly above the bottom line."
   5. The procedure was repeated in the opposite direction and the two findings, averaged together, constituted one measurement.
   6. Between each phoria measurement, binocular viewing was restored for ten seconds.
   7. Measurements were taken for a total of 5 trials for each test condition.
8. Prism vergence conditions: Base in and base out prism vergences were taken at 6 m, .50 m, .40 m, and .33 m test distances through various control lenses. At 6 m, prism vergences were taken through 7A and 7A - 1.00D. At .50 m, prism vergences were taken through +2.00D over 7A, +1.50D over 7A, +1.00D over 7A, and 7A. At

.40 m, prism vergences were taken through 7A. At .33 m, prism vergences were taken through +3.00D over 7A, +2.00D over 7A, +1.00D over 7A, and 7A. At each test distance, the subject was instructed to report blur out, break, and recovery. Binocular vision was restored between findings as was done with phoria testing.

9. Prism vergence instructions: Instructions were given as follows:
    1. "How many rows of letters are there?" (one)
    2. "I am going to change the lenses and cause that row of letters to change. The letters may blur out (letters no longer readable but still seen singly), break (line of letters now seen as two), or return to one."
    3. "It is important that you try to keep the letters single and clear as long as possible and that you you return to single and clear as soon as possible."
    4. "If the letters blur out, say "blur out", if the letters break into two, say "two", and if the line returns to one, say "one"."
    5. Between each prism vergence measurement, binocular viewing was restored for ten seconds.
    6. Measurements were taken for a total of 5 trials.
10. Testing sequence:
    1. #8, far point lateral phoria through 7A
    2. far point lateral phoria through 7A - 1.00D

3. #11, far point prism vergence base in through 7A and 7A - 1.00D
4. #9 and #10, far point prism vergence base out through 7A and 7a - 1.00D
5. #13B, near point phoria at 40 cm through 7A
6. #17A/B, near point base in prism vergence at 40 cm through 7A
7. #16A/B, near point base out prism vergence at 40 cm through 7A
8. lateral phoria at .50 m with +2.00D over 7A
9. lateral phoria at .50 m with +1.50D over 7A
10. lateral phoria at .50 m with +1.00D over 7A
11. lateral phoria at .50 m with 7A
12. lateral phoria at .33 m with +3.00D over 7A
13. lateral phoria at .33 m with +2.00D over 7A
14. lateral phoria at .33 m with +1.00D over 7A
15. lateral phoria at .33 m with 7A
16. prism vergences BI/BO at .50 m with +2.00D over 7A
17. prism vergences BI/BO at .50 m with +1.50D over 7A
18. prism vergences BI/BO at .50 m with +1.00D over 7A
19. prism vergences BI/BO at .50 m with 7A
20. prism vergences BI/BO at .33 m with +3.00D over 7A
21. prism vergences BI/BO at .33 m with +2.00D over 7A
22. prism vergences BI/BO at .33 m with +1.00D over 7A
23. prism vergences BI/BO at .33 m with 7A

For each test condition, base in testing was done prior to base out testing. Plus adds were used in order of decreasing value, thereby, increasing the accommodative demand with each plus add reduction. Therefore, both convergence and accommodation were inhibited prior to stimulation at each test distance.

11. Base out visual training was instituted for a four week period of time. Patients were seen weekly for thirty minutes per visit and home training of 30 minutes per day was assigned. Various training techniques were used including rotoscope, loose prisms, eccentric rings, three dot cards, vectograms, pencil pushups, Vodnoy aperture rule, and Brock string. In all training conditions, the patient was instructed to keep the letters clear to control accommodation. At the end of four weeks of training, the above testing sequence was repeated so that the effects of the training could be determined. Identical testing sequences and procedures were used for both pre and post training conditions. All post training data was taken without reference to pretraining data so as to eliminate examiner bias.

12. Data Corrections:

    1. Because convergence stimulus is dependent on the interpupillary distance, all findings were corrected for the various pds. The following equation was used to determine the actual convergence stimulus[16]:

$$C_s = \frac{Pd}{d + .027\ m}$$

in which, C_s = convergence stimulus in prism diopters

Pd = interpupillary distance (far)

d = distance from spectacle plane to the center of rotation

2. Because all lens values were presented in the phoropter lens banks and all patients had different refractive errors and because prisms have a 1.0 prism effectivity only at 6 m, it was necessary to correct all findings for prism effectivity. The following equation was used to determine the proper prism effectivity[17]:

$$\text{Prism effectivity} = \frac{t}{(1 - .027\ D)\ (t + s) + .027}$$

in which, t = distance from object to the spectacle plane in meters

D = horizontal lens power at spectacle plane

s = .03 m distance of prism from spectacle plane

3. It should be noted that break findings were used in data analysis whenever blur out responses were not reported by the subjects.

13. Proximal convergence was computed using phoria, base out and base in data. The following equation was used to compute proximal convergence[18]:

$$\text{Proximal convergence} = \frac{\text{Conv. response far - Conv. response near}}{\text{reciprocal of the near distance}}$$

when the accommodative stimulus is made equal for both far and near distances.

III. RESULTS

Ten subjects began this project and seven successfully completed it. Figures 1-4 represent the average findings of all subjects who completed the project. Figures 5-13 and Tables 1-6 represent individual subject findings. All tables and figures represent corrected findings as previously described. On all tables and figures, pretraining data is shown as PRE and post training as POST.

Tables 1 and 2 show individual pretraining and post training base out and base in to blur out findings taken at three distances through various lens adds. Each entry is the average of five measurements, corrected for prism effectivity and lens power induced errors. The average pretraining and post training base out and base in to blur out findings for all subjects are found in Figure 1 as derived from Tables 1 and 2. It is apparent that the base out training program was successful in extending the base out prism vergence ranges of the subjects in this study. The greatest increase in the base out range occurred at the 6 m distance, followed by the .50 m, and .33 m distances, respectively. It is also seen that the base in prism vergence ranges showed a slight increase following the training program.

Table 3 shows individual pretraining and post training

TABLE 1. BASE OUT TO BLUR OUT SUMMARY IN PRISM DIOPTERS

	at 6 m through 7A		at 6 m through 7A - 1.00	
	PRE	POST	PRE	POST
Subject				
1.	15.5	18.8	19.4	22.3
2.	8.9	11.8	11.1	21.1
3.	8.4	22.2	7.0	28.0
4.	21.1	43.2	23.9	43.2
5.	22.3	39.4	23.8	35.0
6.	19.0	31.0	23.5	41.0
7.	12.3	15.3	13.6	19.2
Average	15.4	26.0	17.5	30.0

	at .50 m through 7A		at .50 m through 7A +1.00	
	PRE	POST	PRE	POST
Subject				
1.	10.3	14.9	10.1	13.5
2.	15.3	17.9	11.7	17.6
3.	7.4	16.6	7.3	16.5
4.	25.7	35.7	22.6	39.2
5.	28.1	32.0	27.8	31.3
6.	20.9	32.2	19.0	31.2
7.	10.1	14.5	10.7	11.9
Average	16.8	23.4	15.6	21.3

	at .50 m through 7A +1.50		at .50 m through 7A +2.00	
	PRE	POST	PRE	POST
Subject				
1.	9.8	13.4	11.6	13.7
2.	10.9	16.7	14.1	19.7
3.	6.4	14.3	9.1	16.1
4.	20.3	27.9	18.0	31.4
5.	27.6	31.5	28.3	32.4
6.	14.8	30.6	19.0	25.5
7.	10.0	12.1	9.0	12.3
Average	14.2	20.9	15.6	21.6

TABLE 1. continued

	at .33 m through 7A		at .33 m through 7A +1.00	
	PRE	POST	PRE	POST
Subject				
1.	13.4	16.5	13.8	15.7
2.	13.6	23.9	16.6	24.9
3.	9.7	16.7	8.6	16.2
4.	30.0	28.0	24.8	32.4
5.	26.5	25.4	18.7	25.8
6.	24.5	30.7	22.8	30.2
7.	13.9	15.6	12.4	15.3
Average	18.8	22.4	16.8	22.9

	at .33 m through 7A +2.00		at .33 m through 7A +3.00	
	PRE	POST	PRE	POST
Subject				
1.	15.0	13.7	14.8	12.0
2.	11.7	23.0	10.7	22.1
3.	8.7	13.1	5.0	13.7
4.	25.4	31.3	21.0	33.0
5.	21.7	26.3	21.9	31.4
6.	19.6	30.4	19.3	27.3
7.	9.7	13.3	6.5	11.9
Average	16.0	21.6	14.2	21.6

TABLE 2. BASE IN TO BLUR OUT SUMMARY IN PRISM DIOPTERS

	at 6 m through 7A		at 6 m through 7A -1.00	
	PRE	POST	PRE	POST
Subject				
1.	7.7	9.8	6.9	7.0
2.	6.7	6.1	5.8	6.6
3.	7.6	5.8	6.0	6.0
4.	9.3	6.5	6.3	6.3
5.	6.2	6.6	5.8	5.3
6.	6.7	7.1	6.8	6.9
7.	10.5	10.4	6.9	8.4
Average	7.8	7.5	6.4	6.6

	at .50 m through 7A		at .50 m through 7A +1.00	
	PRE	POST	PRE	POST
Subject				
1.	9.6	8.1	9.3	10.0
2.	7.3	6.7	9.0	7.9
3.	9.3	11.4	9.6	12.7
4.	10.3	11.2	11.4	11.9
5.	11.5	12.0	12.2	12.8
6.	10.9	9.9	13.0	13.8
7.	12.2	16.4	13.3	15.3
Average	10.2	10.8	11.1	12.0

	at .50 m through 7A +1.50		at .50 m through 7A +2.00	
	PRE	POST	PRE	POST
Subject				
1.	10.5	12.2	13.5	12.2
2.	10.5	9.1	8.9	10.3
3.	9.2	12.3	9.3	12.1
4.	12.0	13.1	13.0	12.6
5.	12.0	12.6	11.8	10.4
6.	13.6	14.0	15.0	14.8
7.	13.3	13.8	14.0	16.2
Average	11.6	12.4	12.2	12.6

TABLE 2. continued

	at .33 m through 7A		at .33 m through 7A +1.00	
	PRE	POST	PRE	POST
Subject				
1.	10.0	7.5	10.9	12.2
2.	10.7	9.1	11.6	11.3
3.	13.0	14.7	16.1	17.3
4.	11.2	18.0	15.9	16.6
5.	11.5	16.2	15.2	17.2
6.	9.5	8.8	12.0	13.9
7.	17.1	18.5	18.5	19.5
Average	11.8	13.2	14.3	15.4

	at .33 m through 7A +2.00		at .33 m through 7A +3.00	
	PRE	POST	PRE	POST
Subject				
1.	9.7	16.3	14.8	18.4
2.	13.2	12.8	14.8	15.2
3.	16.1	17.9	15.1	18.0
4.	17.1	17.5	14.7	19.2
5.	15.4	17.1	17.3	17.5
6.	13.9	17.5	17.1	20.6
7.	20.5	20.5	21.7	22.4
Average	15.1	17.1	16.5	18.8

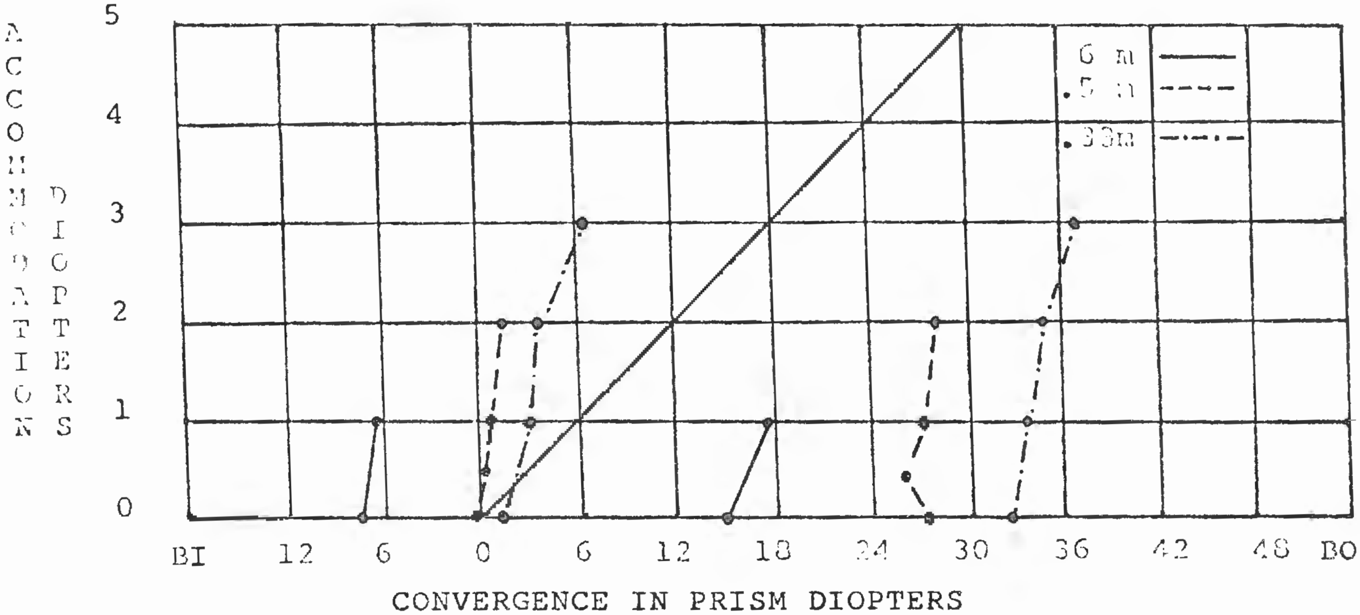

FIGURE 1a. BASE OUT AND BASE IN TO BLUR OUT, AVERAGE OF ALL SUBJECTS. PRETRAINING

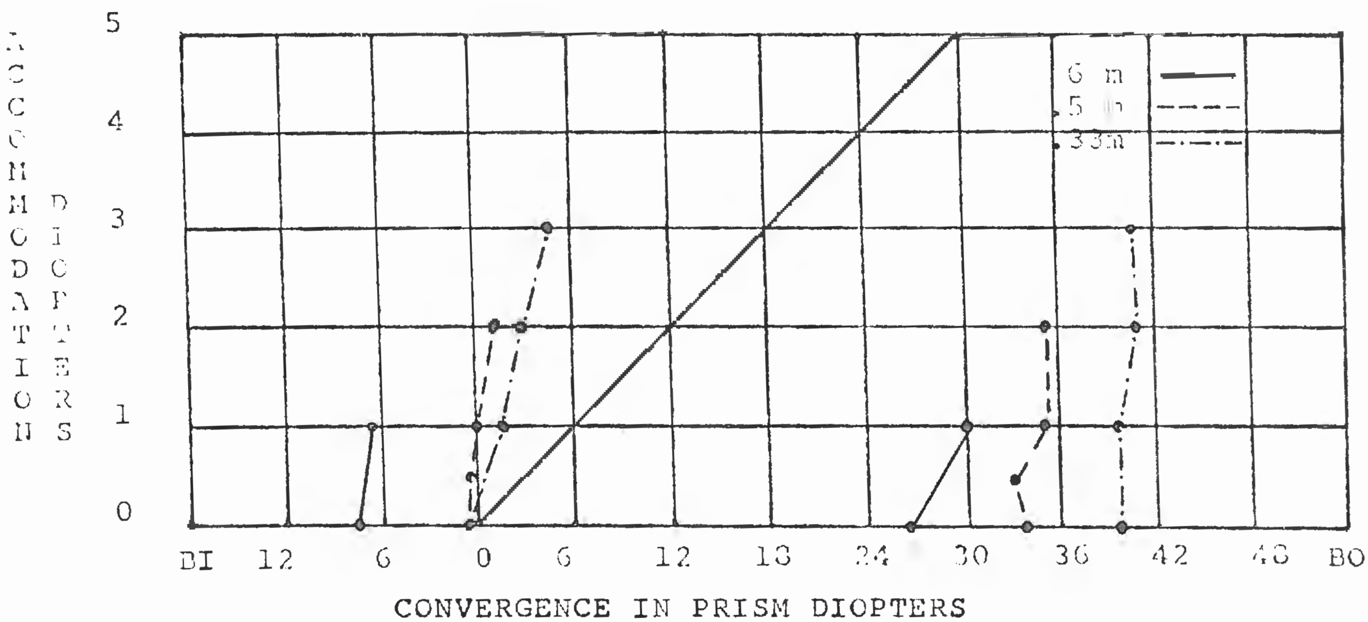

FIGURE 1b. BASE OUT AND BASE IN TO BLUR OUT, AVERAGE OF ALL SUBJECTS. POST TRAINING

TABLE 3. PHORIA SUMMARY IN PRISM DIOPTERS (- = exo)
(+ = eso)

	at 6 m through 7A		at 6 m through 7A -1.00	
	PRE	POST	PRE	POST
Subject				
1.	-2.2	+1.2	+0.8	+4.0
2.	-3.0	-1.9	-2.2	-0.9
3.	-0.8	-1.5	-1.3	-0.1
4.	-1.9	-1.3	+0.4	+0.7
5.	-0.8	-0.1	-0.6	-0.1
6.	+4.2	+3.0	+6.6	+5.8
7.	+1.5	+0.6	+2.3	+0.8
Average	-0.3	0.0	+0.8	+1.4

	at .50 m through 7A		at .50 m through 7A +1.00	
	PRE	POST	PRE	POST
Subject				
1.	-2.4	+0.2	-6.0	-3.2
2.	-0.5	+1.2	-1.8	-1.1
3.	-1.8	+0.1	-2.0	-0.7
4.	-3.0	-1.8	-4.4	-3.0
5.	-2.9	-2.6	-4.0	-4.7
6.	+2.6	+5.0	+0.8	+3.4
7.	-0.1	-2.7	-2.1	-5.4
Average	-1.2	-0.6	-2.8	-2.1

	at .50 m through 7A +1.50		at .50 m through 7A +2.00	
	PRE	POST	PRE	POST
Subject				
1.	-3.4	-4.8	-6.4	-7.2
2.	-2.3	-1.9	-3.6	-3.0
3.	-1.7	-1.3	-3.2	-3.1
4.	-6.1	-3.0	-6.2	-3.4
5.	-4.8	-4.8	-6.5	-4.2
6.	-0.8	+1.4	-0.4	+0.7
7.	-3.2	-6.6	-4.6	-7.9
Average	-3.2	-3.0	-4.4	-4.0

TABLE 3. continued

	at .33 m through 7A		at .33 m through 7A +1.00	
	PRE	POST	PRE	POST
Subject				
1.	-0.3	+1.9	-1.7	-4.6
2.	+0.8	+0.5	-0.4	-0.4
3.	-2.1	-1.4	-2.6	-2.2
4.	0.0	-0.9	-2.0	-2.7
5.	-1.2	-2.9	-3.6	-6.2
6.	+6.9	+7.5	+2.6	+2.2
7.	-1.3	-3.4	-2.8	-5.9
Average	+0.4	+0.2	-1.5	-2.8

	at .33 m through 7A +2.00		at .33 m through 7A +3.00	
	PRE	POST	PRE	POST
Subject				
1.	-6.8	-8.4	-11.4	-11.4
2.	-2.3	-2.3	-3.4	-4.5
3.	-3.0	-3.2	-4.2	-3.7
4.	-7.0	-7.0	-10.1	-8.6
5.	-5.6	-8.4	-8.4	-8.8
6.	-2.4	-2.8	-6.0	-5.6
7.	-5.6	-8.1	-8.0	-9.4
Average	-4.7	-5.7	-7.4	-7.4

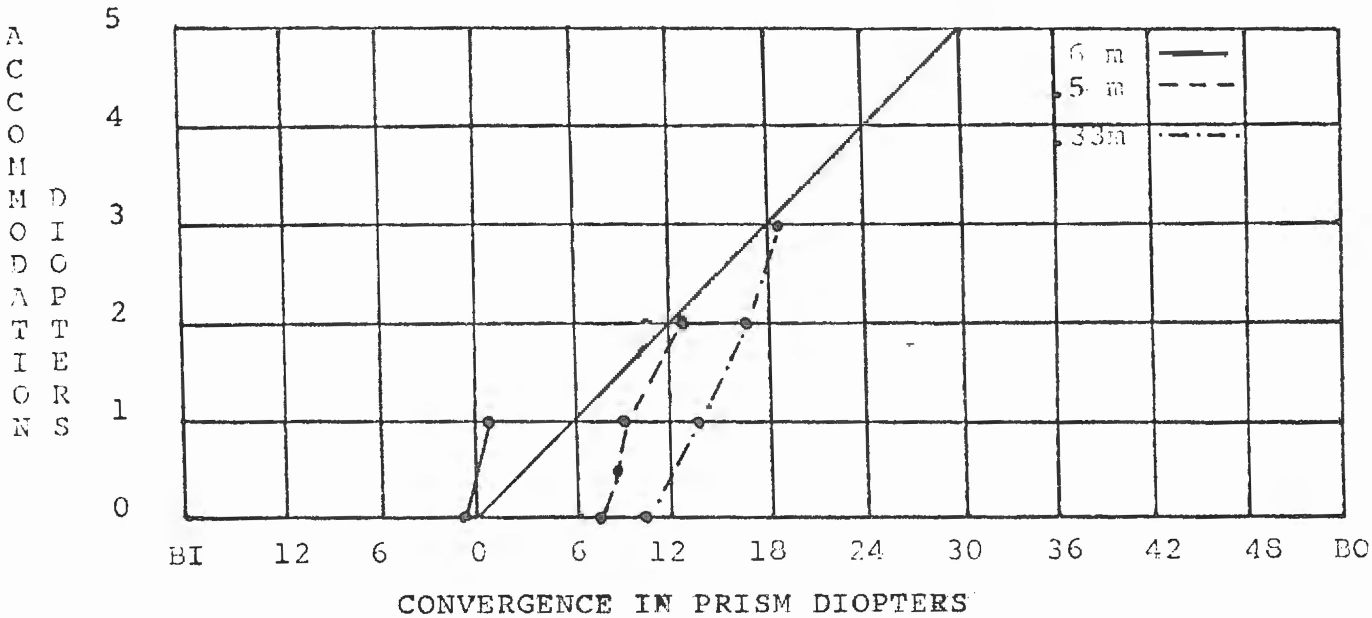

FIGURE 2a. PHORIA, AVERAGE OF ALL SUBJECTS. PRETRAINING

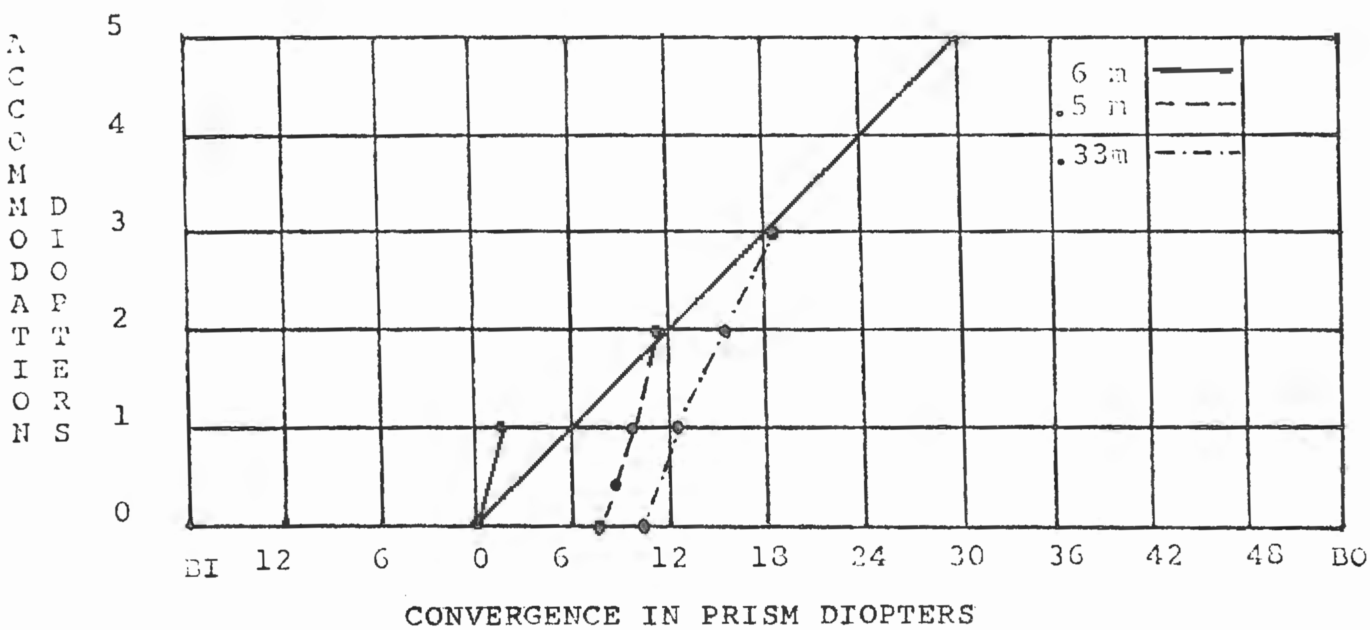

FIGURE 2b. PHORIA, AVERAGE OF ALL SUBJECTS. POST TRAINING

phoria findings taken at three distances through various lens adds. Each entry is the average of five measurements, corrected for prism effectivity and lens power induced errors. Figure 2 represents average pretraining and post training phoria findings for all subjects at three distances through various lens adds. It can be seen that on the average, either no change or a slight increase in esophoria occurred following training.

Proximal convergence/nearness ratio (PC/D) is calculated by determining the change in convergence response between two distances while keeping the stimulus to accommodation constant. This change in convergence response is then divided by the 'nearness' as expressed in diopters, D, which is the reciprocal of the testing distance in meters. When the accommodative stimulus, A_s, is equal to zero, plus lenses must be added to the distance correction, equal to the reciprocal of the near test distance. When A_s is equal to 1.0, a -1.00D lens is added to the distance correction at 6m and plus lenses must be added to the distance correction at the near test distance, equal to 1.0D less than the reciprocal of the near distance. In each of the above cases, A_s must remain constant for both far and near distances.

Tables 4, 5, and 6 represent pretraining and post training proximal convergence/ nearness ratios (PC/D) as calculated with base out, base in, or phoria data. The

TABLE 4a. BASE OUT PROXIMAL CONVERGENCE/ NEARNESS RATIOS (Δ/D)

	6m to .50 m		6 m to .33 m	
	PRE	POST	PRE	POST
Subject				
1.	4.1	3.5	5.8	3.7
2.	8.6	10.0	6.6	9.4
3.	6.4	3.0	4.9	3.2
4.	4.4	0.1	6.0	2.6
5.	9.0	2.5	5.9	3.3
6.	6.0	3.2	6.1	4.8
7.	4.4	4.5	4.1	4.9
Average	6.1	3.8	5.6	4.5

Accommodative stimulus = 0

TABLE 4b. BASE OUT PROXIMAL CONVERGENCE/ NEARNESS RATIOS (Δ/D)

	6 m to .50 m		6 m to .33 m	
	PRE	POST	PRE	POST
Subject				
1.	1.4	1.6	4.5	3.1
2.	6.3	4.3	6.2	6.3
3.	6.1	0.3	6.6	1.0
4.	5.4	4.0	6.5	2.0
5.	8.0	4.2	5.3	3.1
6.	3.8	1.1	4.7	2.5
7.	4.6	2.4	4.7	4.0
Average	5.1	2.6	5.5	3.1

Accommodative stimulus = 1.0

TABLE 5a. BASE IN PROXIMAL CONVERGENCE/ NEARNESS RATIOS (Δ/D)

	6 m to .50 m		6 m to .33 m	
	PRE	POST	PRE	POST
Subject				
1.	3.6	4.8	3.6	3.1
2.	4.9	3.9	3.3	3.0
3.	5.2	2.8	3.5	1.9
4.	4.2	3.0	4.2	1.8
5.	3.2	4.1	2.3	2.4
6.	1.8	2.2	1.9	1.5
7.	4.3	3.1	2.3	2.0
Average	3.9	3.4	3.0	2.2

Accommodative stimulus = 0

TABLE 5b. BASE IN PROXIMAL CONVERGENCE/ NEARNESS RATIOS (Δ/D)

	6 m to .50 m		6 m to .33 m	
	PRE	POST	PRE	POST
Subject				
1.	4.8	3.0	5.1	2.9
2.	4.4	3.6	3.5	3.9
3.	4.2	1.8	2.6	2.0
4.	3.5	2.1	2.4	2.3
5.	2.8	1.5	2.8	2.1
6.	2.9	1.7	3.6	2.5
7.	2.8	1.7	1.5	2.0
Average	3.6	2.2	3.1	2.5

Accommodative stimulus = 1.0

TABLE 6a. PHORIA PROXIMAL CONVERGENCE/ NEARNESS RATIOS (Δ/D)

	6 m to .50 m		6 m to .33 m	
	PRE	POST	PRE	POST
Subject				
1.	3.9	1.8	2.9	1.8
2.	5.7	5.4	5.9	5.1
3.	4.8	5.2	4.9	5.3
4.	3.8	4.9	3.3	3.6
5.	3.2	4.0	3.5	3.1
6.	3.7	4.8	2.6	3.1
7.	3.0	1.8	2.9	2.6
Average	4.0	4.0	3.7	3.5

Accommodative stimulus = 0

TABLE 6b. PHORIA PROXIMAL CONVERGENCE/ NEARNESS RATIOS (Δ/D)

	6 m to .50 m		6 m to .33 m	
	PRE	POST	PRE	POST
Subject				
1.	2.6	2.4	3.5	1.9
2.	6.2	5.9	6.0	5.6
3.	5.8	5.7	5.4	5.0
4.	3.6	4.2	3.5	3.4
5.	4.3	3.7	4.3	3.2
6.	3.1	4.8	3.0	3.1
7.	3.8	2.9	3.4	3.0
Average	4.2	4.2	4.2	3.6

Accommodative stimulus = 1.0

individual PC/Ds were calculated using appropriate findings from Tables 1, 2, and 3, as previously described. Average PC/Ds for all subjects were also calculated and appear in the respective tables. Group average PC/Ds from Tables 4, 5, and 6 are shown in Figures 3, 4, and 5. PC/Ds decreased in all cases except for the 6 m to .50 m phorias where it remained constant. The largest decrease in PC/D was found when computed with base out to blur out data, followed by base in and phoria data, respectively.

The average gradient AC/A of all subjects at both .50 m and .33 m test distances, pre and post training, is demonstrated in Figure 6. Average base out, base in, and phoria data from Tables 1, 2, and 3 make up each point in Figure 6. The very similar slopes between pre and post training plots indicates no change in the gradient AC/A. A slight esoward movement is seen in the .50 m phoria line and a slight exoward movement is seen in the .33 m phoria line, but with no change in slope. The dramatic increase in the base out limit and small increase in the base in limit are also apparent.

Individual subject base out, base in, and phoria data are presented in Figures 7-13. The individual plots are unremarkable from the average plots of all subjects.

To identify whether depth of focus differences might influence the computations, PC/D was calculated using both $A_s = 0$ and $A_s = 1$. An accommodative stimulus of 1.0

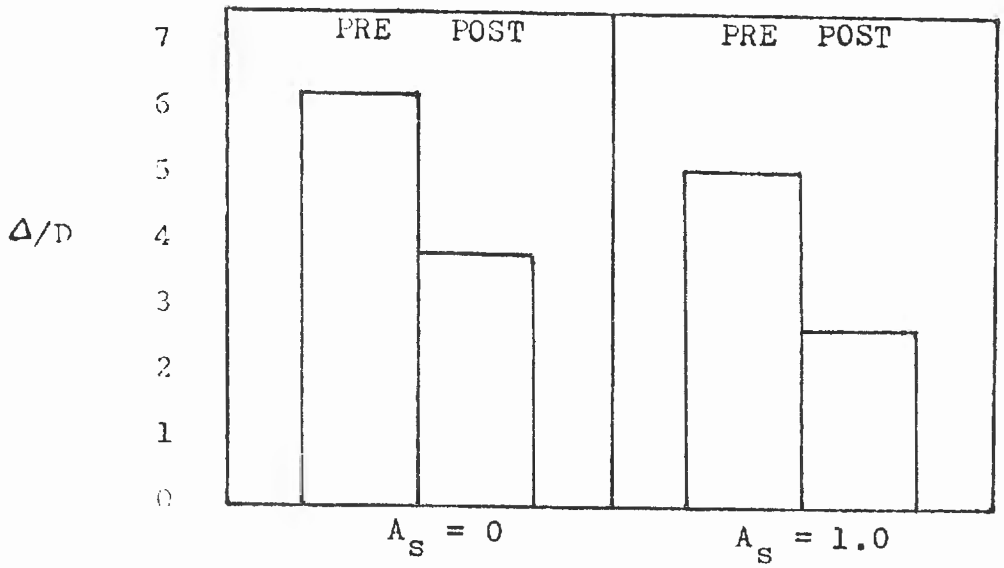

FIGURE 3a. AVERAGE OF ALL SUBJECTS BASE OUT PROXIMAL CONVERGENCE/NEARNESS RATIOS, 6 m to .50 m.

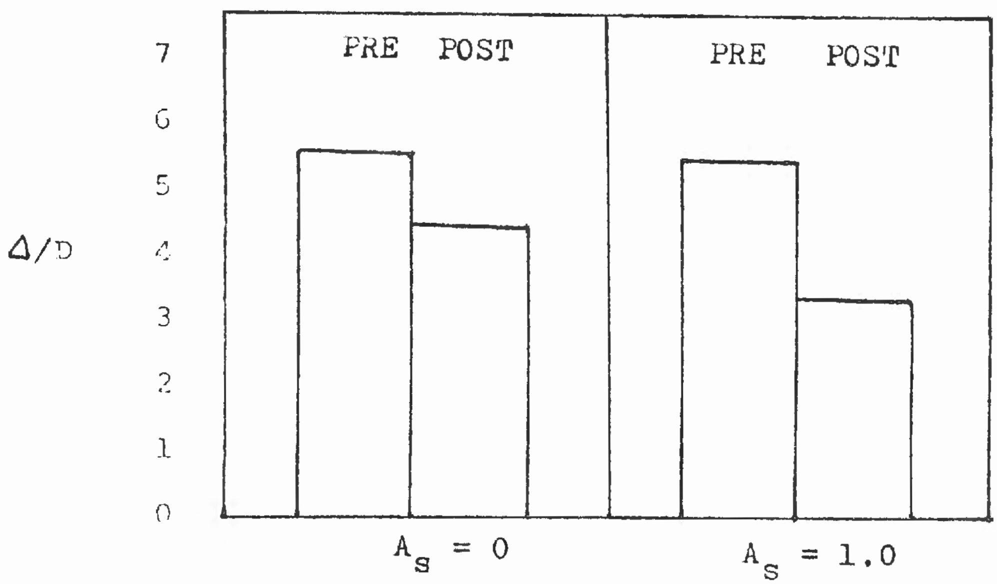

FIGURE 3b. AVERAGE OF ALL SUBJECTS BASE OUT PROXIMAL CONVERGENCE/NEARNESS RATIOS, 6 m to .33 m.

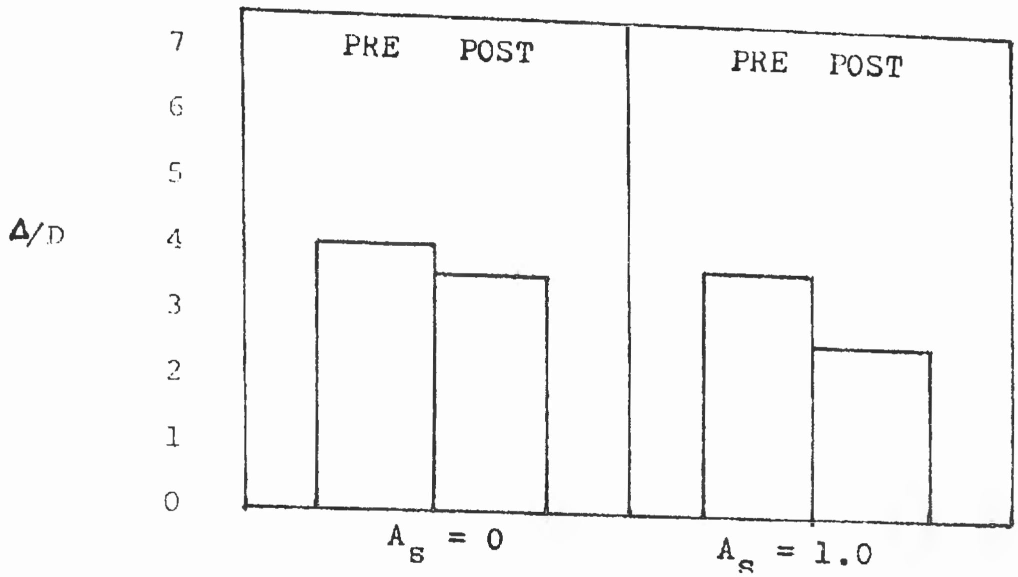

FIGURE 4a. AVERAGE OF ALL SUBJECTS BASE IN PROXIMAL CONVERGENCE/NEARNESS RATIOS, 6 m to .50 m.

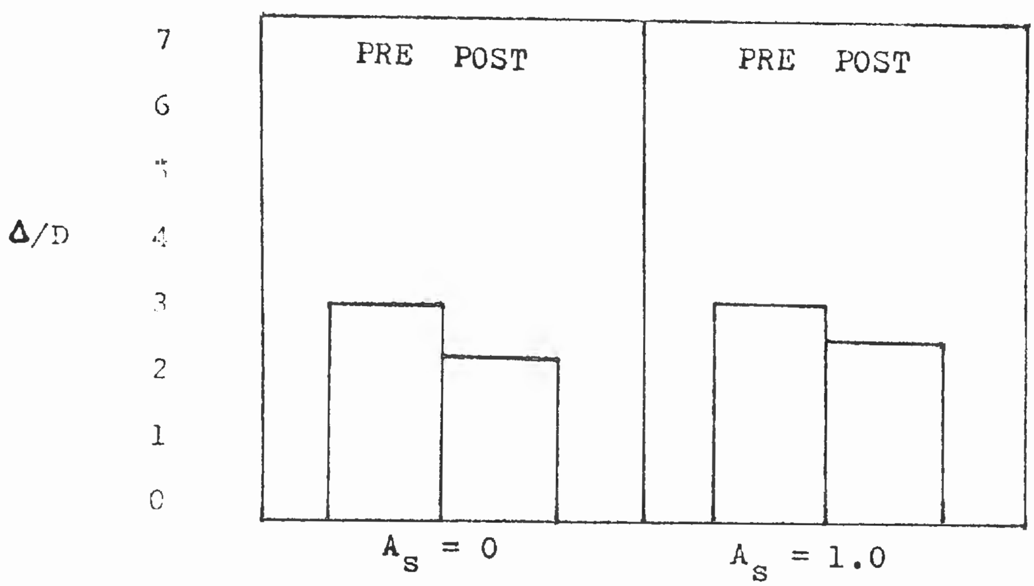

FIGURE 4b. AVERAGE OF ALL SUBJECTS BASE IN PROXIMAL CONVERGENCE/NEARNESS RATIOS, 6 m to .33 m.

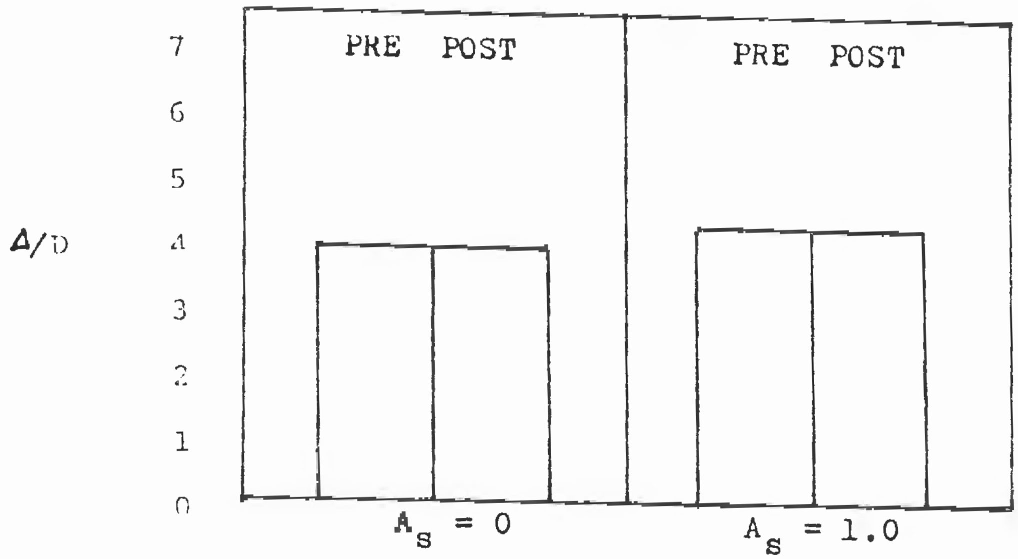

FIGURE 5a. PHORIA PROXIMAL CONVERGENCE/ NEARNESS RATIOS, 6 m to .50 m.

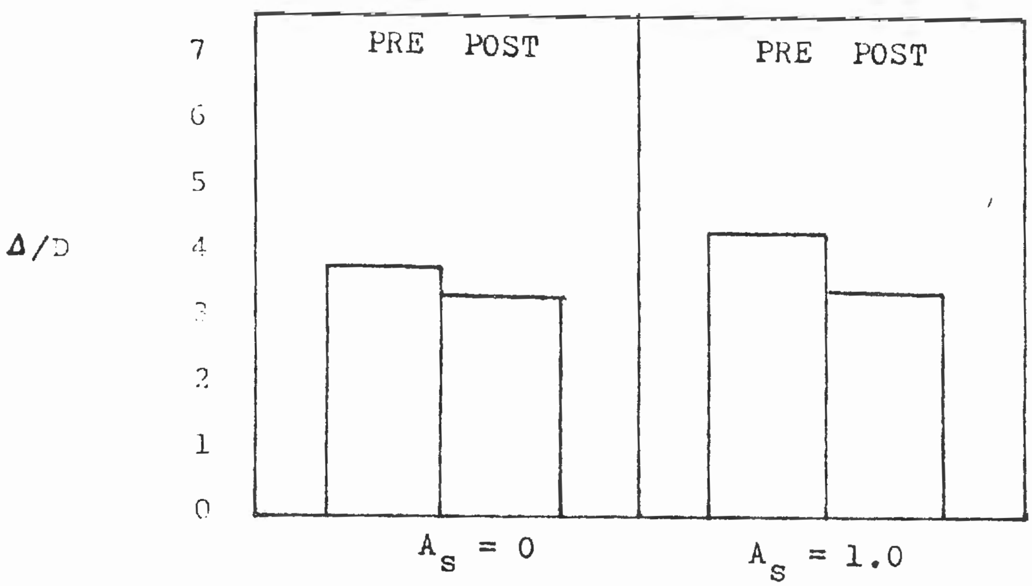

FIGURE 5b. PHORIA PROXIMAL CONVERGENCE/ NEARNESS RATIOS, 6 m to .33 m.

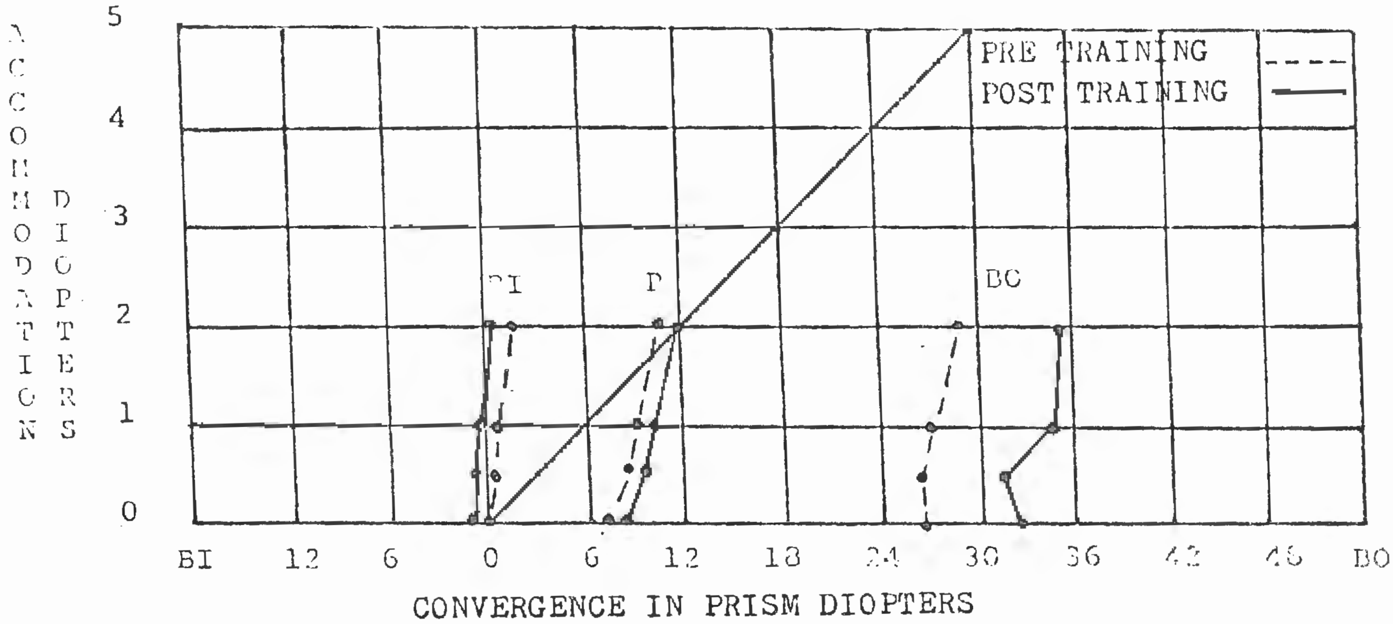

FIGURE 6a. GRADIENT AC/A, AVERAGE OF ALL SUBJECTS AT .50 m TEST DISTANCE. BASE IN = BI, PHORIA = P, BASE OUT = BO IN THE ABOVE FIGURE.

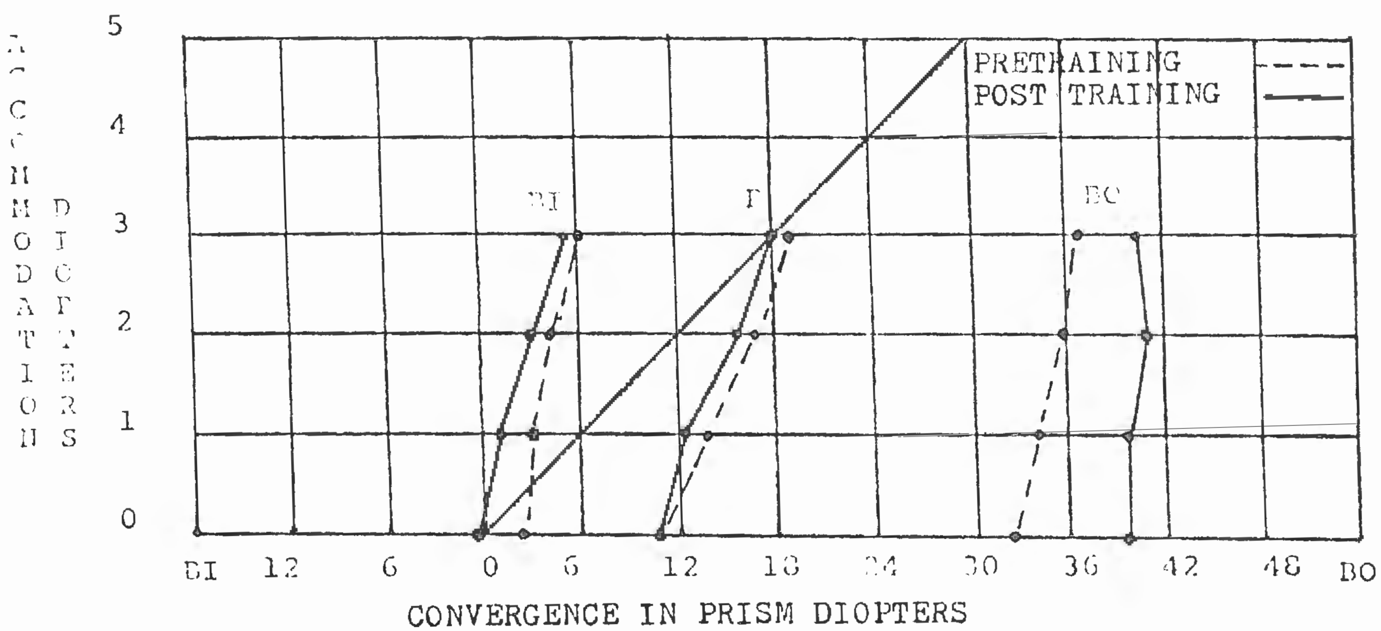

FIGURE 6b. GRADIENT AC/A, AVERAGE OF ALL SUBJECTS AT .33 m TEST DISTANCE. BASE IN = BI, PHORIA = P, BASE OUT = BO IN THE ABOVE FIGURE.

exceeds the depth of focus normally found operating at the extremes of the base out and base in limits. Therefore, if the depth of focus is having an effect, a difference should be found between $A_s = 0$ and $A_s = 1$ PC/Ds. We expected no contamination, of course, when comparing $A_s = 0$ PC/Ds pre and post training, since the same focus effect would be present in both testing sessions. Curiously, though, $A_s = 0$ and $A_s = 1$ PC/Ds were identical.

The .40 m data was taken but is not presented due to the advantage of using a larger stimulus interval, .50m to .33m.

Raw data, subject release forms, training schedules, and training instructions are found in APPENDIX 1.

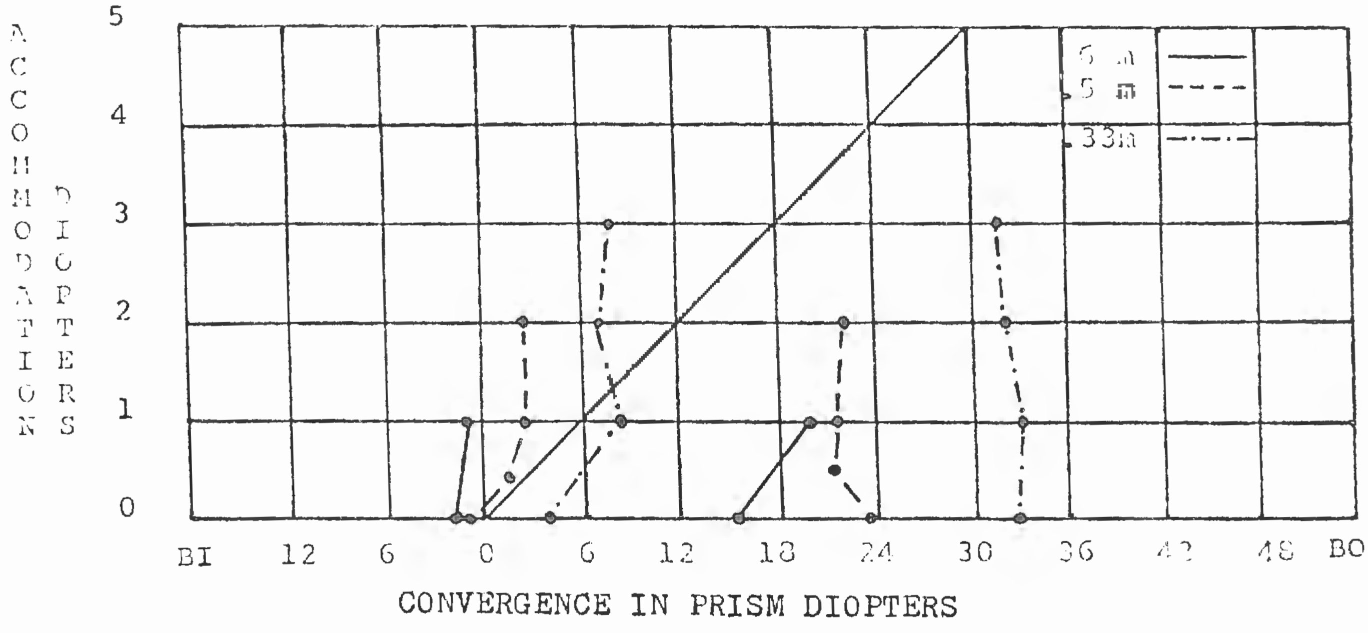

FIGURE 7a. SUBJECT 1. BASE OUT AND BASE IN TO BLUR OUT.
PRETRAINING

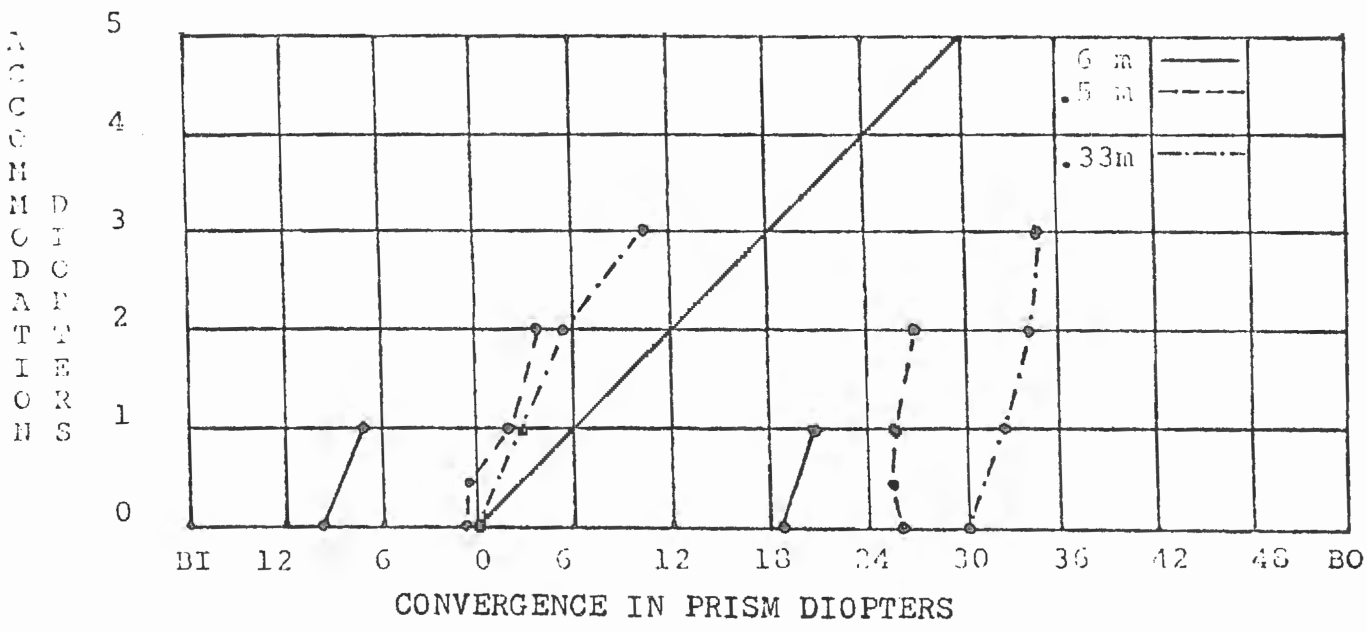

FIGURE 7b. SUBJECT 1. BASE OUT AND BASE IN TO BLUR OUT.
POST TRAINING

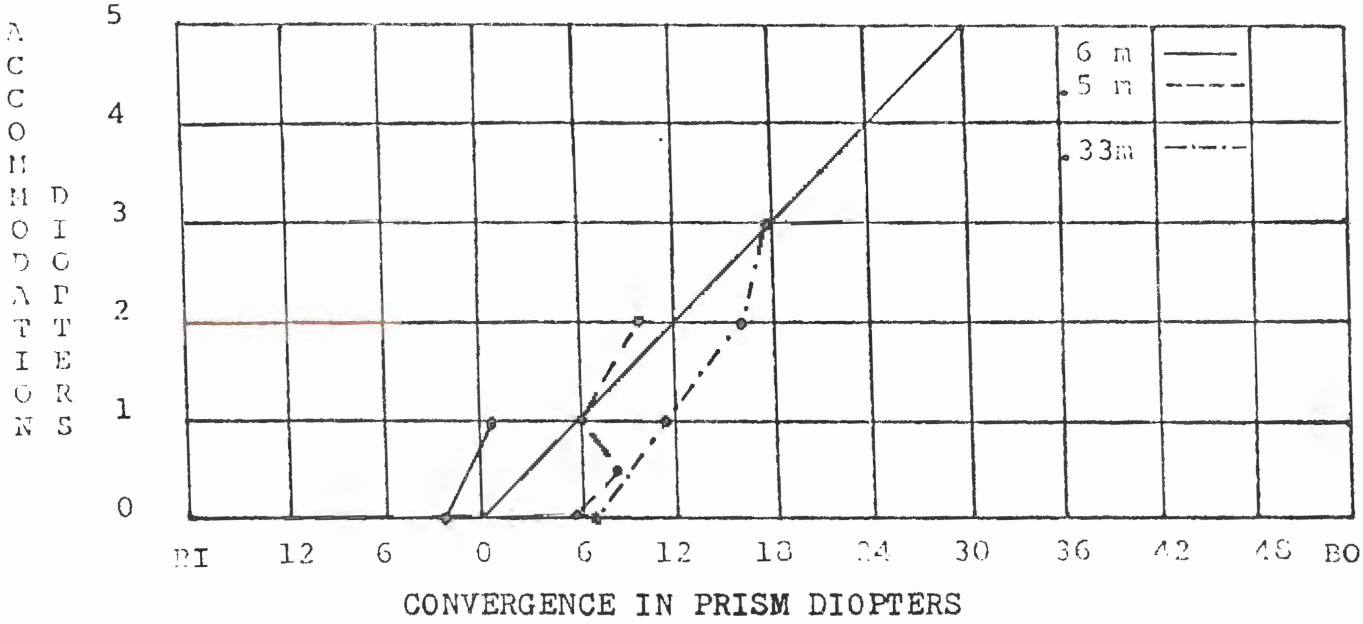

FIGURE 7c. SUBJECT 1, PHORIAS PRE TRAINING

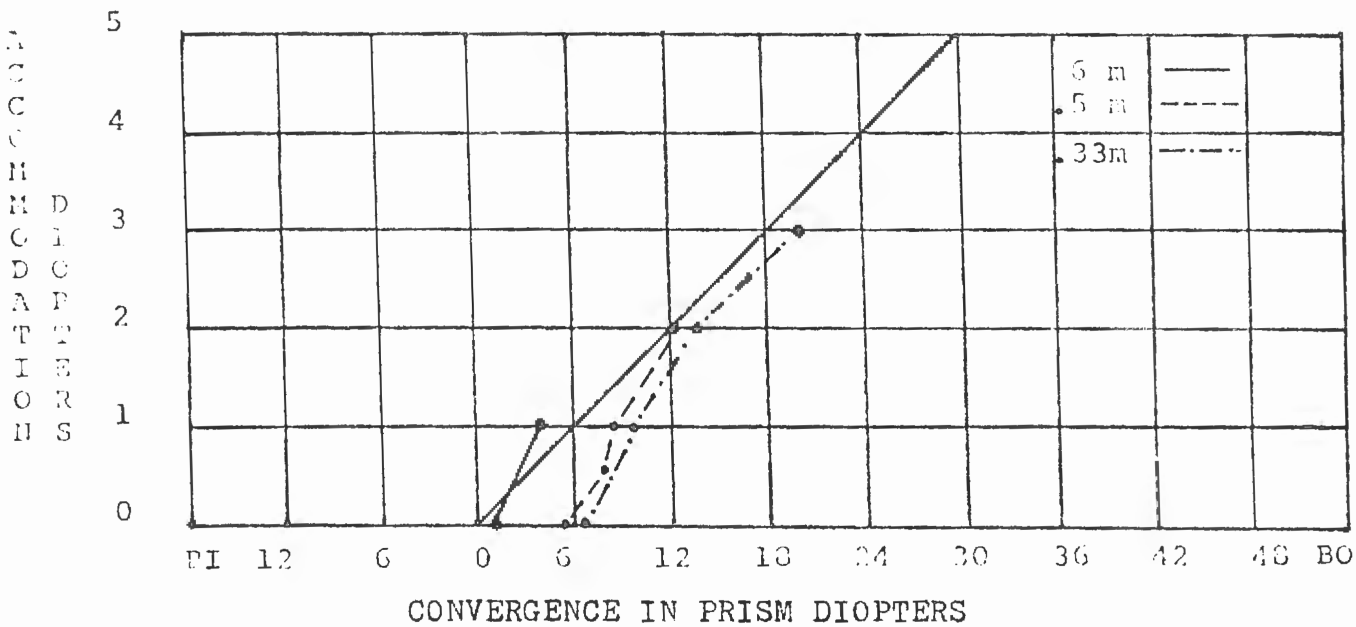

FIGURE 7d. SUBJECT 1, PHORIAS POST TRAINING

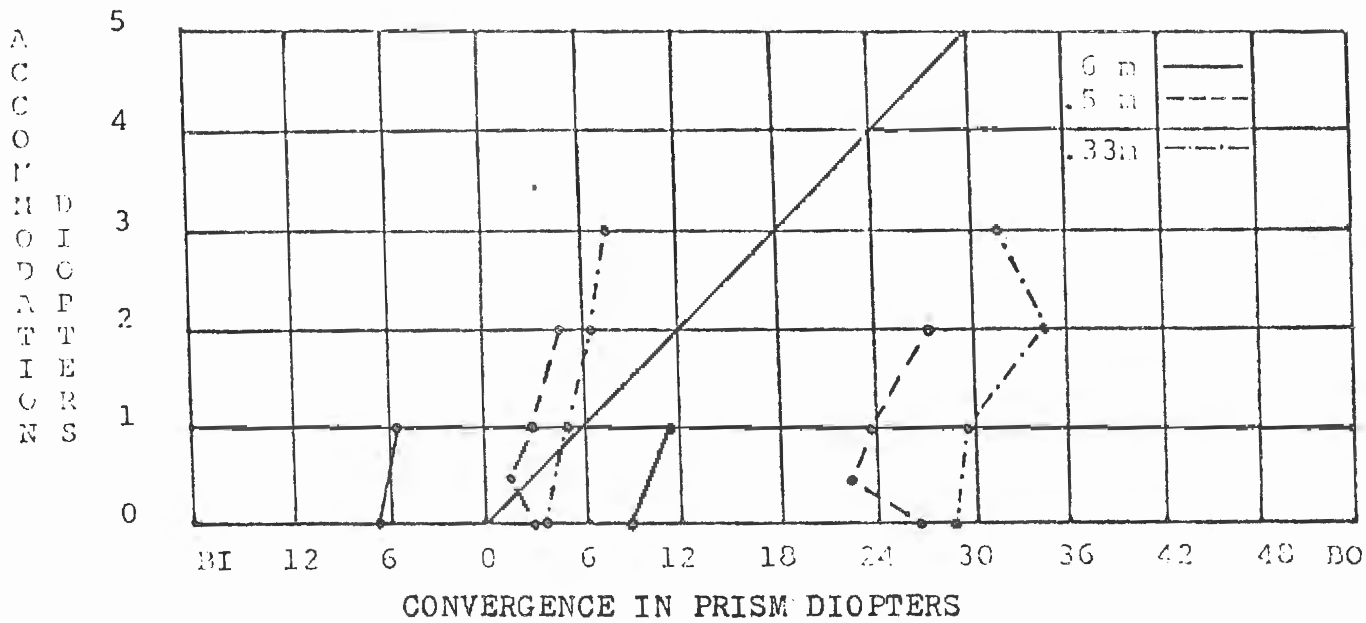

FIGURE 8a. SUBJECT 2, BASE OUT AND BASE IN PRISM VERGENCES PRETRAINING

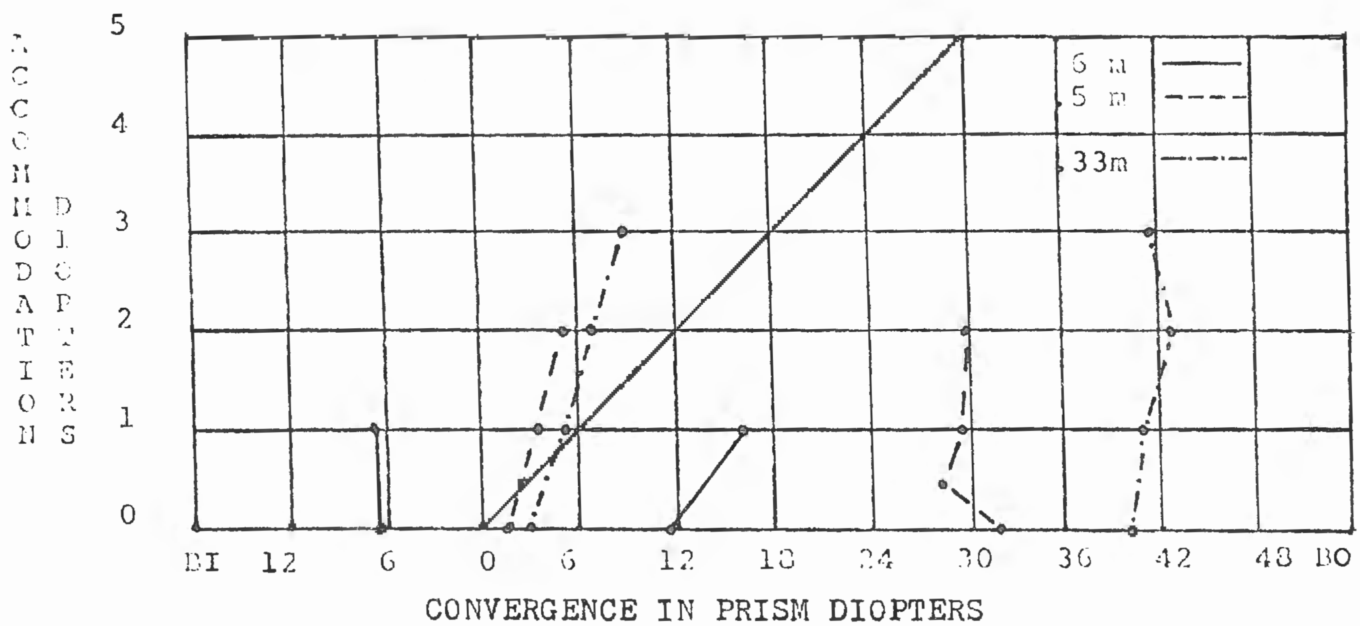

FIGURE 8b. SUBJECT 2, BASE OUT AND BASE IN PRISM VERGENCES POST TRAINING

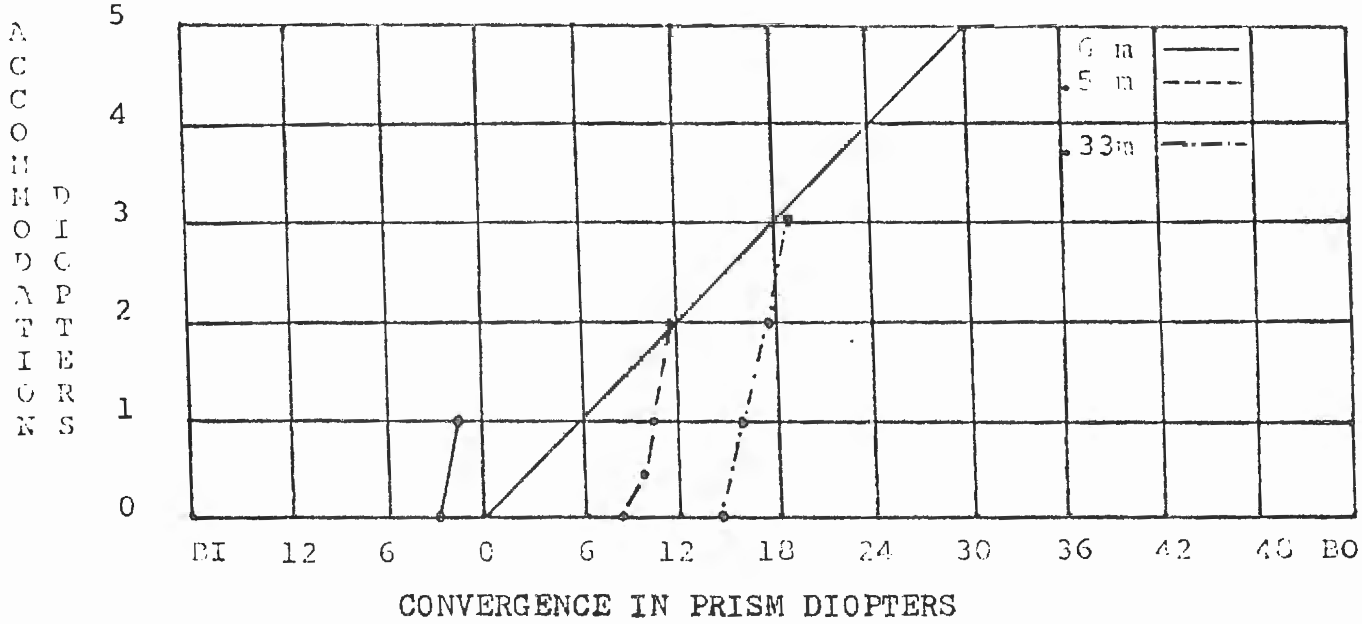

FIGURE 8c. SUBJECT 2, PHORIAS PRE TRAINING

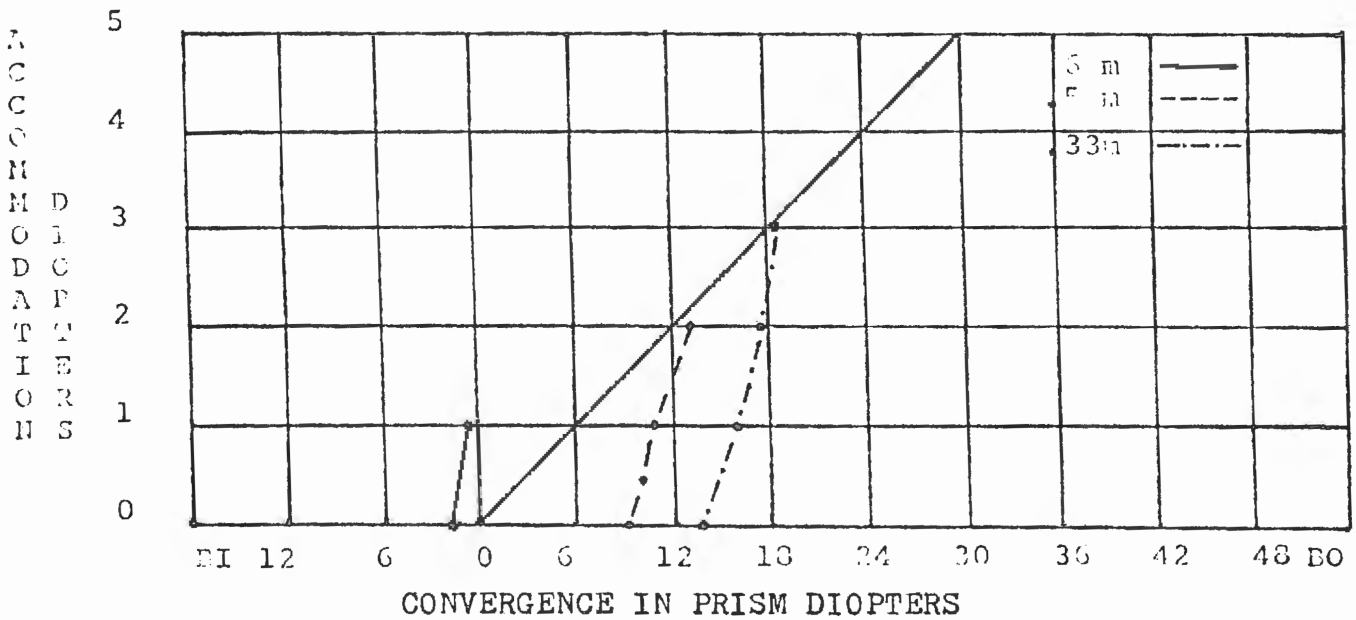

FIGURE 8d. SUBJECT 2, PHORIAS POST TRAINING

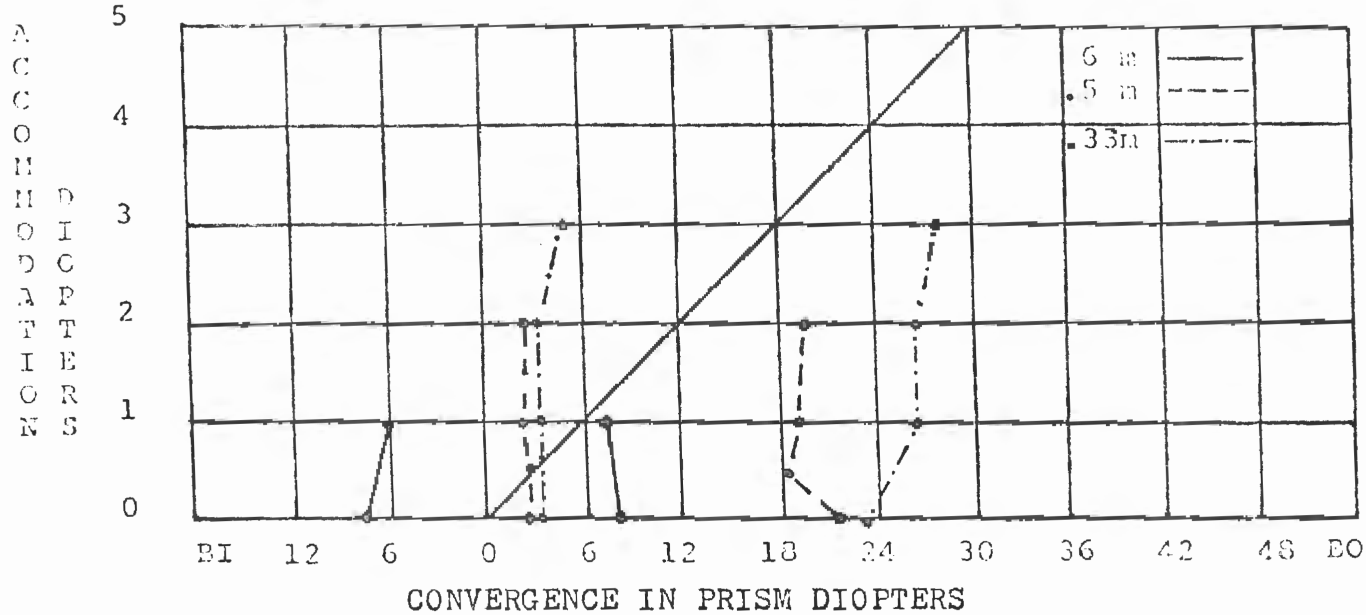

FIGURE 9a. SUBJECT 3, BASE OUT AND BASE IN PRISM VERGENCES PRETRAINING

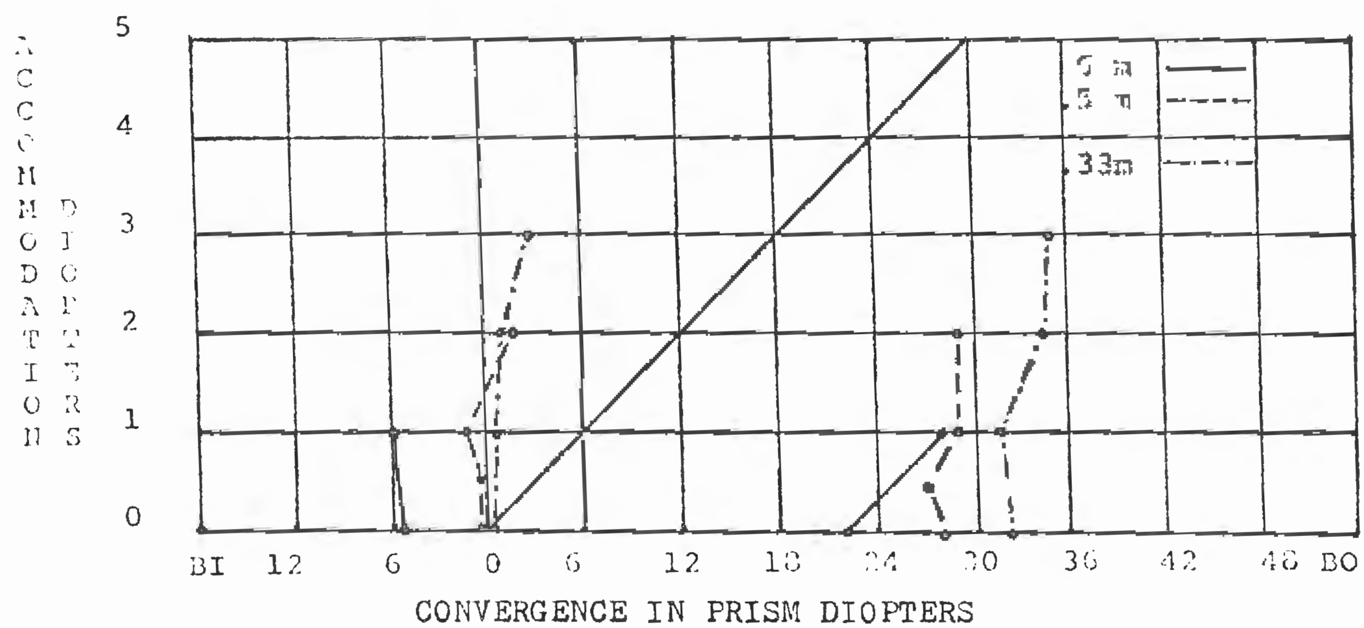

FIGURE 9b. SUBJECT 3, BASE OUT AND BASE IN PRISM VERGENCES POST TRAINING

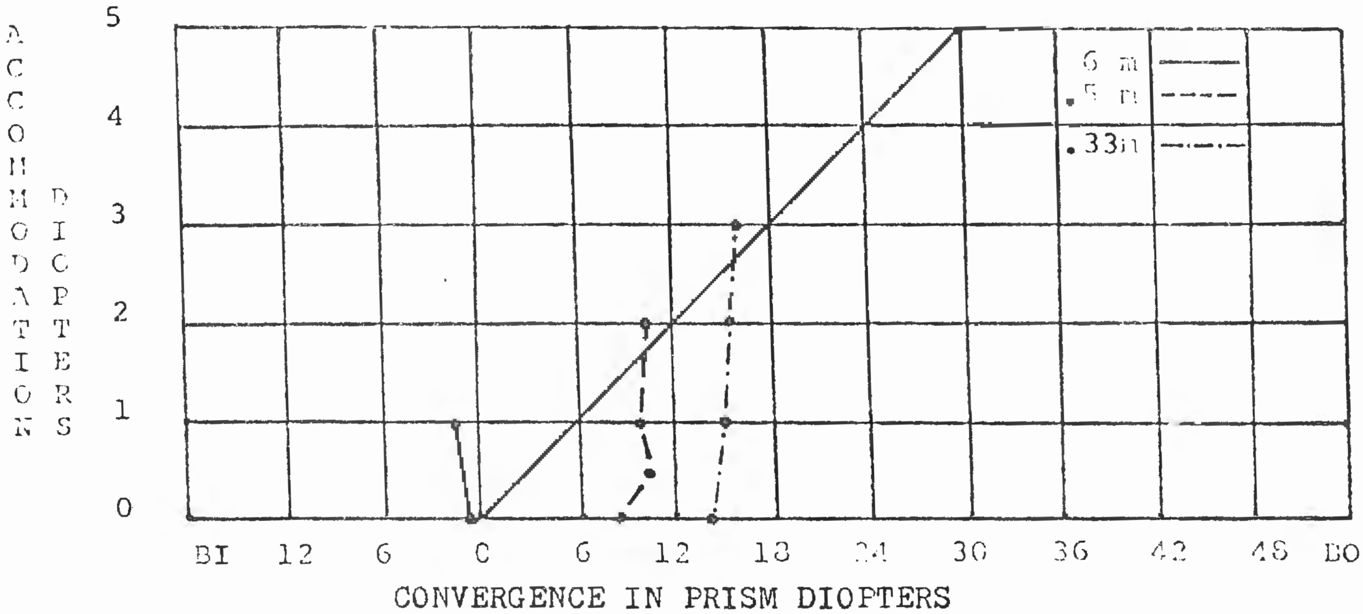

FIGURE 9c. SUBJECT 3, PHORIAS PRE TRAINING

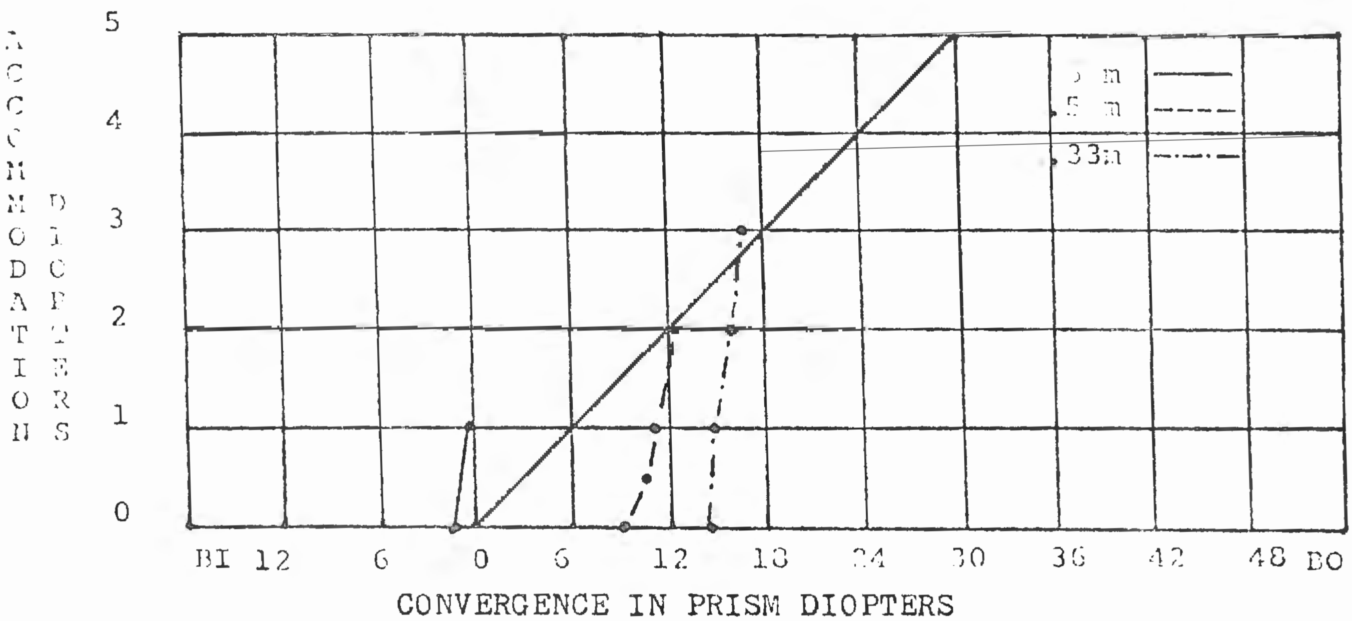

FIGURE 9d. SUBJECT 3, PHORIAS POST TRAINING

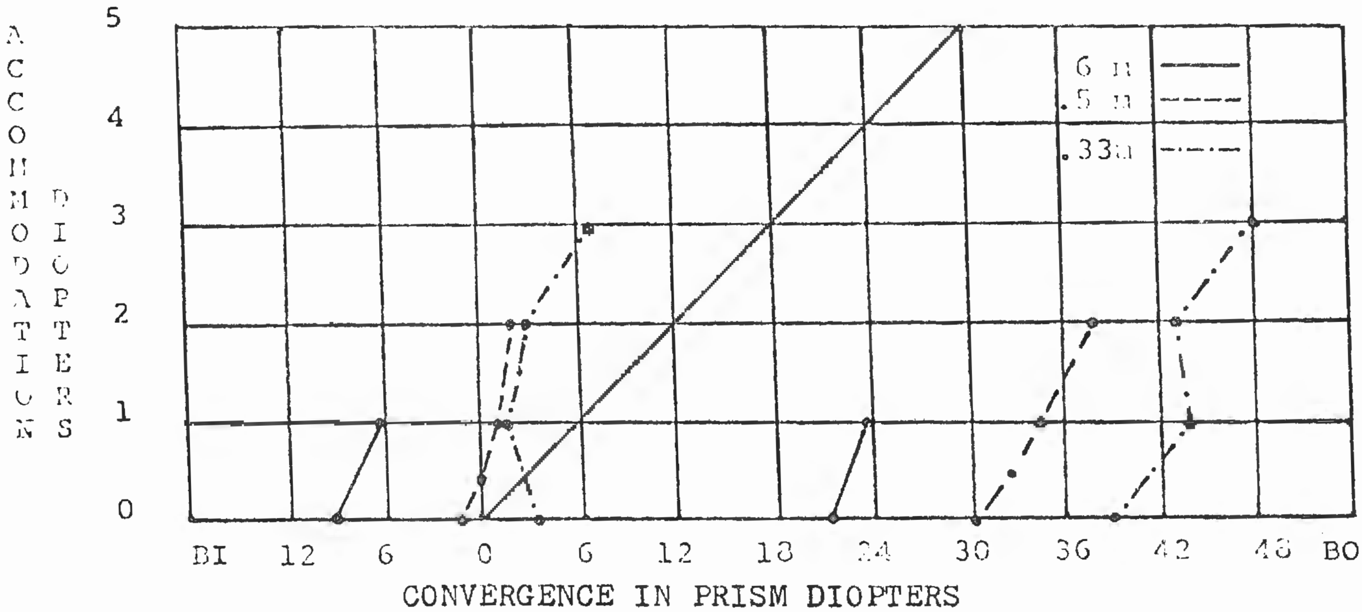

FIGURE 10a. SUBJECT 4, BASE OUT AND BASE IN PRISM VERGENCES PRE TRAINING

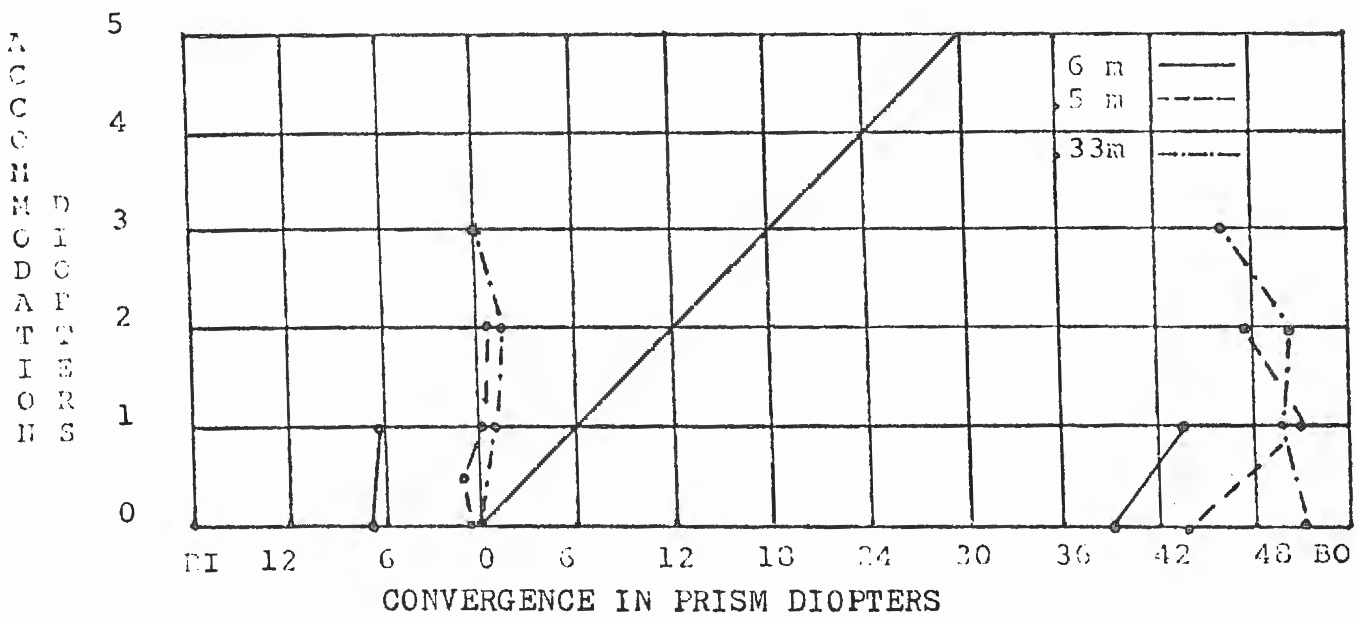

FIGURE 10b. SUBJECT 4, BASE OUT AND BASE IN PRISM VERGENCES POST TRAINING

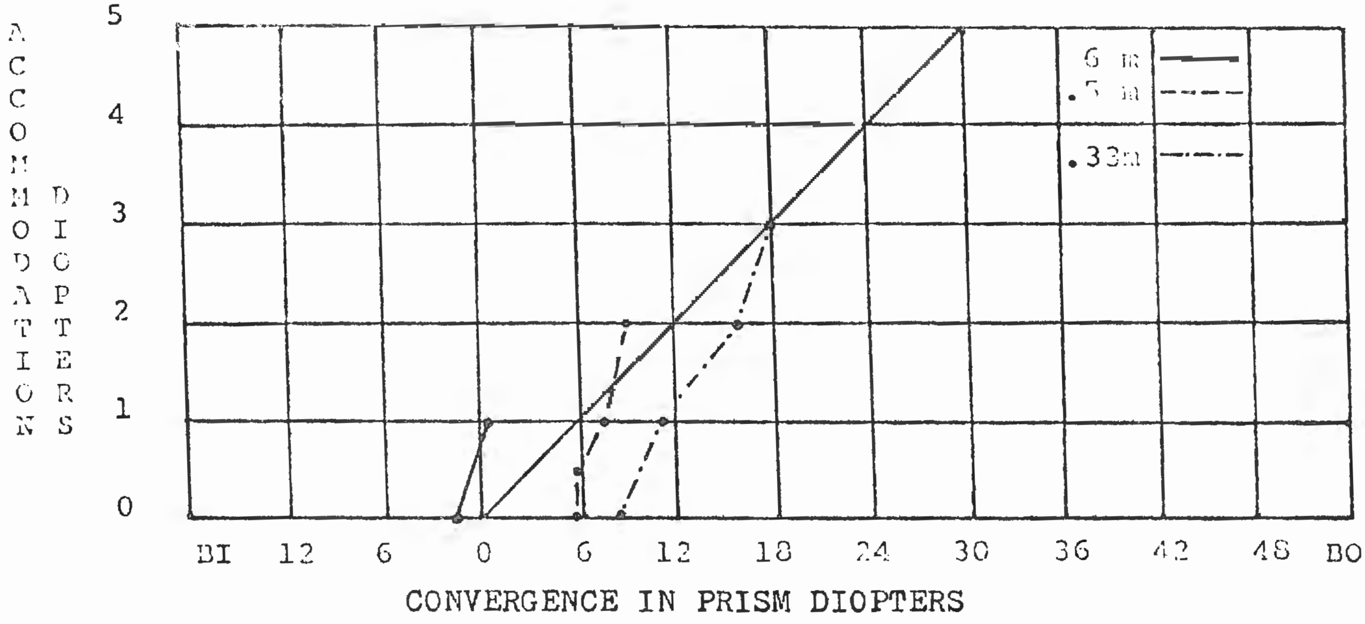

FIGURE 10c. SUBJECT 4, PHORIAS PRE TRAINING

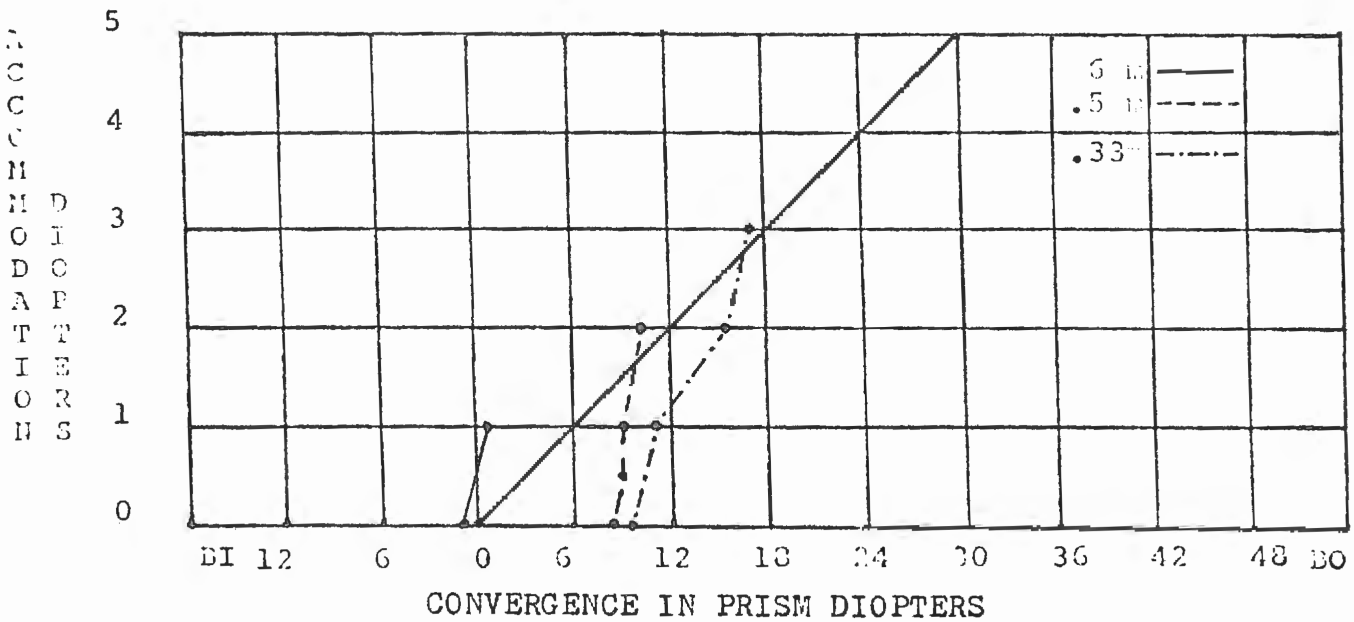

FIGURE 10d. SUBJECT 4, PHORIAS POST TRAINING

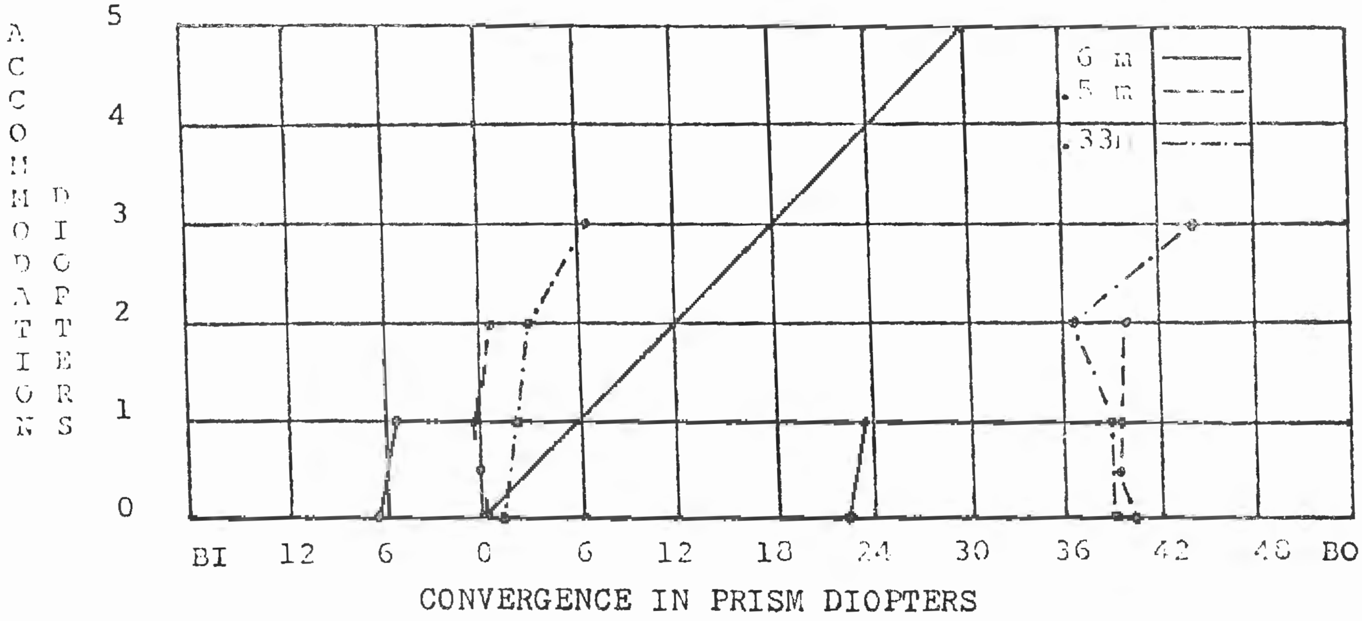

FIGURE 11a. SUBJECT 5, BASE OUT AND BASE IN PRISM VERGENCES PRE TRAINING

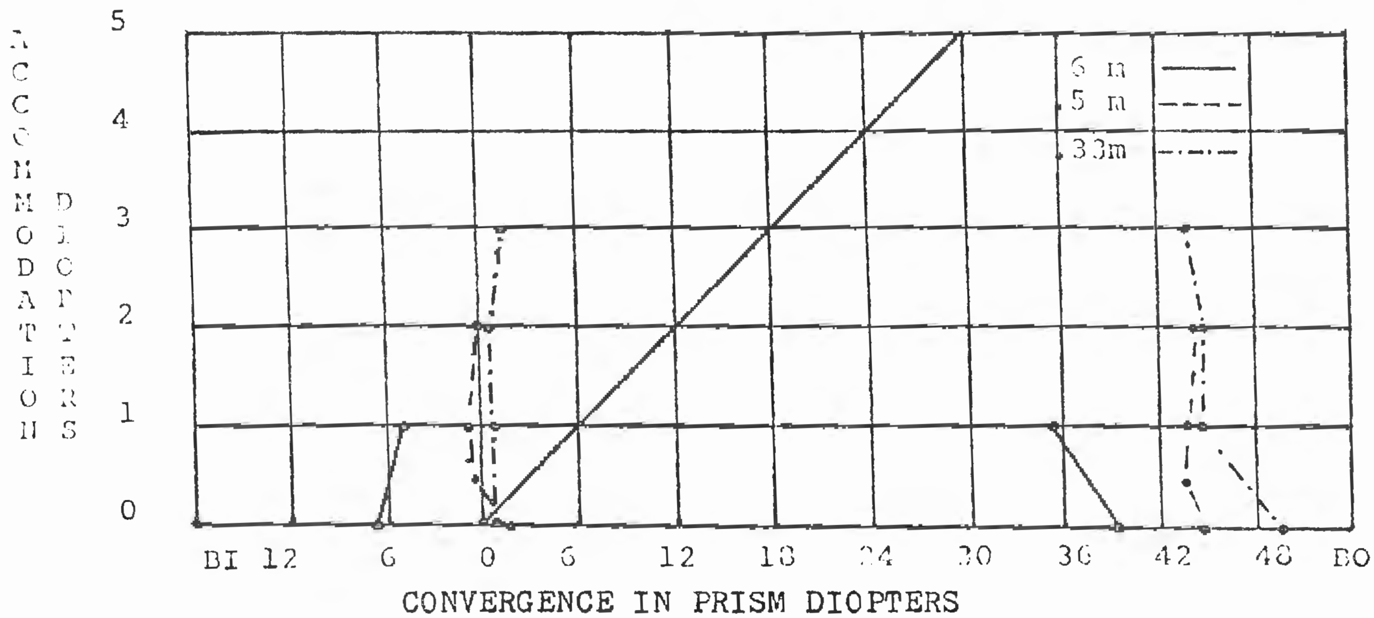

FIGURE 11b. SUBJECT 5, BASE OUT AND BASE IN PRISM VERGENCES POST TRAINING

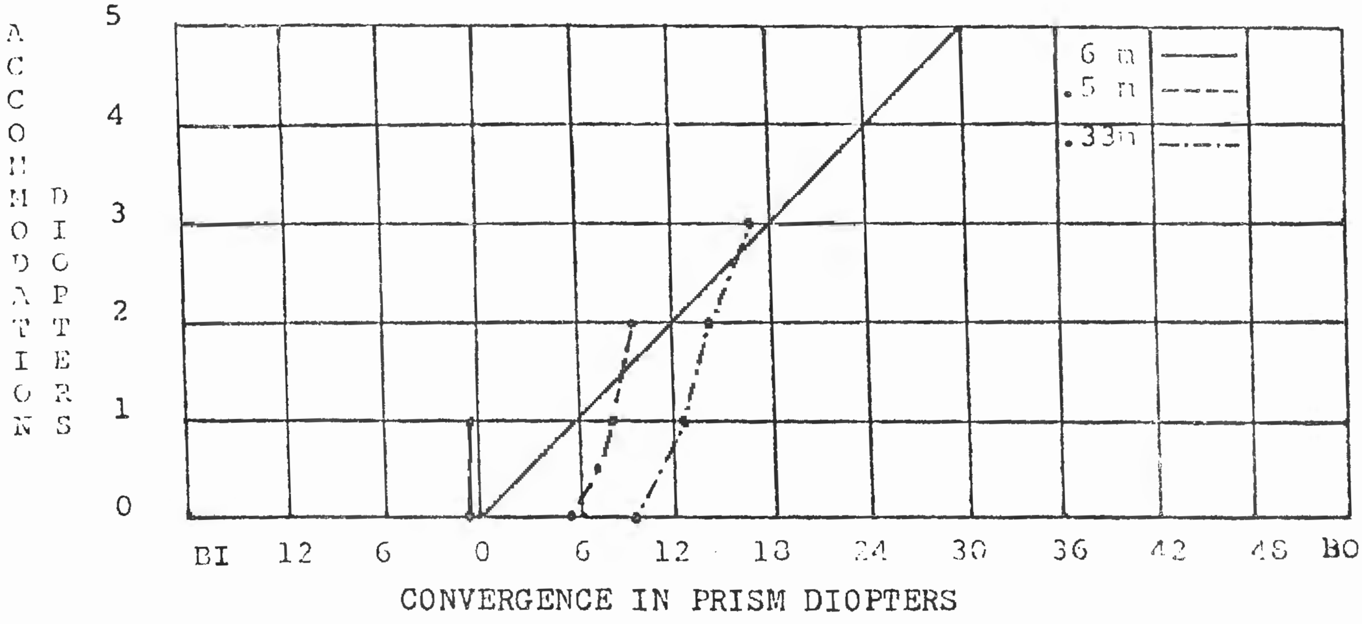

FIGURE 11c. SUBJECT 5, PHORIAS PRE TRAINING

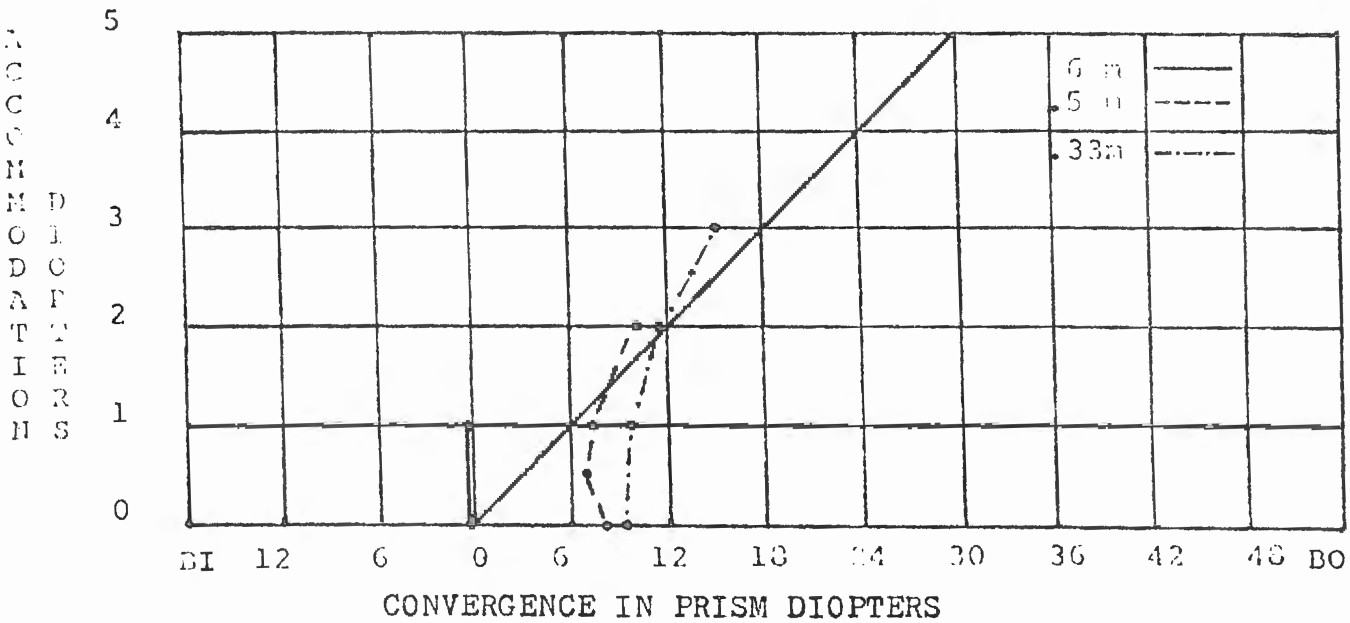

FIGURE 11d. SUBJECT 5, PHORIAS POST TRAINING

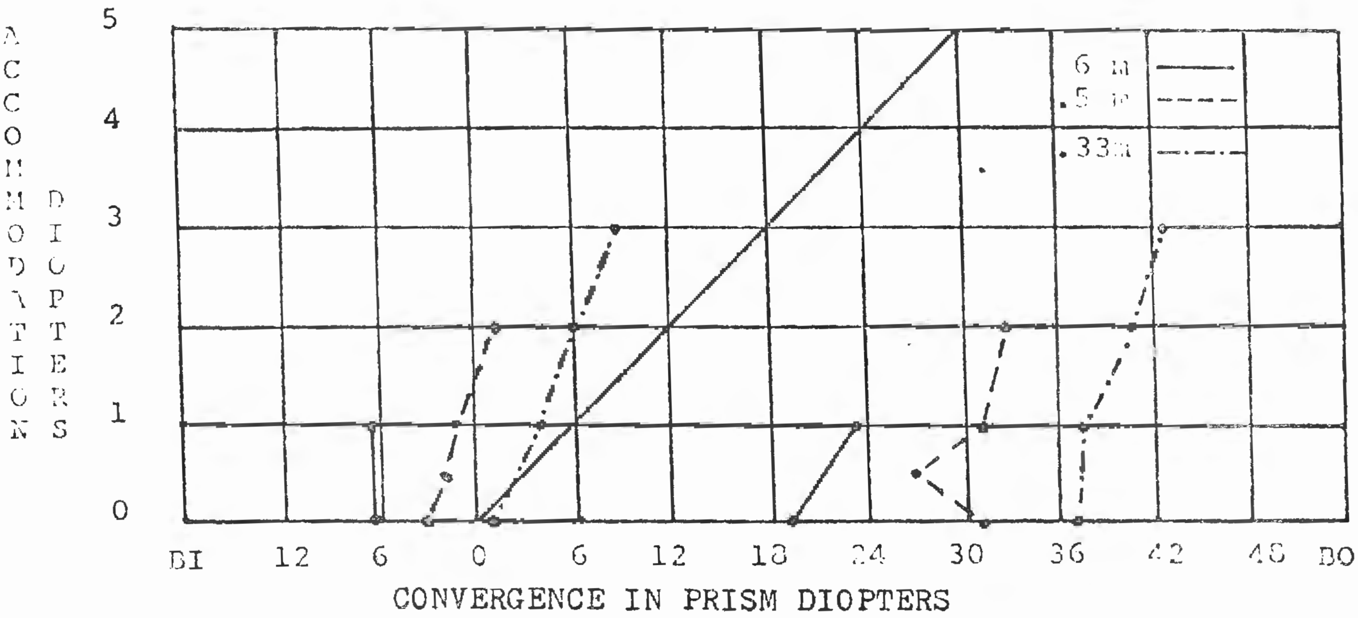

FIGURE 12a. SUBJECT 6, BASE OUT AND BASE IN PRISM VERGENCES PRE TRAINING

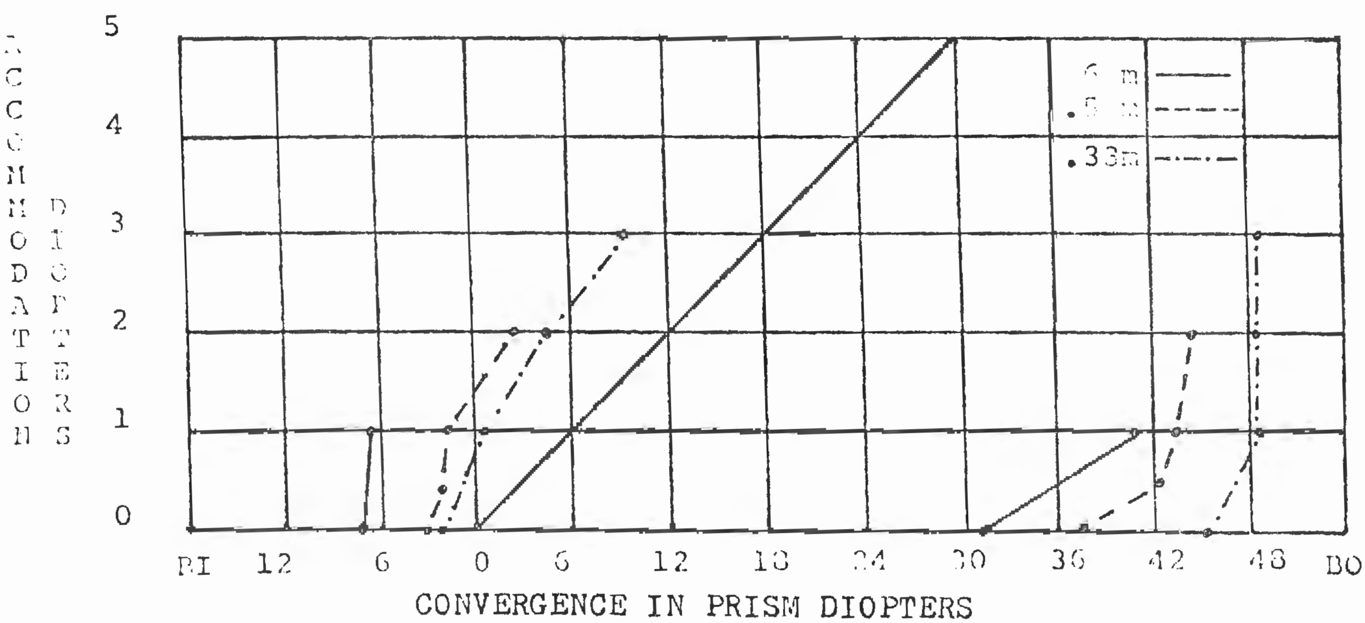

FIGURE 12b. SUBJECT 6, BASE OUT AND BASE IN PRISM VERGENCES POST TRAINING

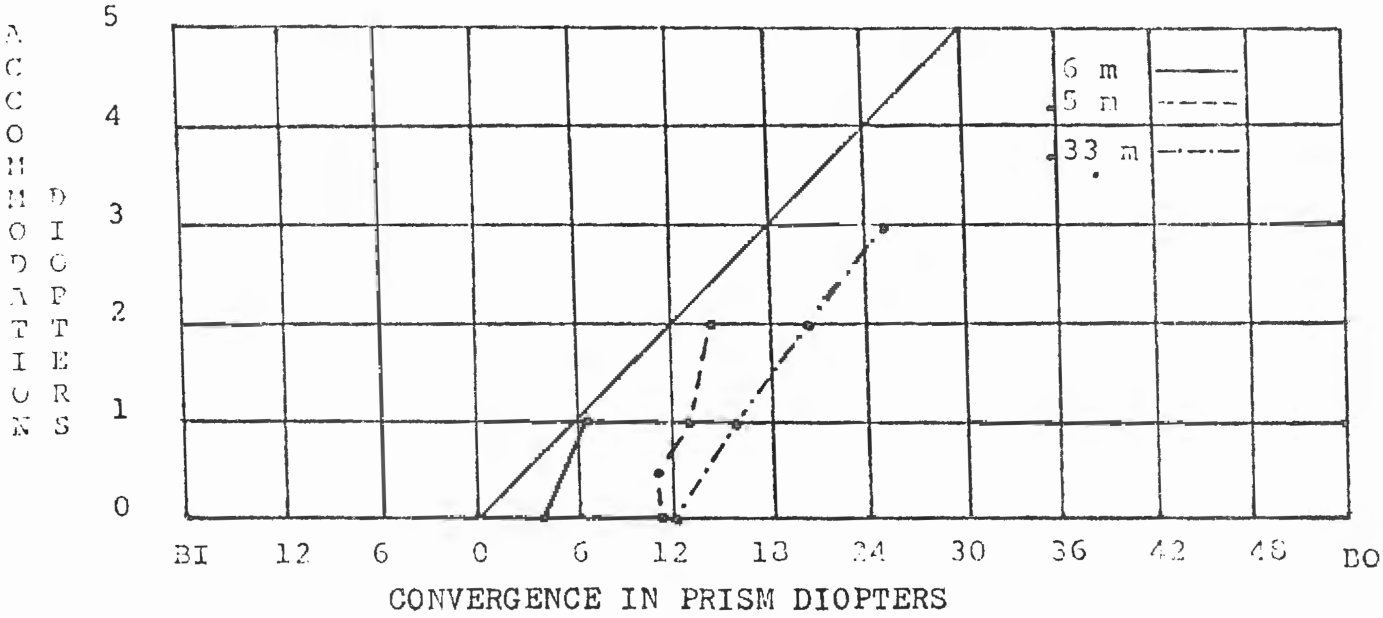

FIGURE 12c. SUBJECT 6, PHORIAS PRE TRAINING

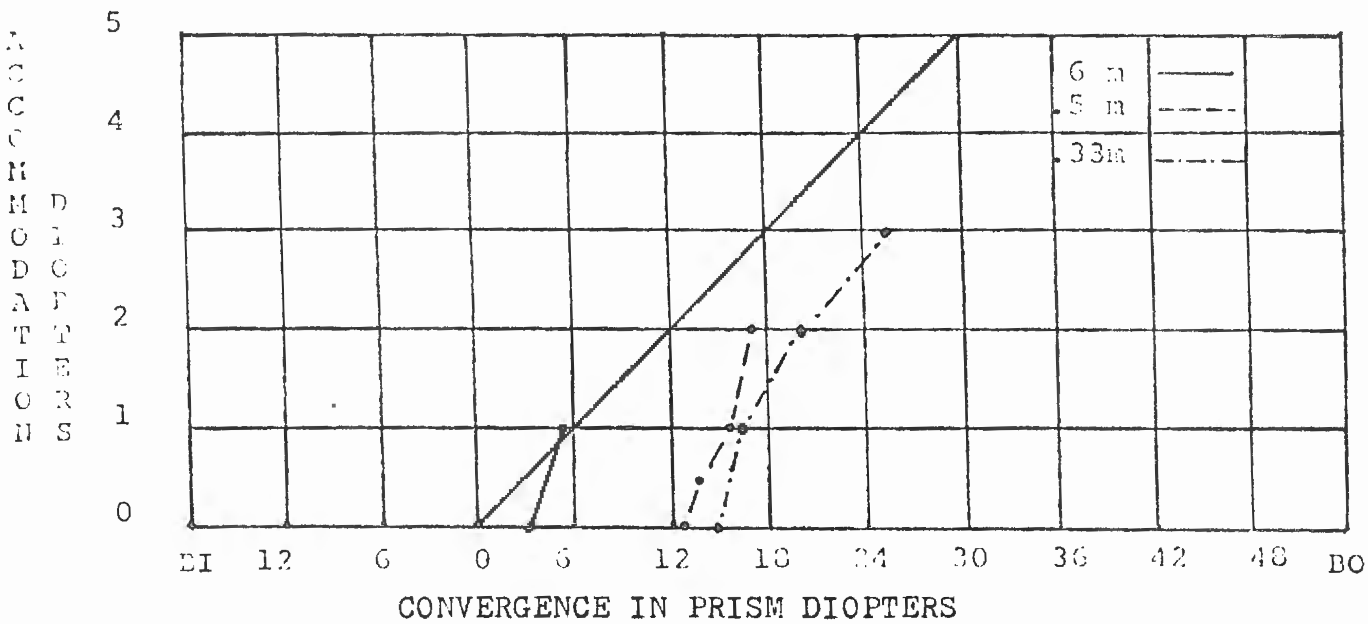

FIGURE 12d. SUBJECT 6, PHORIAS POST TRAINING

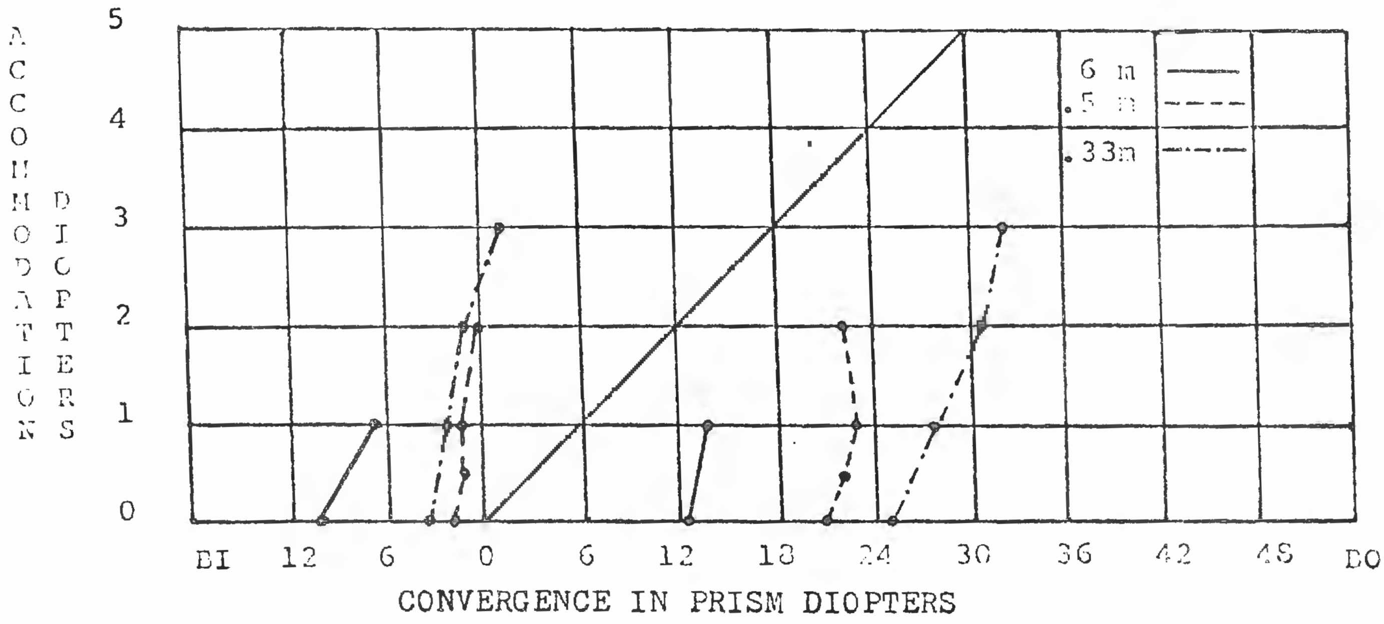

FIGURE 13a. SUBJECT 7, BASE OUT AND BASE IN PRISM VERGENCES PRE TRAINING

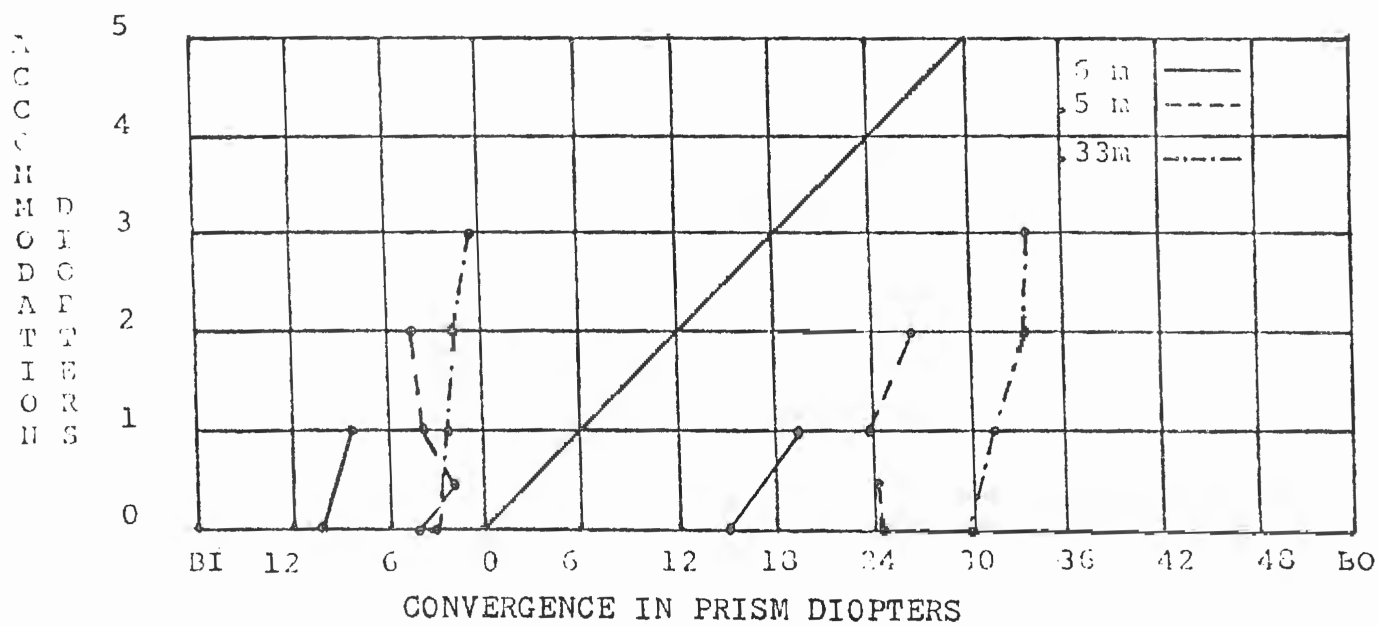

FIGURE 13b. SUBJECT 7, BASE OUT AND BASE IN PRISM VERGENCES POST TRAINING

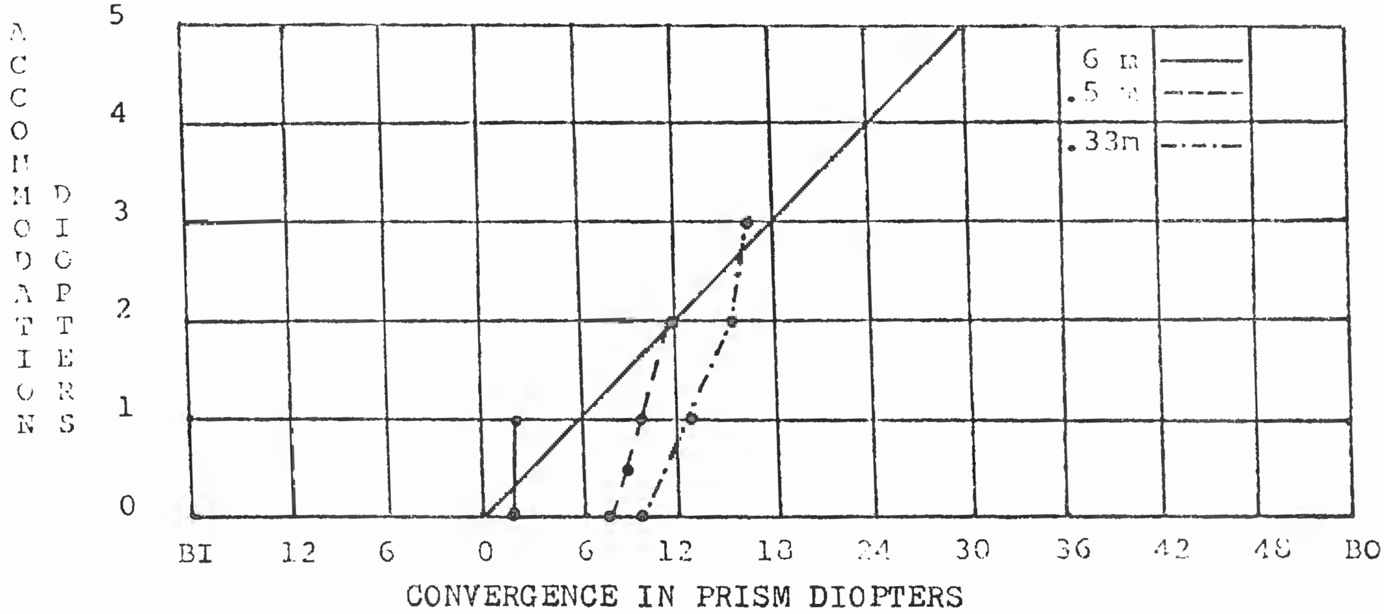

FIGURE 13c. SUBJECT 7, PHORIAS PRE TRAINING

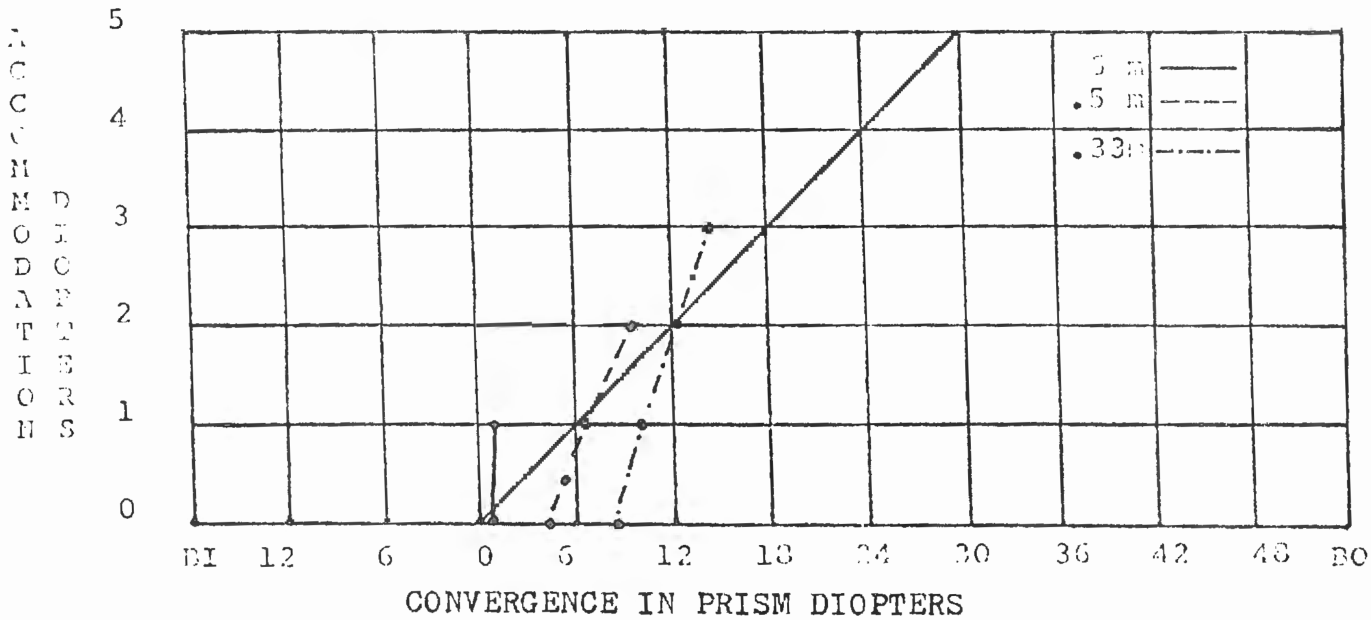

FIGURE 13d. SUBJECT 7, PHORIAS POST TRAINING

IV. DISCUSSION

Data have been presented for a study in which proximal convergence/ nearness (PC/D) ratios were determined, both before and after base out visual training. Base out, base in, and phoria data taken at several test distances with various lens adds were used to calculate PC/D ratios.

It is clear that the base out vision training program was successful in expanding the limits of the base out prism vergence ranges. Unexpectedly, a slight increase in the base in zone resulted following training. We do not feel that the widened base in zone is due to base out training, but rather due to a training effect which probably occurred during the testing sequence. A very small eso shift in the phoria line also occurred with training.

The data clearly shows that proximal convergence ratios did not increase with base out vision training, but in fact, decreased slightly. The dramatic increases in the base out zones cannot be attributed to proximal convergence increases. Likewise, although a slight increase in tonic convergence occurred, the change is insignificant when compared to the large change in the base out limit. A constant gradient AC/A between pre and post training conditions implies no change in accommodative convergence. Therefore, the increases found in the base out prism vergence ranges must be attributed to actual increases in positive fusional convergence. Also, it is clear that proximal convergence is a separate, identifiable component of convergence as suggested by Fry.[19]

All subjects in this study exhibited positive proximal effects, present even at the base in limit. As expected, PC/D was largest when computed with base out data, followed by phoria, and base in data. This was true both before and after training, even though the PC/D was found to decrease with base out vision training. Hofstetter[20] has suggested that proximal convergence may be the facilitator of positive fusional convergence. It was found in our study that PC/D decreased when positive fusional convergence increased. This suggests to us that proximal convergence may actually function as a reserve to make up for deficiencies in positive fusional convergence. As the positive fusional convergence range increased, the need for proximal convergence was lessened, hence, its reduction. For any given individual, a stronger positive fusional convergence range may imply less need for proximal convergence.

Both Alpern[21] and Ogle[22] have suggested the existance of positive, negative, and zero proximal convergence responders. In this study, all subjects were positive proximal convergence responders. Possible further study might involve seeking out negative and zero proximal convergence responders to determine training prognosis for base out training.

Flom[23] has stated that changes which occur in the AC/A with orthoptics are real changes and not due to changes in PC/D. The findings in this study agree with Flom's contention that orthoptic improvements are not due to changes in PC/D. In fact, PC/D was found to decrease with base out training while positive fusional convergence increased. In this study, no appreciable change occurred in the AC/A with training.

In summary, it was found that proximal convergence/nearness ratios decreased with increases in positive fusional convergence. This provides strong evidence that proximal convergence may serve as a reserve for any deficiencies in positive fusional convergence. Further, it was demonstrated that proximal convergence is an identifiable component of convergence, separate from all others. It was also found that the gradient AC/A did not change with vision training. Finally, it was demonstrated that the increases in base out prism vergence which occurred with training are primarily due to actual increases in positive fusional convergence.

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