Pacific University

CommonKnowledge

College of Optometry

Theses, Dissertations and Capstone Projects

5-1988

# The effect of oculomotor training on reading efficiency

Bradley B. Rounds
*Pacific University*

Cory W. Manley
*Pacific University*

Randy H. Norris
*Pacific University*

## The effect of oculomotor training on reading efficiency


### Abstract

The effect of oculomotor training on reading efficiency



### Degree Type

Thesis

### Degree Name

Master of Science in Vision Science

### Committee Chair

Hannu Laukkanen O.D.

### Keywords

visual training, oculomotor skills, reading disabilities, reading efficiency, dyslexia

### Subject Categories

Optometry

# THE EFFECT OF OCULOMOTOR TRAINING ON READING EFFICIENCY

By

BRADLEY B. ROUNDS
CORY W. MANLEY
RANDY H. NORRIS

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
for the degree of
Doctor of Optometry
May, 1988

Advisor:

Hannu Laukkanen O.D.

signature page

Bradley B. Rounds

Cory W. Manley

Randy H. Norris

Hannu Laukkanen O.D. (adviser)

## ABSTRACT

In a pilot study, ten first year optometry students were administered a four week program of exclusively oculomotor visual training for reading eye movement enhancement. Their eye movements were monitored while reading by a photoelectric monitoring system coupled with an Apple IIE computer. These subjects were matched to a control group, receiving no special instruction. Following a twelve hour program of in office and home training, the group receiving oculomotor training showed an improvement in reading skills. This change, however, fell short of significant statistical difference ($p \leq 0.05$) compared to the control group as measured by a one tailed t-test.

## KEY WORDS

visual training, oculomotor skills, reading disabilities, reading efficiency, dyslexia

## ACKNOWLEDGMENTS

We would like to thank Dr. Anita McClain and Trudy Sundstrom from the Pacific University Education Department for their assistance in the gathering of test material, the Beta Sigma Kappa organization for their financial support and Dr. Hannu Laukkanen for his guidance throughout this study.

# THE EFFECT OF OCULOMOTOR TRAINING ON READING EFFICIENCY

Bradley B. Rounds
Cory W. Manley
Randy H. Norris

## ABSTRACT

In a pilot study, ten first year optometry students were administered a four week program of exclusively oculomotor visual training for reading eye movement enhancement. Their eye movements were monitored while reading by a photoelectric monitoring system coupled with an Apple IIE computer. These subjects were matched to a control group, receiving no special instruction. Following the twelve hour program of in office and home training, the group receiving oculomotor training showed an improvement in reading skills. This change, however, fell short of significant statistical difference ($p \leq 0.05$) compared to the control group as measured by a one tailed t-test.

## KEY WORDS

visual training, oculomotor skills, reading disabilities, reading efficiency, dyslexia

## INTRODUCTION

Reading eye movements simply put, are a series of very quick eye movements (saccades) with short pauses between each movement (fixations). A longer saccade at the end of each line back to the beginning of the next is the return sweep. It is during fixations that the information from the text is gathered for comprehension. For an individual to read quickly yet efficiently, both eyes must act as team as to make saccades and fixations smooth and accurate with a minimal of inaccuracy or waste of movement. According to Getz[1] "over shooting" (eyes moving past the word) forward saccades and return sweeps may act to change the context of the reading material and decrease comprehension. Instability in these saccades and fixations lead to an increased number of regressions, no matter what the cognitive level of text[2,3]. Increased concentration and a sustained effort are required if ocular movements are not efficient. This may result in increased ocular fatigue and headaches making the possibility of an avoidance reaction more likely[4].

Previous research has shown that a majority of reading disabled individuals have deficiencies in some of the basic visual skills[5-13]. Studies by Sherman[3], Wold et al,[6] and Hoffman[10] have shown that children with perceptual motor difficulties and mechanical vision problems show a higher incidence of learning disabilities than those with 'Eye Problems' ie; pathology, visual acuities poorer than 20/40, strabismus or uncorrected refractive errors. If these mechanical and/or motor problems can be detected and then remediated to a "skill level", reading efficiency can be improved and avoidance and other subjective symptoms may decrease[1,5,14]. A population that exhibits such anesthenoptic complaints traverses a large range of ages and backgrounds. Proper optometric intervention can have a positive influence on this population.

The detection of mechanical (oculomotor) visual problems during reading has been investigated for many years. Pavlidis noted differences between 'dyslexic' and normal groups of readers in his studies of saccadic eye movements and tracking of sequentially illuminated lights[15,16]. Further research by Olson[17], Alder-Grinberg and Stark[8] as well as Black et al[9,18] and Bogacz et al[19] has shown that normal and poor readers responded similarly to "meaningless" targets suddenly displaced in their visual field". Visual-perception tasks (fixation location, fixation duration and appropriateness of areas fixated of a pictorial stimulus), as well, were not statistically different between the two groups. However, all authors indicated the eye movements <u>while reading text</u> were quite different between the normal and 'dyslexic' reader[8,9,17,18,19]. Poynter et al.[20] concluded that there is a reciprocal-causation between reading ability and oculomotor functions (forward fixation frequency, regressive-fixation frequency and average duration of fixation). The benefits of vision therapy in these reading disabilities has been shown in numerous studies[1,2,5,6,13,21].

The population of the reading disabled includes a wide range of ages and backgrounds. Individual studies by Solan and Ingram and Dettenmair have shown that the population of reading disabled is not only made up of school-aged youngsters. Ingram and Dettenmair's study indicated that a there is a college aged population having good IQ's, enrolled a normal college curriculum suffering from what were considered to be reading disabilities. Their reading scores were below normal (≤ grade ten) while their math and general knowledge scores were at the expected level. They found that there was a correlation between grade point average (GPA) and the type of courses taken. In classes that traditionally included more reading (history, humanities, and other like courses) the GPA's were generally low, or considered to be at a problem level. In the courses that did not involve a great deal of reading (e.g., math, P.E., science labs and other courses with visual stimuli to support lectures and discussions) their GPA's were at or above average[22]. Unfortunately the authors suggested a strategy to compensate for the reading difficulties instead of remediating the underlying problems.

In Solan's study, a group of achieving high school, college and professional school students, who were reading at the fifth grade level, were trained for increased eye movement efficiency. Post training, the students were reading at their respective academic levels.

STATEMENT OF PURPOSE

The purpose of this pilot study was to identify and measure the reading ability of a sample of "poor readers" from an adult professional school population, then administer a program of "pure" oculomotor skill enhancement training and to compare their pre and post training reading performance to that of a matched control group. Most studies in the past were performed with pre-teen, grade school children (with the fore mentioned exceptions). Can the success of these previous studies be replicated in an adult sample using <u>just</u> oculomotor training?

METHODS

The entire "Class of 92" of the Pacific University College of Optometry was given the sample reading section of the California Basic Educational Skills Test (CBEST). The CBEST is given to prospective teachers in Oregon and California to test their proficiency in basic reading, writing and mathematics skills. The CBST reading section assesses three skill areas of reading, literal, critical and logical comprehension. In Oregon, the passing level is set by the Teachers Standards and Practices Commission at 70%. We used this same passing criteria, from only the reading section of the sample CBEST as a screening criterion for our subjects. Those individuals who failed to meet the passing criteria ranked in the lower percentiles of the CBEST compared to students who passed and were of the same age and grade level.

Only those students who receive less than a seventy percent score on the reading section of the CBEST were asked to take part in this study.

For inclusion in this study the subjects had to have correctable near vision to 20/20 in both eyes (with no more than one line difference between the eyes) and stereoacuity that could be measured at $\leq$ 40 arc seconds (level 9), on the Wirt Rings Test. Nineteen subjects were selected for the study. All subjects were then given the current Iowa Silent Reading Test (ISRT) level III 'E' and tested on the Visagraph Eye-Movement Recording System at level 13 (college). The ISRT surveys the subject's vocabulary, reading comprehension, speed of reading with comprehension, and understanding of the author's point of view. The norms established for use in interpreting test results are based on a large sample of students representative of the national school population. The percentile scores of our subjects were compared to scores of a standardized sample of twelfth grade students planning on entering a four year college or university.

The Visagraph Eye-Movement Recording system was incorporated into this study to measure and record actual reading eye movements of the subjects while reading college level text. The Visagraph was introduced in 1985 and was the first eye movement recording system to employ a microcomputer as a means of tabulating and analyzing oculomotor performance during reading. The Visagraph can automatically calculate the individual reading performance characteristics of: fixations, regressions, direction of attack (left to right survey tendency), average span of recognition, average duration of fixation, rate without re-reading (words/minute), rate with re-reading (words/minute) and relative efficiency. The relative efficiency is a fraction calculated from; the rate (w.p.m.) divided by the sum of [the fixations (per 100 words) and the regressions (per 100 words)]. In a recent study by Grisham[23], the Visagraph compared favorably to the Eye Trac for measures of fixation, span of recognition, reading rate, relative efficiency and grade equivalency. Test-retest data was acceptable for the measures of span of recognition, relative efficiency and fixations. The Visagraph, has the capability of storing the subject's data for comparing pre and post training performance and can print a hard copy if linked to a printer.

The subjects were matched by their combined ISRT comprehension and reading efficiency scores. The matched subjects were then randomly separated into experimental and control groups, with the experimental group receiving the nineteenth subject. The experimental group received four weeks of exclusively oculomotor skill enhancement visual training. The training consisted of three, twenty minute group "office" sessions, and six, twenty minute "home" sessions per week for four weeks. The group sessions were conducted in the Pacific University College of Optometry visual training laboratory. Each subject was placed in a sub group of two or three subjects, each group having one instructor through out the entire training period. The control group was instructed to engage in no visual training activities during these four weeks and to go about life in a normal fashion.

Home training consisted of:

1. Marsden ball pursuits (horizontally, diagonally and circles)
   a. lying on back
   b. standing
2. Four Color Call
   a. four colors of paper at differing distances in front of the subject,
   b. subject calls out color of paper as they move their fixation from one piece to another at the same time "keeping time" with foot and hand
3. Star Chart
   a. at near, subject calls out fixated number, moves to next number
   b. at the same time "keeping time" with foot and hand
4. dueling pointers
   a. a two inch square piece of paper on tip of pointer, held at arms length, subject tries to obscure view of partners pointer, or Marsden ball while it swings in front of the subject

This routine was done for the four weeks with the following modifications each week. The first week the subjects wore an eye patch (alternating eyes on alternating days). The second week, the subjects used a septum between the eyes for 'biocularity'. Week three, the subjects incorporated a prism (6-8^) BO or BD and the forth week, the subjects were completely binocular.

The office eye-movement training consisted of a variety of devices and techniques, including:

1. Rotating Peg Board; subject pushing a golf tee into the "target hole" while tracking the target for one revolution using only pursuit eye movement
2. Hart charts eye movement training; far to near saccades, column saccades, (with bar readers at near and red/green acetate at dis-

tance [red/green glasses]) and on the balance beam
3. Eye span; calling out the numbers of the moving lights, number calls with red/green glasses
4. computer saccades program
5. Near point DST charts; column saccades (right to left, left to right vertically and diagonally)

The above techniques were administered monocularly during the first four sessions. Then biocularly, during the next four weeks, with the use of red/green glasses. The last four sessions were done binocularly in an increasingly more challenging environment ie; including increased speed of the rotator and eye span, increased speed of the metronome with the Hart and DST eye movement charts, and use of the balance beam and mini trampoline to further escalate the demand level.

After four weeks of training, all subjects were administered the ISRT level III 'F' test. All subjects were then re-tested with the Visagraph Eye-Movement System using the same level of difficulty but different text.

RESULTS

Based on a one tailed "t" test, the visagraph post training data between control and experimental groups, was not significant to a $p = \leq 0.05$ level. The findings of the ISRT also were not significant to a $p = \leq 0.05$ level. Chart A shows the actual "mean difference" of pre and post training data, the standard deviation and the standard error of the group data. The mean difference is calculated so that all negative numbers indicate a decrease in performance after the four week study.

## CHART A

| TEST | GROUP | Mean diff. | Std. Dev. | Std. Error |
|---|---|---|---|---|
| Diff V Comprehension(%) PST-PRE | C | 0.233 | 0.122 | 0.041 |
| | X | 0.220 | 0.187 | 0.059 |
| Diff V Relative Efficiency PST-PRE | C | -0.173 | 0.841 | 0.280 |
| | X | 0.175 | 0.924 | 0.292* |
| Diff V number Regressions PRE-PST | C | -3.444 | 11.293 | 3.746 |
| | X | 6.500 | 9.583 | 3.030* |
| Diff V number fixations/100 wds PRE-PST | C | -4.440 | 19.520 | 6.507 |
| | X | 9.200 | 25.068 | 7.927 |
| Diff length Fixations PST-PRE | C | -0.017 | 0.041 | 0.014 |
| | X | 0.013 | 0.043 | 0.014* |
| Diff V Speed PST-PRE | C | 4.667 | 27.331 | 9.110 |
| | X | 12.800 | 36.092 | 11.413 |
| Diff V Span Recogn. PST-PRE | C | -0.031 | 0.164 | 0.055 |
| | X | 0.066 | 0.233 | 0.074* |
| Diff ISRT Comprehension(%) PST-PRE | C | -0.046 | 0.107 | 0.036 |
| | X | -0.006 | 0.099 | 0.031 |
| Diff ISRT Reading Efficiency(%) PST-PRE | C | 0.121 | 0.165 | 0.055 |
| | X | 0.050 | 0.162 | 0.051 |

C=CONTROL GROUP, X=EXPERIMENTAL GROUP, V=Visagraph data, negative (-) numbers show a decrease in performance, (*) noted in aside

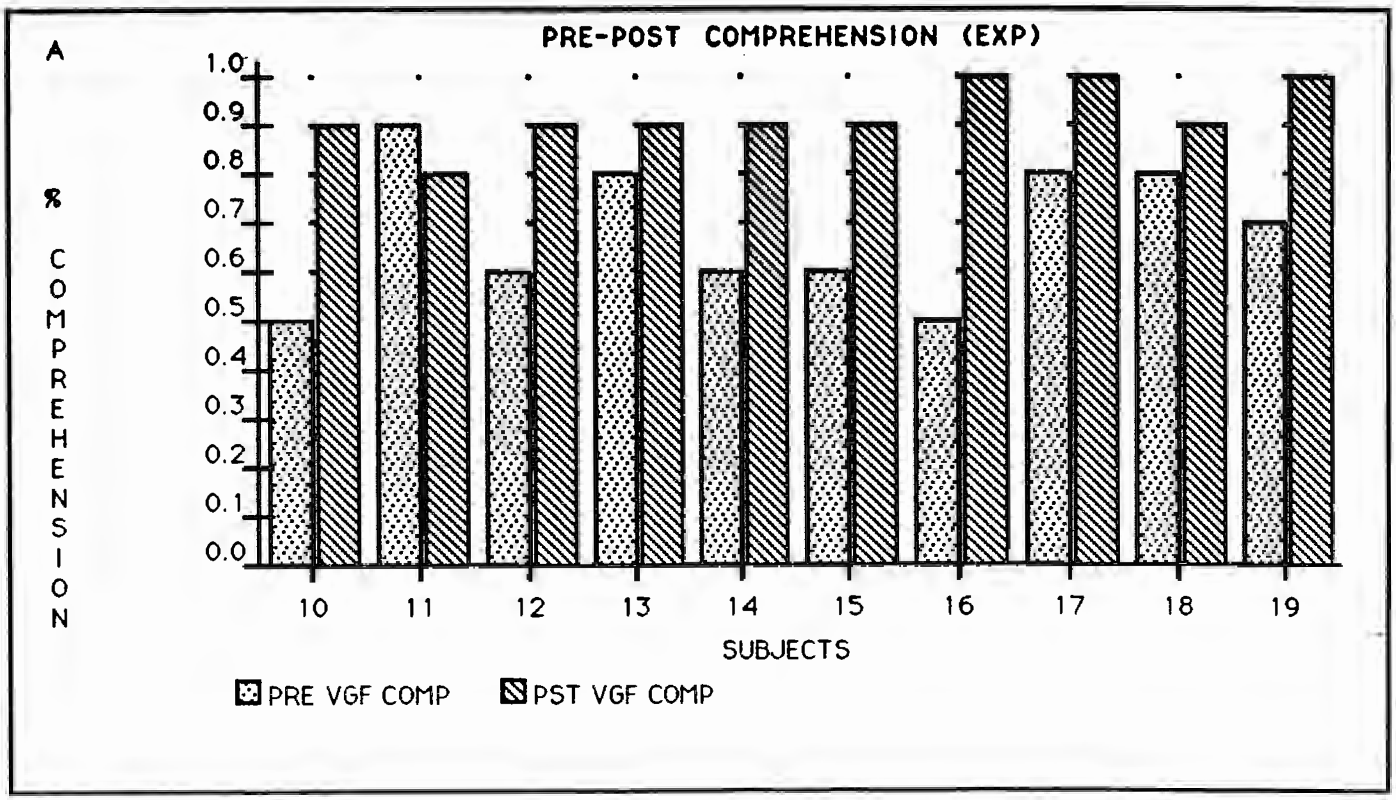
## DISCUSSION

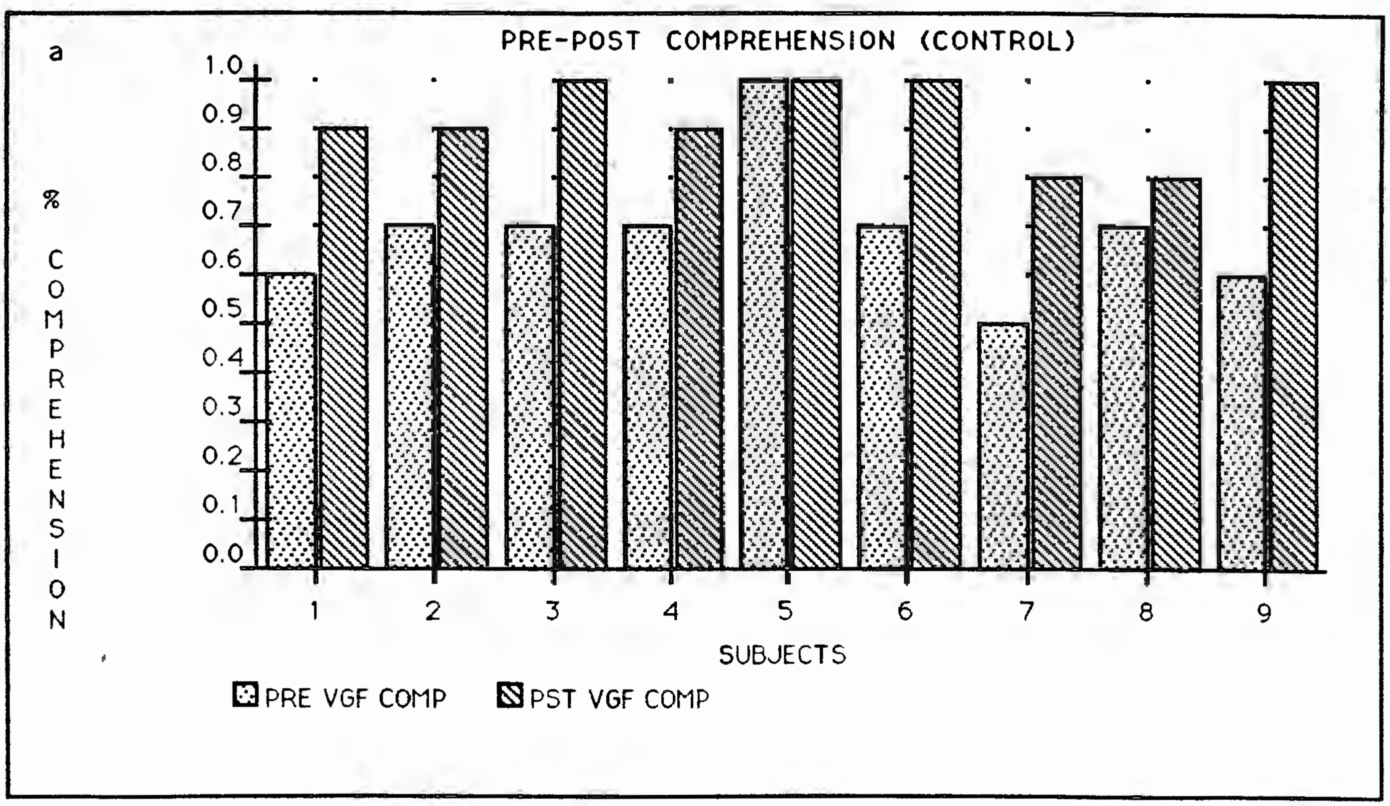
In conclusion, this pilot study showed that in training "pure" oculomotor eye movements in an adult sample, the subjects showed a definite increase in reading skills as compared to the control group. Both groups increased their comprehension level on the Visagraph text by approximately 20%. That is, each group averaged two correct answers more on the post-test than on the pre-test. The Visagraph relative efficiency for the group receiving training was double that of the Control group. The Experimental group's average speed (rate/wpm) increased by 2.74 times compared to the Control group's. The Experimental group's fixations and regressions decreased by 3 times (+/- 0.10) compared to the Control group's. This shows that the group that received training could move their eyes faster and more efficiently with fewer regressions than the group who did not receive training. The number of regressions is indicative of the need to verify or "re-examine" a word or word group. The decreasing number of regressions seen with the Experimental group suggests an increase in stability in eye movements. That is, by increasing the accuracy and control of eye movements the subjects were able to "reach, grasp and release" the target (words) easier and more efficiently. The span of recognition also increased in the experimental group. An increased span of recognition allows the student to perceive, organize and process more information per fixation[2,5,10,19]. This may explain the increased duration of fixation. The reading efficiency index scores of the two groups were comparable ($\leq 0.07$). The ISRT's comprehension section showed little change from the pre-test data in both groups. Both groups actually regressed (the Experimental group less than the Control).

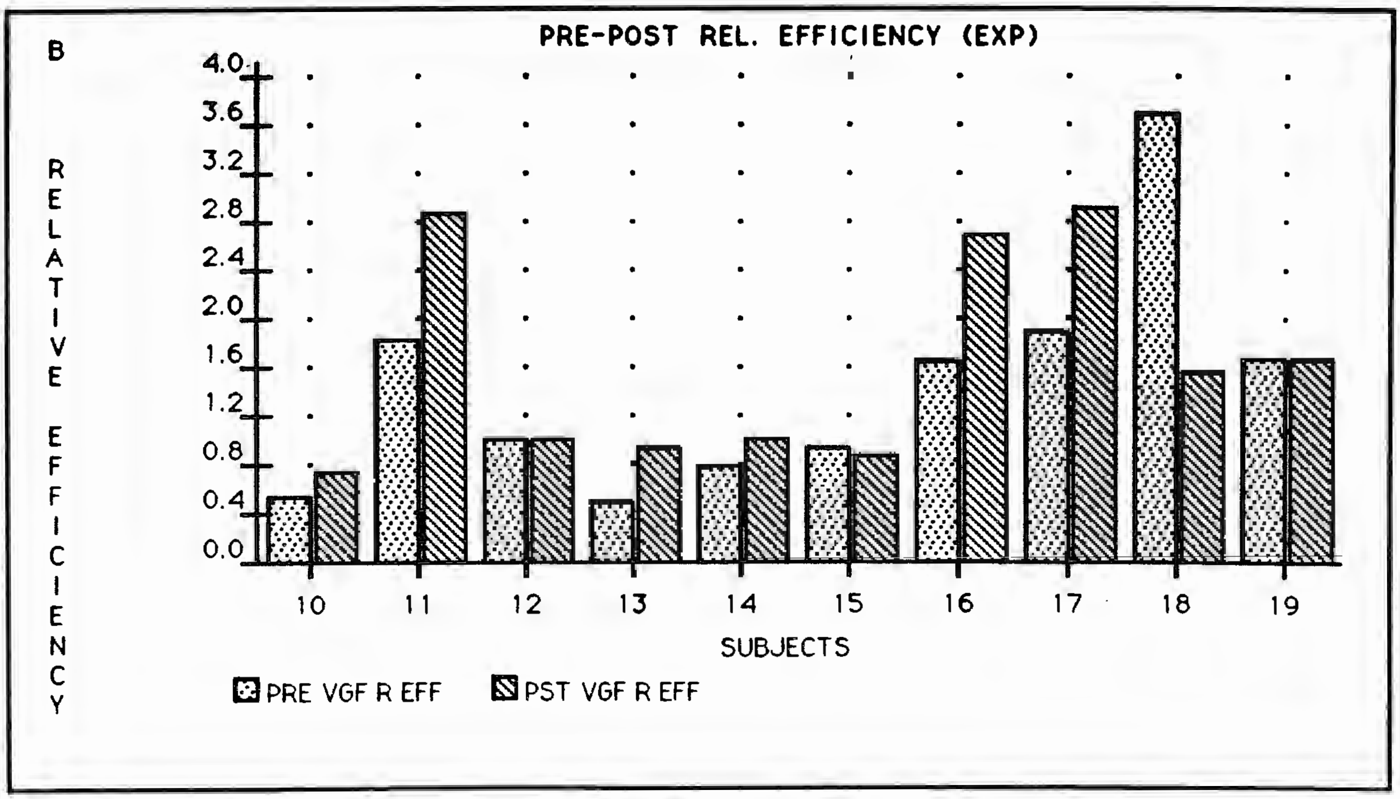
Although an increase in performance was noted, it fell short of statistical significance. Possible reasons for finding no statistical significance are (1) oculomotor training in "isolation" is not adequate to change embedded eye movement patterns of adults, (2) the techniques used were not adequate to "break" the embedded behavioral patterns, (3) the duration of training was not long enough, (4) individual subject motivation "variables" and (5) instrument and researcher reliability are always factors. Further research should emphasize (1) a more stringent inclusionary criteria, (2) a longer training period and maintenance training program and (3) a larger sample size with possibly varying age groups.

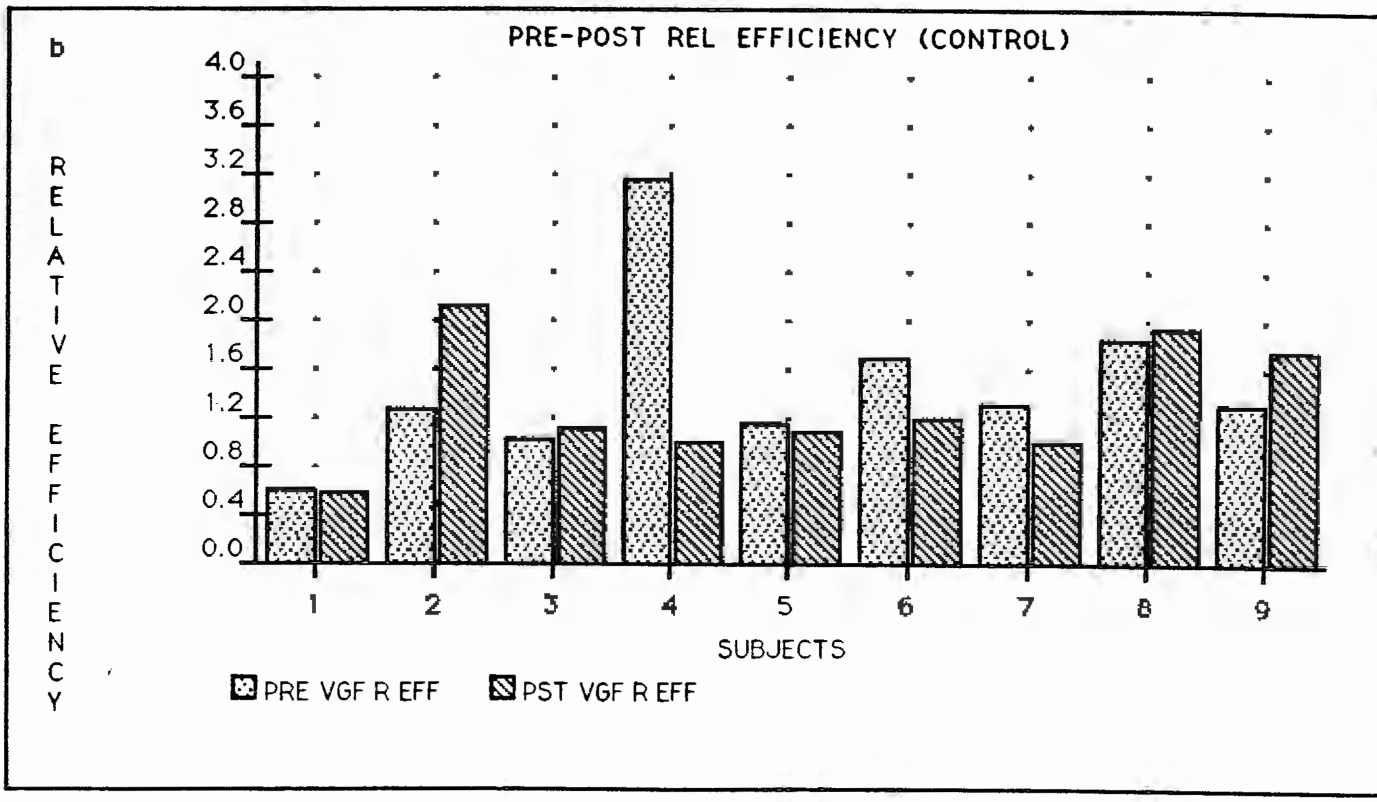
It is our contention that the underlying problems behind many reading problems (poor eye movements being one) can be remedied through vision therapy. It is our hope that by informing other practitioners and educators of this option the population of "inefficient readers" can be recognized and through appropriate measures can be remediated.

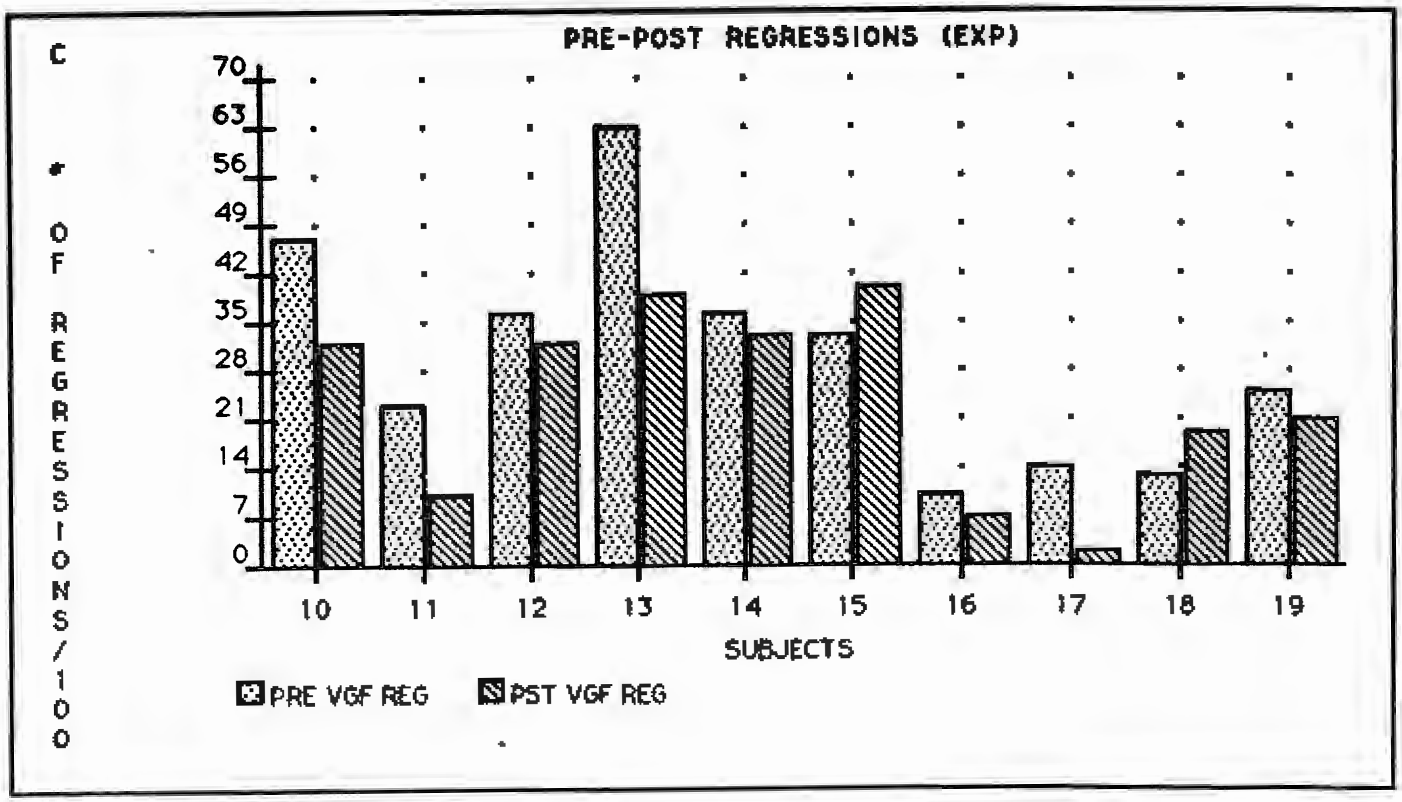
As an aside;
In review of the within groups bar graphs (A-I and a-i) one individual showed consistently little or no improvement with the training. This person was noted in the office training for failure to fuse secondary fusion targets with red and green glasses on. In reviewing the visual case record of this individual, an oculomotor and-accommodative/convergence problem was found, specifically: high exo and vertical phoria at near. No other experimental group subject exhibited such findings. (*)In a recalculation of the data excluding this subject, **relative efficiency, regressions, fixations and the span of recognition** became statistically significant to a $p = \leq 0.05$ level. In a subjective questionnaire following training, the subjects were asked about post-training comprehension, time on task and retention of reading material. What may be more important than any of the statistical data the study accumulated is that eight of the ten experimental subjects stated their comprehension, time on task and retention of material read improved after undertaking the training, and they experienced an overall increase in their individual reading performance.

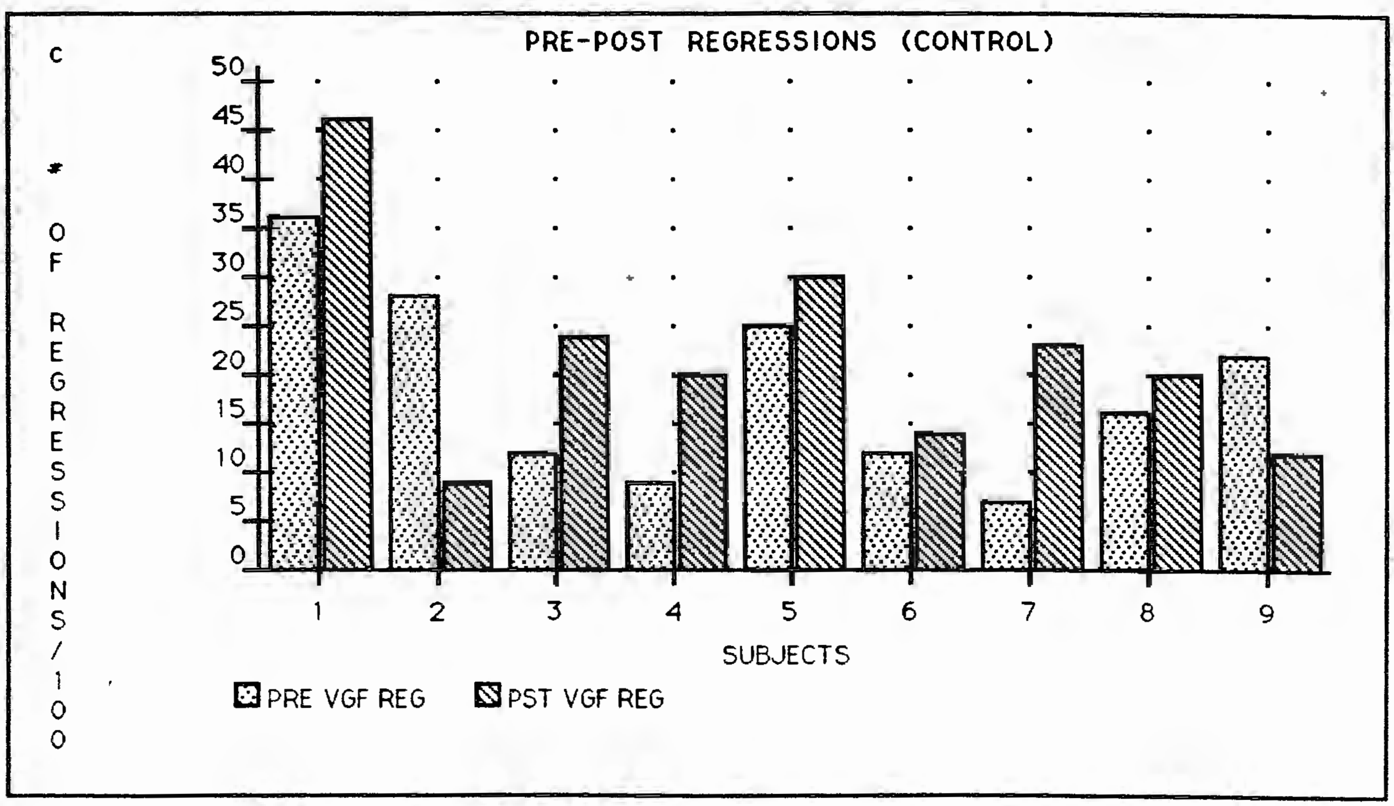

A
PRE-POST COMPREHENSION (EXP)
% COMPREHENSION
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10
11
12
13
14
15
16
17
18
19
SUBJECTS
PRE VGF COMP
PST VGF COMP

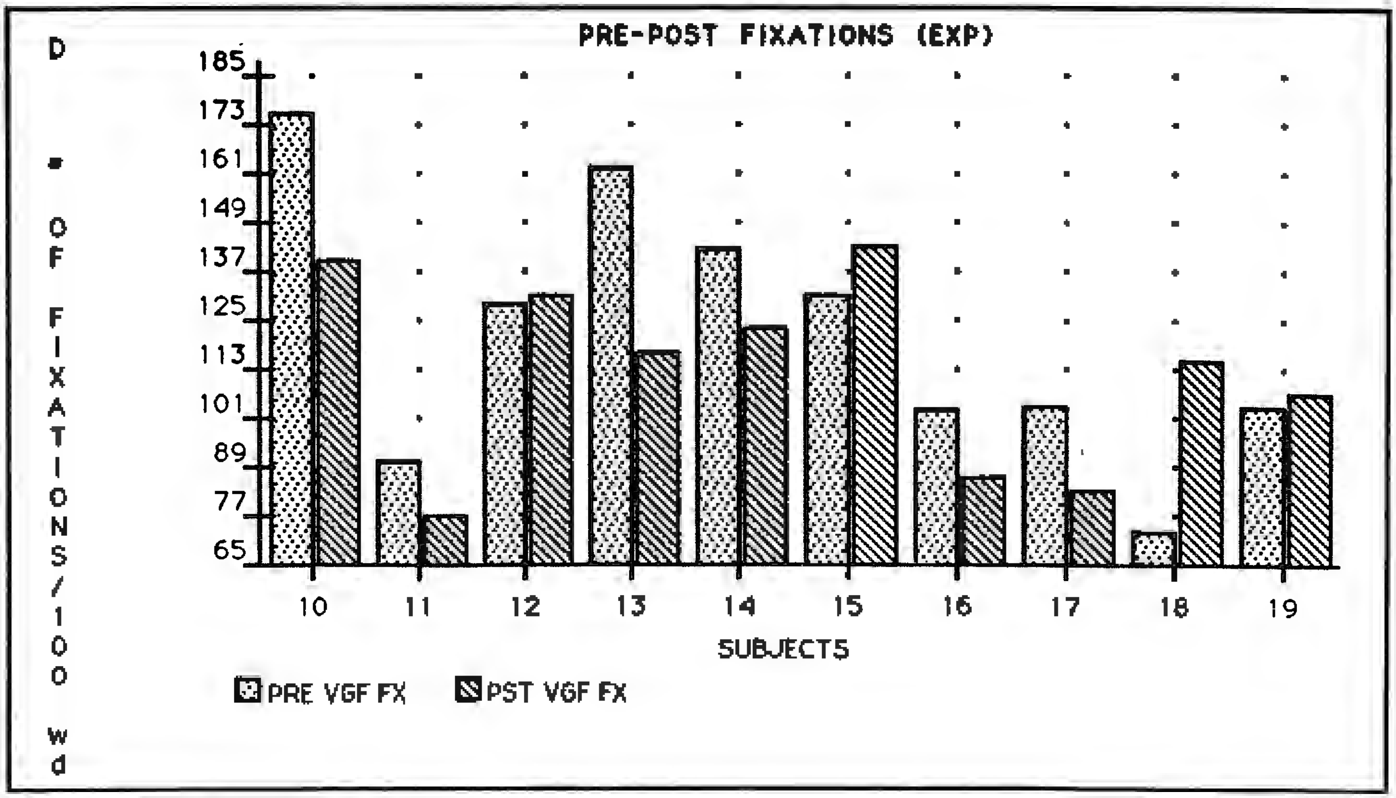

a
PRE-POST COMPREHENSION (CONTROL)
% COMPREHENSION
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
9
SUBJECTS
PRE VGF COMP
PST VGF COMP

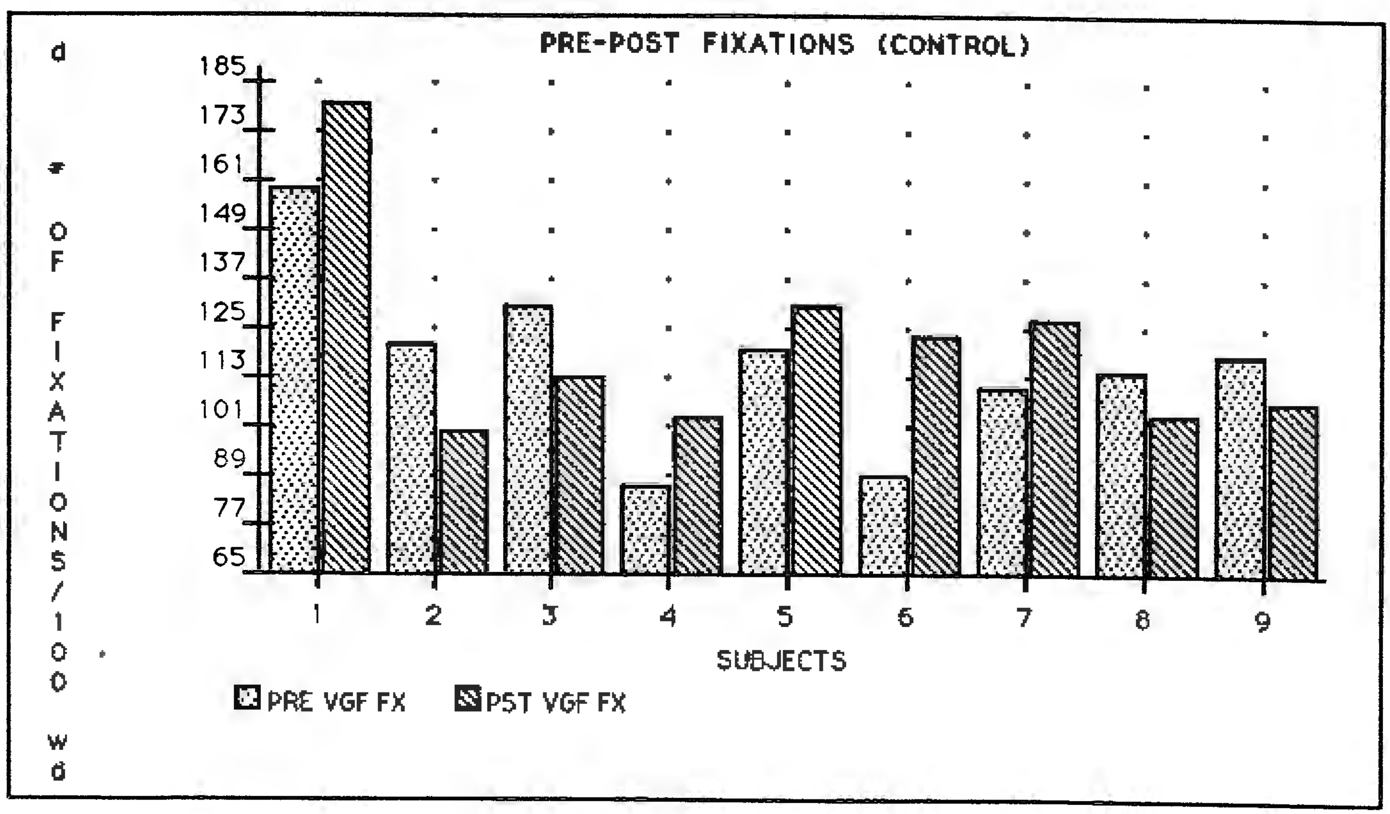

B
PRE-POST REL. EFFICIENCY (EXP)
RELATIVE EFFICIENCY
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
10
11
12
13
14
15
16
17
18
19
SUBJECTS
PRE VGF R EFF
PST VGF R EFF

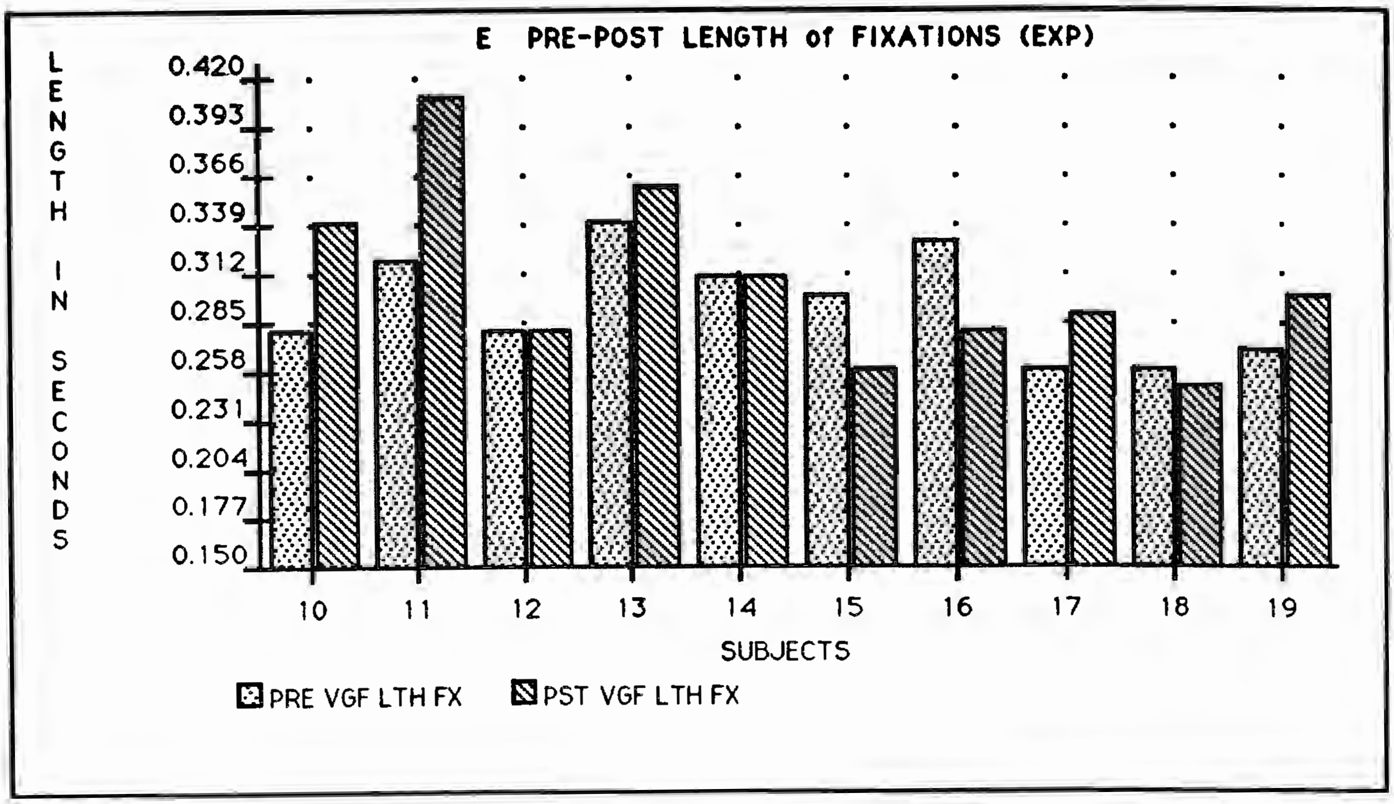

b
PRE-POST REL EFFICIENCY (CONTROL)
RELATIVE EFFICIENCY
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
1
2
3
4
5
6
7
8
9
SUBJECTS
PRE VGF R EFF
PST VGF R EFF

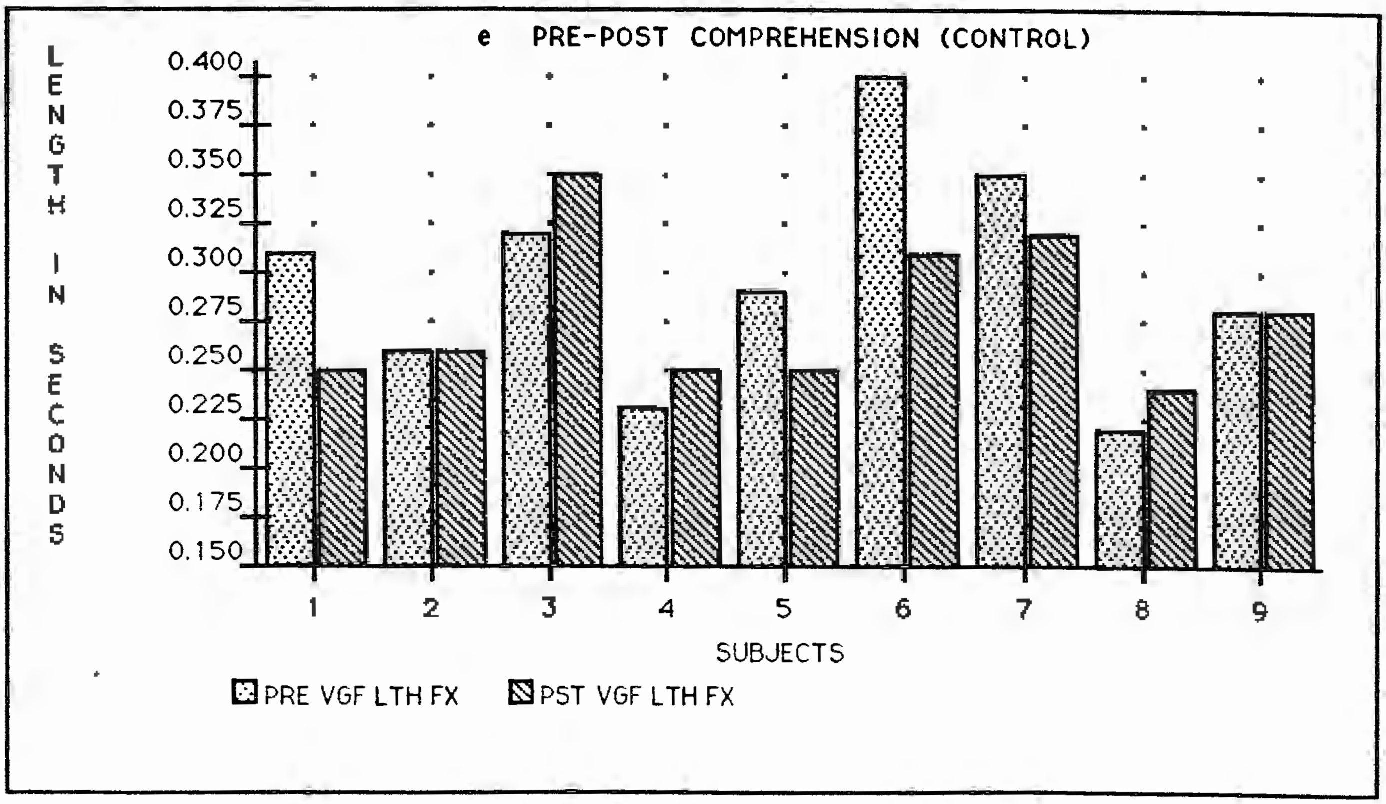

PRE-POST REGRESSIONS (EXP)
C # OF REGRESSIONS/100
70
63
56
49
42
35
28
21
14
7
0
10
11
12
13
14
15
16
17
18
19
SUBJECTS
PRE VGF REG
PST VGF REG

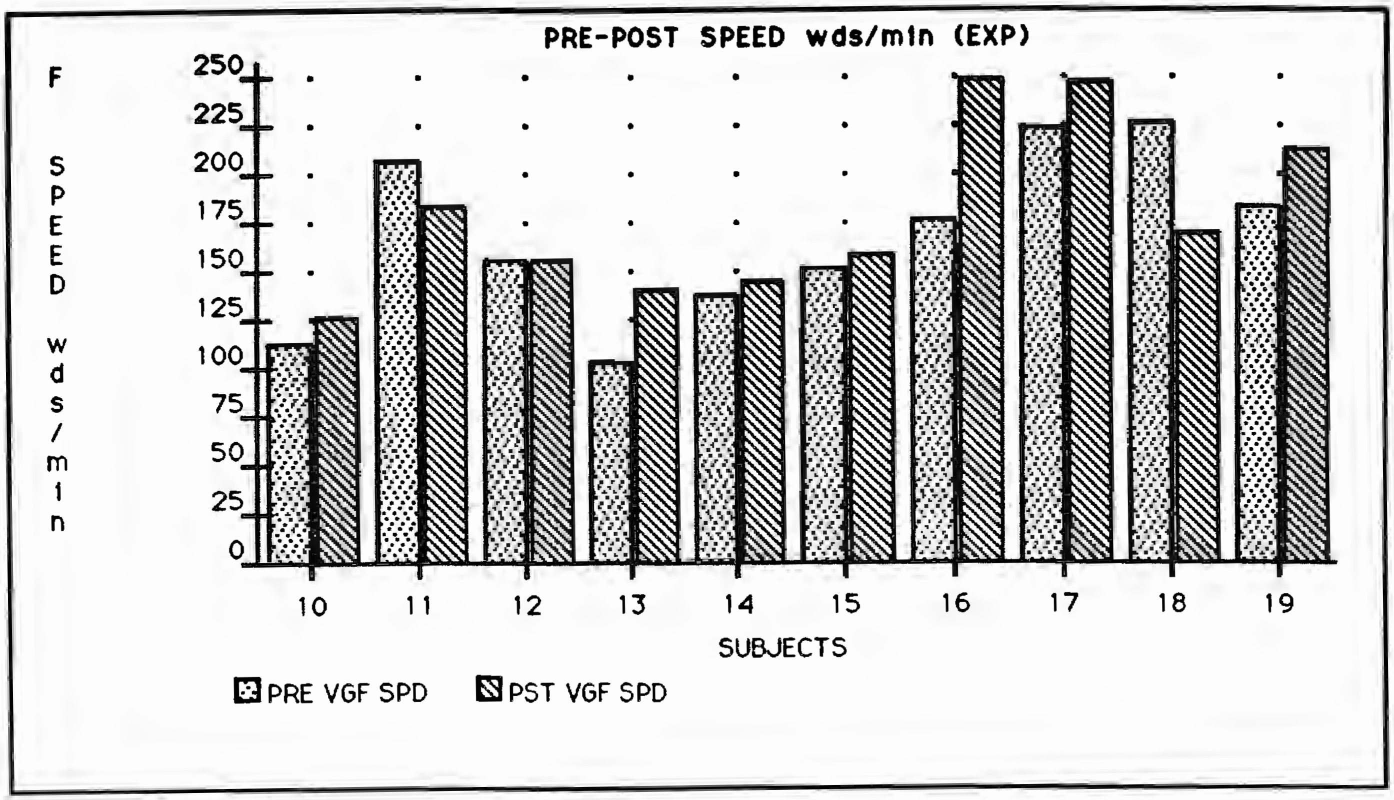

PRE-POST REGRESSIONS (CONTROL)
C # OF REGRESSIONS/100
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
SUBJECTS
PRE VGF REG
PST VGF REG

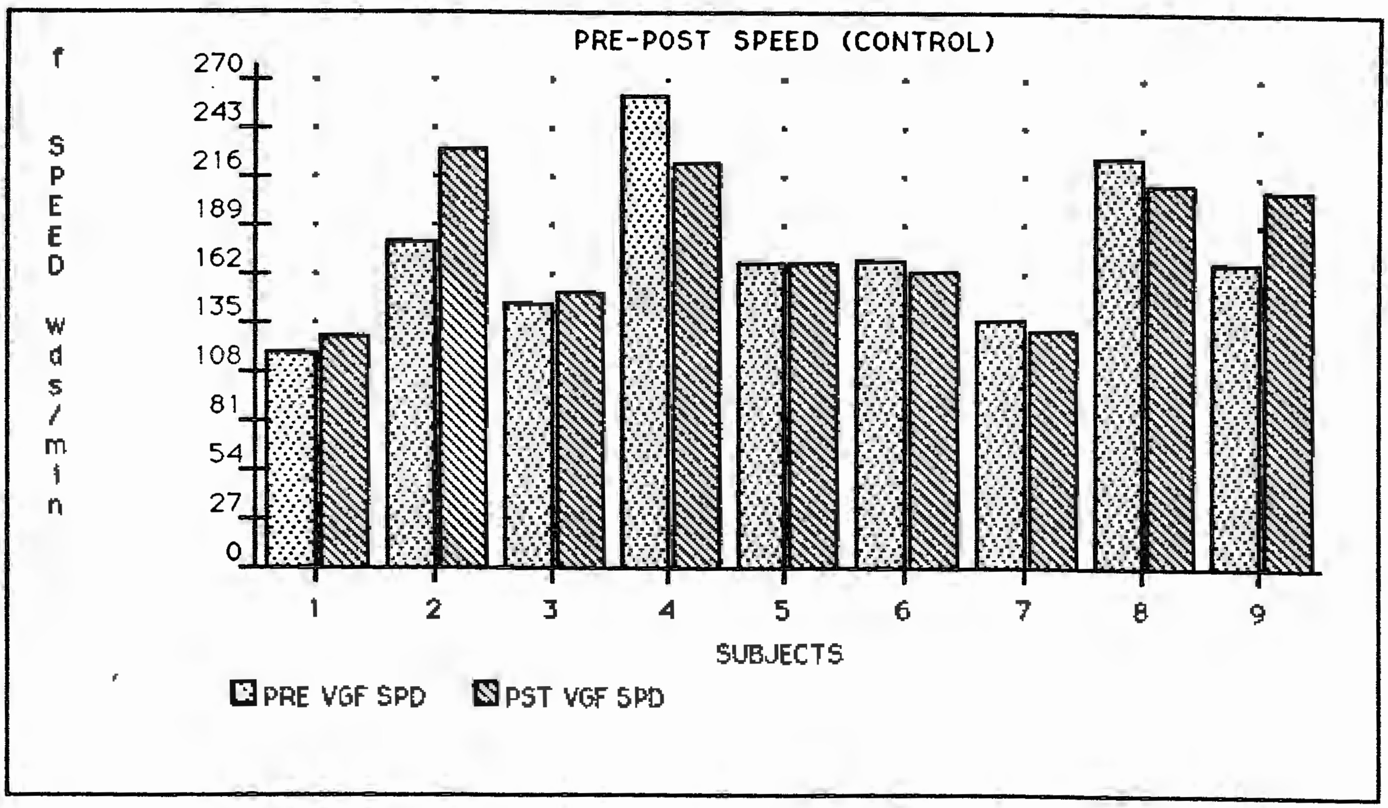

PRE-POST FIXATIONS (EXP)
D
# OF FIXATIONS/100 wd
185
173
161
149
137
125
113
101
89
77
65
10
11
12
13
14
15
16
17
18
19
SUBJECTS
PRE VGF FX
PST VGF FX

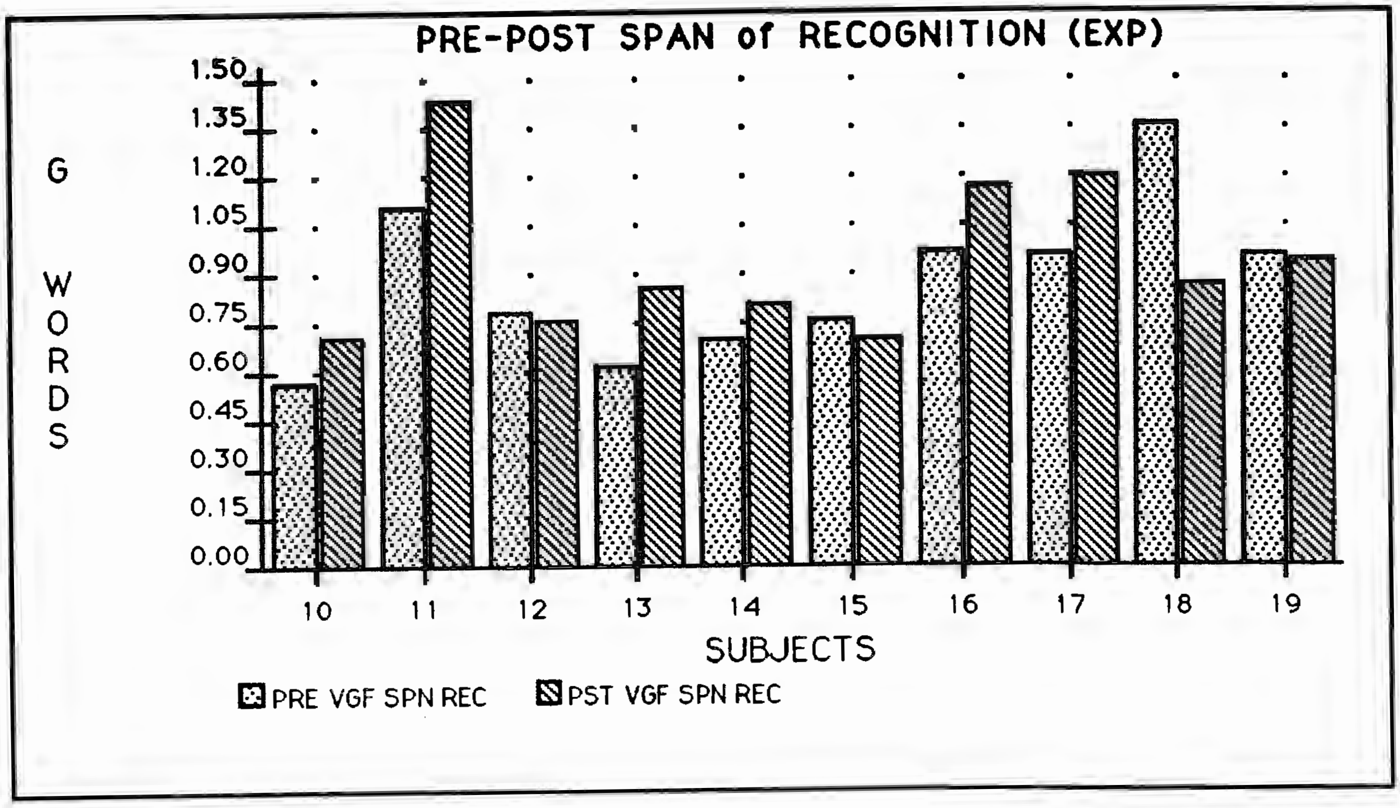

PRE-POST FIXATIONS (CONTROL)
d
# OF FIXATIONS/100 wd
185
173
161
149
137
125
113
101
89
77
65
1
2
3
4
5
6
7
8
9
SUBJECTS
PRE VGF FX
PST VGF FX

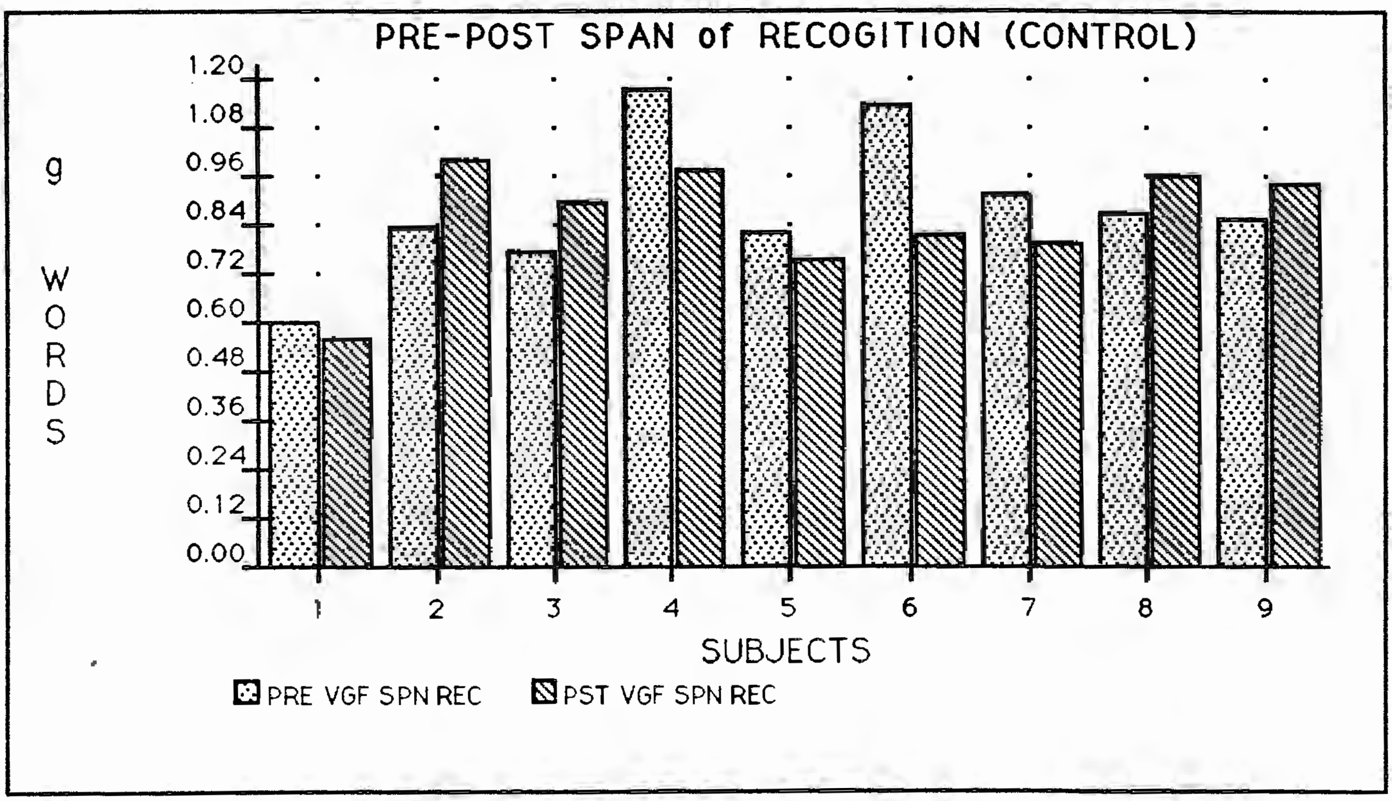

E PRE-POST LENGTH of FIXATIONS (EXP)
LENGTH IN SECONDS
0.420
0.393
0.366
0.339
0.312
0.285
0.258
0.231
0.204
0.177
0.150
10 11 12 13 14 15 16 17 18 19
SUBJECTS
PRE VGF LTH FX
PST VGF LTH FX

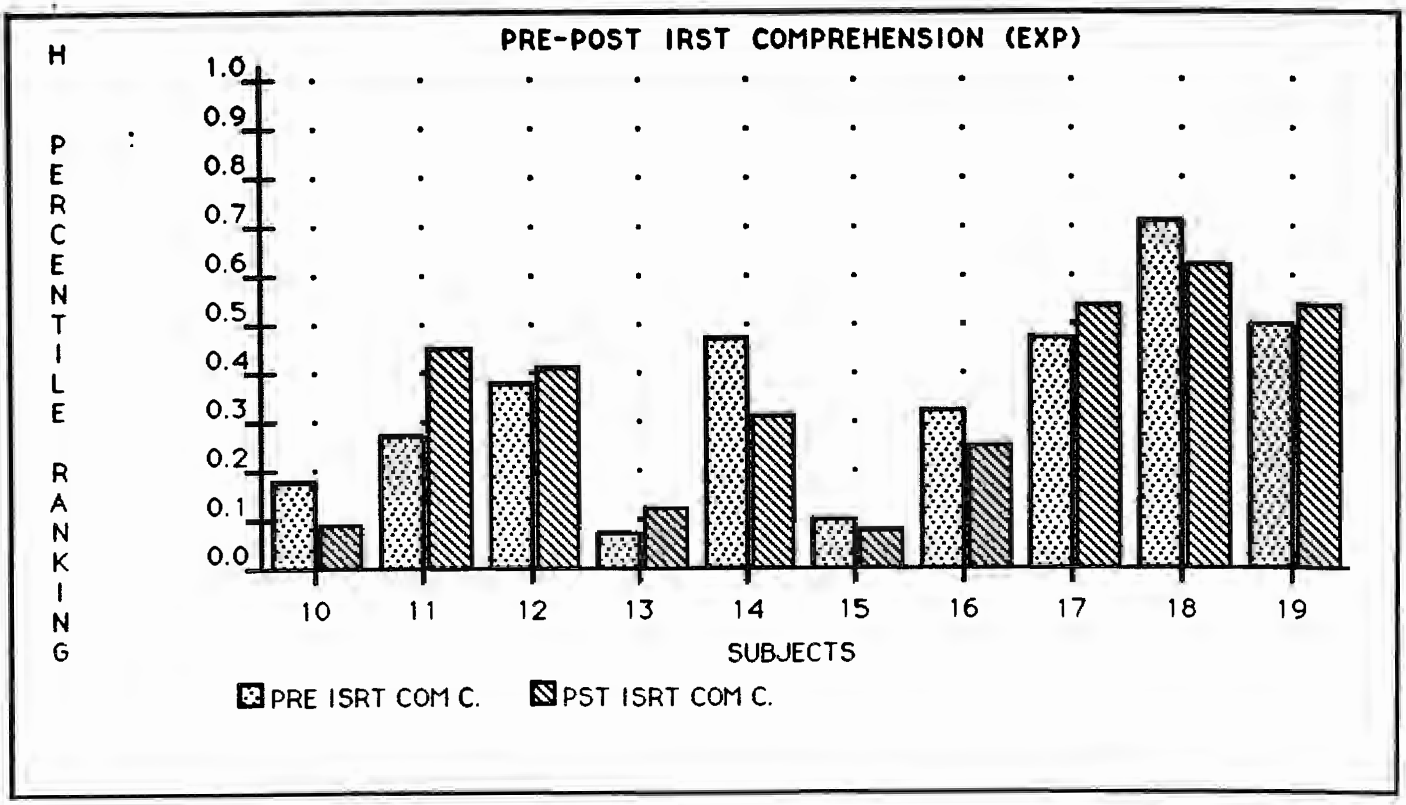

e PRE-POST COMPREHENSION (CONTROL)
LENGTH IN SECONDS
0.400
0.375
0.350
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
1 2 3 4 5 6 7 8 9
SUBJECTS
PRE VGF LTH FX
PST VGF LTH FX

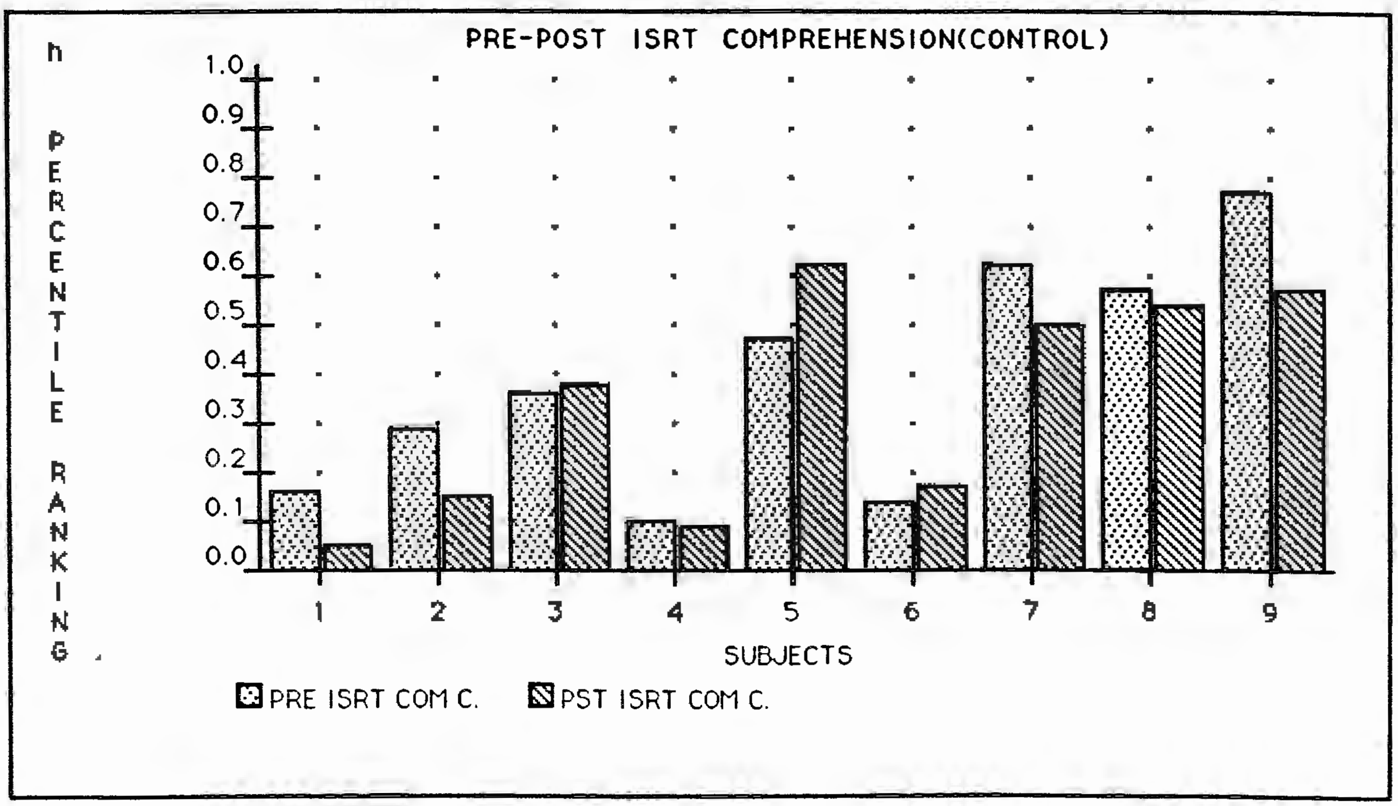

PRE-POST SPEED wds/min (EXP)
F SPEED wds/min
250
225
200
175
150
125
100
75
50
25
0
10 11 12 13 14 15 16 17 18 19
SUBJECTS
PRE VGF SPD
PST VGF SPD

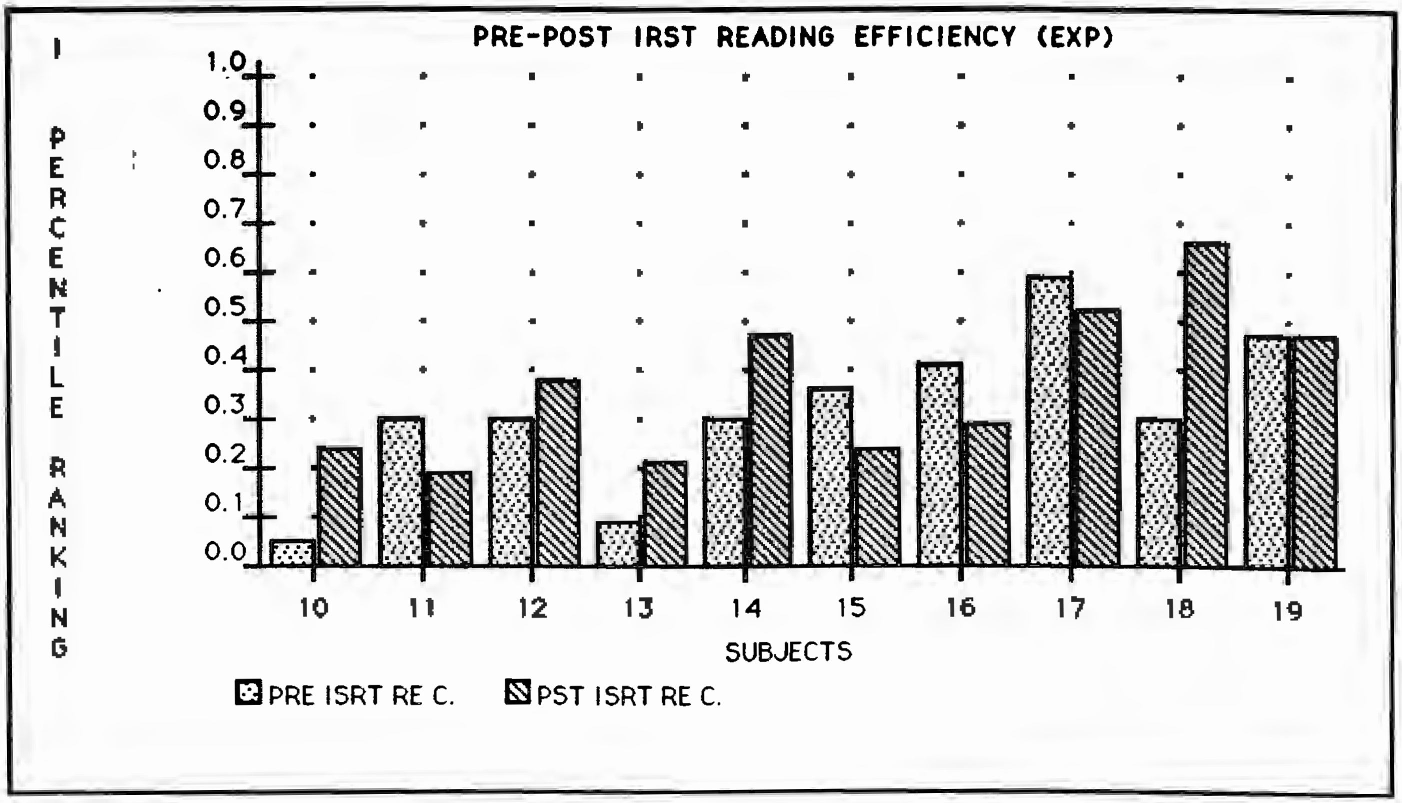

PRE-POST SPEED (CONTROL)
f SPEED wds/min
270
243
216
189
162
135
108
81
54
27
0
1 2 3 4 5 6 7 8 9
SUBJECTS
PRE VGF SPD
PST VGF SPD

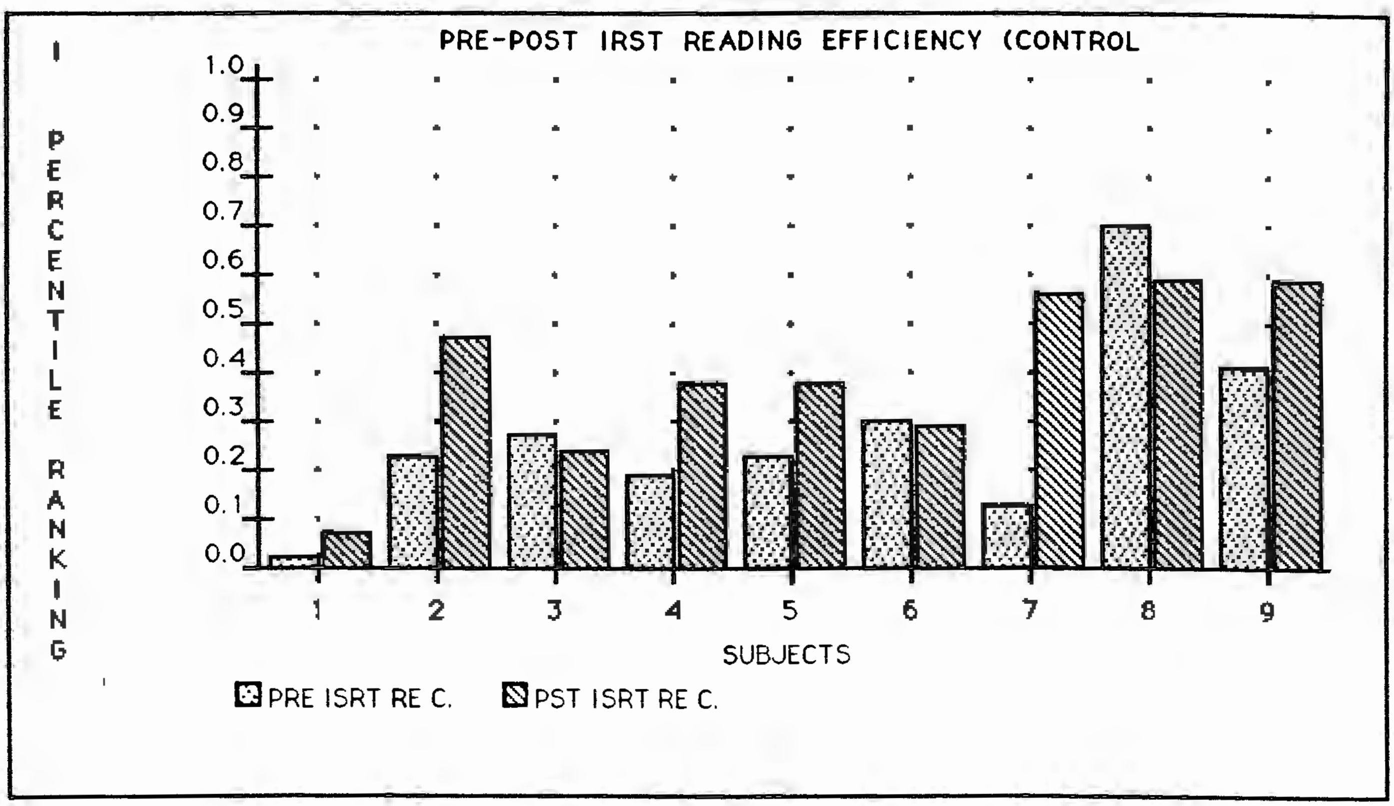

PRE-POST SPAN of RECOGNITION (EXP)
G WORDS
1.50
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
10
11
12
13
14
15
16
17
18
19
SUBJECTS
PRE VGF SPN REC
PST VGF SPN REC


PRE-POST SPAN of RECOGITION (CONTROL)
g WORDS
1.20
1.08
0.96
0.84
0.72
0.60
0.48
0.36
0.24
0.12
0.00
1
2
3
4
5
6
7
8
9
SUBJECTS
PRE VGF SPN REC
PST VGF SPN REC


PRE-POST IRST COMPREHENSION (EXP)
H
PERCENTILE RANKING
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10
11
12
13
14
15
16
17
18
19
SUBJECTS
PRE ISRT COM C.
PST ISRT COM C.


PRE-POST ISRT COMPREHENSION(CONTROL)
h
PERCENTILE RANKING
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
9
SUBJECTS
PRE ISRT COM C.
PST ISRT COM C.


PRE-POST IRST READING EFFICIENCY (EXP)
PERCENTILE RANKING
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10
11
12
13
14
15
16
17
18
19
SUBJECTS
PRE ISRT RE C.
PST ISRT RE C.


PRE-POST IRST READING EFFICIENCY (CONTROL
PERCENTILE RANKING
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
9
SUBJECTS
PRE ISRT RE C.
PST ISRT RE C.

## REFERENCES


1. Getz D. Learning enhancement through vision training. Academic Therapy, 15; 4:457-466.
2. Solan HA. Eyemovement problems in achieving readers: an update. Am J Optom Physio Opt 1985; 62: 812-19.
3. Sherman A. Relating vision disorders to learning disabilities. J Am Optom Assoc 44(2): 140-141, Feb. 1973.
4. Flax N, Solan HA, Suchoff IB.. Optometry and dyslexia. J Optom Vis Devel, 1983. Vol. XIV, no. 2:14-16.
5. Heath EJ, et al. Eye exercises and reading efficiency. Academic Therapy 1976; 11:435-45.
6. Wold RM, Pierce JR, Keddington J. Effectiveness of optometric vision therapy. J Am Optom Assoc 1978; 49:1047-59
7. Taylor SE. Eye movements and reading: Facts and Fallacies (Huntington, New York: Educational Developmental Laboratories, 1963).
8. Alder-Grinberg D, Stark L. Eye movements and dyslexia. Am J Optom Physio Opt 1978; 55: no. 8, 557-570.
9. Black JC, Collins DW, DeRoach JN, Zubrick SR. Dyslexia: saccadic eye movements. Perceptual and Motor skills, 1984, 58:903-910.
10. Hoffman LG. Incidence of vision difficulties in children with learn ing disabilities J Am Optom Assoc, May 1980; 51:447-451.
11. Pavlidis G. Eye movement differences between dyslexics, normal and retarted readers while sequentially fixating digits. Am J Optom Physio Opt 1985, 62; 12:820-83.
12. Ciuffreda KJ, Bahill AT, Kenyon RV, Stark L.. Eye movements during reading: case reports. Am J Optom Physio Opt, 1976. 53, 8:389-395.
13. Young BS, Pollard T, Poynter S, Cox RB. Effect of eye exercises in improving control of eye movements during reading. J Optom Vis Dev 1982; 13, no. 2: 4-7
14. Seiderman AS. Optometric vision therapy-results of a demonstration project with a learning disabled population. J Am Optom Asso May 1980; 51:489-492.
15. Pavlidis G. The dyslexic's erratic eye movements: case studies. Dyslexia Review, 1978,1:22-28.
16. Pavlidis G. Do eye movements hold the key to dyslexia? Neuropsychologia 1981,19:57-64.

17. Olson RK, Kliegl R, Davidson BJ. Dyslexic and normal readers' eye movements. J Exper Psych Human Percept and Perform. 1983, 9: 816-825.
18. Black JC, Collins DW, DeRoach JN, Zubrick SR.. A detailed study of sequential saccadic eye movements for normal and poor reading children. Perceptual Motor Skills, 1984, 59, 423-434.
19. Bogacz J, Mendilaharsu C, De Mendilaharsu SA. Electro-oculographic abnormalities during pursuit movement in developmental dyslexia. Electroencephalography and Clinical Neurophysiology, 1974, 36:651-656.
20. Poynter HL, Schor C, Haynes HM, Hirsh J.. Oculomotor functions in reading disability. Am J Optom Physiol Opt, 1982. 59; 2:116-127.
21. Busby RA. Vision development in the classroom. J Learning Disabilities, May 1985. 18; 5:266-272.
22. Ingram C, Dettenmaier L. LD college students and reading problems. Academic Therapy/22:5 May 1987.
23. Grisham D, Low L, Scolaro D, Greenwood B. Validity and reliability of the Visagraph reading eye movement system. presented OEP conf. Dec. 10 1988.