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ABSTRACT

The changes in eye movement as a function of reading improvement were investigated for two samples. Measurement of change was made by a new electronic eye-tracking instrument. The samples consisted of 30 secondary students enrolled in a tutorial reading clinic and 17 repeating first-grade students from a public school. Eye-movement recordings (three and four, respectively) were administered with standardized reading selections. The five variables considered were fixations per 100 words, regressions per 100 words, duration of fixation, span of recognition, and reading rate. From an analysis of the data, it was determined that changes in eye graphs for fixations, regressions, and rate did occur as a result of training in reading; that consistent patterns of change occurred for fixations, regressions, and rate; and that the pattern of correlations of eye graph data and standardized test scores was consistent, although the correlations were too low to be considered predictive. The basic deficiencies in this study were the number of eye graphs administered and the lack of standardized test data for comparison. Studies in progress will include data from a minimum of five graphs and both pretest and post-test standardized test results. Tables are included. (Author/DH)

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The Analysis of Eye-Movement Recordings from a Sample of Underachieving Secondary Students and a Sample of Underachieving Primary Students

The changes in eye movement as a function of reading improvement were investigated for two samples. Measurement of change was made by an electronic eye-tracking instrument.

The first sample consisted of thirty-nine secondary students enrolled in a tutorial reading clinic. The second sample consisted of seventeen repeating first-grade students from a public school. Data from the eye-movement recordings (three and four recordings respectively) were analyzed by analysis of variance and subsequent tests for trend.

Five variables (fixations per 100 words, regressions per 100 words, duration of fixation, span of recognition and reading rate) were considered. No significant change over time was detected for duration of fixation. The line of best fit for the reading rate variable was linear. For the variables fixations, regressions, and span of recognition, a quadratic curve proved to be the line of best fit.

The Analysis of Eye-Movement Recordings From a Sample of Underachieving Secondary Students and a Sample of Underachieving Primary Students

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The measurement of eye movements during the reading act is certainly not new. A variety of approaches to the measurement of eye movements have been used with varying degrees of success and comfort for the subject. The most promising, the photographic techniques of the corneal reflection method of measurement, was first perfected by Miles Tinker of the University of Minnesota. The camera designed and developed by Dr. Tinker allowed well-controlled studies of eye movements with a clinical setting. Lack of portability made this technique impossible to use in the classroom. Subsequent development of a portable binocular eye-movement camera made non-clinical use of the technique more feasible, but difficulty of camera use, the film development process, and delayed feedback of results have limited general classroom or reading laboratory acceptance. An instrument designed by Biometrics, Inc., was introduced in 1969 which makes tracking of eye movements far easier, faster, and more economical. With this instrument, the corneal reflection is monitored by independent pairs of photocells and the signals are amplified and recorded on heat-sensitive graph paper by two heat pens.

The present findings are the results of an ongoing series of field trials. The purpose of this paper is to present the results of initial trials with the new instrument. It is hoped that an indication of consistent growth curves associated with the physiological aspects of reading improvement regardless of the subject's age or reading entry behavior will be found. Correlations of the five basic measurements (number of fixations and number of regressions per 100 words read, duration of fixation, span of word recognition, and rate of reading with comprehension) obtained by analyzing the graphs of the

students' eye movements with results from standardized tests have been computed. It is assumed that if growth patterns prove to be consistent and if correlations between variables are significant and consistent with respect to direction of improvement, eye-movement recordings may prove to be valuable tools in diagnosis and evaluation within the classroom setting.

The samples considered are a group of secondary students enrolled in a private tutorial reading laboratory and a group of public school second-grade students in a remedial reading laboratory.

Secondary Sample

Thirty-nine secondary students were enrolled in a tutorial reading laboratory for ten to eleven weeks during the summer months. The curriculum was designed to provide directed practice in reading and reading comprehension skills. No emphasis was placed upon speed reading or skimming techniques.

Three eye-movement recordings were made for each student at five-week intervals: One upon entering, the second at the midway point, and a final recording upon completion of the course.

Primary Sample

Thirteen second-grade children were enrolled in a primary reading laboratory installation within the public school structure. Each child had been evaluated by the first-grade teachers as a potential problem learner. Each child had been given the school-administered intelligence test and had been given physical examinations by school district personnel. According to district records, no students in the laboratory could be considered retarded, nor did any have limiting physical or psychological problems.

The laboratory director concentrated on providing each child with a well-structured and largely individualized training program. The primary skills normally taught in grade one classrooms were reviewed, and opportunity for extensive practice in reading materials of an appropriate level was provided. The laboratory activity replaced reading instruction for these children.

Eye-movement recordings were made for each child near the beginning of the laboratory activity and at approximately six-week intervals during the second semester of the normal school year (a total of three recordings).

Results

Eye-movement recordings were administered with standardized reading selections.[1] The secondary students were asked to read selections at the high school level, and primary children read grade one selections. After each subject completed the reading activity, he was asked to respond to ten true-false questions related to the selection read. A seventy per cent level of comprehension was the minimal level at which the recording would be considered valid. All values have been reported relative to one hundred words read.

Tables I and II list mean values for secondary and primary subjects. These results and the accompanying graphs, Figures 1-5, indicate that although the values are different for secondary and primary students, the direction and magnitude of change over time are similar for both groups.

[1] Reading Eye File of Test Selections, EDL/McGraw-Hill, Huntington, New York

TABLE I

MEAN VALUES OF EYE-MOVEMENT DATA FOR THIRTY-NINE SECONDARY STUDENTS

Variable	Pretest	Interim Test	Posttest
Fixations/100 words	120.9	90.1	85.2
Regressions/100 words	31.1	19.0	16.4
Duration of Fixation (in sec.)	.24	.24	.23
Span of Word Recognition	.91	1.15	1.23
Reading Rate with 70% Comprehension	223.7	288.6	319.4

TABLE II

MEAN VALUES OF EYE-MOVEMENT DATA FOR THIRTEEN PRIMARY STUDENTS

Variable	Pretest	Interim Test	Posttest
Fixations/100 words	252.3	236.0	209.1
Regressions/100 words	76.8	68.1	61.9
Duration of Fixation (in sec.)	.35	.30	.29
Span of Word Recognition	.41	.41	.51
Reading Rate with 70% Comprehension	72.4	84.8	109.6

It was necessary to first determine if the variables measured changed significantly from the pre- to the posttest and secondly, if the trend of the increases or decreases deviated from linearity.

Tables III and IV give the results of the analysis of variance. The number of fixations per one hundred words read decreased significantly, the number of regressions per one hundred words decreased significantly, and rate of reading increased significantly for both samples. For the older students, the span of word recognition was significantly increased while for the primary students, the duration of fixation was significantly decreased. The last two results may prove to be, in the studies of samples now in progress, the major differences to be expected as a result of the subject's age and entry skill. Duration of fixation, a function of the difficulty of the material read[2], may vary from approximately .22 to .32 seconds. Therefore, once a reader achieves a certain level of reading ability, duration of fixation is only a factor in the reading process in interaction with the number of fixations made.

It can be seen by inspection of Figures 1-5 that the variation due to linear trend is clearly significant for several variables. Where significant change over training time was detected and where it appeared that significant variation due to higher-order components might exist, tests for linear trend have been computed. Table V is a summary of these selected tests. It can be seen from this table and the computation of ratios that eighty-four and eighty-one per cent of the variation in number of fixations can be predicted from a linear regression equation for secondary and primary students respectively. Eighty-eight and eighty-two per cent of the variation in regressions can be predicted

[2]Tinker, Miles A., "Recent Studies of Eye Movements in Reading," Psychological Bulletin, 55(4):215-31, 1958.

TABLE III

ANALYSIS OF VARIANCE FOR EYE-MOVEMENT DATA FOR THIRTY-NINE SECONDARY STUDENTS

Variable	Source of Variation	SS	df	MS	F
Fixations	Between Students	129466.92	38		
	Within Students	35994.00	78		
	Treatment	29235.84	2	14617.92	164.39**
	Residual	6758.16	76	88.92	
Regressions					
	Between Students	15567.66	38		
	Within Students	10648.00	78		
	Treatment	4736.94	2	2368.47	30.45**
	Residual	5911.06	76	77.78	
Duration of Fixation					
	Between Students	739.81	38		
	Within Students	442.00	78		
	Treatment	28.17	2	14.09	2.28
	Residual	470.17	76	6.19	
Span of Recognition					
	Between Students	70179.81	38		
	Within Students	37352.00	78		
	Treatment	21165.60	2	10582.80	49.69**
	Residual	16186.40	76	212.98	
Reading Rate					
	Between Students	72180.66	38		
	Within Students	364066.00	78		
	Treatment	185907.20	2	92953.60	39.65**
	Residual	178158.80	76	2344.19	

**$p < .01$, $F_{(2,60)} = 4.98$

TABLE IV

ANALYSIS OF VARIANCE FOR EYE-MOVEMENT DATA FOR THIRTEEN PRIMARY STUDENTS

Variable	Source of Variation	SS	df	MS	F
Fixation					
	Between Students	87533.33	12		
	Within Students	57808.11	26		
	Treatment	12073.90	2	6036.95	4.15*
	Residual	35459.43	24	1477.48	
Regressions					
	Between Students	5294.97	12		
	Within Students	11870.00	26		
	Treatment	7460.66	2	3730.33	8.60**
	Residual	10409.34	24	433.72	
Duration of Fixation					
	Between Students	.05	12		
	Within Students	.12	26		
	Treatment	.04	2	.02	6.06**
	Residual	.08	24	.0033	
Span of Recognition					
	Between Students	.16	12		
	Within Students	.48	26		
	Treatment	.09	2	.045	2.81
	Residual	.39	24	.016	
Reading Rate					
	Between Students	9156.41	12		
	Within Students	28881.33	26		
	Treatment	9309.28	2	4654.64	5.70**
	Residual	19572.05	24	815.50	

*$p < .05$, $F(2,26) = 3.37$
**$p < .01$, $F(2,26) = 5.53$

TABLE V

SUMMARY OF TESTS FOR LINEAR TREND

Variable	Source of Variation	df	MS	F
Fixations	(Secondary)			
	linear trend	1	24841.81	171.52**
	dev. from lin.	77	144.83	
Fixations	(Primary)			
	linear trend	1	9308.65	3.23
	dev. from lin.	25	3027.45	
Regressions	(Secondary)			
	linear trend	1	4180.01	49.76**
	dev. from lin.	77	83.99	
Regressions	(Primary)			
	linear trend	1	6165.12	8.62**
	dev. from lin.	25	714.45	
Reading Rate	(Secondary)			
	linear trend	1	178370.51	73.96**
	dev. from lin.	77	2411.62	
Reading Rate	(Primary)			
	linear trend	1	9047.12	11.40**
	dev. from lin.	25	792.97	

**$p < .01$, $F_{(1,60)} = 3.15$ and $F_{(1,24)} = 5.61$

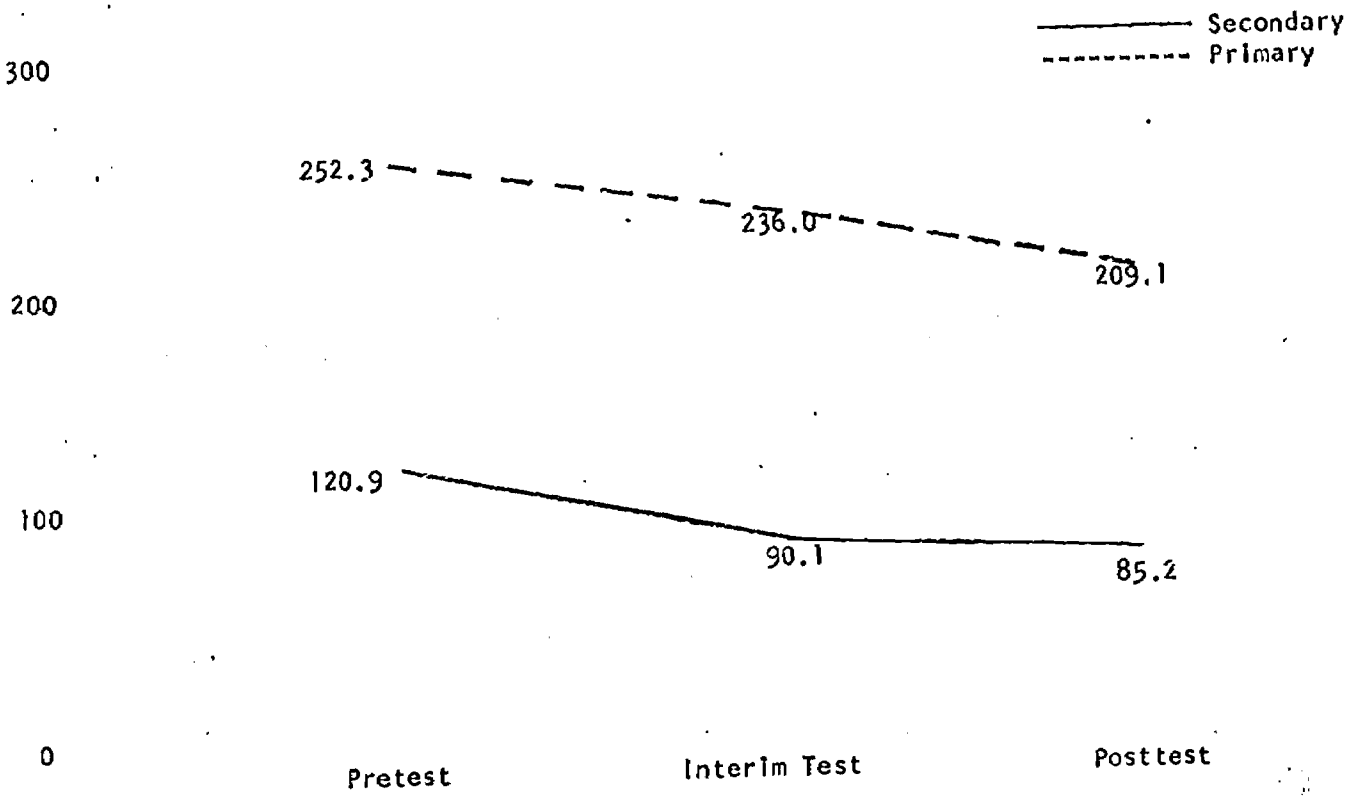

Figure 1

Mean Values of the Number of Fixations per 100 Words Read for Primary and Secondary Students

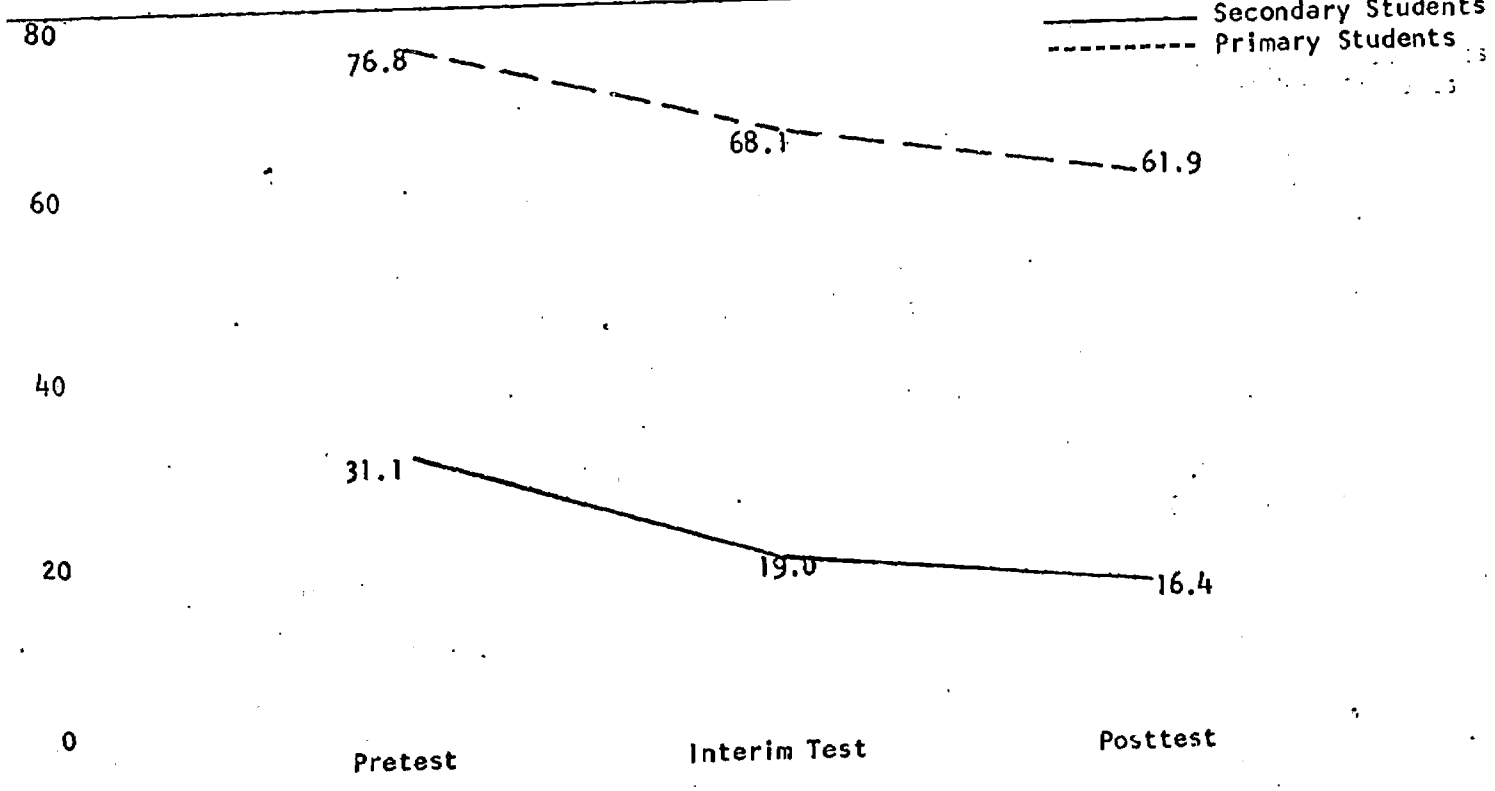

Figure 2

Mean Values of the Number of Regressions per 100 Words Read for Primary and Secondary Students

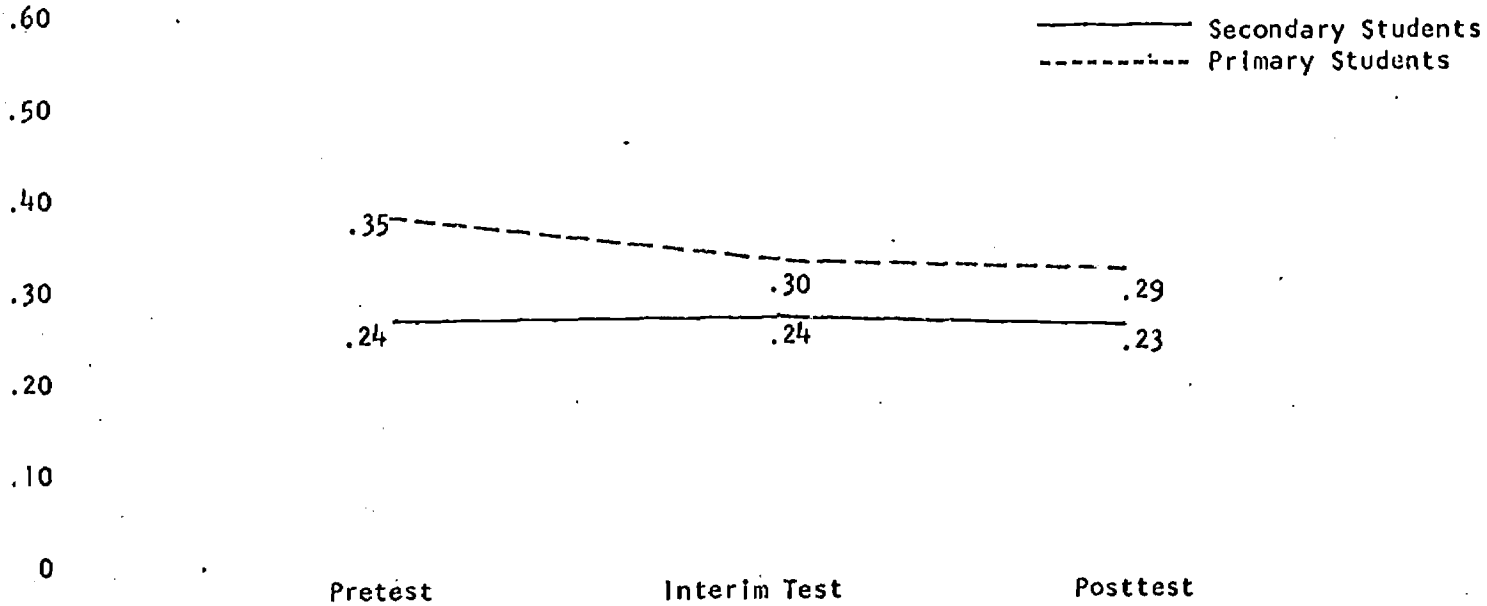

Figure 3

Mean Values of the Duration of Fixation in Seconds for Primary and Secondary Students

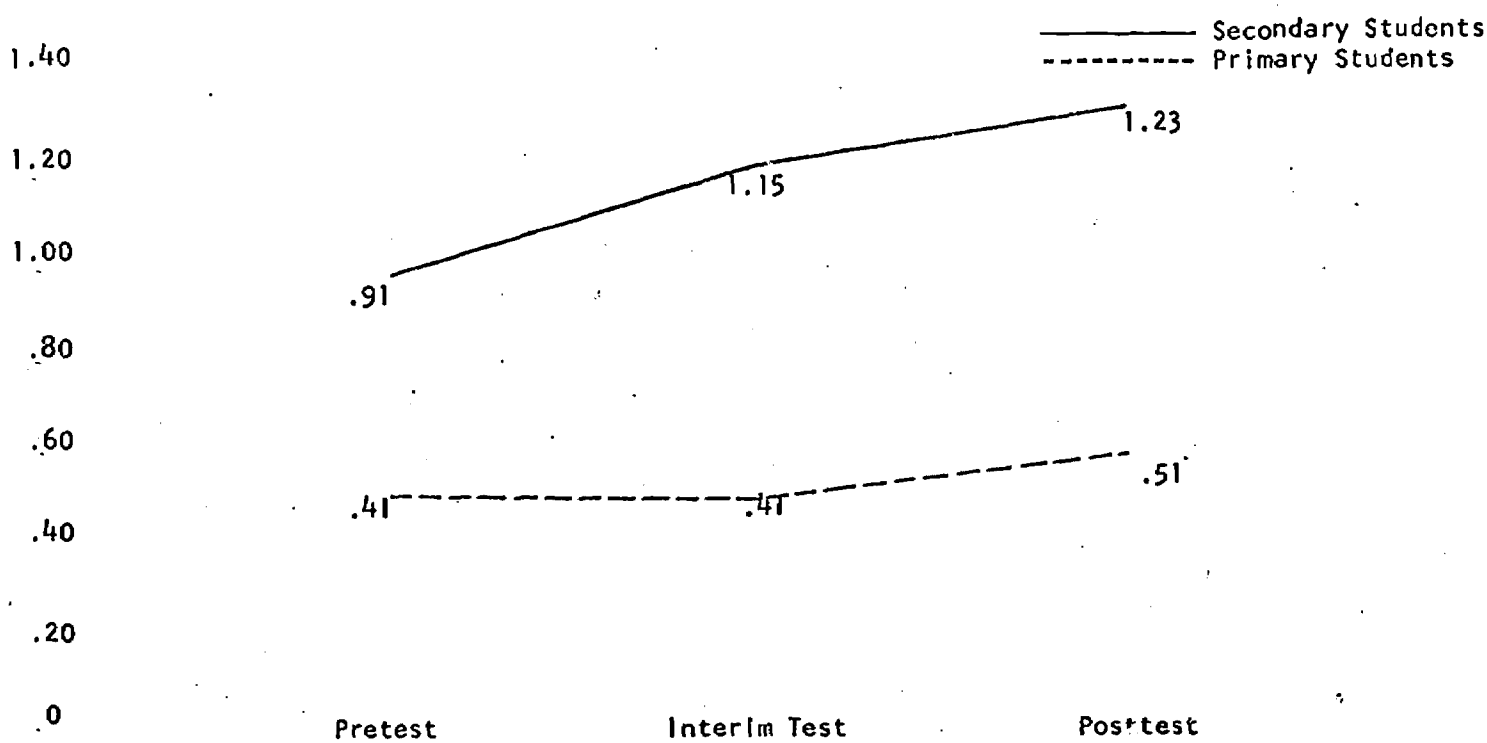

Figure 4

Mean Values of Span of Word Recognition for Primary and Secondary Students

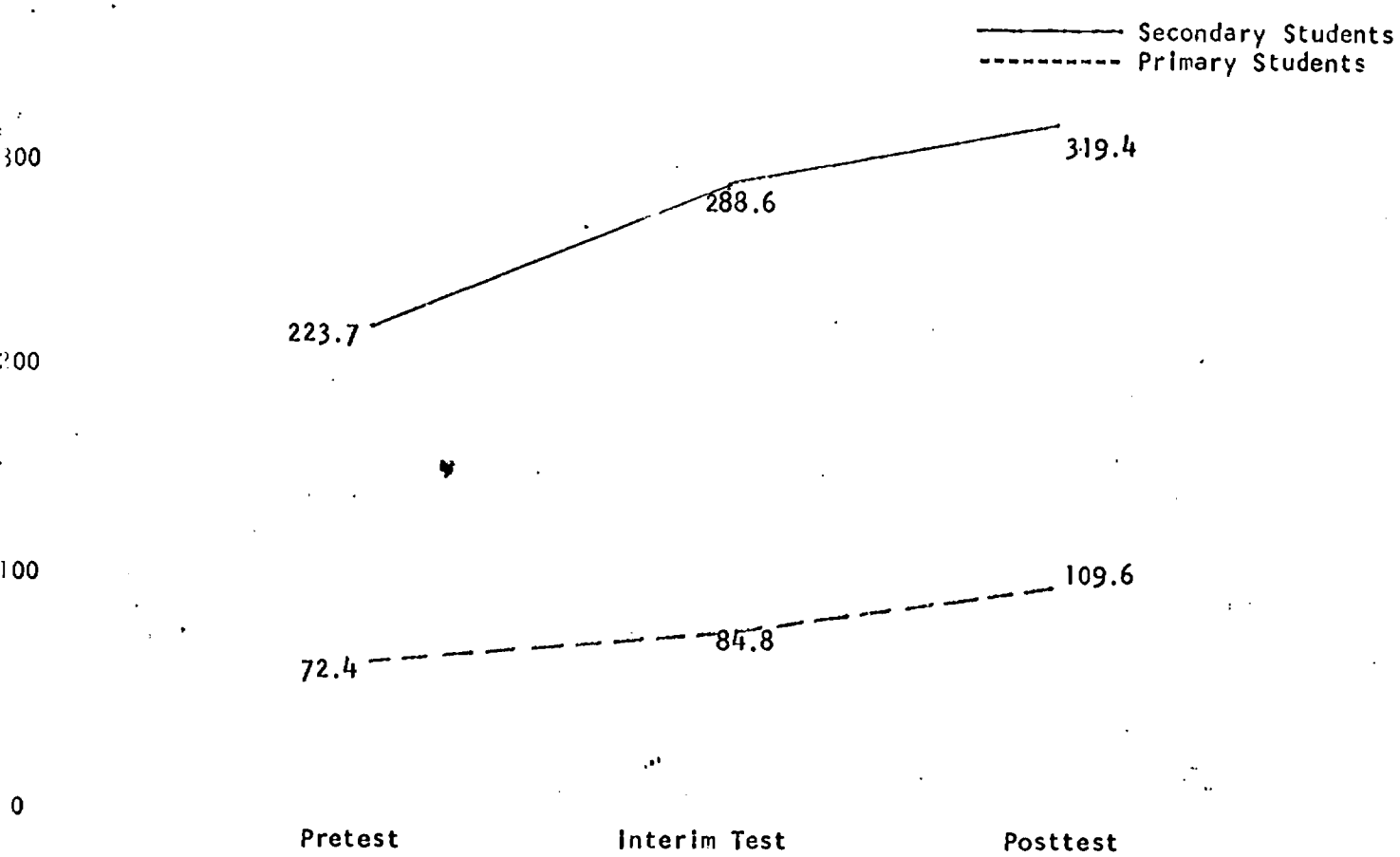

Figure 5

Mean Values of Words Read per Minute with 70% Comprehension for Primary and Secondary Students

from a linear regression equation (secondary and primary respectively). Well over ninety per cent of the variation in reading rate for both samples can be predicted from a linear equation. It will be necessary, in order to further define the manner in which fixations and regressions decrease as a function of training in reading, to obtain a minimum of five graphs for subjects in further studies.

Correlations have been computed for eye-movement variables and standardized reading test scores for both samples. Ideally, standardized test results should be obtained each time eye graph recordings are made but this is not practical. It would require the administration of a standardized test at approximately six-week intervals which, in addition to requiring excessive time of the student and laboratory director, would tend to invalidate the standardized test results. Therefore, the only standardized tests administered to subjects from both samples was at the completion of the training period. Table VI is a listing of Pearson r correlations for standardized reading test results and the values from the eye-movement graphs.

TABLE VI

CORRELATIONS FOR READING TESTS[a] AND EYE GRAPH DATA

	Total Reading: Secondary	Total Reading: Primary
Fixations	-.436**	-.307
Regressions	-.591**	-.404
Duration of Fixation	.088	.126
Span of Recognition	.580**	.611*
Reading Rate	.116	.073

[a]Secondary Students: Nelson-Denny Reading Test, Form B, Total Vocabulary-Comprehension
Primary Students: Stanford Achievement Test, Primary II, Form W, Total Word Meaning-Paragraph Meaning

*$p < .05$, $r_{(11)} = .553$

**$p < .01$, $r_{(35)} = .418$

It can be seen from this table that, for the two samples considered, the total pattern of correlations is consistent. As the numbers of fixations and regressions decrease and as the span of word recognition increases, a degree of increase in standardized reading tests is achieved. It must be noted, however, that the computed correlations are much lower than could be considered adequate for predictive purposes.

Summary

The graphing of eye movements during the reading act may prove to be a valuable tool for the reading laboratory director. It can be seen from the analysis of data from the initial samples tested that changes in eye graphs for fixations, regressions, and rate do occur as a result of training in reading; that consistent patterns of change occur for fixations, regressions, and rate; and that the pattern of correlations of eye graph data and standardized test scores is consistent although the correlations are too low to be considered predictive.

The basic deficiencies in the present study are the number of eye graphs administered and the lack of standardized test data for comparison at the time of eye graph administration. Studies in progress at this time will include data from a minimum of five graphs and both pre- and posttest standardized test results will be available.