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Visagraphic eye movement analysis and subjective correlates

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VISAGRAPHIC EYE MOVEMENT ANALYSIS AND SUBJECTIVE CORRELATES

By

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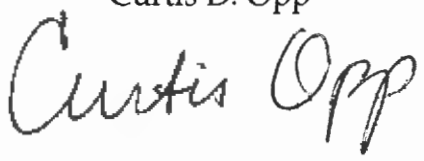
Advisor

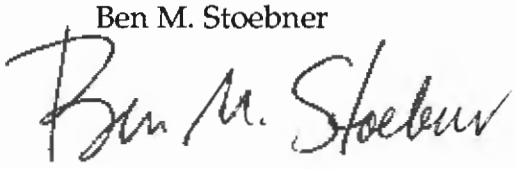
Paul Kohl, OD

Signatures

Curtis D. Opp



Ben M. Stoebner



Paul Kohl, OD

Biographies

Curtis D. Opp grew up in Pierre, South Dakota. He is the son of Norman and Lauretta Opp. He earned his B.S. in biology in 1988 from the University of South Dakota. After graduation, Curtis will be employed in private practice in Wagner and Yankton, South Dakota.

Ben M. Stoebner grew up in Tehachapi, California. He is the eldest son of Mary Jane and Ben E. Stoebner, OD (PUCO '53). He earned his B.A. in Biology in 1987 from the University of San Diego. In 1992-93 he served as the 26th President of The American Optometric Student Association. Ben will be in residency at the San Francisco VA Medical Center in 1993-94.

Acknowledgements

Our sincerest thanks goes to Paul Kohl, OD.

For his support and guidance in this thesis, and detication to our optometric education, we are grateful.

Abstract

The Visagraphic eye movement measurements of fifty-two Pacific University College of Optometry students was compared to the subjective answers to thirteen question concerning reading and visual performance asked of each individual. The objective Visagraphic measurements of Reading Rate With Re-reading, Reading Rate Without Re-reading and Relative Efficiency correlated best with overall subjective reading performance, comprehension ability, and necessity to re-read material, other comparisons of subjective ans objective performance showed low correlations.

Introduction

Reading is a complex process that involves visual/functional, cognitive, and perceptual functions[1] . It is widely accepted that saccades, regressions, and fixations play key roles in the reading process. How do these and other visual, perceptual, and cognitive phenomena affect our ability to learn from reading print? To what extent do our eye movement skills, and subsequent reading ability, affect our performance?

The cognitive aspect of reading involves two basic processes known as decoding and comprehension. Decoding requires the ability to identify and discriminate printed letters, the knowledge that separate sounds are combined into spoken words, the cognition of letter-sound correspondences, and the ability to quickly combine various sounds into words. Decoding allows us to pronounce words, even if they have never been encountered before.

Comprehension allow us to interpret the meaning of previously decoded messages. It involves knowledge of the grammar and syntax of the language, the words meaning, the semantic relationship of words, text structure, and world knowledge.

Perception is the process in which information from the environment, such as reading material is extracted and organized. Perceptions are the product of

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[1] Taylor, S.E., Visagraph: Eye movement Recording System. New York, NY 1985.

experience, previous organization, and nervous system elaboration[2] . Forgus believed that perception is the main process in the acquisition of knowledge[3] .

Visual/functional aspects affecting reading ability, and subsequent learning ability, includes visual acuity, refractive conditions, binocularity, and eye movement skills. Although there is a surprising lack of consistent findings between poor reading performance and low near point visual acuity, obviously the print size must be above the resolution threshold of the reader.

Hyperopia is the refractive condition most cited as being related to reading problems. Other conditions associated with below average readers are esophoria at near, anisometropia, and anisekonia.

Many binocular problems such as heterophoria, convergence insufficiency, deficient vergence ranges, and accommodative dysfunction can contribute to or cause inefficient reading and discomfort. Flax felt that fusion problems may not be manifest until the third or fourth grade of school, when reading demands are increased. Flax summarized his work by saying "it is apparently better to be completely one -eyed than to be inefficiently two-eyed[4] ." Strabismus is the condition of being "one-eyed[5] ."

Normal reading eye movements include saccades, fixations, and regressions. Fixational pauses usually encompass ninety percent of reading time. Rapid

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[2] Rosenbloom, A.A., Morgan M.W., Principles and Practice of Pediatric Optometry. Philadelphia, PA: Lippencott, Co., 1990.
[3] Forgus, R.N., Perception. New York, NY: McGraw-Hill, 1966
[4] Flax, N., The Contribution of Visual Problems to Learning Disability. JAOA, 41(10), p. 844, Oct, 1970.
[5] Griffin, J.R., Binocular Anomalies: Procedures for Vision Therapy. Chicago, IL., Professional Press, 1982.

saccadic eye movements are typically three degree jumps lasting twenty milliseconds each. Regressive saccades account for approximately five to twenty percent of reading time[2] .

Oculomotor activity employed in reading is acquired through years of trial and error, during which many perceptual and visual/functional adjustments are made. With normal maturation, reading becomes more automatic and the number of fixations and regressions decreased, while the span of fixation and reading rate increases.

It is the purpose of this study to analyze and compare objective eye movement data, as measured by the Visagraph eye movement recording device, with subjective responses regarding reading ability, comprehension, reading/visual comfort, and oculomotor performance. It is the authors' opinion that the subjective profile established will correlate with the objective measurements of the Visagraph.

Methods

The cohort of the study is fifty-two third year optometry students attending Pacific University. All participants were instructed on the proper use of the Visagraph as part of the course, Basic Visual Training. The Instructional/Communications Technology, Inc Visagraph was designed and authorized by Stanford E. Taylor. The cohort self selected into pairs, acting as both subject and administrator. An Apple IIc monitor was used with level

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[2]Rosenbloom, A.A., Morgan M.W., Principles and Practice of Pediatric Optometry. Philadelphia, PA: Lippencott, Co., 1990.

thirteen as the reading selection. The authors utilized the Visagraph results by permission. In addition, each participating individual submitted a confidential questionnaire (example 1). The thirteen questions asked pertained to subjective reading ability, comprehension of written material, reading/visual comfort, and oculomotor performance. The cohort size was self selecting by voluntary submission of both questionnaire and Visagraph results. It was comprised of fifty-two students, thirty-four were males and 18 females with ages ranging from 22 to 48 and a mean of 27 years. A standard Visagraph recording form was completed at the time of testing by each member (example 2)[1] .

The statistical analysis used is a correlational study of subjective versus objective findings where reading, comprehension, reading/visual comfort, and performance are concerned. StatView 512+ v1.1 by BrainPower, Inc. was utilized to generate simple second order regression curves, at a 90% confidence interval, for the subjective and objective variables of the study. The scored subjective variables were questions 1-8, 12 and 13 of the student questionnaire. Objective variables were generated by the Visagraph and are Fixations/100 words, Regressions/100 words, Directional Attack/%, Average Span of Recognition, Average Duration of Fixation, Rate Without Rereading, Rate With Rereading, Relative Efficiency, And Comprehension. This analysis was performed comparing each of the scored questions to each of the variables from the visigraph (see Table 1). The R and R^2 value for each comparison is listed with R values in the "Good" or above range printed in distinctive type. A best fit line appears for the "Good" and above correlations (see Graphs 1-21).

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[1] Taylor, S.E., Visagraph: Eye movement Recording System. New York, NY 1985.
6 Francis, Roy G., Beginning Social Statistics. Burgess Publishing Co. Minneapolis, MN 1967.

In addressing the problem of correlation, an assessment of variance was achieved through computation of R and R^2 values. The R^2 value tells us how much of our hypothesis we have solved by appealing to a "best fit" line. R^2 is simply the amount of "explained" variance. The R value is known as the "product correlation" or "coefficient of correlation." The strict interpretation of R is reportedly very difficult, however the following table from Francis[6] provides an approximate and usable scale:

Range of R	Meaning
0.70 or higher	*Extremely Rare.* Has a computational error been made? Recompute to make sure.
0.50 to 0.69	*Very Good.* Few studies sport correlation's of this magnitude.
0.30 to 0.49	*Good.* Not too many studies have zero order correlations like this. Be not ashamed.
0.20 to 0.29	*Quite Ordinary.* Many studies report a number of correlation's in this range.
0.10 to 0.19	*Quite Low.* If N is large enough to reject chance, may mention this But note that when $R = 0.10$, $R^2 = 0.01$, leaving 99% of the unexplained.
0.10 to 0.90	*Really!* After all statistical significance does not imply theoretical importance.

Results

Question 1 asked a fundamental question regarding relative reading ability. The best correlates from the Visagraph to question one were Fixations/100, Rate Without Re-reading, Rate With Re-reading, and Relative Efficiency. These comparisons produced R values of 0.479, 0.532, 0.504, and 0.465 respectively. By Francis' evaluation we may say that the Visagraph's Rate Without and With Re-reading are *very good* correlates to subjective relative reading ability (see Table 1, Graphs 1,2). The correlation of Question 1 to Rate Without Re-reading shows the highest correlation of the study with an R^2 of 0.283 (see Table 1, Graph 1). Also, Fixations/100 and Relative Efficiency prove to be *good* correlates (see Table 1, Graphs 3,4)

Question 2 asked the question of subjective comprehension with a single pass through reading material. As with question 1, the best correlates were Fixations/100, Rate Without Re-reading, Rate With Re-reading, and Relative Efficiency. With R values of 0.389, 0.514, 0.481, and 0.439 respectively we can say that there is *good* correlation in three of the four Visagraph findings, with *very good* correlation relative to Rate Without Re-reading (see Table 1, Graphs 5-8). The third highest correlation of the study is between question 2 and Rate Without Re-reading at R^2 equalling 0.264 (see Table 1, Graph 6) .

Question 3 begged the problem of re-reading. As with questions 1 and 2, 3 also shows greatest correlation to Fixations/100, Rate Without Re-reading, Rate With Re-reading, and Relative Efficiency (see Table 1, Graphs 9-12). Relative to re-reading, all four Visagraph results show *good* correlation. Interestingly, question

3 did not correlate well with directional attack or number of regressions/100, yielding R values of 0.274 and 0.158 respectively (see Table 1).

Question 4 addressed the problem of skipping words. We see that only Fixations/100 demonstrated *good* correlation at an R value of 0.319 (see Table 1, Graph 13). Only ordinary or lower correlation were found to the other variables (see Table 1.

Question 5 asked a fundamental question regarding relative reading speed. Not surprisingly, the highest correlations were to Fixations/100, Rate Without Re-reading, Rate With Re-reading, and Relative Efficiency. Three of the four showed *good* correlation while Rate Without Re-reading gave *very good* correlation with an R value of 0.530 (see Table 1, Graphs 14-17). The correlation of Rate Without Re-reading to Question 5 was the second highest correlation of the study yielding R^2 of 0.281 (see Table 1, Graph 15).

Question 6 probed the subjective importance of the relationship of vision and learning. No Visagraph correlates greater than *quite ordinary* were found (see Table 1).

Question 7 asked about the subjective appeal of reading for pleasure. Only Comprehension, at R value 0.315, is shown to be a *good* correlate (see Table 1, Graph 18).

Question 8 frankly asked about the occurrence of ocular fatigue, headaches, and asthenopia after reading. Average Span of Recognition and Comprehension

were both found to be *good* correlates at R values 0.314 and 0.440 respectively (see table 1, Graph 19,20).

Question 9, 10, and 11 serve as landmarks for sensitivity to reading performance, motivation in performance enhancement and generalized necessity for refractive error correction (see Table 1 bottom left).

Question 12 probed the subjective performance in ball sports. Interestingly, only Comprehension was a *good* correlate at R value 0.492 (see Table 1, Graph 21). With the majority of objective variables being *quite low* correlates (see Table 1).

Question 13 asked the direct question of academic performance as measured by grade point average. Surprisingly, all correlations fell in the *quite low* and *Really!* low categories (see Table 1).

Conclusion

A correctional study of objective eye movement data, as measured by the Visagraph eye movement recording device, to subjective responses regarding reading ability, comprehension, reading/visual comfort, and oculomotor performance has been achieved. This study shows that the objective Visagraphic measurements of reading rate, with and without re-reading, and relative efficiency correlate best with overall subjective reading performance, comprehension ability, and necessity to re-read material. Our results suggest that the Visagraph results correlate best, though not entirely, to subjective responses to questions dealing directly with reading (Questions 1-5, 8). In those questions dealing with performance secondary to reading or fine eye control, the

subjective responses were generally not correlated. For example, questions six and seven regards vision as it pertains to learning and pleasure. It is well known that learning in humans proceeds through a variety of sensory inputs, not exclusively visual. Also, the desirability of reading may lie within intrinsic personal factors and be independent of ocular movement efficiency. Therefore, whether or not the subjects felt vision was important or pleasurable, correlated poorly with Visagraphic findings. Likewise, we see that grade point average, a result of many factors outside of pure reading such as organization, completeness, and time management, did not correlate well. Also subjective ability in ball sports was not a consistent correlate. Obviously, dynamic-reactive sports involve integration of many senses and constitutes more complex behavior than static reading, not surprisingly one may not expecte correlation with Visagraphic findings.

As subjective perception of overall reading ability and speed correlated best with reading rate, overall efficiency, and fixations it is in these areas that the Viasgraph may be best suited for analysis. Based on this study's findings, especially in those adults who's chief complaint includes poor reading ability, low comprehension, necessity of re-reading material, and low reading speed, the Viasgraph is an indicated device in differentially diagnosing the etiology of such complaints.

It is the authors' opinion that the subjective profile established partially correlates with the objective measurements of the Visagraph in these adult subject, despite such unknown variables as user error, differences in subject motivation, and variations in familiarity with the parameters of this study.

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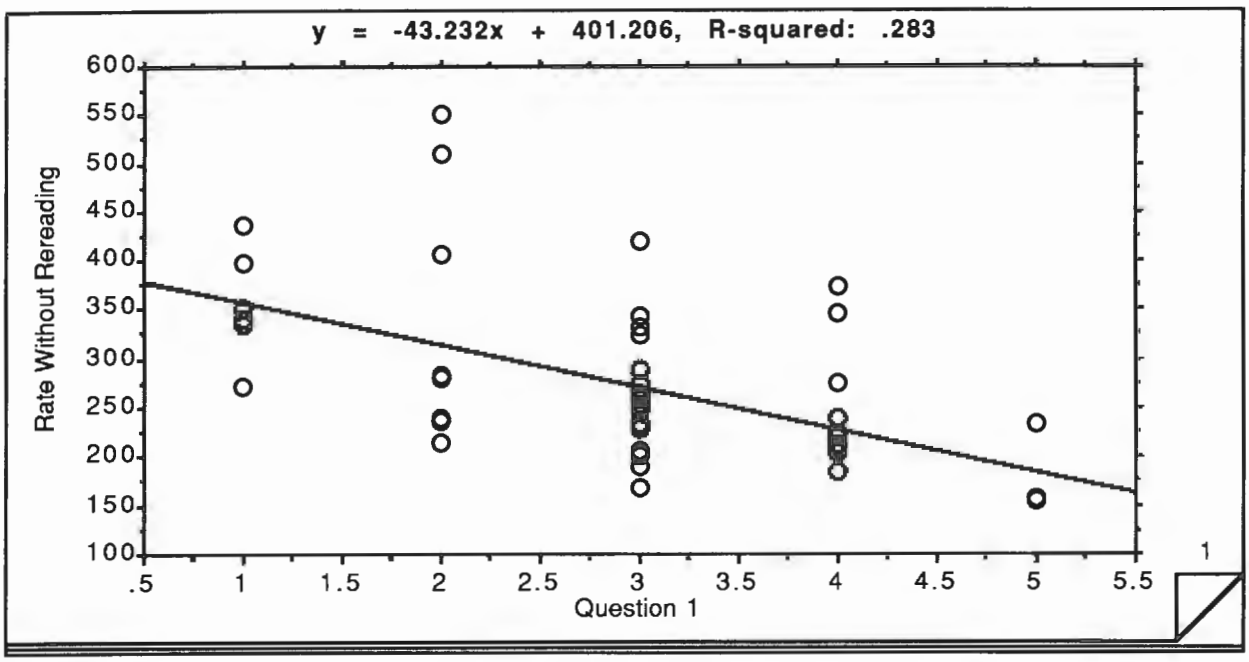
Taylor, S.E., Visagraph: Eye movement Recording System. New York, NY 1985.

Table 1

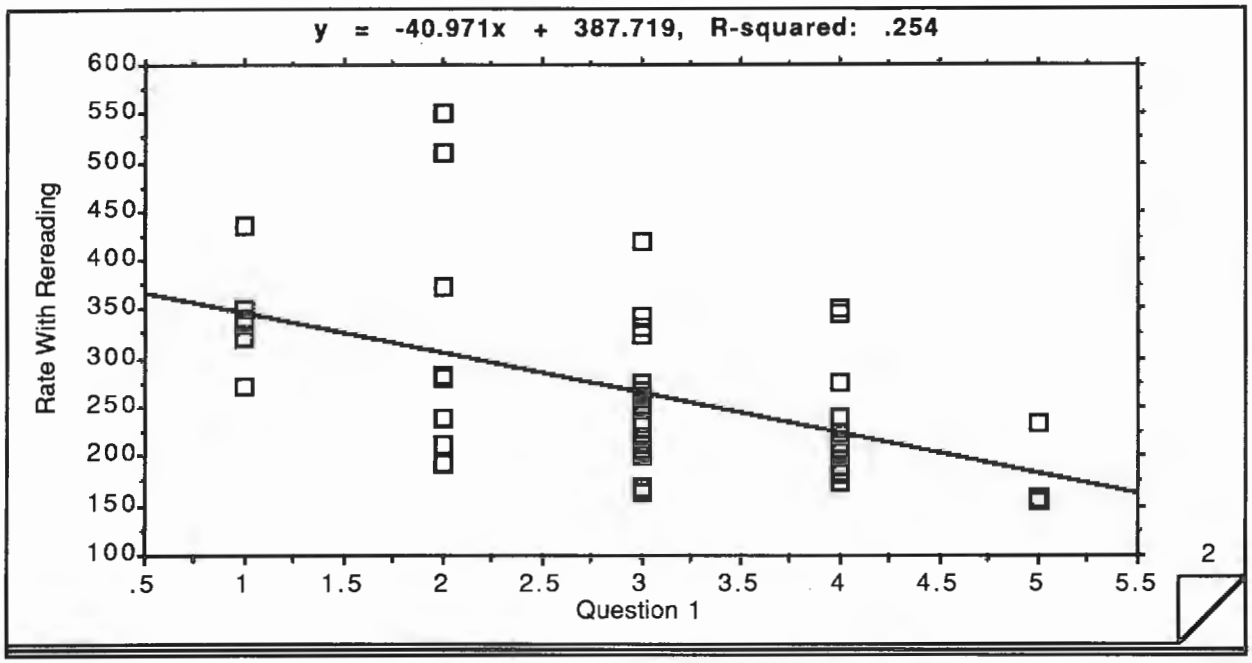
	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 7	Question 8	Question 12	Question 13
Fixations/100	0.479/0.229	0.389/0.151	0.332/0.110	0.319/0.102	0.458/0.210	0.210/0.044	0.176/0.031	0.261/0.069	0.063/0.004	0.016/2.69E-4
Regressions/100	0.205/0.042	0.105/0.011	0.274/0.075	0.130/0.017	0.184/0.034	0.263/0.069	(0.001)/0.032	0.118/0.014	0.141/0.020	0.070/0.005
Directional Attack/%	0.063/0.004	(0.032)/0.001	0.158/0.025	(0.020)/4.03E-4	0.032/0.001	0.214/0.046	(0.126)/0.016	0.019/3.52E-4	0.152/0.023	0.063/0.004
Ave. Span of Recognition	(0.004)/1.94E-5	0.120/0.012	(0.070)/0.005	0.055/0.003	(0.006)/4.05E-5	(0.152)/0.023	0.100/0.010	0.314/0.018	0.032/0.001	(0.070)/0.005
Ave. Duration of Fixation	0.265/0.070	0.122/0.015	(0.063)/0.004	0.063/0.004	0.006/3.52E-5	(0.148)/0.022	0.105/0.011	0.138/0.019	0.031/0.001	(0.070)/0.005
Rate Without Rereading	(0.532)/0.283	(0.514)/0.264	(0.423)/0.179	(0.239)/0.057	(0.530)/0.281	(0.272)/0.074	(0.164)/0.027	(0.114)/0.013	(0.214)/0.046	0.100/0.010
Rate With Rereading	(0.504)/0.254	(0.481)/0.231	(0.411)/0.169	(0.197)/0.039	(0.496)/0.246	(0.270)/0.073	(0.130)/0.017	(0.114)/0.013	(0.245)/0.060	0.070/0.005
Relative Efficiency	(0.465)/0.216	(0.439)/0.193	(0.416)/0.173	(0.217)/0.047	(0.492)/0.242	(0.292)/0.085	(0.105)/0.011	(0.105)/0.011	(0.161)/0.026	0.084/0.007
Comprehension	(0.161)/0.026	(0.141)/0.020	0.089/0.008	(0.130)/0.017	0.122/0.015	0.283/0.080	(0.315)/0.099	(0.440)/0.194	0.492/0.242	0.021/4.22E-4
Legend	( )= negative	Very Good	Good							
% wearing correction.	80									
% believing that their reading performance could be improved.	96									
% that would like to improve their reading performance.	85									

Question 1

Graph 1

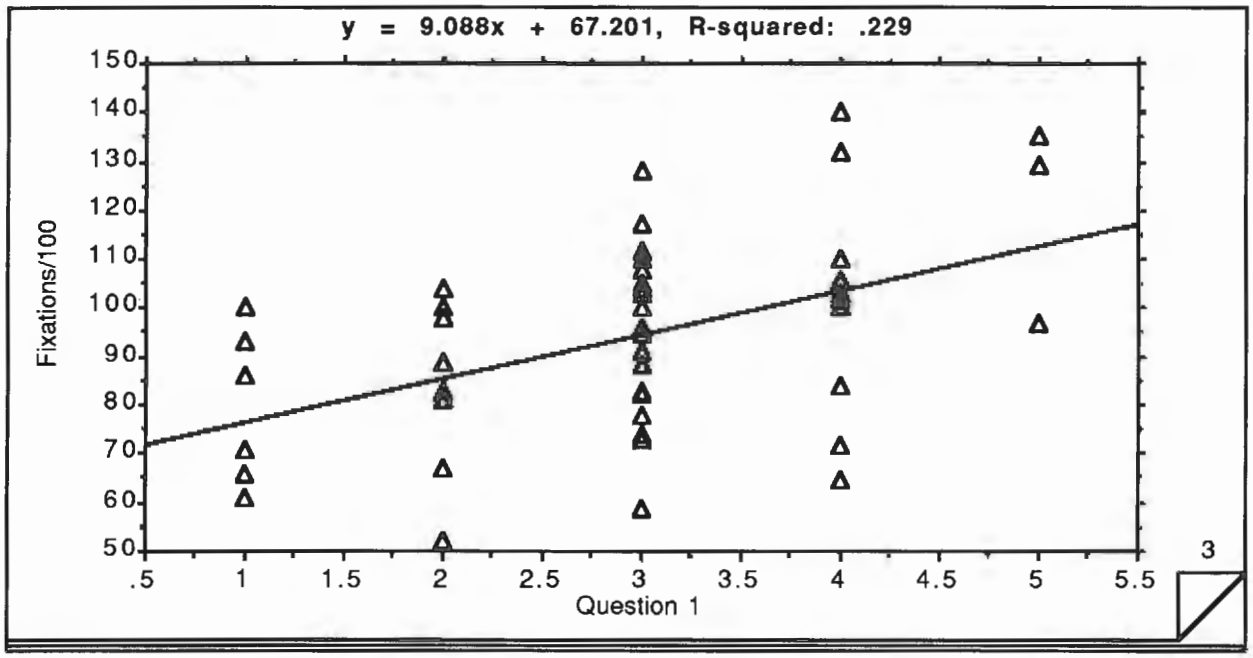


Graph 2

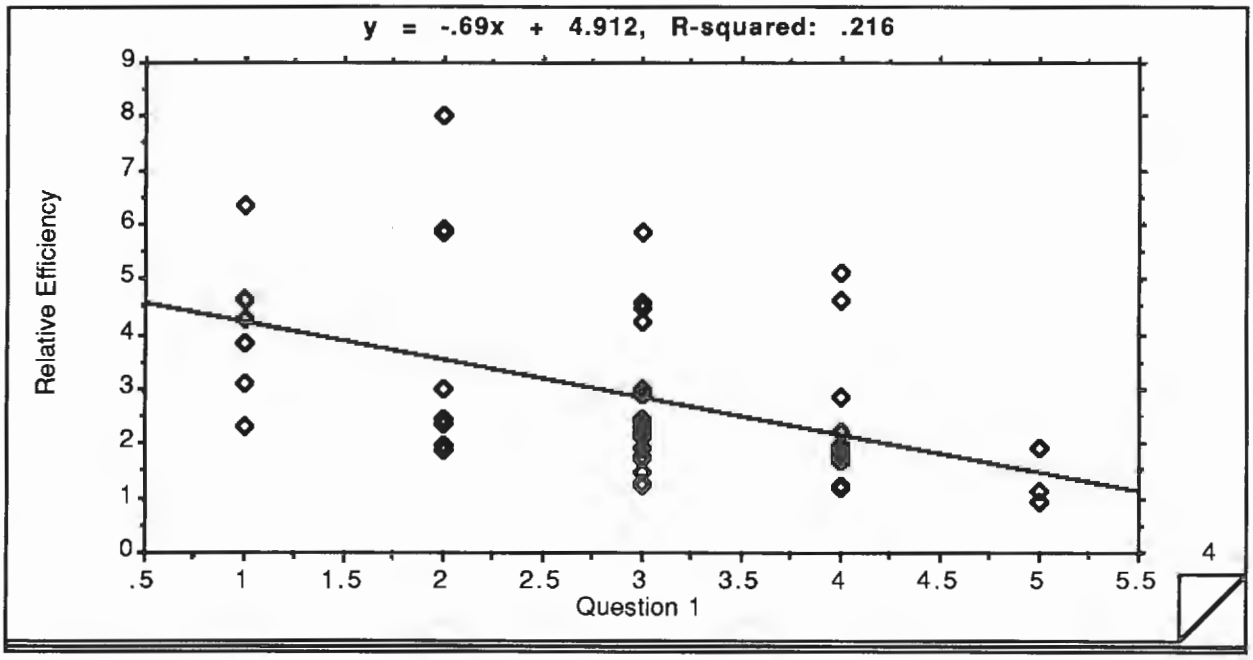


Question 1

Graph 3

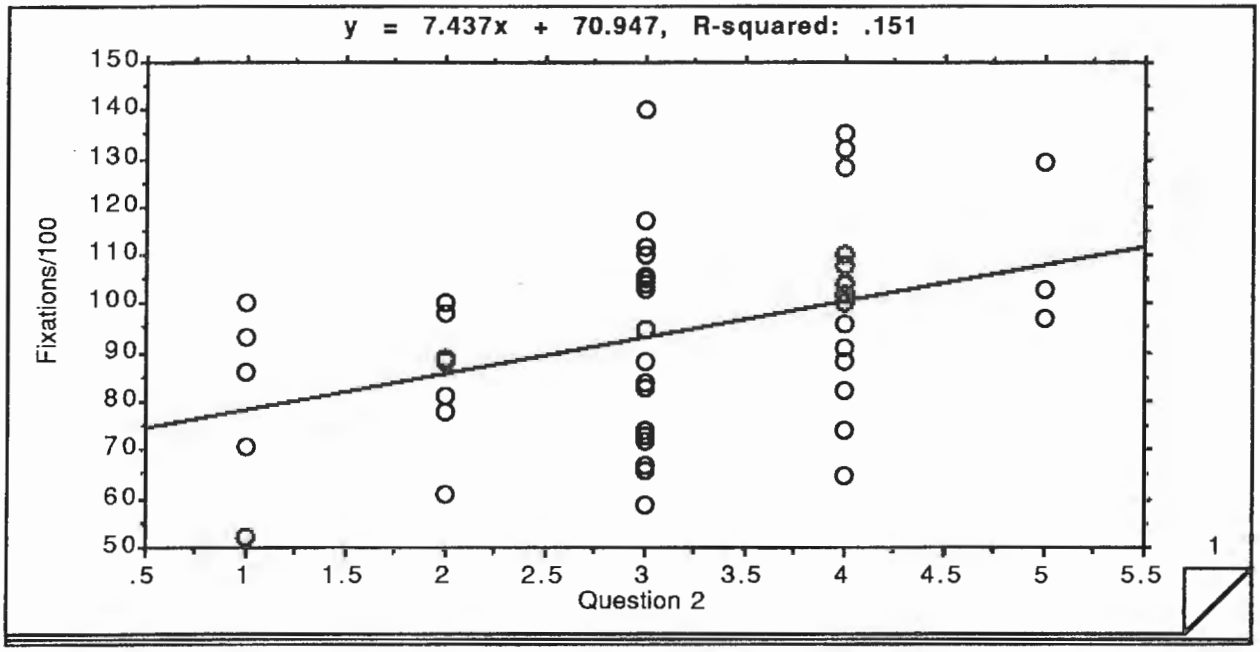


Graph 4

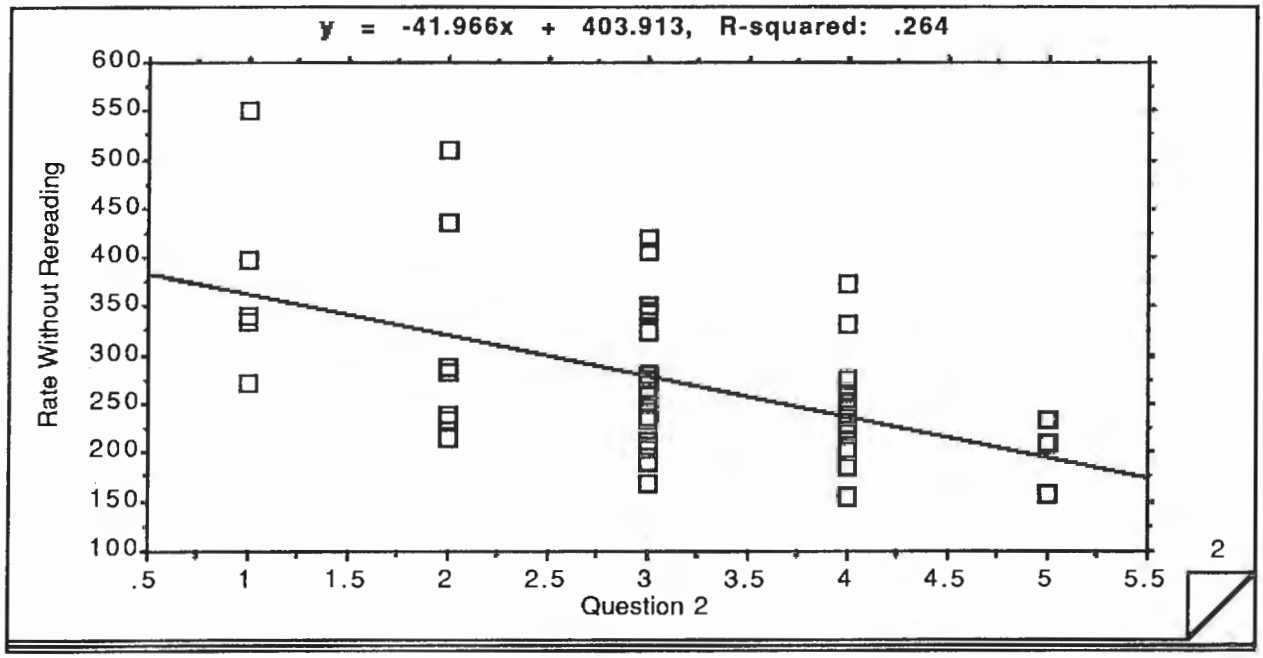


Question 2

Graph 5

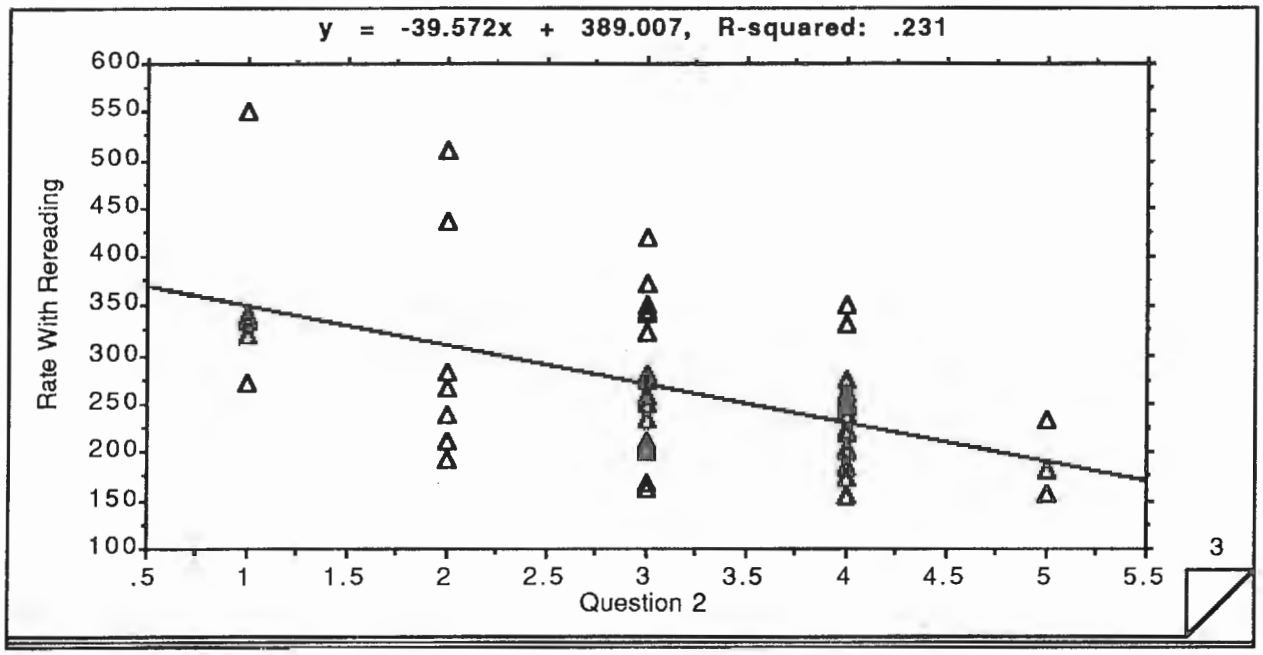


Graph 6

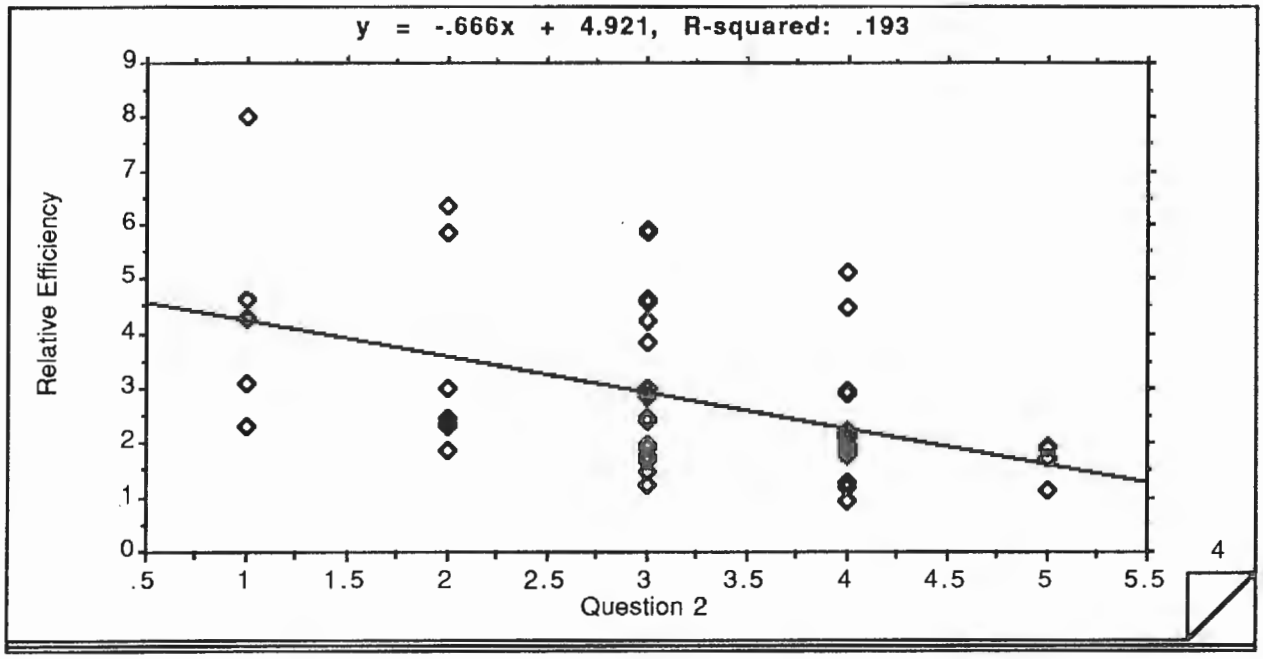


Question 2

Graph 7

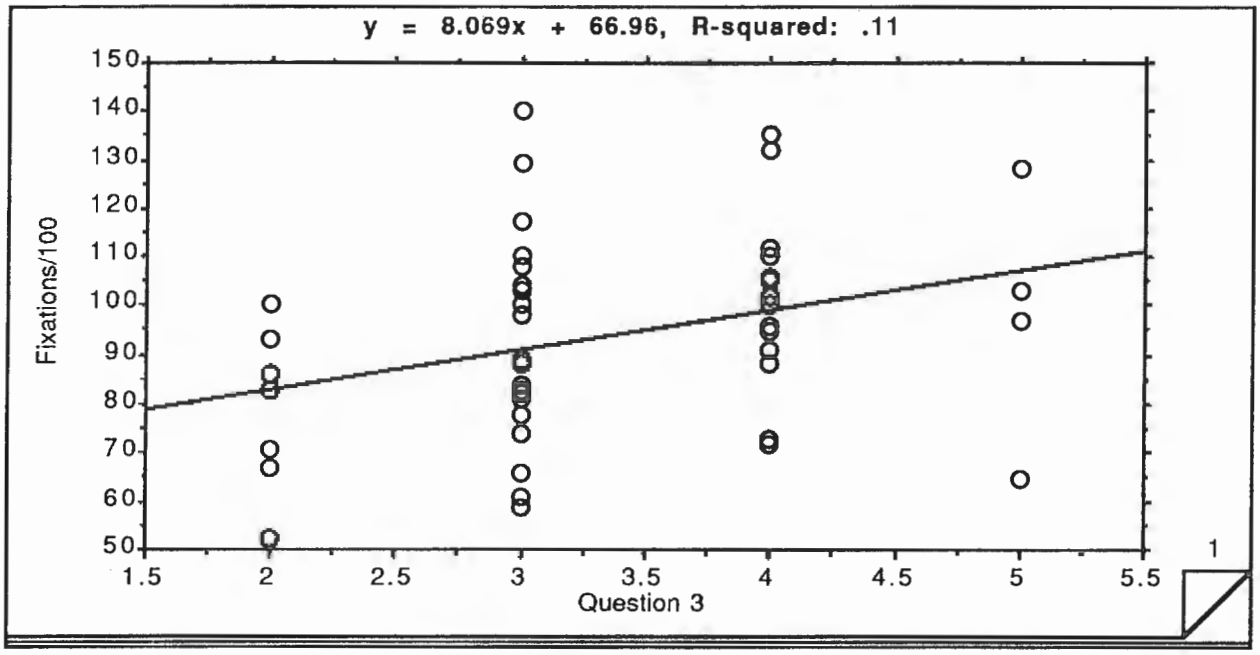


Graph 8



Question 3

Graph 9



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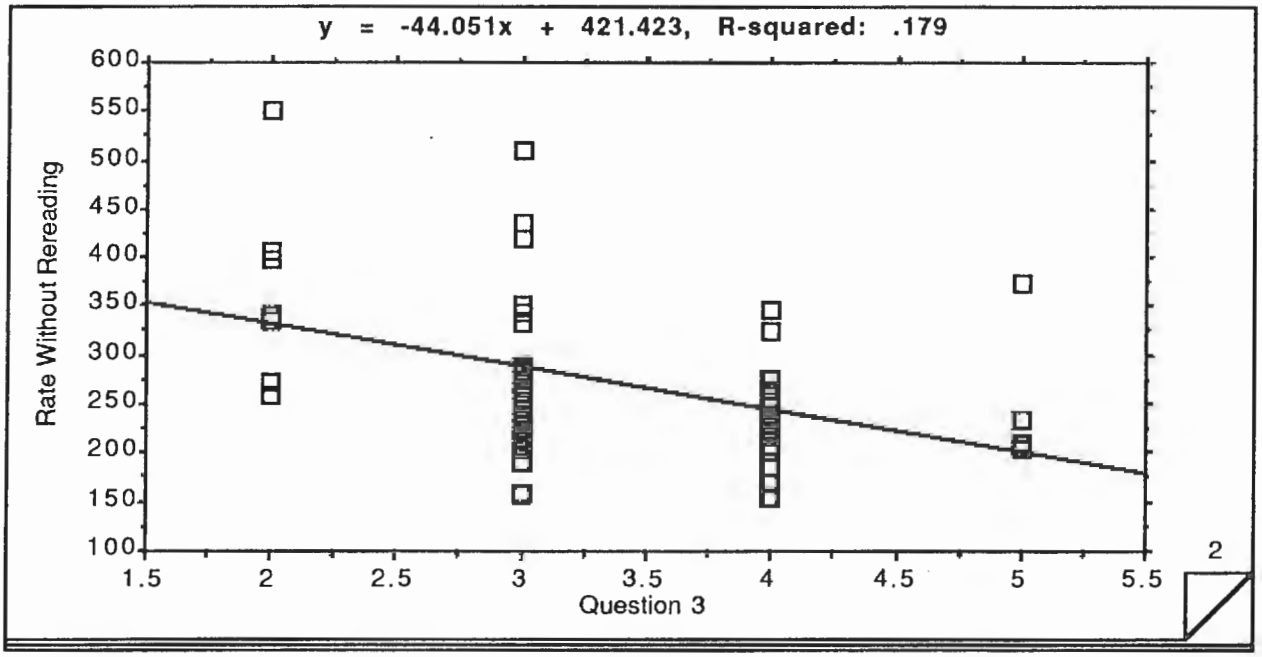
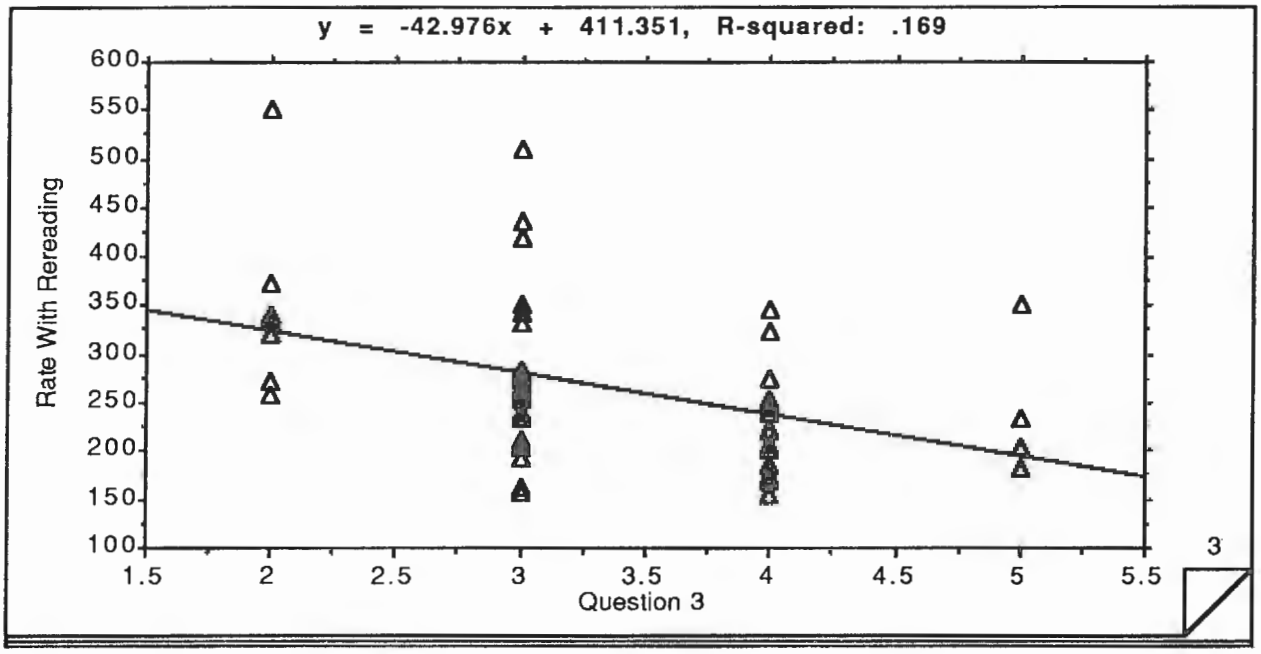
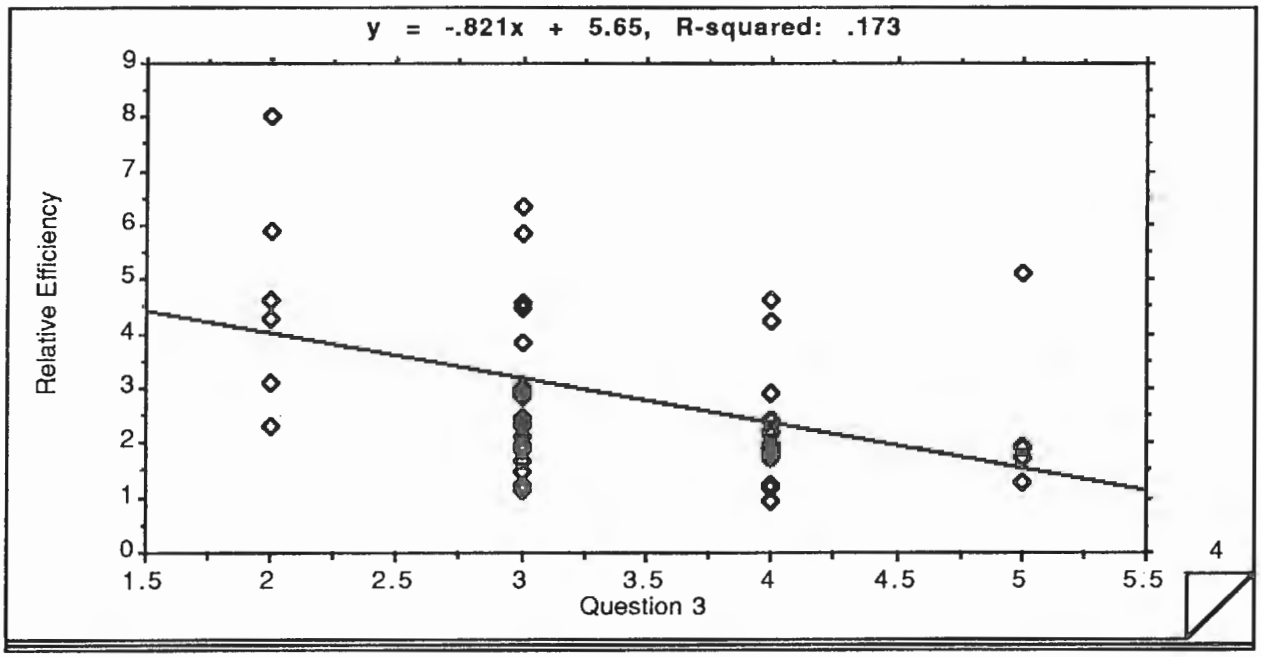


Question 3

Graph 11

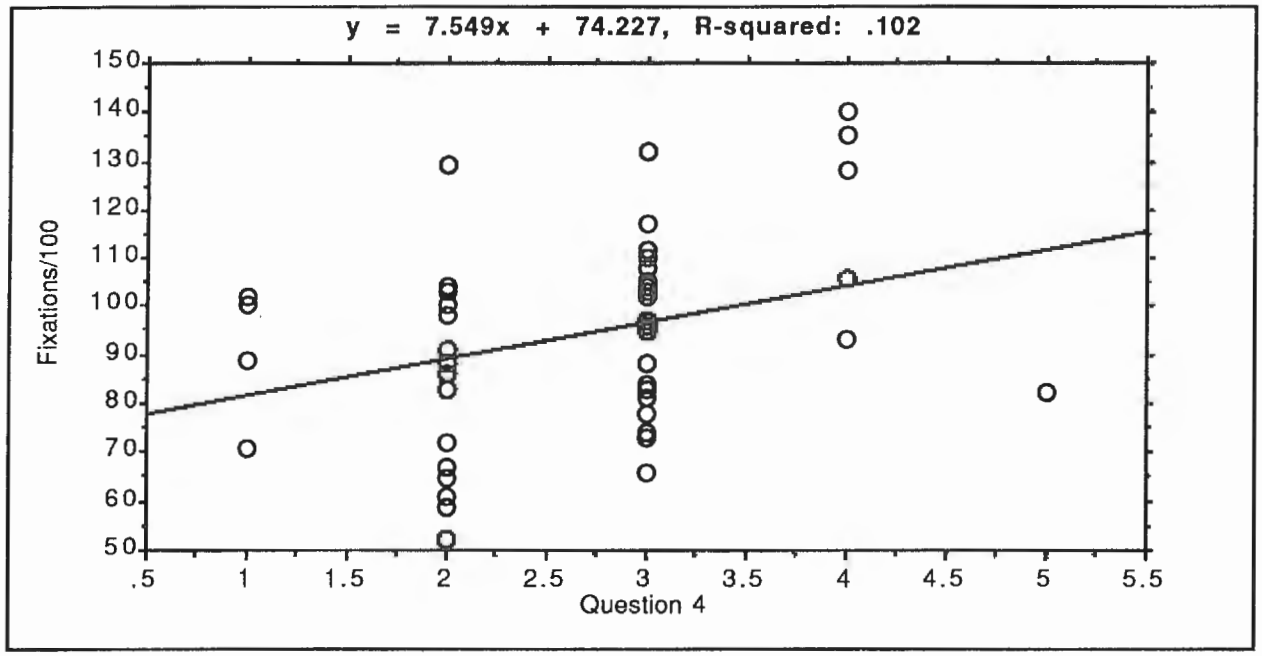


Graph 12



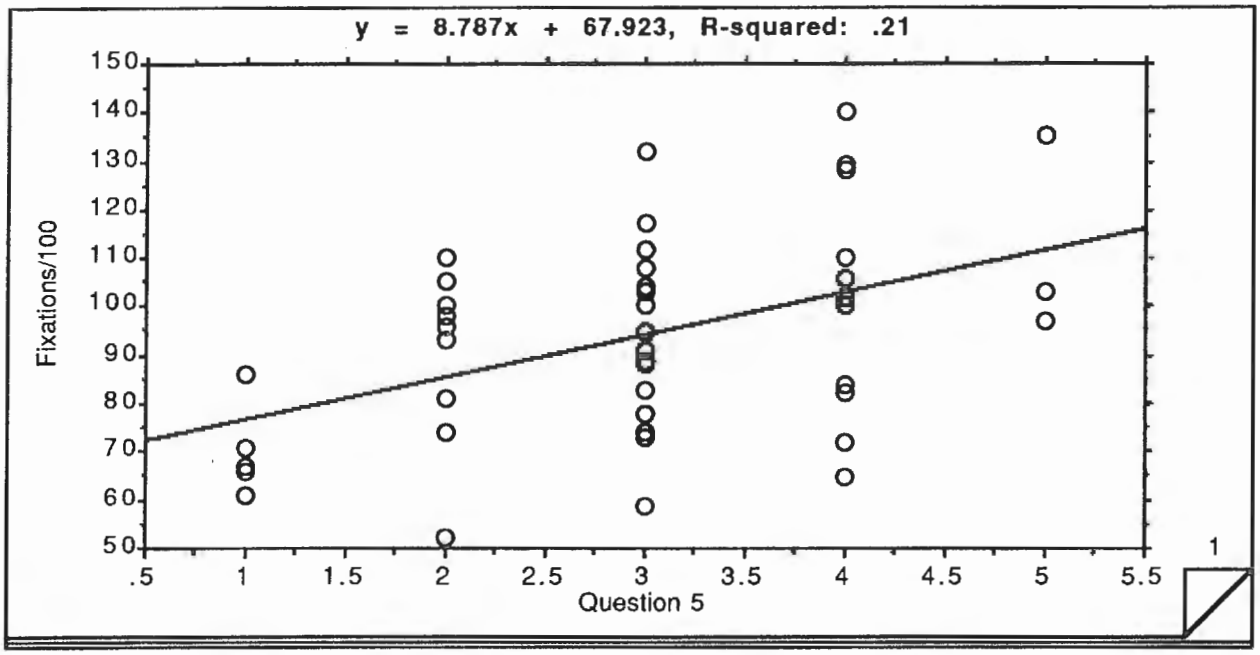
Question 4

Graph 13

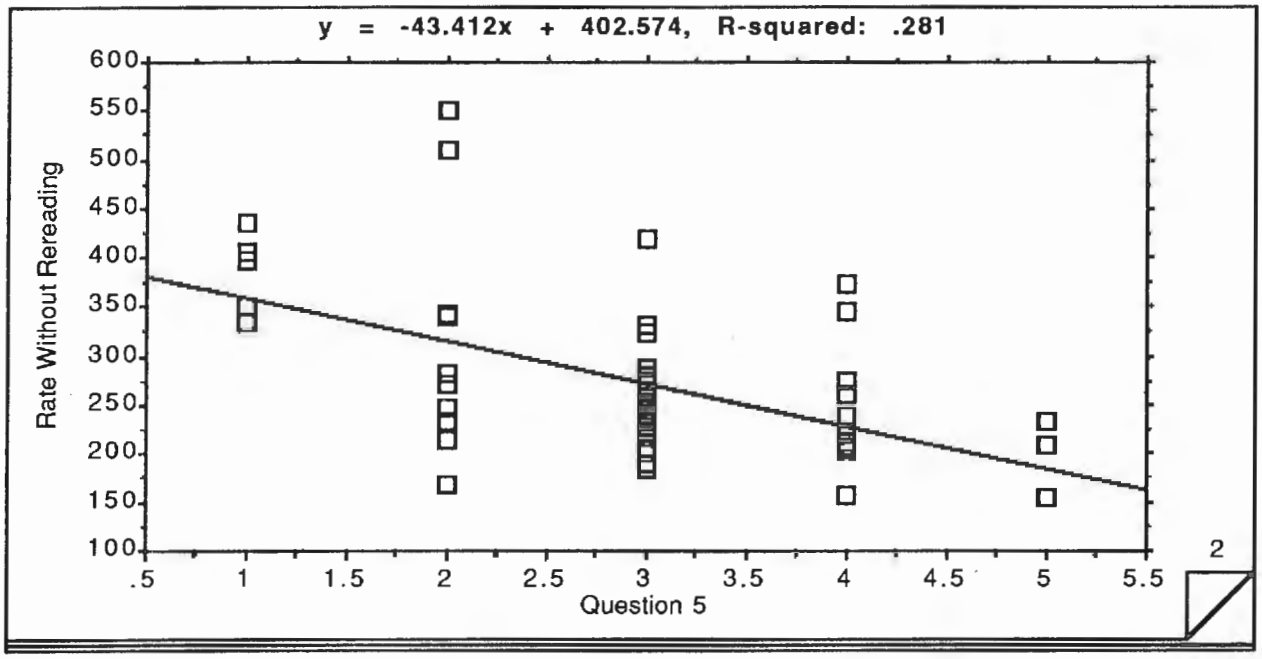


Question 5

Graph 14

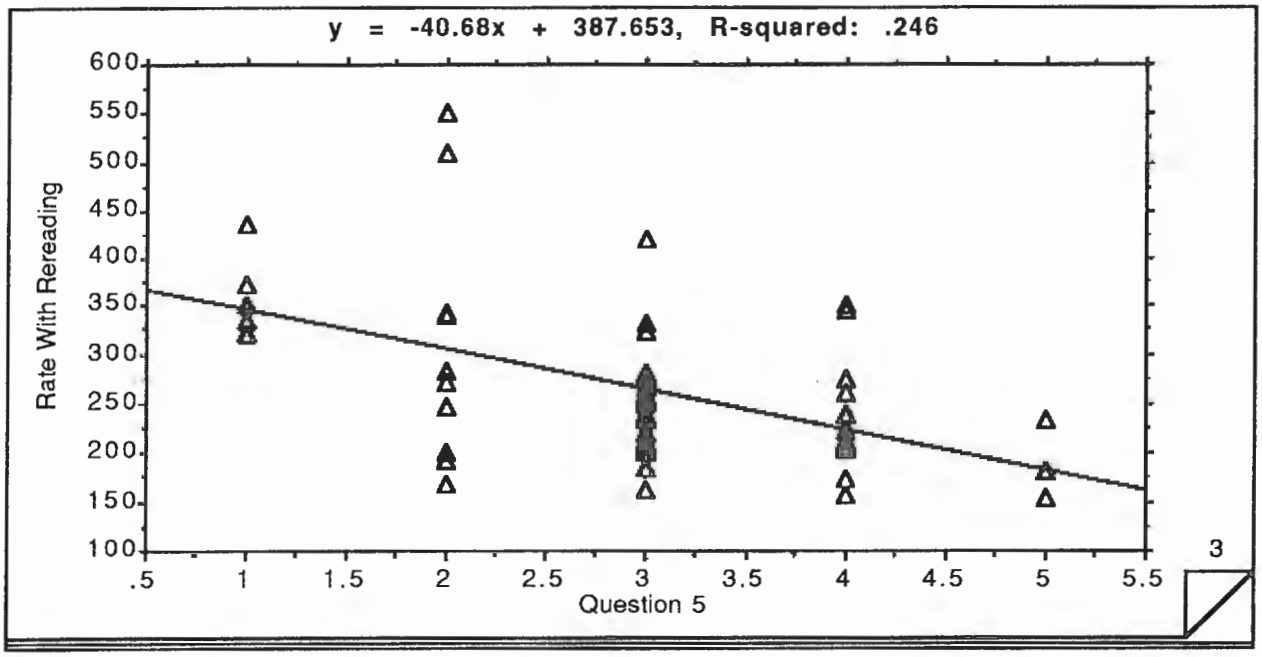


Graph 15

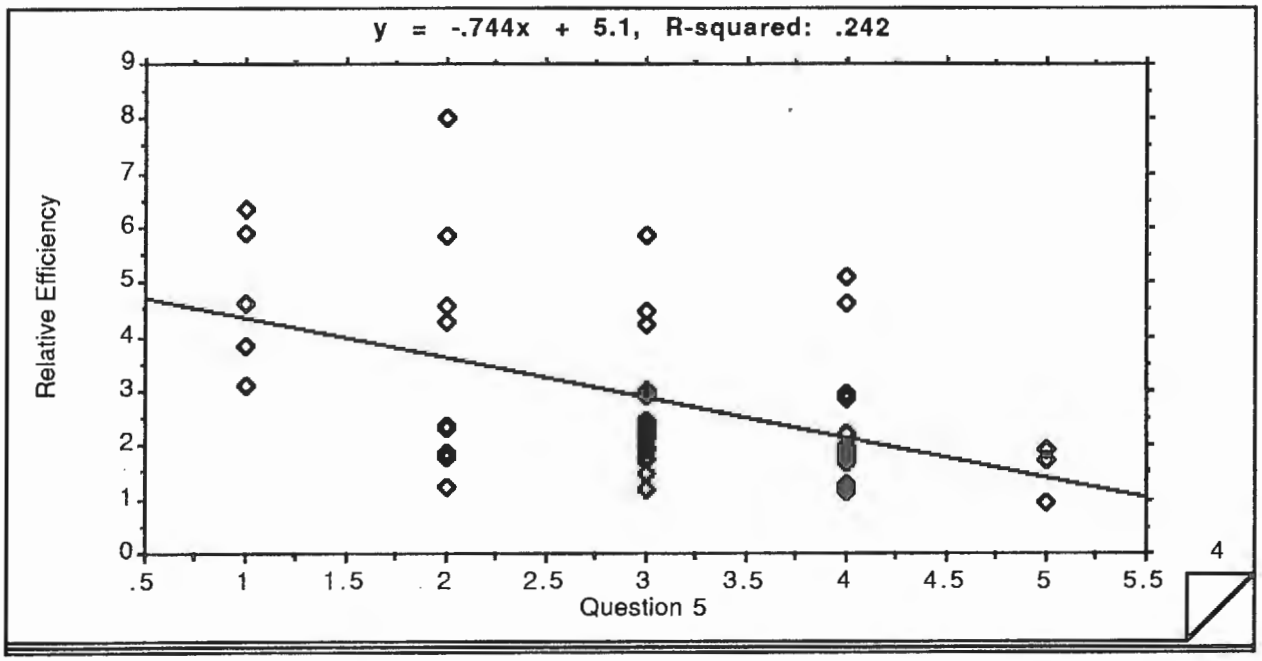


Question 5

Graph 16

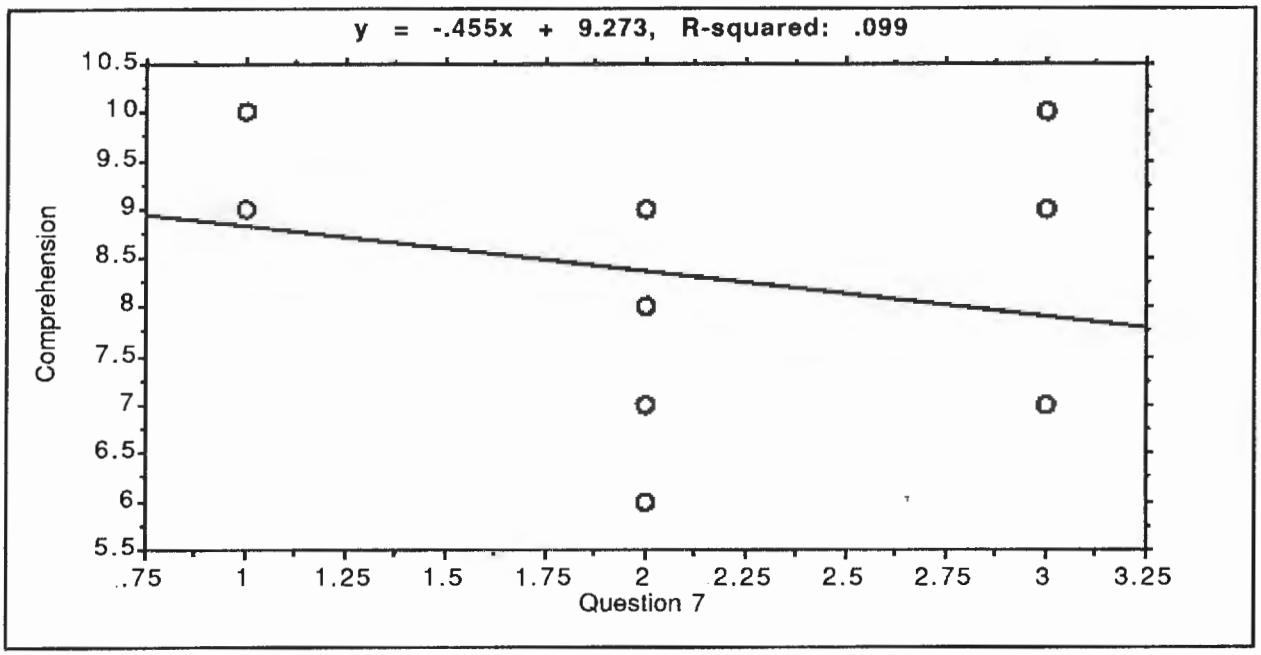


Graph 17



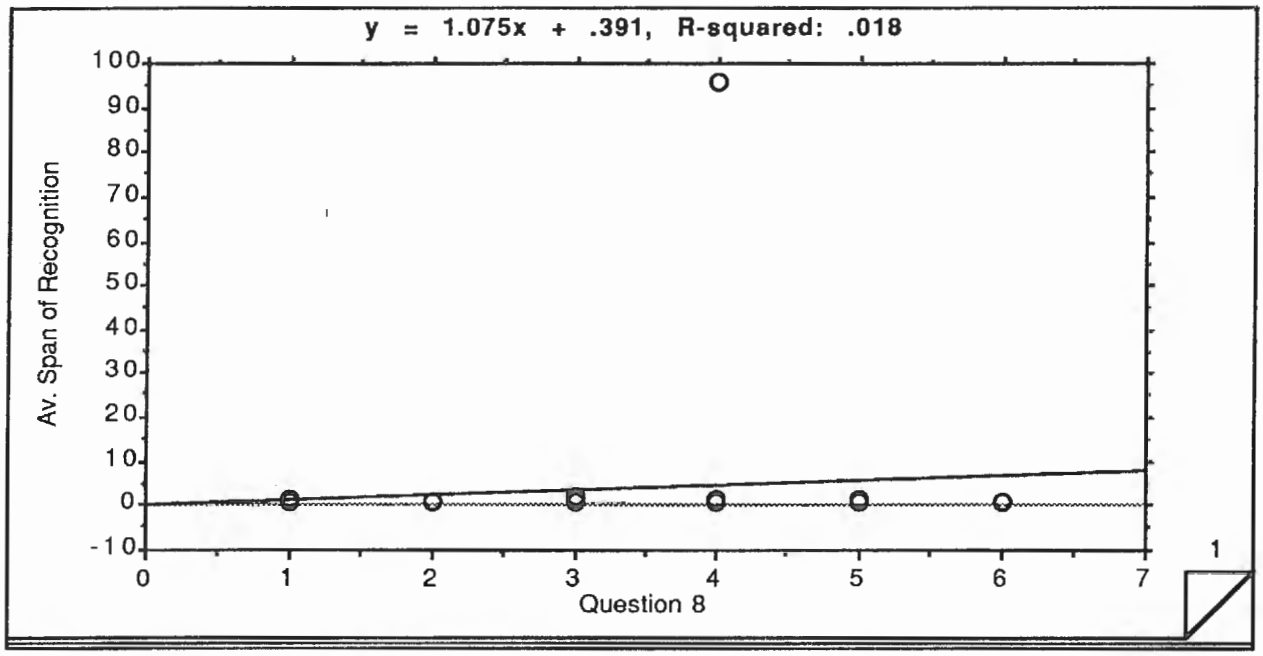
Question 7

Graph 18



Question 8

Graph 19



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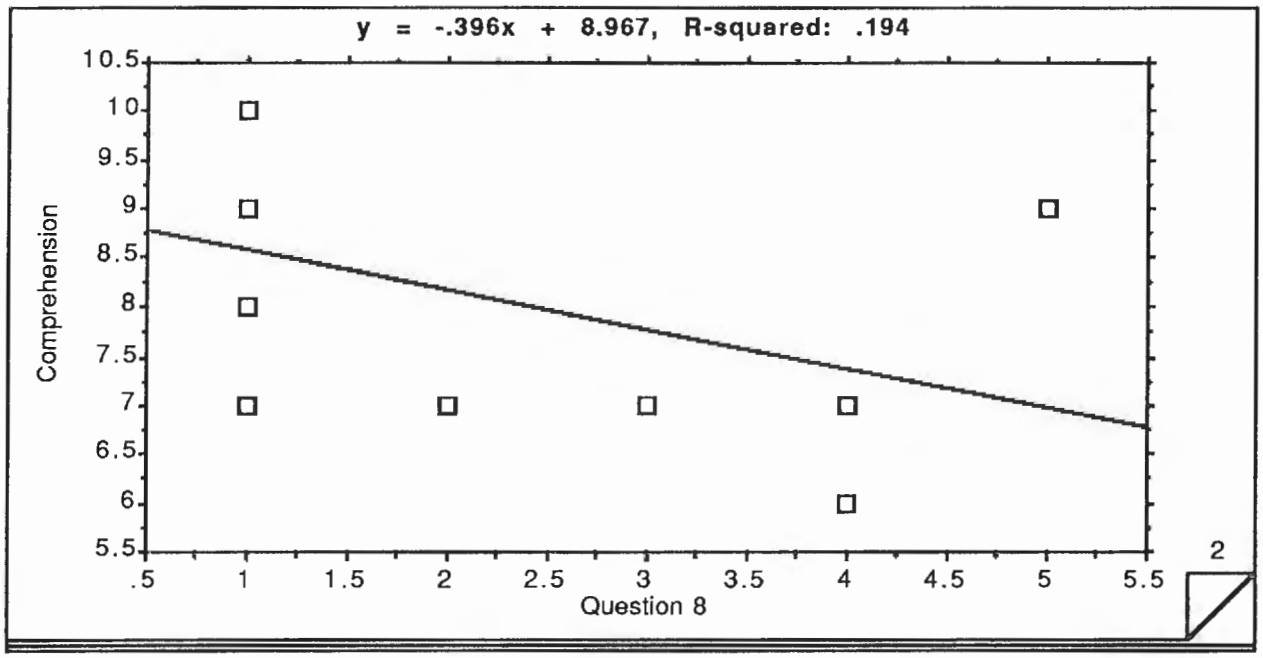
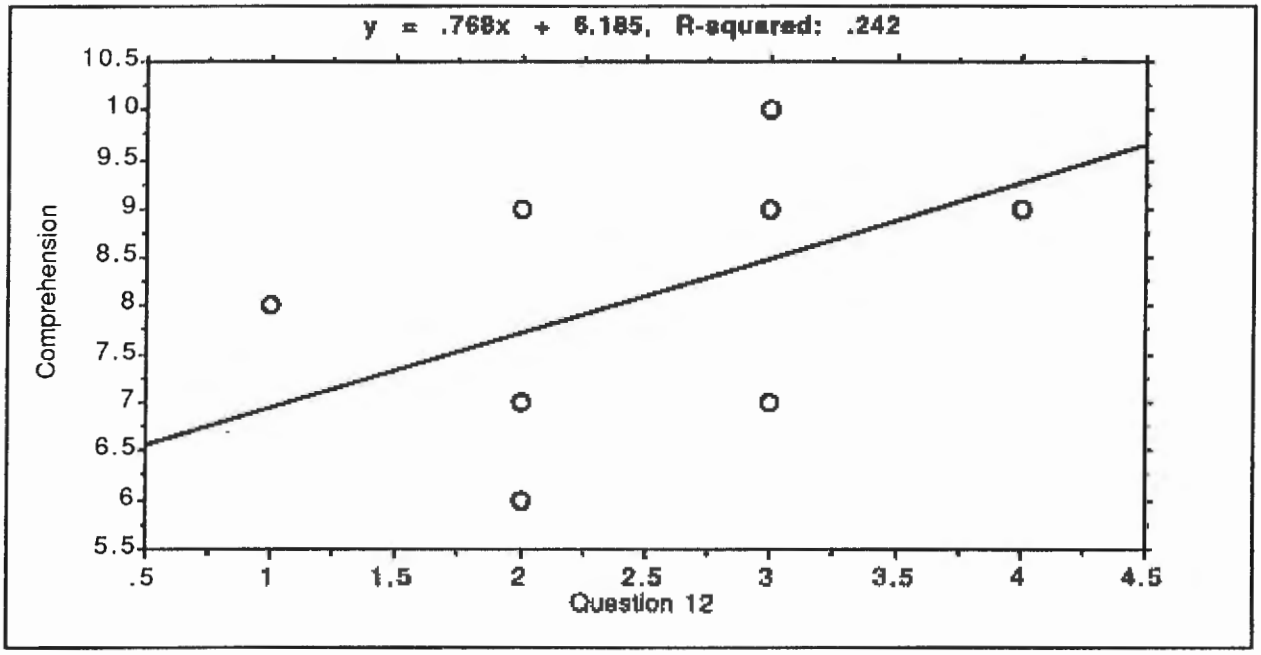


Question 12

Graph 21



The following is a questionnaire pertaining to your vision and its affects on reading ability, comprehension, learning, and performance. Strict confidentiality will be used, but in order to facilitate the study, we would like your full name in the space provided. No names will be cited in the resulting paper, which is based, in part, upon the answers you've given below.

Full name_____ Birthdate_____
(last, first) (month/day/year)

Year in school_____ Female____ Male_____
(ie 1st, 2nd, 3rd....)

1. Do you feel that you are a(n)....
   excellent reader=1, good reader=2, average reader=3, below average=4, or poor reader=5 (please circle one)

2. How do you rate your ability to comprehend written material after reading it the first time?
   excellent=1, good=2, average=3, below average=4, or poor=5 (please circle one)

3. How often is it necessary to re-read material?
   never=1, hardly ever=2, sometimes=3, quite frequently=4, or frequently=5 (please circle one)

4. How often do you skip words while reading?
   never=1, hardly ever=2, sometimes=3, quite frequently=4, frequently=5 (please circle one)

5. How do you rate your reading speed?
   very fast=1, fast=2, average=3, somewhat slow=4, or very slow=5

6. How important is your vision when it comes to learning?
   critical=1, very important=2, important=3, somewhat important=4, unimportant=5 (please circle one)

7. Assuming you had no school reading assignments and had only material to read for pleasure, how often would/do you read?
   as much as possible=1, often=2, sometimes=3, hardly ever=4, never=5 (please circle one)

8. Do you experience ocular fatigue, headaches, or any discomfort after reading?
   yes____ no____. If so, how long do you read before this symptom(s) occur? 1-15 minutes, 16-30 min, 31-60 min, 61 min-3 hrs., or over 3 hrs. (please circle one)

9. Do you use corrective eyewear (including contact lenses) to read?
   yes____, no____

10. Do you think your reading performance can be improved? yes____ no____

turn over please....

11. Would you like to improve your reading performance? yes____ no____

12. How do you rate your athletic ability in **ball** sports?
excellent=1, very good=2, average=3, below ave.=4, poor=5
(please circle one)

13. Your combined undergraduate and optometry school grade point average would be closest to:
(1) a 4.0, (2) a 3.5, (3) a 3.0, (4) a 2.5 or (5) a 2.0

(please circle one)

THANK YOU FOR YOUR TIME AND COOPERATION....

Example 2

ICT VISAGRAPH EYE-MOVEMENT PERFORMANCE RECORD

Name _____ (Last / First / Age)

School/Organization _____ Class/Division _____

Address _____ (Street / City / State / Zip)

Test Date | | | Grade Placement (year and month) | | | Diskette Letter | | | Test Selection Level | | |

A. READING PERFORMANCE PROFILE

Data (most active eye) Pre	Post	Component	Part 1 [1] Grade Level 1	2	3	4	5	6	7	8	9	10	11	12	Col.	Part 2 [2] Adv. 1	Adv. 2	Adv. 3	Adv. 4	Adv. 5
		Fixations/100 words	224	174	155	139	129	120	114	109	105	101	96	94	90	77	65	57	48	44
		Regressions/100 words	52	40	35	31	28	25	23	21	20	19	18	17	15	11	8	5	4	2
		Directional Attack/%	23	23	23	24	22	21	20	19	19	19	19	18	17	14	12	9	8	5
		Av. Span of Recog.	.45	.57	.65	.72	.78	.83	.88	.92	.95	.99	1.04	1.06	1.11	1.30	1.53	1.75	2.08	2.27
		Av. Dur. of Fix.	.33	.30	.28	.27	.27	.27	.27	.27	.27	.26	.26	.25	.24	.23	.23	.22	.22	.22
		Rate Without Rereading	80	115	138	158	173	185	195	204	214	224	237	260	280	340	400	480	560	620
		Rate With Rereading																		
		Number of Lines Read																		

*Less than 15% -- Good
16-22% -- Average
23-40% -- Poor

[1] Part 1 is taken from "Grade Level Norms for the Components of the Fundamental Reading Skill," by Stanford E. Taylor, Helen Frackenpohl, and Jamie L. Pettee, EDL Research and Information Bulletin No. 3, Educational Developmental Laboratories, 1960.

[2] Part 2 represents typical reading performance characteristics for trained readers, accumulated from various reading centers employing instrument training techniques and using eye-movement photography as an evaluative procedure.

B. RELATIVE EFFICIENCY

R.E.	
Grade Equiv.	

Relative Efficiency = $\frac{\text{Rate}}{\text{Fixations + Regressions}}$ = Grade Equiv.

R.E. SCALE

R.E.	Grade Level
.29	1.0
.41	1.5
.54	2.0
.63	2.5
.73	3.0
.83	3.5
.93	4.0
1.01	4.5
1.10	5.0
1.18	5.5
1.28	6.0
1.34	6.5
1.42	7.0
1.50	7.5
1.57	8.0
1.64	8.5
1.71	9.0
1.79	9.5
1.87	10.0
1.97	10.5
2.07	11.0
2.16	11.5
2.25	12.0
2.40	12.5
2.66	13.0
2.77	13.5
2.95	14.0
3.86	Adv. 1
5.48	Adv. 2
7.74	Adv. 3
10.77	Adv. 4
13.48	Adv. 5

C. OBSERVABLE PERFORMANCE CHARACTERISTICS

	1. Head Movement
	2. Rereading
	3. Lack of Return Sweep
	4. Habitual Refixation on Return Sweep
	5. Extreme Variation in Duration of Fixation
	6. Extreme Variations in Fixations
	7. Apparent Difficulty with Binocular Coordination

D. COMMENTS

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VISAGRAPH TEST RESULTS
and
I/CT'S FLUENCY DEVELOPMENT PROGRAMS

Test Results	Fluency Development Progams	
• Excessive number of fixations (eye stops) and accompanying reduced span of recognition (amount of words or word-parts perceived per eye stop)	Guided Reading Tach-Mate Vu-Mate	PAVE Program Word Memory Program Processing Power Program Guided Reading Program
• Excessive number of regressions	Guided Reading	Word Memory Program Processing Power Program Guided Reading Program
• Unusually prolonged duration of fixation (length of eye pause)	Tach-Mate Vu-Mate	PAVE Program Word Memory Program Guided Reading Program
• Poor directional attack Inadequate return sweeps	Guided Reading (especially Visual Efficiency training)	PAVE Program Processing Power Program Guided Reading Program
• Habitual re-reading	Guided Reading Read/Along READ	Processing Power Program Guided Reading Program Comprehension Power Program
• Inadequate rate with comprehension	Guided Reading	Processing Power Program Guided Reading Program
• Poor information processing	Guided Reading	Processing Power Program Guided Reading Program Comprehension Power Program

The use of I/CT's programs of fluency development will improve an individuals's visual/functional, perceptual, and information processing capabilities. These improvements will reflect in both reading efficiency, as measured by eye-movement recording, as well as increased effectiveness, as measured by standardized reading tests or other appraisals.