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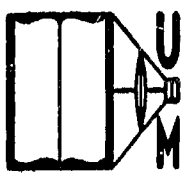
TITLE AGE CHANGES IN MEASURES OF EYE-MOVEMENTS IN SILENT READING

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1950

AGE CHANGES IN MEASURES OF EYE-MOVEMENTS IN SILENT READING

by
Francis A. Ballantine

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of the requirements for the degree of
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F.A.B.

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CHAPTER I

THE PROBLEM

This has been a cross-sectional study of age changes in the eye-movements in the silent reading of typical children selected from the Ypsilanti Public Schools. Eye-movement photographs were made for pupils in grades two, four, six, eight, ten, and twelve. Each subject read two selections before an eye-movement camera, a second-grade selection and a selection for his own grade.

The primary purpose was to obtain growth curves for various eye-movement measures. The second purpose was to discover at what age growth for the measures levels off and is no longer significant. The third purpose was to compare the growth curves for the easy and graded passages. The next section explains how the present study is related to and emerges from previous work. The two studies of which the present one is most directly the outgrowth are those of Buswell (2) and Morse (13).

A. Development of the Problem

Buswell investigated the growth changes in the eye-movements of subjects reading an easy passage. His subjects were 186 pupils representing grades IB through

college. He attempted to confine his study to average subjects at all these levels. The pupils in the elementary grades were selected by means of standardized tests and teachers' judgments. The high school and college subjects were selected on the basis of average school marks.

All the subjects read the same passage except the first-grade pupils who had an easier passage to read. The object in using the same passage throughout all grades except the first was to avoid introducing an additional variable, namely, variations in the difficulty of material. Buswell obtained measures for (1) average number of fixations per line, (2) average duration of fixations, and (3) average number of regressions per line. His results showed a rapid growth until the fourth grade with definite leveling off after the fourth grade for number of fixations per line and regressions per line. Pause duration seemed to change over a slightly longer period.

When it comes to interpreting Buswell's results, it is important to keep in mind that he used the same passage with all of his grade groups except the first. This standard passage had to be easy enough for the second-grade pupils to read. Buswell's results showed a definite leveling off by the fourth grade. This result has generally been taken to mean that growth in the eye-movements in reading ceases by approximately the fourth grade. It may also be taken to

mean that the standard passage was so easy that it did not provide enough "ceiling" for the older groups. How would the results vary if passages of corresponding difficulty or graded material were used with the older groups? This is the question which Morse attempted to answer. He wanted to find out whether the use of graded passages would bring out further growth changes.

Morse made a comparison of the eye-movements of 54 fifth-grade pupils and 54 seventh-grade pupils while they read material of equal or corresponding difficulty. The subjects were selected so as to be in the proper grade with respect to chronological age, mental age, and reading age; they were average children for their grades. The average reading achievement was exactly two grades apart. The reason Morse selected fifth- and seventh-grade pupils was to pick up Buswell's study immediately beyond the point where Buswell's results had reached a plateau. By using graded passages at the fifth- and seventh-grade levels, Morse was able to demonstrate a further growth change between the two grades. On all measures of eye-movement, the seventh-grade pupils reading seventh-grade material performed significantly more efficiently than the fifth-grade pupils reading fifth-grade material. Now the question arises whether still further growth changes could be demonstrated if Morse's technique were extended to even higher age or grade levels. This question constitutes one of the problems of the present

study. The use of graded passages in this investigation was extended through the twelfth grade. The reason that the easy passage was also included is related to the results of another part of Morse's study, in which he investigated the effect of variation in the difficulty of material on the eye-movement measures.

In addition to the fifth-grade passage, the fifth-grade children in Morse's study read a third- and seventh-grade passage; and in addition to the seventh-grade passage the seventh-grade subjects in his experiment read a fifth- and seventh-grade passage. In spite of the fact that each of the three passages were separated by two years in difficulty, Morse found no statistically significant differences for any of the eye-movement measures between passages read by either the fifth- or seventh-grade pupils. Morse summed up the results on this portion of his study with the statement, "The total pattern of the results did not indicate any clear relationship between the eye-movement measures and the difficulty of the material" (13, pp. 98-99).

However, there is some evidence that seems to indicate that in the case of superior adult readers variation in difficulty of material does have some effect upon eye-movements. Walker (33) varied the passages according to difficulty in a study made with fifty good readers. All of his subjects were University of Iowa freshmen selected from the top tenth of their class on the basis of scores on the Iowa

Silent Reading Test. Each subject read three passages--one easy, one moderately difficult, and one very difficult. The results indicated reliable differences both between the easy and very difficult passages and between the moderately difficult and the very difficult passages on the four measures--pause duration, rate of reading, fixation frequency, and regression frequency. Reliable differences were found between the easy and the moderately difficult passages for fixation frequency, rate of reading, and regression frequency. In all of these comparisons, of course, the easier passage was read more efficiently.

Other investigators, notably Tinker (26) and Judd and Buswell (10), have also found evidence to support the thesis that different types of material or variation in the difficulty of the material affect the eye-movement efficiency of superior adult readers. In a careful review of these and other related studies, Dixon (4) concluded that variations in eye-movements are likely to occur from one type of material to another. Whether variations in eye-movements are due to variation in difficulty of the material, differences in the subject matter of the material, or differences in the reader's familiarity with the subject-matter cannot be determined on the basis of these studies.

In any case, somewhere between the seventh-grade and superior adult levels, individuals begin to differentiate in terms of their eye-movements between materials of varied difficulty. In view of Morse's findings that fifth-grade

children do not vary their eye-movements significantly from third- to seventh-grade reading material and seventh-grade children do not vary their eye-movements from fifth- to ninth-grade reading material, it seems unlikely that children in the second grade through the sixth will differentiate significantly between the easy and graded passages used in this study. At what ages do children begin to differentiate between materials of different difficulty? This study is planned to permit an answer to this question at least through the twelfth grade.

The next section will explain how the present study is designed to answer the questions which this review of earlier work has raised.

B. The Plan of the Present Study

The present study is essentially a repetition of the Buswell study and an extension of the Morse study to lower and higher grade levels. It is a repetition of the Buswell study in that all the subjects in grades two through twelve read the same easy passage. This passage was carefully selected and revised so that by objective standards it was of second-grade difficulty. The present study is an extension of the Morse study to lower and higher grade levels in that the subjects in each of the six grades read, in addition to the easy passage, a passage graded for difficulty at their particular grade level. As in the Buswell and Morse studies,

the subjects in the present study were average pupils in reading achievement. We may review the principal conditions of the present experiment as follows: (1) the subjects were of the same relative intelligence and reading ability according to age and grade; (2) all subjects read an easy passage of second grade difficulty; and (3) all subjects read a graded passage which was adjusted to their grade placement.

If, in selecting the subjects for the various grades, groups that had the same relative intelligence and reading ability were obtained for each grade, then it might be assumed that the reading performance by these subjects as a whole would be similar to that made by much larger unselected groups.

Since carefully selected passages equated for difficulty by objective standards were used, the factor of intellectual development was merely a matter of relativity. The passage for grade two was actually of grade two difficulty, the passage for grade four was actually of grade four difficulty, and so on for the other grades; therefore it could be assumed that the graded selections were of the same relative difficulty for all grades. Because there is considerable evidence to show that the nature of content of material being read may influence eye-movements in reading, the present experiment provided that all the passages be of a semi-scientific nature.

The provision in this experiment for all subjects to read the second-grade passage and for all above the second grade to read, in addition, a passage for their own grade permits the development of growth curves for subjects reading both easy and graded materials. This was the primary purpose of the study.

By statistical analysis of the group data for each of the eye-movement measures, it was possible to determine where growth levels off and is no longer significant, a second purpose of the study. If the differences between the grades were significant above the fourth grade on the second grade passage, then it might be assumed that growth was still taking place. The same would also be true if significant differences should occur on the graded passages. If, contrary to the Buswell findings, growth should continue after the fourth grade on the second-grade passage, then the explanation would have to be that the passage differentiated more between grades than Buswell's because of greater difficulty or that other conditions of the study had caused the results to be different. The continued growth on the graded passages would further support Morse's findings. If growth on the second-grade passage should stop appreciably earlier than on the graded passages, the evidence might tend to support both of the earlier studies.

Since each of the grades except grade two read an easy passage and a graded passage, a comparison of the effect of

a variation of difficulty of material upon eye-movements is easily determined by a statistical analysis of the significance of the difference between the two curves at any grade level. By this method, then, a study of the point at which individuals begin to differentiate between materials of different difficulty can be made.

C. Significance of the Investigation

No other study has been made that fits all of the conditions of the present experiment although Gray (8) and Schmidt (19) have carried out studies which are broadly related to the present problem. Gray made a study of 59 subjects from the third grade through college. He used different passages selected from a basal reader series for each grade.[1] The selections varied in length. No objective data showing the difficulty of the passages were offered. Gray's results seemed to indicate that growth in fixation frequency and regression frequency continue until the sixth grade. Pause duration closely followed Buswell's results. One condition which was lacking in Gray's study was that he did not use an easy passage together with his graded passages. This omission leaves important problems unanswered.

Schmidt's study included 83 subjects from grade two through the adult level. He varied the passages although he did not have one for each grade. The results of his study

[1]Morse (13) has demonstrated that basal reading materials are often poorly graded.

did not reveal any consistent trends. Schmidt found that, taken separately, the elementary, high school, and adult groups read with about the same fixation frequency. His results led him to believe that, after learning the technique, all subjects, regardless of age, will read on the average with the same fixation frequency providing the subjects are reading material within their comprehension level. Schmidt believes that the mechanics are learned by the end of the second grade. For that reason he believes that no differences in fixation frequency appear between the three later groups, elementary, high school, and adult. Schmidt's study is also limited in that he did not include an easy passage either.

It would seem, then, that there is a place for the present study. Although a complete discussion of the significance of this investigation will be made in a later chapter, a few words may well be said concerning what significance the investigation may have. Many schools stop teaching reading by the end of the fourth, fifth, or sixth grades. But Morse has demonstrated that a growth factor is still present at the seventh-grade level. If the present study should reveal significant growth changes at even higher grade levels, it would seem that an argument could be made for the idea that continuing attention should be given to reading, perhaps even through high school. The importance of grading material for higher grade levels would also seem to follow from such a finding.

CHAPTER II

THE METHODS AND CONDITIONS OF THE EXPERIMENT

This chapter describes the procedures used in carrying out the experiment. Included in this chapter are sections on the selection of the subjects, selection of the passages, the camera procedure, the eye-movement measures obtained, and the comprehension tests.

A. Selection of the Subjects

The subjects for this experiment were selected from grades two, four, six, eight, ten, and twelve. The measurements were started with second-grade pupils rather than with the first-grade pupils since so many children are non-readers during their first year in school. The twelfth grade was included in order to obtain the most mature pupils in school in the experiment.

Twenty subjects, ten boys and ten girls, were included in each grade. All of the subjects attended the Ypsilanti Public Schools.

The criteria used in selecting the subjects were chronological age, mental age, intelligence quotient, reading age, reading quotient, and reading grade. The reading quotient was obtained by dividing the reading age by the chronological age.

For each grade the goal was to obtain subjects whose chronological age was within the limits that are acceptable for that grade. These limits were based upon the ages at which the Ypsilanti Public Schools admit children into kindergarten. No child who had repeated any grade was used in the experiment. In order to obtain twenty average or typical children for each grade, it was, of course, necessary to test many more children in each grade than were eventually included in the study. In all, 1700 children were tested.

Mental age was determined by administering the proper form of the California Test of Mental Maturity (22). This test provides, in addition to a total mental age, language and non-language ages. No subject was used whose scores revealed a great discrepancy between language and non-language factors. Subjects were selected whose chronological age and mental age agreed as closely as possible.

Reading age was determined by administering the proper form of the Progressive Reading Achievement Test (24). This test was used for selection purposes because it has forms for all grades, two through twelve. The reading age was matched as closely as possible with the chronological age and mental age.

Both intelligence quotient and reading quotient were obtained from the foregoing measures. The ideal subject for this experiment would have had equal chronological, mental, and reading ages and, consequently, reading and intelligence quotients of exactly 100.

The reading grade was as near the actual grade placement as could be obtained for all cases. Table I contains the means, standard deviations of the distribution, and the range for all the criteria used in the selection of the groups. Within certain limits, all grades on all measures were in relatively the same position. The twelfth grade group was the farthest from the ideal, probably because of the selective factor. In order to determine whether the six groups were comparable, the significance of the differences between the groups was tested for the different selection measures. Table II reveals that there were no groups that differed significantly in intelligence at either the 1 percent or 5 percent level. For the reading quotient the results were not quite so satisfactory. Between grades six and eight there was a significant difference at the 5 percent level in favor of the sixth grade. There was also a significant difference between grades ten and twelve at the 1 percent level in favor of grade twelve. As for the other criteria--chronological age, mental age, reading age, and reading grade--there were significant differences between each of the successive grades. Table II seems to indicate that, in general, the groups were at about the same relative level for intelligence and reading ability. It also indicates that in all cases except one the differences between successive grades for the other measures were significant at the 1 percent level. One other comparison was made for

TABLE I

A COMPARISON OF GRADE GROUPS ON SELECTION CRITERIA[1]

Grade	Chronological Age			Mental Age			Intelligence Quotient		
	Mean	Range	S. D.	Mean	Range	S. D.	Mean	Range	S. D.
II	91.9	85-96	2.903	92.0	85-101	5.338	100.1	92-110	6.278
IV	114.5	110-128	4.448	114.6	100-125	7.552	99.9	90-110	6.978
VI	137.5	125-143	4.236	136.7	124-153	7.924	99.5	90-108	5.920
VIII	165.7	156-177	4.775	165	152-192	11.840	100.8	90-110	6.705
X	187.7	181-193	3.300	185	165-221	17.388	101.4	87-121	9.468
XII	212.2	207-217	3.035	201.2	178-230	15.835	105.2	93-120	8.225

[1]Tables of the individual selection data may be found in Appendix A.

TABLE I (Continued)

Grade	Reading Age			Reading Quotient			Reading Grade		
	Mean	Range	S. D.	Mean	Range	S. D.	Mean	Range	S. D.
II	94.2	88-100	3.108	101.5	89-114	6.328	2.51	2.0-2.9	.239
IV	119.3	113-125	3.257	103.8	89-115	5.287	4.5	4.0-4.9	.241
VI	143.7	139-151	3.015	104.5	97-112	3.232	6.3	6.0-6.9	.231
VIII	169.7	154-182	7.302	102	93-107	4.080	8.7	7.2-9.7	.691
X	191	175-229	14.232	102.2	94-125	7.606	10.5	9.2-13.8	1.234
XII	207	191-228	10.258	108.3	99-119	5.404	12.1	10.9-13.7	.834

TABLE II

T VALUES FOR THE DIFFERENCES BETWEEN SUCCESSIVE GRADES ON THE CRITERIA USED TO SELECT THE SUBJECTS[1]

Measures	Degrees of Freedom	II-IV	IV-VI	VI-VIII	VIII-X	X-XII	1 Percent	5 Percent
Chronological Age	38	18.9	16.35	19.15	16.60	23.53	2.713	2.025
Mental Age	38	10.68	8.94	9.12	4.87	2.07	2.713	2.025
Intelligence Quotient	38	1.16	.166	.609	.244	1.303	2.713	2.025
Reading Age	38	24.30	24.36	14.37	5.63	4.31	2.713	2.025
Reading Quotient	38	1.211	.527	2.091	.074	2.845	2.713	2.025
Reading Grade	38	25.59	24.87	14.14	5.78	4.46	2.713	2.025

[1]In this and all other tables in which grades are compared t values that are negative indicate significance in favor of the lower grade. Absence of a sign means the difference is positive in favor of the higher grade. A single line under a figure identifies a value significant at the 5 percent level of confidence, and a double line, a value significant at the 1 percent level of confidence.

the selection data. The results of this comparison are shown in Table III which gives the significance of the differences between the reading quotient and intelligence quotient for each grade. No significant differences were obtained. This tends to prove that for each grade level the intelligence and reading ability were comparable.

In so far as it was feasible, children with the same educational background were selected as subjects. A large percentage of the subjects had most of their educational experience in the Ypsilanti Public Schools. The tests for grades two, four, and six were given in December when .4 of the school year was past. The tests for grades eight, ten, and twelve were given in March when .6 of the school year was past. This difference in time may safely be ignored.

B. Selection of the Passages

One practice and one test passage were selected for each grade. All passages were semi-scientific in nature, each about 200 words in length. Each passage was printed on two cards of 100 words each. The passages were adapted from two series of textbooks in science and equated for corresponding difficulty by means of special formulas for estimating the difficulty of reading material.

The formulas that were used in the present study were those that could be applied to passages as short as 100 words. The Yoakum (35) formula which measures reading

TABLE III

T VALUES FOR THE DIFFERENCES BETWEEN THE READING QUOTIENT AND INTELLIGENCE QUOTIENT FOR EACH GRADE

Degrees of Freedom	t						1 Percent	5 Percent
	II	IV	VI	VIII	X	XII		
38	.660	1.941	.969	.694	.263	1.373	2.713	2.025

difficulty entirely on the basis of the ratio between hard words and the total number of words is the only one which is designed to predict difficulty for all the passages of all the grades. Yoakum uses the Thorndike Teacher's Word Book (31) to determine the hard words.[1] The other formulas used were the Lorge (12) for grades two through eight, the Dale and Chall (3) for grades four through twelve, and the New Flesch (6) for grades four through twelve.

The Lorge formula predicts difficulty through the use of four factors: (1) the number of words, (2) the number of sentences, (3) the number of hard words, and (4) the number of prepositional phrases. Lorge considers the hard words those not appearing on the Dale list.[2] The Lorge formula makes it very difficult to obtain low enough scores on the second-grade passage and high enough scores after grade eight.

The Dale and Chall formula predicts readability on the basis of three factors: (1) hard words, (2) sentence length, and (3) the number of words. The hard words are those that do not appear on the Dale list of 3000 words.[3] This formula

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[1]Yoakum derives a raw score for difficulty by totaling the Thorndike assigned index numbers for all words with an index of 4 or above; that is, all words that are not in the 3000 most common words.

[2]The Dale word list is composed of the 769 words that are common to the most frequent thousand words in Thorndike's Teacher's Word Book and the word list prepared by the Child Study Committee of the International Kindergarten Union.

[3]The Dale list of 3000 words was developed for giving a prediction of readability. It is composed of approximately 3000 words that are known by at least 80 percent of the children in Grade IV.

is designed to predict readability for grades four through twelve.

The New Flesch (6) formula is a revision of the older Flesch formula. Both the old and new formulas are designed to predict the difficulty of reading material in terms of the amount of education the average adult needs in order to read the material with comprehension. Flesch made the revision in order to divide the prediction into two parts and to simplify it for ease in figuring. In the new formula Flesch makes possible the prediction of reading ease and human interest. The prediction of reading ease depends on three factors: (1) sentence length, (2) number of syllables, and (3) number of words. The prediction of human interest depends on the number of personal references and the number of personal sentences.

Flesch divided the new formula into two separate predictions when it was found that the human interest element was weighted too heavily in the old formula. This difference in the predictions of the two formulas is well illustrated in this study. With the old formula the passages all rated as extremely difficult reading material suitable for college or graduate college readers. On the new formula they rated at the approximate level for which they were written. The question may be raised as to whether or not the human interest element is needed in children's reading material. Williams (34) may have furnished at least a partial answer to this question. She investigated children's

choices in the selection of science books. Her results indicate that children prefer that science material be written in a straightforward factual style. She summarizes her findings in this way:

> From their overt and verbal responses it is apparent that the children preferred books in which the material is presented in the direct manner as distinguished from the essay type approach. Most of the children preferred factual material to narratives. Most of the children ignored personification in a book. A few of them were angered by it (34, pp. 153-54).

Since William's work seemed to indicate that the personal touch may be omitted in children's reading material, the fact that the human interest element was kept at a minimum is probably not a serious factor. The human interest prediction in Table IV indicates that all passages for grades four through twelve, with the exception of the practice passage for grade four, were rated as dull. Though the Flesch formula is not applicable to material of second-grade difficulty, neither of the passages for that grade had any personal words or personal sentences. Vernon (32) has shown that eye-movements vary with variations in the interest value of material. The fact that the passages used in this investigation were uniform with reference to human interest avoids the introduction of this variable in the study.

Because eye-movement photographs were not made of the entire passage but only of the second card of 100 words, it was thought advisable to develop readability scores for each of the two paragraphs of each selection as well as for

TABLE IV

GRADE PLACEMENT OF PRACTICE AND TEST SELECTIONS[1]

Title	Grade	Paragraph	Formula Rating				
			Lorge	Yoakum	Dale and Chall	New Flesch Reading Ease	New Flesch Human Interest
Plants	II (P)	1	2.57	2.1			
		2	2.47	2.8			
		Total	2.52	2.43			
Woods and Trees	II (T)	1	2.46	2.25			
		2	2.32	2.00			
		Total	2.40	2.01			
Air	IV (P)	1	3.96	3.71	4.6	4th	Mild
		2	4.14	5.28	4.6	4th	Dull
		Total	3.93	5.28	4.6	4th	Mild
Controlling the Rivers	IV (T)	1	4.25	6.00	4.4	4th	Dull
		2	4.02	3.85	4.2	4th	Dull
		Total	4.07	4.92	4.3	4th	Dull
Soil	VI (P)	1	6.04	4.85	6.1	6th	Dull
		2	6.02	6.25	6.1	7th or 8th	Dull
		Total	5.79	5.92	6.1	6th	Dull
Light	VI (T)	1	6.25	6.0	6.2	6th	Dull
		2	6.00	6.0	6.1	6th	Dull
		Total	6.01	6.14	6.0	6th	Dull

[1]Copies of all practice and test passages may be found in Appendix C.

TABLE IV (Continued)

Title	Grade	Paragraph	Formula Rating				
			Lorge	Yoakum	Dale and Chall	New Flesch Reading Ease	New Flesch Human Interest
Sunspots	VIII (P)	1	7.94	8.22	8.0	Some high school	Dull
		2	8.03	8.11	8.3	7th or 8th	Dull
		Total	7.84	7.93	8.1	Some high school	Dull
Rayon	VIII (T)	1	7.70	8.33	8.2	7th or 8th	Dull
		2	8.07	8.44	8.2	7th or 8th	Dull
		Total	7.73	8.06	8.1	7th or 8th	Dull
Cancer	X (P)	1		10.11	10.0	Some high school	Mild
		2		10.00	10.2	Some high school	Dull
		Total		9.82	10.0	Some high school	Dull
Toadstools and Mushrooms	X (T)	1		10.0	10.1	Some high school	Dull
		2		10.27	10.1	Some high school	Dull
		Total		9.29	10.1	Some high school	Dull
Gravity	XII (P)	1		12.2	12.0	Some high school	Dull
		2		12.0	12.0	High school or some college	Dull
		Total		12.0	12.0	Some high school	Dull
The Weather Bureau	XII (T)	1		12.0	12.0	High school or some college	Dull
		2		12.33	12.0		Dull
		Total		11.55	12.0		Dull

the entire selection. The data in Table IV indicate that the test passage was in every case the passage that most nearly approached the grade level desired. Two of the four formulas were used for grade two; all four formulas were used for grades four, six, and eight; and three formulas were used for grades ten and twelve.

For many years Paterson and Tinker (15) have investigated the problem of typographical arrangement of material for optimum legibility. As a result of their research, Paterson and Tinker have established certain limits for optimum readability. These are:

Type face. Any modern type face is acceptable, among these being Garamond, Antique, Scotch Roman, Old Style, Caslon, and Cheltenham (15)(29).

Type form. Lower case type should be used except for proper nouns, beginnings of sentences, and so on. Bold face is preferred by readers (15).

Type size. The optimum type size is 11 point; 10 or 12 point is next best; and 8 or 14 point is acceptable (15)(18).

Width of line. For 10 or 11 point type, line width may range from 17 to 40 picas (14)(15)(16)(17).

Leading. 11 point type may be leaded 1 or 2 points (15).

Spatial relationships. Margin sizes are unimportant. Irregular left margins have no value (15).

Print color and paper. Black on white is most easily read. Readers prefer unglazed paper (15)(30).

The passages were printed within these limits. Passage

2a was set in Munder Venezian 14 point type on a twenty-five pica line. All other passages were set in Antique Bold 11 point type on a 13 point base, leaded two points on a twenty-five pica line. All passages were printed in black ink on white opaque unglazed bristol board paper. Passage 2a was set in larger type and with more leading because in preliminary trials with the passages it was found that the combination of a rather difficult passage and relatively fine printing was a greater handicap than most second-grade subjects could overcome.[1]

C. The Camera Procedure

At the present time, there are two methods in use for recording eye-movements in reading. These two are the corneal reflection technique and the electrical potential technique. According to Hoffman, Wellman, and Carmichael (9) the results obtained by the two methods are highly related. After comparing the advantages and disadvantages of the two methods, Tinker (28) concluded that the corneal reflection technique is the more satisfactory of the two for reading investigations. The corneal reflection or photographic method was used in the present study. Since the reliability and validity of eye-movement measures made by the photographic method seem to be well established, no further investigation of these factors has been made in this study.[2]

[1]Copies of all practice and test selections may be found in Appendix C.

[2]In a review of evidence Anderson and Morse (1) concluded the eye-movement measures are both reliable and valid under certain conditions.

The camera used was the Ophthalmograph.[1] The film, moving at the rate of one-half inch per second records the shifts of light which are caused by movements of the eye. It is necessary to have the complete cooperation of the subject if the picture is to be of any value. To be sure that the conditions for taking pictures with the Ophthalmograph would be the same for all subjects, a standard procedure was followed.

The writer called for the subject at his own room rather than have him come unescorted to the examining room. The walk from the classroom provided an opportunity to allay any fears the subject might have. In the examining room the first few minutes were spent in getting acquainted. This time was well spent for it seemed to do away with signs of nervousness better than any other method. With the younger children the time often stretched into many minutes. In every case the subject was informed that what he was doing had absolutely nothing to do with his school marks or his passing or failing. All were told that the results might possibly help teachers in teaching reading. The need for sitting absolutely still was emphasized several times. No subject was forced to have the pictures made.

Any subject who seemed extremely nervous was excused or the picture was not made. The subjects were instructed to read the cards as they would a story for a teacher. They were warned that they would be asked a few questions. All

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[1] A portable eye-movement camera manufactured by the American Optical Company, Southbridge, Massachusetts.

were assured that no one was expected to know the answers to all of the questions. In every case they were told that they would read a practice story first. Before reading the test passage, they were informed it was exactly like the practice passage. They were cautioned to read each card only once. Last of all, they were instructed to read silently. When necessary, the basic directions were reinforced between the practice passage and the test passage.

All subjects except those in the second grade read four passages, a practice and test passage for grade two and a practice and test passage for their own grade. The practice passage always preceded the test passage. To prevent a practice effect from contaminating the results, the passages were alternated so that half the boys and half the girls for each grade read the second-grade passage first while the remainder read the passage for their own grade first. After each selection the subject was tested for comprehension.

With the exception of the 2a passages all passages were approximately 200 words in length. They were printed on 3 x 5 cards, 100 words to a card. The 2a passages, which were used by the second grade only, were about 150 words in length with about 75 words on each card. The photographic record was made of the eye-movements of the subject reading the second card of the test passage. Table V contains the various specifications for that part of each card from which the individual eye-movement data were obtained. The various

TABLE V

LENGTH OF EACH TEST PASSAGE PHOTOGRAPHED[1]

Grade Level	Number of Words	Number of Lines	Number of Inches	Total Number of Ems
2a	66	7	35.88	149.9
2b	87	8	41	218.1
4	82	7	35.88	190.8
6	89	8	41	218.1
8	82	7	35.88	190.8
10	84	8	41	218.1
12	84	9	46.13	245.4

[1]These figures are exclusive of the first and last lines of the middle 100 words which were photographed but not used in the analysis of results. In working with eye-movement records, it is customary to leave out the first and last lines of the card. Research has shown that these lines are read atypically.

differences enable one to see how the use of ems as a unit of measure makes possible better comparisons.

Stone (21) and Seibert (20) reported on the problem of what portion of a passage should be photographed in order to obtain a representative sample of reading performance. They found that either the second or third 100 words are acceptable. The third 100 words are read slightly more efficiently than the second 100 words. On the basis of this evidence the photographs were made of the eye-movements of the subjects while they read the second 100 words.

Table V indicates the amount of material which entered into the record of the reading for each test passage. The amount of material in each case is sufficient to permit reliable group comparisons. Tinker (27) has demonstrated that as few as five or six lines of reading material are sufficient for group comparisons.

D. The Measures Obtained

Four measures were obtained directly from the film. The fifth measure, comprehension, was obtained by a comprehension test given immediately following completion of a passage. The four measures obtained from the film were (1) rate of reading in ems per minute, (2) number of fixations per em, (3) number of regressions per em, and

(4) number of refixations per line.[1] The em, introduced by Morse into eye-movement research, is a standard unit of measurement regardless of word length, size of type, or length of line. The em bases three of the measures upon a fixed visual traveling distance rather than upon the number of words read. Neither the number of lines nor the number of inches relates directly to the number of words. More difficult material takes more inches and more lines than simple material. Table V illustrates this fact. Although passage 2b has more words than passage 12, passage 12 has more lines, a larger number of inches, and the greater number of ems. The use of the em makes possible more accurate inter-passage comparisons.

E. The Comprehension Tests

The comprehension tests for both the practice and test passages were developed so that for each grade the relative difficulty of the questions was the same. To make tests of equal difficulty a standardization procedure was developed. About twenty questions were written for each passage. To eliminate those questions that were common knowledge the questions were administered to about thirty pupils in the grade for which the questions were designed. The performance of each pupil was tabulated to determine what questions

[1]Refixations are essentially inaccurate return sweeps, in which the subject undershoots the beginning of the line and must make an additional shift or two to the left before the beginning of the line is located. Refixations are distinguished from regressions. Regressions occur within the line after the individual has made his first forward shift.

the pupils could already answer. About twelve questions were left after the above elimination. In most cases not more than five pupils knew the correct answer to any one question. The questions were divided into two tests of six questions with three questions on each of the two cards of each selection. Each test was then tried out on a separate class of about thirty pupils. The pupils were asked to read the passage through once and then to turn their papers over. The questions were dictated to the pupils. The final test questions were selected on the basis of a tabulation of the results of these tests. All tests were designed for an average attainment of 50 percent. Wherever possible, the six questions were evenly distributed so that there would be three questions for each of the two cards. The group procedure described above did not prove successful in grade two. Therefore, the process was repeated with three other sections of second-grade pupils on an individual basis. The standardization for grade two was carried on in the Willow Run, Michigan Schools. For grades four, six, eight, and ten, children of the Romulus, Michigan Public Schools were used. The twelfth grade of the Wayne, Michigan High School was used for standardizing the two grade twelve passages. These communities are all quite close to Ypsilanti, and, in general, the populations are similar.[1]

Chapter III will include a discussion of the method of treating the experimental data in this study as well as a presentation of the results.

[1]The final comprehension tests for each grade are shown in Appendix D.

CHAPTER III

THE RESULTS

A. Treatment of the Data[1]

As stated before, the three purposes of this study were (1) to obtain growth curves for various eye-movement measures in silent reading, (2) to discover at what age growth in these measures tends to level off and ceases to be significant, and (3) to compare the growth curves for the easy and graded passages. This chapter presents the results which were obtained.

Before presenting the detailed findings, however, the statistical methods employed in treating the data should be described. The first operation involved computing the means for each measure on both passages for each grade group. These values were needed to construct the growth curves. F values and t values for the differences between the various mean scores were then computed. The F test was needed to determine whether the ratio of the variances of the samples being compared was significant or not. The t test was used to determine whether there were significant differences between the means of the groups on each passage as well as between the means of each group on the two passages.

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[1]The writer is indebted to Professor Paul S. Dwyer for the assistance he gave in the statistical treatment of the data obtained in this study.

The steps below describe the procedure employed in determining the F and t values for the eye-movement measures as well as for the comprehension tests. First, the individual scores were squared and summed. Second, the quantity A was computed for each group by the formula $A = N\Sigma X^2 - (\Sigma X)^2$ where N is the number of cases in each group. Third, the F was computed for various combinations of the grade groups. When the two groups being compared are composed of the same number of cases, the F value is computed from the formula $F = \frac{A_2}{A_1}$ in which A_2 is greater than A_1. Since in all cases N = 20, the degrees of freedom were the same in every comparison; in this case $n_1 = n_2 = N - 1 = 19$. Fourth, the t values were computed for the same combination of grade groups as the F values. The t value is computed with the formula, $t = \frac{(\Sigma X_1 - \Sigma X_2)\sqrt{N - 1}}{\sqrt{A_1 + A_2}}$. This particular formula was used because of the ease of computation since N, ΣX_1, and A_1 are easily computed. Since the groups being compared were equal in number of cases, the t formula from Kenny (11, p. 141), $t = \frac{(\bar{X}_1 - \bar{X}_2)\sqrt{N - 1}}{\sqrt{s_1^2 + s_2^2}}$, was applicable. The above formula becomes, by multiplying both numerator and denominator by N, $t = \frac{N(\bar{X}_1 - \bar{X}_2)\sqrt{N - 1}}{\sqrt{N^2(s_1^2 + s_2^2)}}$, which in turn becomes $t = \frac{(\Sigma X_1 - \Sigma X_2)\sqrt{N - 1}}{\sqrt{A_1 + A_2}}$ since $A_1 = N^2 s_1$ and $A_2 = N^2 s_2^2$.

Again, due to the fact that in each group there were twenty measures, the degrees of freedom were the same for every comparison; in this case DF = 2N - 2 = 38.

The calculations in Table VI are presented to illustrate the computational techniques and to show the method of interpreting the results. The upper half of Table VI contains the values for N, ΣX, and $\bar{X}$ of the ems per minute on the second-grade passage for the six groups measured. The lower half of Table VI contains in column two the difference between the means, $\bar{X}_2 - \bar{X}_1$; in columns three and five the t and F values obtained with the use of the formulas described above; and in columns four and six the probability values which are obtained from the tabulated t and F functions.[1] The probability listed in column four is the probability that in random samples of twenty cases from the same normal population the absolute value of the difference between the sample means is as great or greater than that observed. If the probability is .05 or less but greater than .01, the difference is said to be significant at the 5 percent level. A statement at the 5 percent level of significance is warranted, in general, 95 percent of the time. If the probability is .01 or less, the difference is said to be significant at the 1 percent level. This statement is warranted, in general, 99 percent of the time.

The probability listed in column six is the probability that in random samples of twenty cases from the same normal

[1]Tables for F and t values are available in many texts using small sample theory, for example, Goulden (7 , pp. 267, 269-272).

TABLE VI

SAMPLE TABULATION TABLES USED IN COMPUTING F AND t VALUES FOR EMS PER MINUTE FOR THE SECOND-GRADE PASSAGE

Grade	N	ΣX	X^2	A	$\overline{X}$
2	20	3,077	568,761	1,907,291	153.8
4	20	6,543	2,421,167	5,612,491	327.1
6	20	7,538	3,167,324	6,525,036	376.9
8	20	10,404	5,602,374	3,804,264	520.2
10	20	11,877	7,257,522	4,087,371	593.8
12	20	12,097	7,595,089	5,564,371	604.8

X_1 to X_2	X_2-X_1	t	Probability	F	Probability
2-4	3,466	5.520	P .01	2.943	P .05
4-6	995	1.245	P .10	1.163	P .10
6-8	2,866	3.887	P .01	1.715	P .10
8-10	1,473	2.286	P .05	1.074	P .10
10-12	220	.309	P .10	1.361	P .10
8-12	1,693	2.411	P .05	1.463	P .10

population the ratio of the variance of the sample having the larger variance to the variance of the sample having the smaller variance will be equal to or greater than that observed. The interpretation of the significance of the probability at the .05 and .01 levels is similar to that of column four which has been explained above.

Many investigators use the t test without using the F test. In using the t test, they assume that the ratio of variation of the groups compared is not significant or, in other words, that the two groups are from populations with equal variances. In a discussion of this matter, Fisher (5) indicates that a difference in variance may enhance the value of t. He points out that it might be possible that significant t values are not due to differences in the means but rather to differences in the variances. In other words, when the t test is being used as a test of whether two groups being compared may have been selected from the same parent population, no other tests need be applied. Fisher says, "The validity of the t test as a test of this hypothesis is therefore absolute and requires no assumption whatever" (5, p. 125). However, if the F value, the ratio of the variances of two groups, is significant, then the interpretation of a t test for the significance of the <u>means</u> is questionable since the groups being compared are not selected from the same parent population. In the present study the t test was used as a test to determine whether the means of the groups differed significantly. Therefore, the F test

was applied to determine whether the groups selected could have come from populations with equal variances.

B. Specific Findings

1. Growth Curves for Measures of the Eye-Movements in Reading

Growth curves were constructed for each eye-movement measure and for the comprehension scores for both the easy and the graded passages. The mean scores shown in Table VII and Table VIII were used to plot the points on the graphs. The second-grade group read only one passage; hence, the same mean values were used with this group to construct both curves. The reader should bear in mind that the discussion in this chapter is based upon a visual inspection of the curves. A discussion of the significance of the differences within and also between the two curves follows in the next two sections.

In order to discover whether the growth pattern for the various scores followed a straight line, the data for all measures were plotted on three types of graph paper. These were rectangular, semi-logarithmic, and logarithmic. None of the graphs fitted exactly such a straight-line pattern. The nearest approach to a straight line was found for the data on regressions per em plotted on semi-logarithmic paper. The use of rectangular paper revealed what appeared to be a parabolic type curve for the three measures--fixations per em, regressions per em, and ems per minute.

TABLE VII

MEAN EYE-MOVEMENT AND COMPREHENSION SCORES AND THE STANDARD DEVIATION OF THE DISTRIBUTIONS FOR ALL AGE-GRADE GROUPS ON THE EASY PASSAGE [1]

Measure	Grade					
	II	IV	VI	VIII	X	XII
Fixations per Em	1.311	.707	.599	.432	.417	.402
	.467	.221	.153	.071	.059	.082
Regressions per Em	.398	.169	.133	.073	.052	.051
	.215	.098	.073	.033	.016	.037
Rate in Ems per Minute	153.8	327.1	376.9	520.2	593.8	604.8
	69.05	118.45	127.72	97.52	101.80	117.94
Refixations per Line	1.485	1.272	1.090	.785	.829	.721
	.556	.621	.493	.336	.362	.338
Percent Comprehension	44.12	74.14	88.31	89.14	84.14	89.98
	24.32	24.43	11.92	11.92	13.42	14.35

[1] In Tables VII and VIII the upper figure in each set is the mean; the lower figure in each set is the standard deviation of the distribution.

TABLE VIII

MEAN EYE-MOVEMENT AND COMPREHENSION SCORES AND THE STANDARD DEVIATION OF THE DISTRIBUTIONS FOR ALL AGE-GRADE GROUPS ON THE GRADED PASSAGES

Measure	Grade					
	II	IV	VI	VIII	X	XII
Fixations per Em	1.311 6.467	.775 6.310	.613 6.154	.443 .094	.433 .067	.391 .084
Regressions per Em	.398 .215	.211 .145	.141 .063	.062 .034	.059 .028	.051 .043
Rate in Ems per Minute	153.8 69.05	311.1 135.63	364.5 89.98	513.6 99.13	537.3 102.77	596.0 121.56
Refixations per Line	1.485 .556	1.257 .620	1.116 .533	.900 .334	.822 .322	.877 .363
Percent Comprehension	44.12 24.32	51.63 21.65	50.80 31.83	49.97 30.49	52.46 21.26	61.63 29.40

a. Fixations per Em. Figure 1 presents the growth curves for fixations per em for both the second-grade passage and the graded passages. The pattern of growth for both curves is very similar although the mean values vary. A discussion of the differences between the two curves follows in a later section of the results. These curves indicate a period of rapid growth between grades two and four, a period of decelerated growth between grades four and eight, and then a definite leveling off after grade eight. There is virtually no difference between grades eight, ten, and twelve on either of the curves. According to this measure and these samples, growth has ceased by grade eight.

b. Regressions per Em. The growth curves for regressions per em are presented on Figure 2. The two curves again are alike in pattern although in this case also, the mean values vary. The curves follow much the same trend as the curves for fixation frequency. Rapid growth occurs between grades two and four. After grade ten there is no further growth at all on the easy passage and only a slight amount on the graded passage. Both curves meet at a common point for grade twelve.

c. Rate in Ems per Minute. Rate is a composite measure of eye-movements in reading and may be expected, therefore, to follow the same course of growth as regression and fixation frequency. Figure 3 shows this to be the case. There is fairly rapid increase in rate of reading between grades two and four. The rate of growth seems to decrease between

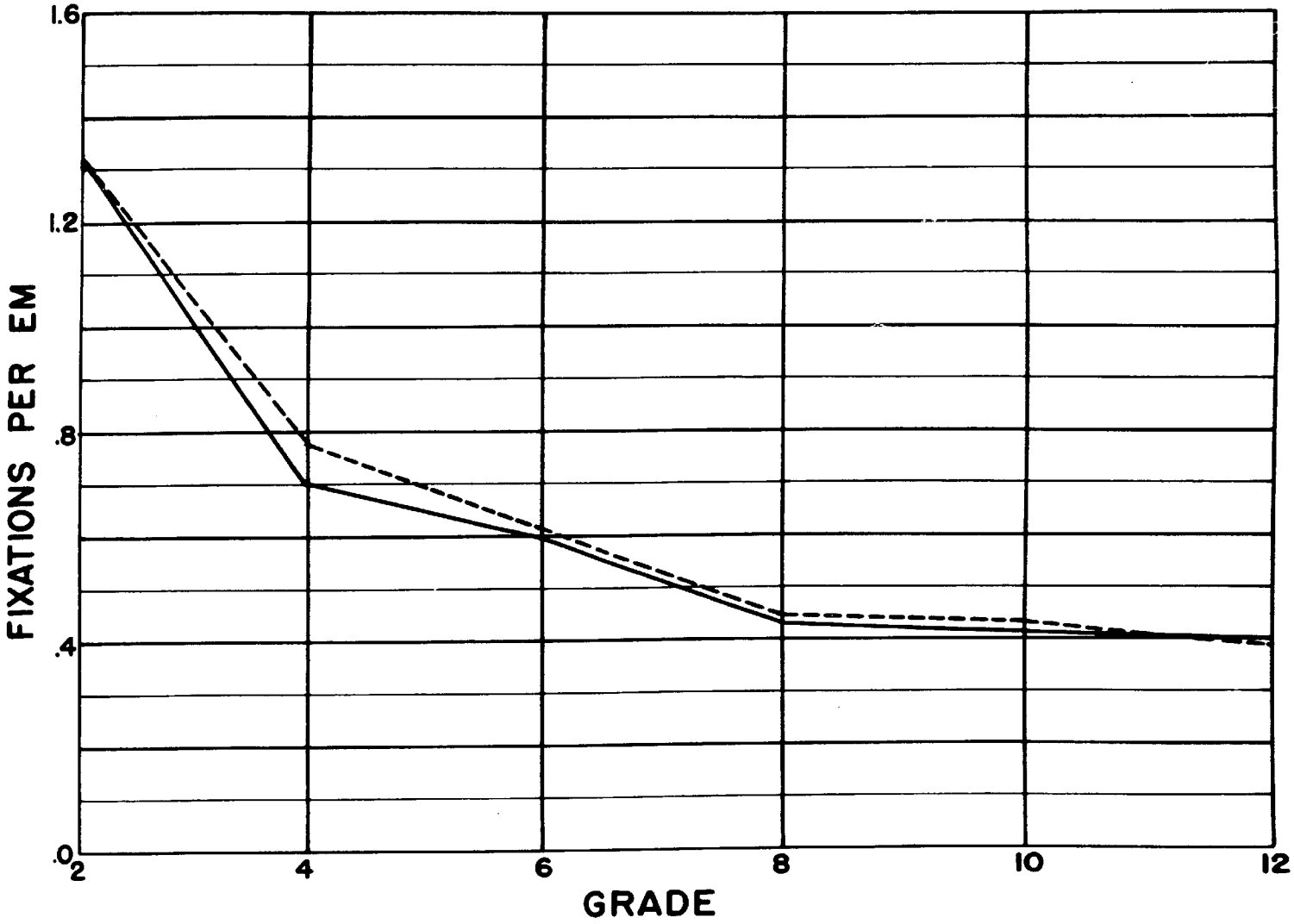


Fig. 1.--Growth curves for fixation frequency (solid line, easy passage; broken line, graded passages).

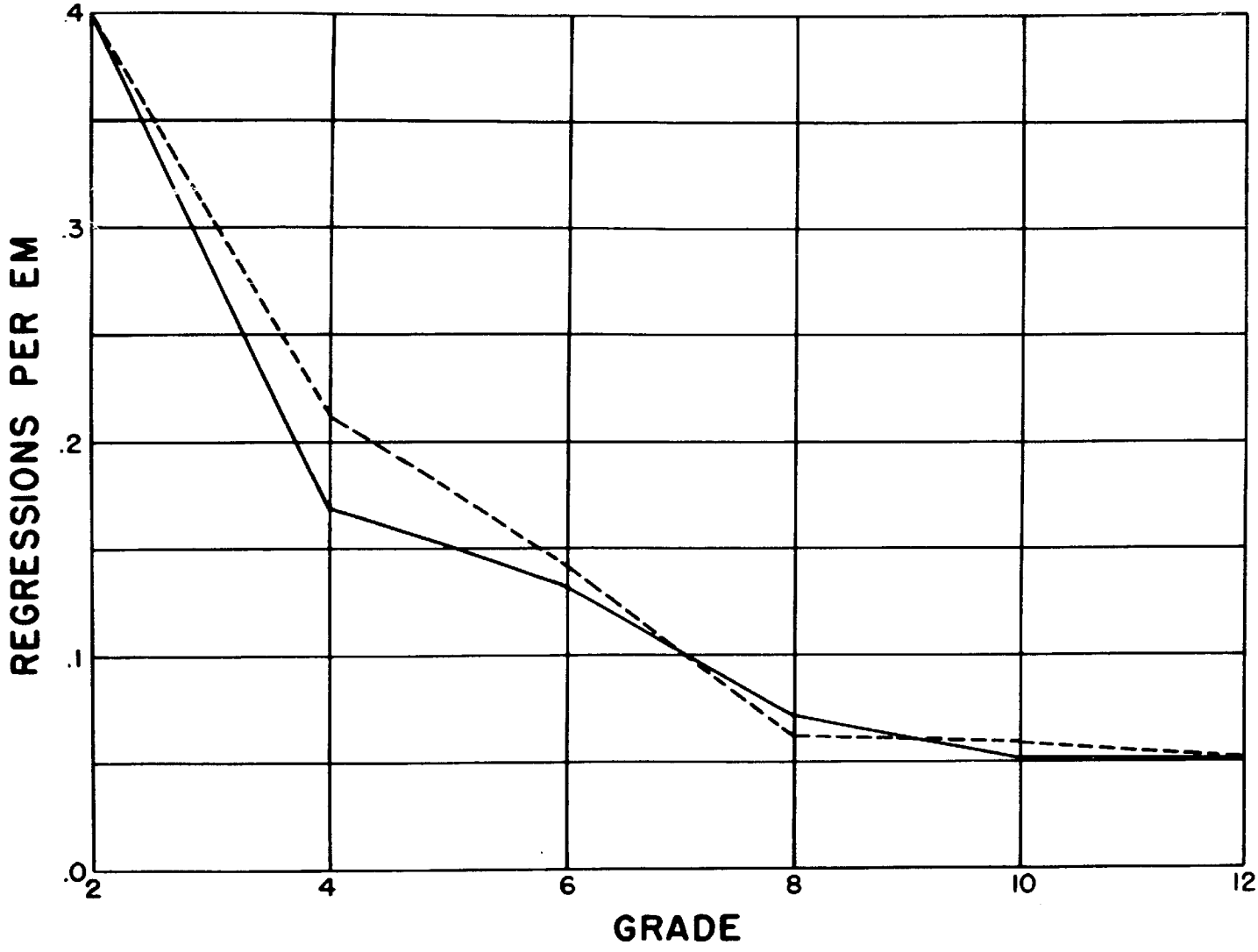


Fig. 2.--Growth curves for regression frequency (solid line, easy passage; broken line, graded passages).

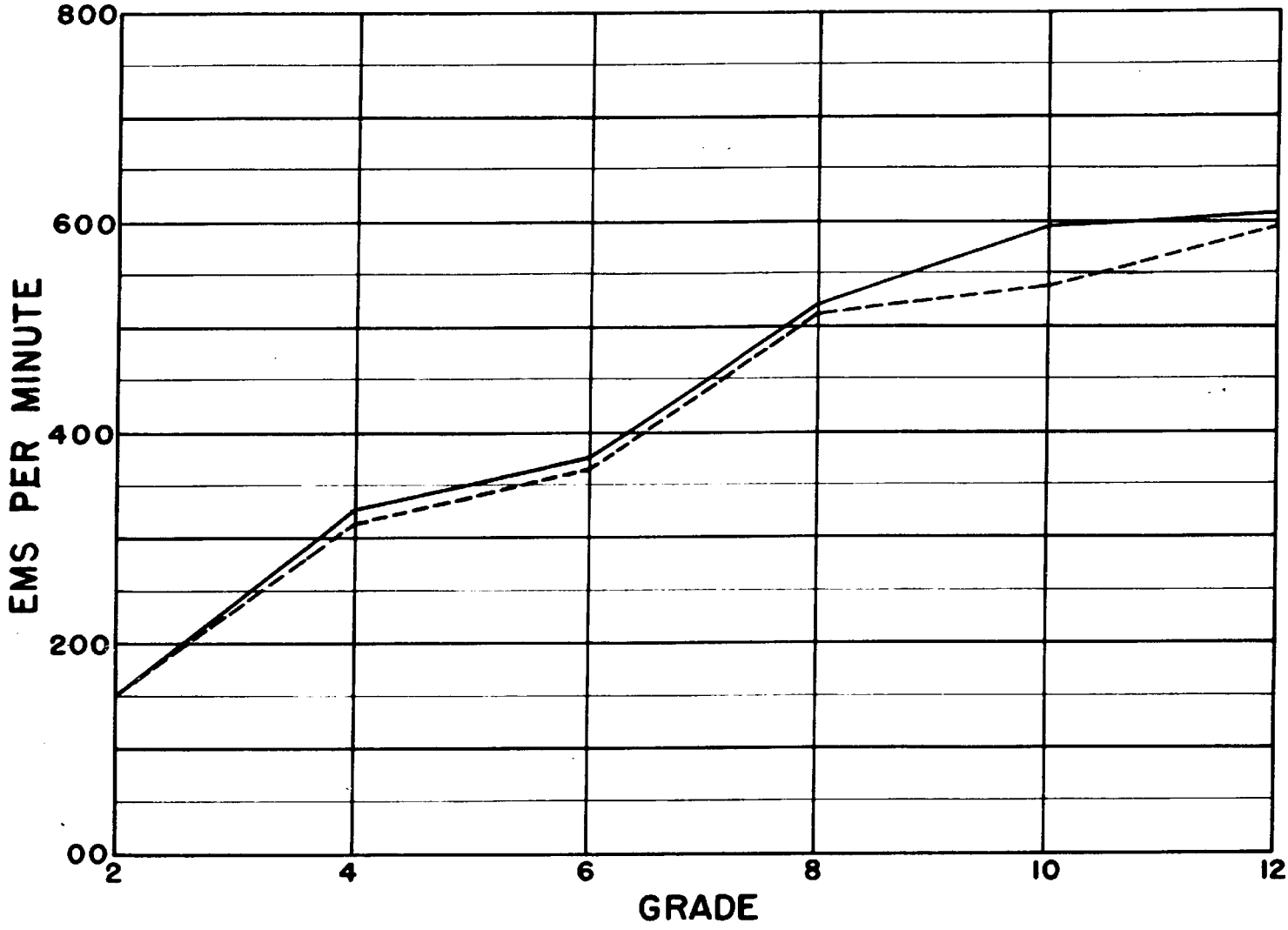


Fig. 3.--Growth curves for rate of reading in ems per minute (solid line, easy passage; broken line, graded passages).

grades four and six and then to increase between grades six and eight. The rate of change from the eighth to the tenth grades seems to be very much like that between the fourth and sixth grades, especially on the second-grade passage. The curve for the graded passages indicates a new spurt in rate of reading between the tenth and twelfth grades. The separation of the curves at grade ten seems inexplicable inasmuch as the pattern for both the easy and graded passages to that point has been much alike as shown by Figure 3, and the points are found to come together at grade twelve. In general, two cycles of growth in rate are shown by both curves. One cycle is shown between grades two and six; the other, between grades six and twelve.

d. Refixations per Line. Figure 4 presents the growth curves for refixations per line. Fairly steady growth is shown for both the easy and graded passages until grade eight. After grade eight the curves follow no uniform pattern although an average between the curves between grades eight and twelve would indicate a decided leveling off. The reason for the irregular relationship between the curves from grades eight to twelve is not apparent although it is probably due to errors in measurement.

In general, all of the eye-movement measures on both passages follow much the same pattern of growth. This pattern shows rapid growth early in the grades followed by a period of deceleration in growth and, finally, a definite leveling off of growth in the later grades. It is doubtful

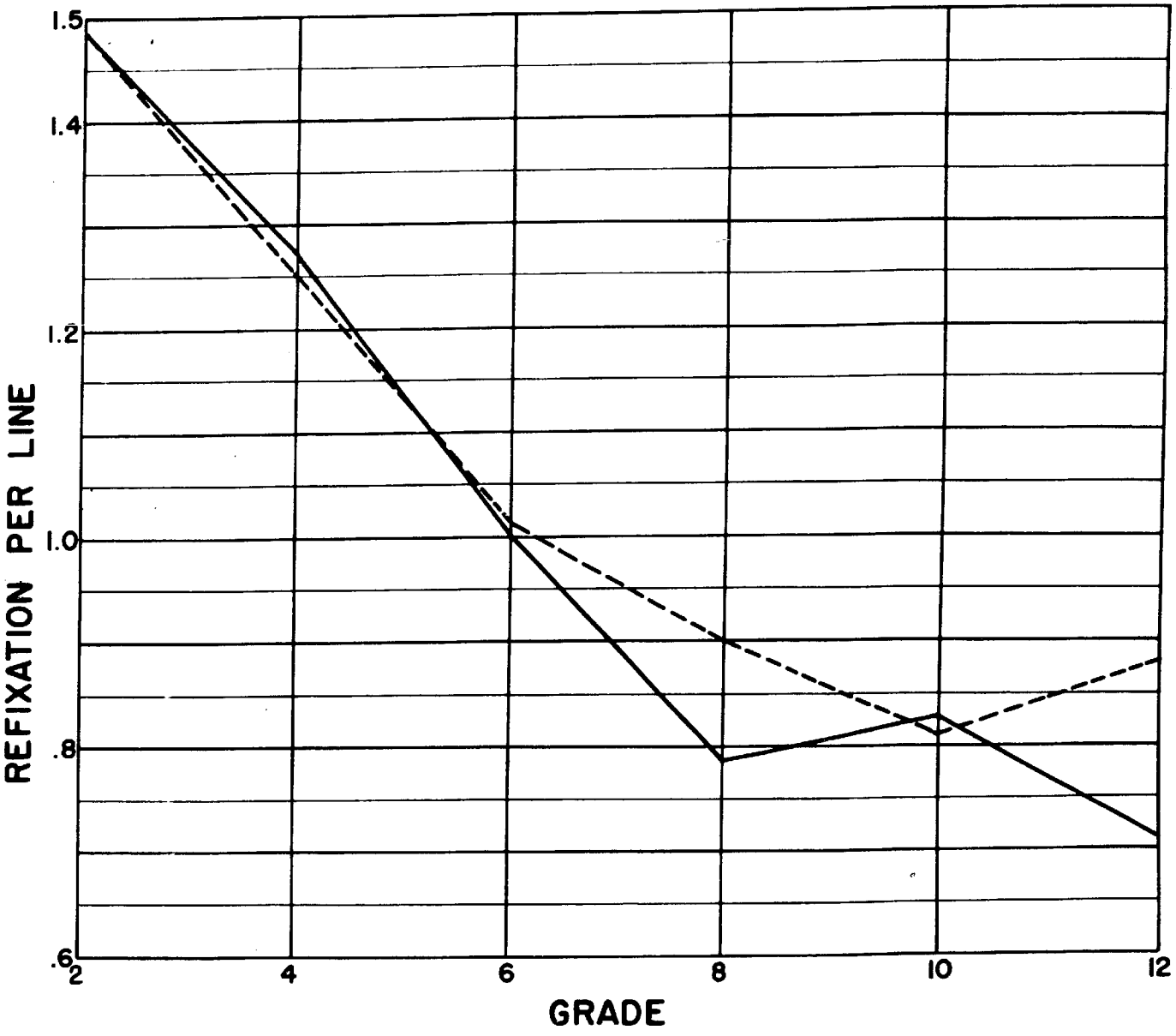


Fig. 4.--Growth curves for refixation frequency (solid line, easy passage; broken line, graded passages).

that important growth changes occur after the eighth or tenth grades. The failure of the curves to show much change after grade eight is shown on the sample eye-movement records exhibited on Figure 5. These records were selected in such a way as to represent the average performance of each grade on the graded passage. An obvious reduction in fixation and regression frequency is apparent until the eighth grade. After the eighth grade it is difficult to detect from the records any further improvement in reading efficiency. The rates of reading represented by these records are indicative of the general trend. These rates in ems per minute from grades two through twelve were 166, 301, 358, 514, 523, and 566. Translated into words per minute, these rates were 71, 129, 146, 221, 201, and 193. The value of the em as a unit of measure is very well illustrated by these figures. Due to the greater length of words in each succeeding passage, grades eight through twelve, it appears that students in grade twelve read at a slower rate than grade ten, and grade ten in turn read at a slower rate than grade eight.

e. Percent of Comprehension. The growth curves for the comprehension scores are shown on Figure 6. The design of the experiment itself accounts for some of the differences which occur in the pattern of the two curves. It should be remembered that the passages were carefully selected for difficulty. In addition, comprehension tests that would result in 50 percent comprehension by the pupils of that grade after they had read the passage through once were

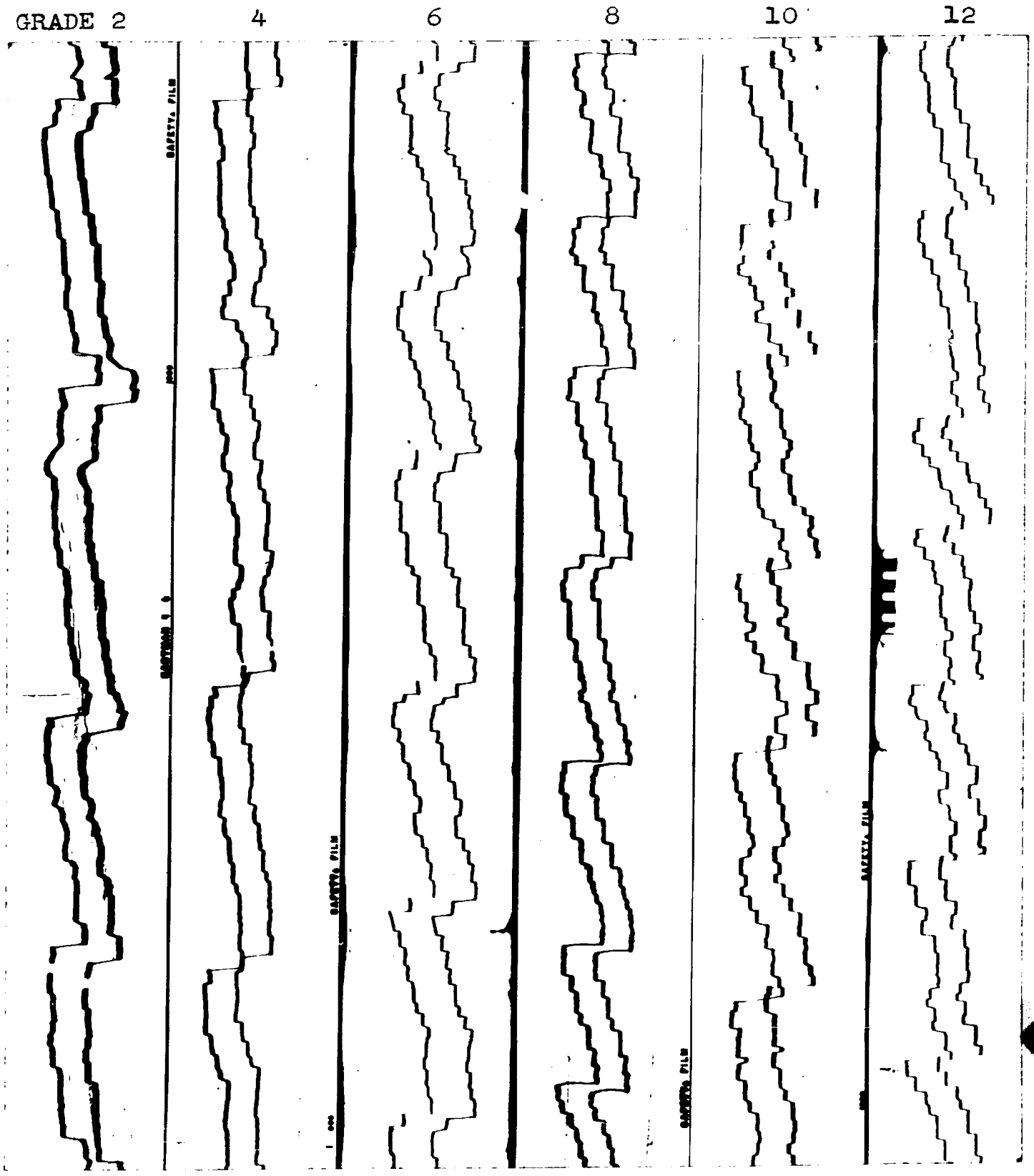


Fig. 5--Typical eye-movement records for grade groups on the graded passages.

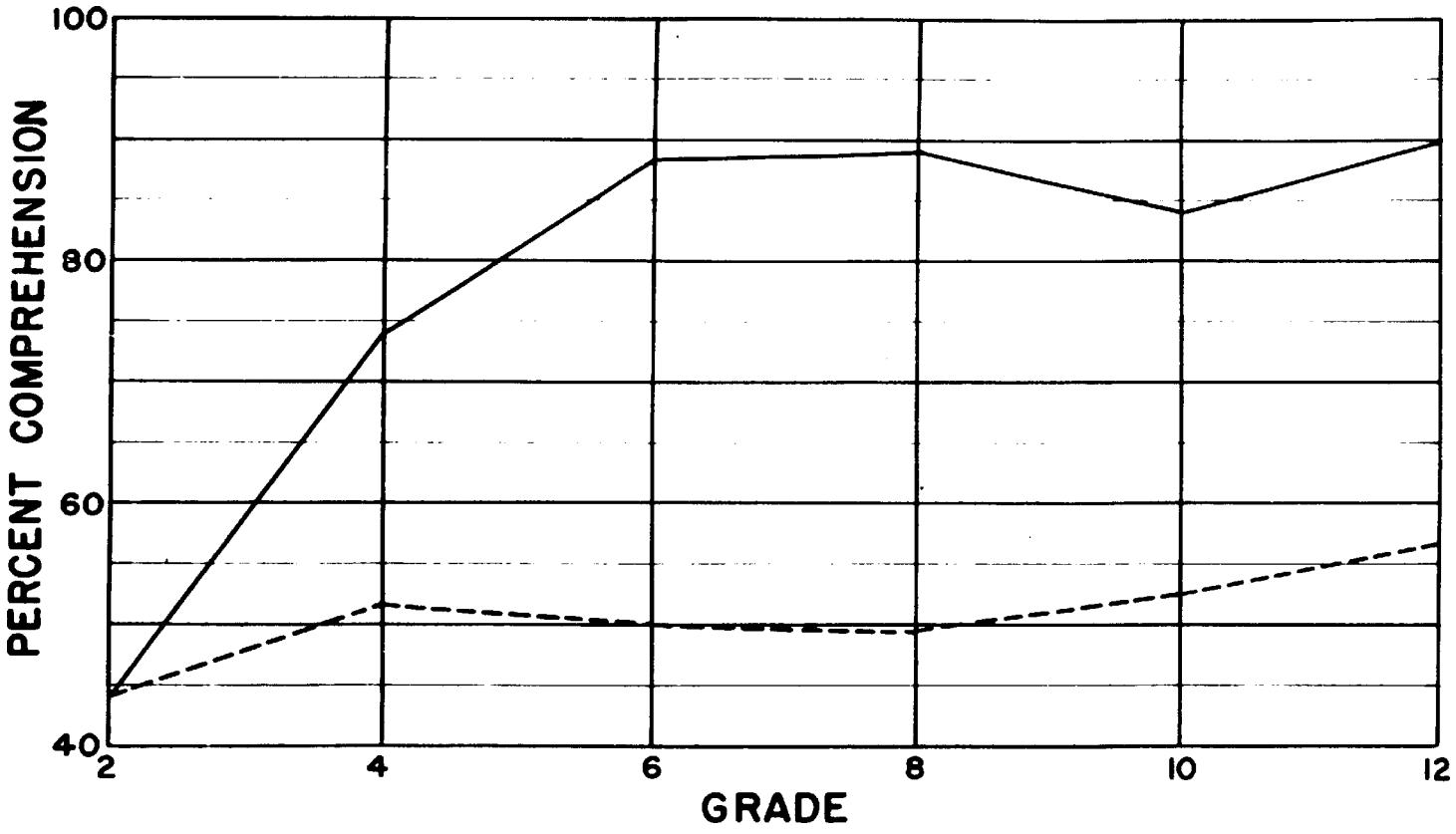


Fig. 6.--Growth curves for percent of comprehension (solid line, easy passage; broken line, graded passages).

designed for each passage. Theoretically, then, the curve for the graded passages should be a straight line at the 50 percent level. The curve for the graded passages shows that this condition was fairly well attained between grades four and ten. However, the second-grade children averaged slightly less than 50 percent comprehension on their passage while the twelfth-grade subjects averaged above the 50 percent comprehension level. In other words, there is a slight overall improvement or growth in comprehension from grades two through twelve.

On the second-grade passage one would expect that comprehension would improve from grade to grade. This is the result as the curve shows. There is rapid growth between grades two and four. Unlike the curves for the eye-movement measures, the fourth- to sixth-grade growth is only slightly less than that between the second and fourth grades. After the sixth grade there is no evidence of any further growth in comprehension of the second-grade passage. The average scores for the sixth, eighth, and twelfth grades are almost identical. For some unknown reason the average score for the tenth grade drops down somewhat.

2. Significance of the Change in Growth between Grades

In this section a statistical analysis of the trends revealed by the growth curves is presented. This analysis should serve to show the statistical significance of the growth changes portrayed on the graphs. As has been earlier explained, the significance of the change was determined by

means of the t test for the significance of the differences between the means. At the same time, a test for the F values was made.

F may be defined as the ratio of the variations of the groups. If the ratio of the variations of the groups was not significant, then the t test for significance of the difference between the means was a valid test in this study. The F values for the second-grade passage in Table IX reveal that the ratio of the variances is proved significant in only nine of twenty-six grade combinations. Of these nine, seven are significant at the 1 percent level, and two at the 5 percent level. There were no significant ratios revealed for variation in refixations per em and only one for rate in ems per minute.

The F values for the graded passages in Table X are even more favorable. Of the twenty-nine grade combinations, in only four was the ratio of variation proved significant at the 1 percent level, and in only eight was the ratio of variation proved significant at the 5 percent level. The above mentioned F values therefore would seem to indicate that the samples could have come from populations having equal variances.

It should be noted that none of the values on either Table IX or X is high. Even those that are significant at the 1 percent level or 5 percent level are just barely so. That the ratio of variation is significant is not surprising ir one considers what is actually being tested. It should

TABLE IX

RATIOS OF THE VARIANCES FOR VARIOUS COMBINATIONS OF THE GRADE GROUPS READING THE EASY PASSAGE

Measure	Degrees of Freedom	F							1 Per-cent	5 Per-cent
		II-IV	IV-VI	VI-VIII	VIII-X	X-XII	II-VI	VIII-XII		
Fixations per Em	19	4.455	2.088	4.618	1.438	1.889		1.314	3.03	2.17
Regressions per Em	19	4.833	1.781	4.866	4.012	6.961		1.238	3.03	2.17
Rate in Ems per Minute	19	2.943	1.163	1.715	1.074	1.361		1.463	3.03	2.17
Refixations per Line	19	1.247	1.588	2.147	1.163	1.143	1.274	1.330	3.03	2.17
Percent Comprehension	19	1.009	4.196	1.000	1.267	1.143		1.448	3.03	2.17

TABLE X

RATIOS OF THE VARIANCES FOR VARIOUS COMBINATIONS OF THE GRADE GROUPS READING THE GRADED PASSAGES

Measure	Degrees of Freedom	F									1 Per-cent	5 Per-cent
		II-IV	IV-VI	VI-VIII	VIII-X	X-XII	II-VI	IV-VIII	VI-X	VIII-XII		
Fixations per Em	19	2.276	4.042	2.666	1.975	1.569				1.259	3.03	2.17
Regressions per Em	19	2.188	5.273	3.429	1.435	2.286				1.593	3.03	2.17
Rate in Ems per Minute	19	3.858	2.271	1.214	1.075	1.399		1.872		1.504	3.03	2.17
Refixations per Line	19	1.242	1.349	2.541	1.080	1.275	1.087	3.429	2.745	1.181	3.03	2.17
Percent Comprehension	19	1.261	2.160	1.090	2.057	1.913				1.070	3.03	2.17

be remembered that the F test is a test of variation. That variation might be expected between grade groups is natural. Since maturity is the factor being measured, one would expect variation from grade to grade. The fact that the F values are not proved significant for many more grade combinations may be due to the fact that the sample for each group may not have been large enough.

The t values for the measures for various grade combinations are shown in Table XI for the second-grade passage and in Table XII for the graded passages. As in all other tables of significance, a single line under a figure denotes significance at the 5 percent level, and a double line under a figure denotes significance at the 1 percent level. T values are presented for all measures for the grade combinations II to IV, IV to VI, VI to VIII, VIII to X, X to XII, and VIII to XII. A few other t values are presented where inspection of the computation table could not make possible accurate prediction.

a. Fixations per Em. As would be expected from the curves for this measure, the difference between the means from grades two to four is significant on both passages. The significance is at the 1 percent level. The graphs have previously revealed that the period between grades four and six seems to be a period of slower growth. This observation is further supported by the statistical analysis which discloses that the difference between means for these grades is not proved significant on the second-grade passage and is

TABLE XI

T VALUES FOR DIFFERENCES BETWEEN MEAN SCORES OF EYE-MOVEMENT MEASURES FOR VARIOUS COMBINATIONS OF GRADES READING THE EASY PASSAGE

Measure	Degrees of Freedom	t							1 per-cent	5 per-cent
		II-IV	IV-VI	VI-VIII	VIII-X	X-XII	II-VI	VIII-XII		
Fixations per Em	38	6.410	1.724	4.332	.634	.668		1.165	2.713	2.025
Regressions per Em	38	4.315	1.298	3.229	.576	.135		1.987	2.713	2.025
Rate in Ems per Minute	38	5.520	1.245	3.887	2.286	.309		2.411	2.713	2.025
Refixations per Line	38	1.113	1.000	2.231	-.387	.882	2.315	.539	2.713	2.025
Percent Comprehension	38	3.796	2.271	.216	-1.215	1.331		.199	2.713	2.025

TABLE XII

T VALUES FOR DIFFERENCES BETWEEN MEAN SCORES OF EYE-MOVEMENT MEASURES FOR VARIOUS COMBINATIONS OF GRADES READING THE GRADED PASSAGES

Measure	Degrees of Freedom	t									1 Per-cent	5 Per-cent
		II-IV	IV-VI	VI-VIII	VIII-X	X-XII	II-VI	IV-VIII	VI-X	VIII-XII		
Fixations per Em	38	4.166	2.064	4.117	.376	1.101				1.799	2.713	2.025
Regressions per Em	38	3.148	1.900	4.814	.304	.658				.864	2.713	2.025
Rate in Ems per Minute	38	4.505	1.429	4.850	.723	1.609				2.258	2.713	2.025
Refixations per Line	38	1.198	.751	1.494	.727	-.494	2.088	2.359	2.052	.203	2.713	2.025
Percent Comprehension	38	1.020	-.094	-.082	.212	1.101				1.200	2.713	2.025

significant only at the 5 percent level on the graded passages. The fact that the difference between the means on fixation frequency for grades six and eight is significant at the 1 percent level on both passages indicates a spurt in rate of growth between these grades. This finding may also have been predicted from a visual inspection of the curves for fixation frequency. No further significant growth for this measure is indicated on either passage although all grade combinations reveal a t value in favor of the higher grade. This finding supports the earlier contention that growth for fixation frequency reaches a plateau by the eighth grade. Even the difference between the means for grades eight and twelve, a four year period, is not proved significant on either passage according to the criteria of significance used.

b. Regressions per Em. The t values for regressions per em shown in Tables XI and XII present much the same picture as the t values for fixations per em. As with fixation frequency, the difference between the means for grades two and four is significant at the 1 percent level on both passages. But between grades four and six the difference is not proved significant on either passage. The difference again becomes significant at the 1 percent level on both passages between grades six and eight. After the eighth grade there are no further significant differences between any grade combinations although the differences that do exist are uniformly in favor of the higher grade. The

statistical evidence for regressions is entirely compatible with the trends revealed by the growth curves for this measure. These curves show the rapid growth between grades two and four, the slower growth between grades four and six, the spurt between grades six and eight, and the leveling off after grade eight until almost no change after grade ten is evident.

c. Rate in Ems per Minute. The reader may recall that the growth curves for rate in ems per minute reveal two cycles of growth--one between grades two and six and another between grades six and twelve. The statistical data indicate a similar fluctuation. On the second-grade passage differences between the means at the 1 percent level occur for grades two and four and for grades six and eight. As in the case of regression and fixation frequency, the difference between the means for grades four and six is not proved significant. Unlike the results for regression and fixation frequency, which showed no significant differences after the eighth grade, the statistical data for rate of reading reveal significant differences between the means at the 5 percent level for grades eight and ten and grades eight and twelve. However, the difference between the means for grades ten and twelve is not proved significant. The t values for the graded passages are significant at the same level and for the same grade combinations as the second-grade passage except that, due to the unexplainable drop in rate of reading by grade ten on the graded passage, the difference between

grades eight and ten is not proved significant. It is doubtful that significant growth in rate of reading occurs on either passage after grade ten.

d. Refixations per Line. The results for refixations only approximate the trends shown for the other eye-movement measures. In general, there is steady growth to the eighth grade on both passages. Because of the inconsistencies which occur in the means after grade eight, it is difficult to interpret the statistical evidence after that point. For the first time, a negative factor appears. Though slight, nevertheless, the .387 between grades eight and ten is negative and favors grade eight. No significant growth is indicated for successive grades on the graded passages. By changing the grade interval to four years, though, significant growth is indicated all the way to the tenth grade. Significant differences in the means at the 5 percent level are indicated between grades two and four, four and eight, and six and ten. Since grade twelve read with more refixations than grade ten on the graded passages, the t value, though not proved significant at the 1 percent level or 5 percent level, is negative.

To summarize the results for the eye-movement measures: The t values for the three most important eye-movement measures--fixations per em, regressions per em, and rate in ems per minute--agree closely in general import. The data for these measures indicate a period of rapid growth between grades two and four followed by a period of much slower

change between grades four and six and then a new spurt in growth between grades six and eight. After grade eight there is a definite slowing down of growth for these measures although significant growth at the 5 percent level in rate of reading is noted between grades eight and ten on the easy passage and between grades eight and twelve on both passages. However, no growth is evident between grades ten and twelve on either passage. The statistical data and the trends revealed by the graphs reinforce each other in showing that significant growth in measures of the eye-movements continues at least until the eighth grade but probably not beyond the tenth grade. For all practical purposes, growth in these measures may be said to have ceased by the tenth grade.

e. Percent of Comprehension. As has been mentioned before, the results for comprehension must be considered in the light of the technique used to test comprehension. Theoretically, t values for the graded passages should be at or near zero for all grade combinations. No trend should be noticeable. Table XII reveals that this is almost the case. Of six grade combinations tested, two are negative and four are positive. The greatest positive values were between grades two and four and grades ten and twelve. This is to be expected due to the deviation from 50 percent comprehension by grades two and twelve. The t values for the second-grade passage in Table XI reveal that there is significant growth at the 1 percent level between grades two and four and at the 5 percent level between grades four and six.

After grade six the values are not proved significant at either the 1 percent level or 5 percent level. A negative value results between grades eight and ten. It is interesting how closely growth in comprehension and growth in the eye-movement measures parallel each other on the easy passages. This finding tends to emphasize the unity of the total reading process.

3. Significance of the Differences between the Growth Curve for the Easy Passage and the Growth Curve for the Graded Passages

An inspection of the graphical data reveals that the easy passage was read slightly more efficiently than the graded passage. The question now arises as to whether there are significant differences between the means for the passages. This is the last of the major questions which this investigation was designed to answer.

The F test was again applied to determine whether the two sets of data were drawn from populations with equal variances. The F values in Table XIII for the eye-movement measures show that of the twenty tests for significance of the variation only two are proved significant and these at only the 5 percent level. The F values for percent of comprehension are significant at the 1 percent level for grades six, eight, and twelve, and at the 5 percent level for grade ten. Since the passages were varied in difficulty, one might have expected the F values between the two passages

TABLE XIII

RATIOS OF THE VARIANCES OF THE EASY PASSAGE AND THE GRADED PASSAGES FOR GRADES FOUR THROUGH TWELVE

Measure	Degrees of Freedom	F					1 Percent	5 Percent
		IV	VI	VIII	X	XII		
Fixations per Em	19	1.957	1.012	1.751	1.275	1.059	3.03	2.17
Regressions per Em	19	2.209	1.340	1.059	2.959	1.361	3.03	2.17
Rate in Ems per Minute	19	1.311	1.715	1.033	1.034	1.062	3.03	2.17
Refixations per Line	19	1.004	1.172	1.009	1.259	1.138	3.03	2.17
Percent Comprehension	19	1.272	7.123	6.537	2.508	4.198	3.03	2.17

to be significant for all grades. It should be kept in mind that the comprehension tests were designed to have each class attain approximately 50 percent comprehension on the passage for that grade. On the other hand, all grades were given the test for the second-grade passage. On this comparatively easy test the higher grades made rather high scores as compared with their results on the graded passages.

In order to determine whether the differences between the two curves are significant at any one grade level, t values were found for each grade. Table XIV presents the t values for the differences between the means of the passages for each grade on each of the eye-movement measures and on the comprehension scores.

a. Fixations per Em. Table XIV reveals that there are no statistically reliable differences proved at any grade level between the measures for fixations per em. Although none of the values prove significant, efficiency for this measure favors the second-grade passage for grades four, six, eight, and ten. The highest values are for grades four and ten. The t value for grade twelve is negative; that is, efficiency favors the twelfth-grade passage rather than the second-grade passage.

b. Regressions per Em. As with fixations per em, in four of the five grades the t values obtained for regression frequency indicate that efficiency favors the reading of the second-grade passage. None of the values proves statistically significant. The t value for grade eight is

TABLE XIV

T VALUES FOR DIFFERENCES BETWEEN MEAN SCORES OF EYE-MOVEMENT MEASURES FOR EACH GRADE ON THE EASY AND GRADED PASSAGES

Measure	Degrees of Freedom	t					1 Percent	5 Percent
		IV	VI	VIII	X	XII		
Fixations per Em	38	.771	.290	.442	.753	-.408	2.713	2.025
Regressions per Em	38	1.032	.391	-1.015	.951	.050	2.713	2.025
Rate in Ems per Minute	38	.387	.346	.207	1.71	.362	2.713	2.025
Refixations per Line	38	-.076	.153	1.056	-.059	1.274	2.713	2.025
Percent Comprehension	38	3.006	4.8095	5.315	5.749	3.777	2.713	2.025

negative and indicates that the graded passage was read slightly more efficiently. This value is not proved statistically significant. The value most nearly approaching statistical significance is 1.032 in grade four in favor of the second-grade passage.

c. Rate in Ems per Minute. The t values for rate in ems per minute are all positive; that is, for every grade, efficiency favors the reading of the second-grade passage. None of the values proves statistically significant, and, except for grade ten, all values are quite small. The grade-ten value is considerably higher than the others. As has been stated earlier, just exactly what caused the grade-ten subjects to drop considerably lower in rate of reading on the graded passage is not known.

d. Refixations per Line. The t values for refixations per line seem to vary the most of the four eye-movement measures. The values for grades six, eight, and twelve are positive with efficiency favoring the second-grade passage. None of the values proves statistically significant. The highest value is 1.274 for grade twelve.

Although none of the t values for any of the eye-movement measures establishes significant differences between the results on the two passages, the t values quite consistently favor efficiency on the easy passage. Of twenty comparisons, sixteen favor the easy passage while only four favor the graded passages. Thus, the bulk of the evidence suggests that there may have been some over-all difference

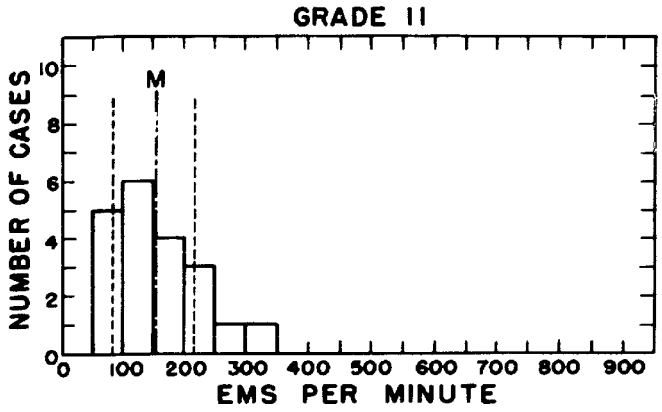
between the results for the passages in favor of the easier one. If so, the number of cases in each group was not large enough to reveal it.

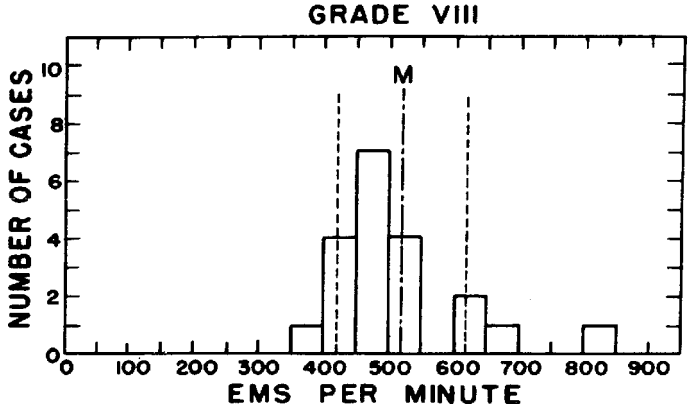
e. Percent of Comprehension. As was expected, the values for percent of comprehension are all positive and significant at the 1 percent level. For every grade, comprehension favors the second-grade passage.

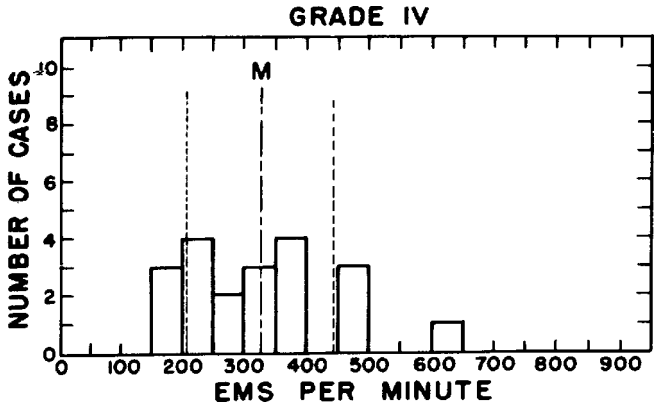
4. Individual Differences in Reading Performance within Each Group

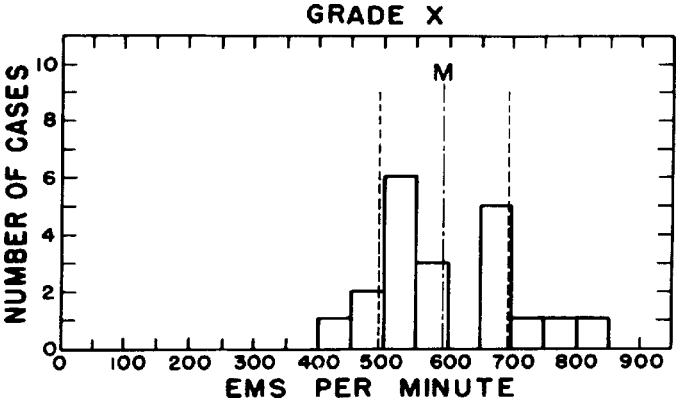
The results so far have been presented in terms of averages. Actually, there were wide individual differences on each of the five measures. Although this investigation was not primarily concerned with a study of these individual variations, it may, nevertheless, be of interest to show how wide the differences were. Results will be presented only for rate of reading. Since rate of reading is a composite measure of eye-movements, it can be assumed that the other eye-movement measures would show similar individual differences. It seems unnecessary, therefore, to present the results for all measures.

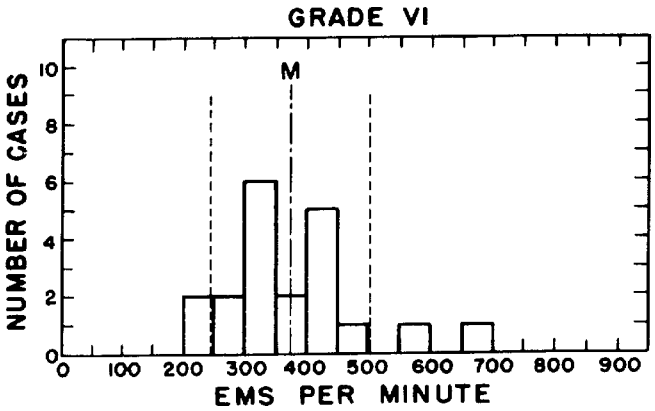
Figures 7 and 8 show the frequency distributions for rate in ems per minute for each grade-group on the second-grade passage and the graded passages, respectively. The center line marked with an M indicates the mean of the distribution on each figure. The fine dotted lines mark off one standard deviation. The histograms are laid out on the











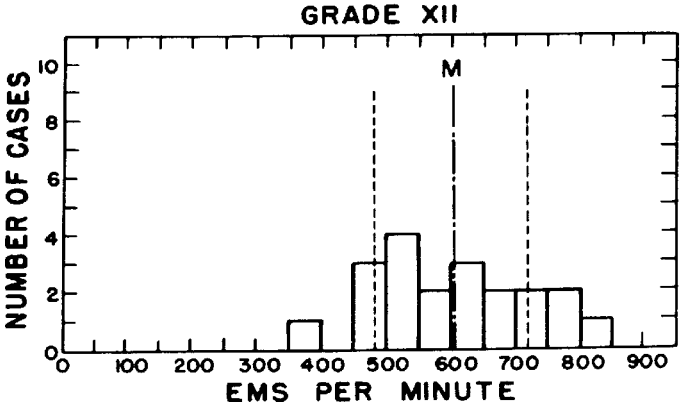
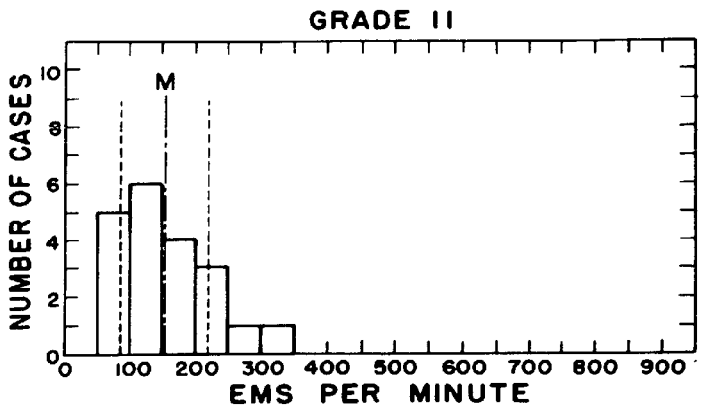
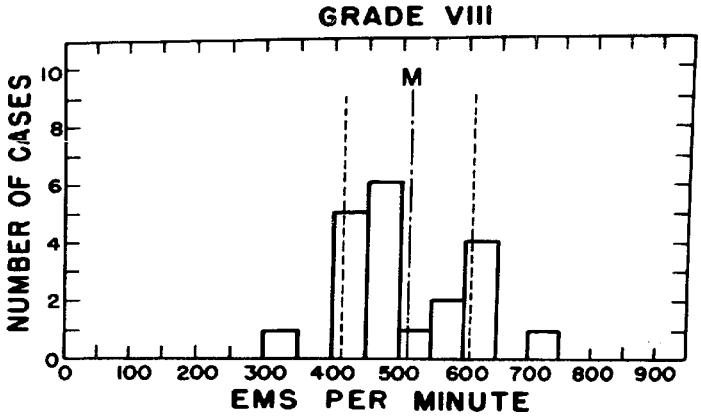
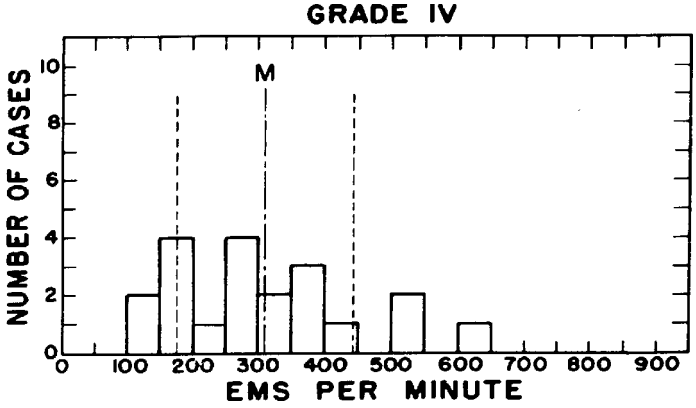
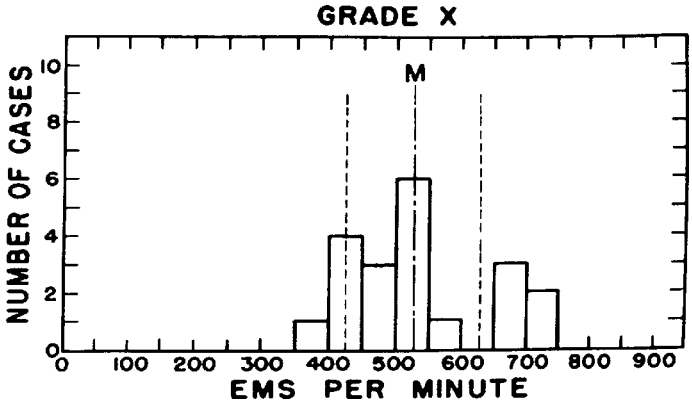


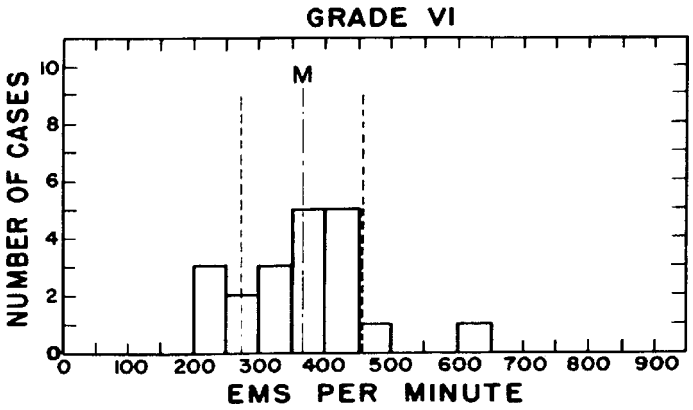
Fig. 7.--Frequency distributions for rate of reading ror each grade on the easy passage.











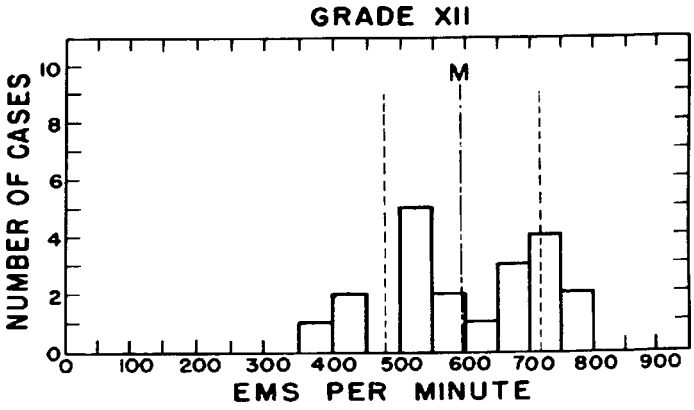


Fig. 8.--Frequency distributions for rate of reading for each grade on the graded passages.

page so that one may note the gradual moving of the means to the right. The histogram for grade two is the same in both figures. For both figures the outstanding feature is that the individual variation for every grade-group is large. The grade-groups overlap considerably. Even between grades two and twelve there is overlapping. One second-grade subject read as many ems per minute as one twelfth-grade subject read on either of the two passages. The closer the grades are to each other, the greater the overlapping. Both figures indicate that the intra-grade variations are far greater than the inter-grade variations.

CHAPTER IV

DISCUSSION OF THE RESULTS

Since the use of the easy passage in this experiment constituted in essence a repetition of Buswell's early study, a comparison of the present results with those of Buswell seems in order. The results of the two studies reveal similarities as well as differences. Buswell's growth curves tended to level off rapidly after the fourth grade. Some growth occurred after grade four, but it was nothing like the change shown to the fourth grade. The curves obtained in the present study are similar to Buswell's in that they also show rapid growth to the fourth grade and a slowing down of growth after grade four, but they are different from Buswell's in that they show a reacceleration between grades six and eight, and then a gradual leveling off.

Actually, there is closer agreement between the results of the two studies than appears from a visual inspection of the growth curves. This fact becomes apparent from a statistical analysis which the writer has made of Buswell's original data. This analysis consisted of computing t values for differences between mean eye-movement scores for various grade combinations as was done in the present study. Table XV contains the t values obtained from the Buswell data.

TABLE XV

T VALUES FOR DIFFERENCES BETWEEN MEAN EYE-MOVEMENT SCORES FOR VARIOUS GRADE COMBINATIONS IN BUSWELL'S STUDY

Measure	t										
	II-IV	IV-VI	VI-VII	VII-IX	IX-X	X-XII	IV-VII	IV-IX	IV-X	IV-XII	VI-XII
Average Number of Fixations per Line	3.47	1.04	.48	.16	1.40	-.23	1.03	1.30	2.57		
Average Duration of Fixations	4.89	3.40	-1.66	-.17	.02	.42				1.79	-1.10
Average Number of Regressive Movements	2.31	.22	.55	.60	1.24	.31		1.31	2.71	2.93	

Since Buswell did not include an eighth-grade group in his study, it was not possible to make comparisons from his data between grades six and eight or between grades eight and ten, but it was possible from his study to compare grades six and seven, seven and nine, and nine and ten. Thus, a comparison could still be made between the two studies over essentially the same age-grade range. Table XV indicates that in Buswell's study there was significant growth between grades two and four for fixation and regression frequency. The differences were at the 1 percent level of significance for fixation frequency and at the 5 percent level of significance for regression frequency. It should be noted that significant growth continued after the fourth grade, although only at the 5 percent level, for these same measures. This is shown by the significant figures in the comparison of grade four with grades ten and twelve. As for pause duration, which was the last of Buswell's measures, Table XV shows that significant growth at the 1 percent level continued until the sixth grade after which no significant values were obtained.

This statistical analysis throws new light on the results of Buswell's study. In the past, Buswell's results have been generally accepted to mean that growth in measures of the eye-movements in reading virtually ceases by the end of the fourth grade. Referring to Buswell's findings, Tinker, for example, has stated, "It would appear that eye-movement habits in silent reading have become fairly stable

by the end of the fourth grade" (25, p. 251). Such generalizations of Buswell's results seem misleading from the standpoint of the statistical analysis which is presented in Table XV.

In the present study, growth on the easy passage was plainly evident beyond the fourth grade. As Table XI shows, growth at the 1 percent level of significance was found for fixation and regression frequency and rate of reading through grade eight except for the period between grades four and six where no significant change was proved. In addition, growth at the 5 percent level of significance was found for rate of reading between grades eight and ten and grades eight and twelve.

It should be noted that the t values between consecutive grades after grade four did not reach significance on Buswell's study. Significant values were obtained only when widely separated grades were compared. In other words, the cumulative growth between grades became statistically significant with a large enough interval. Both Buswell's and the present study have shown growth beyond the fourth grade. There are differences revealed in the pattern of growth between the two studies, but, if wide enough intervals are used on Buswell's data, then both studies indicate that growth may continue as far as the tenth grade. It is extremely doubtful that, in the case of average groups, any change in growth would prove significant after grade ten.

The idea that eye-movements in reading become more or less fixed by the fourth grade does not seem reasonable on the face of it. The finding of this study that growth may continue until the tenth grade is much more in line with what is known about growth in general, notably mental growth. In developing the revised Stanford-Binet Test, for example, Terman and Merrill (23) found that mental growth begins to level off at approximately thirteen years, and by sixteen years the rate of change has become approximately zero. As a consequence, in determining the chronological age divisor for use in computing intelligence quotients at the higher ages, one month out of every three is dropped from the thirteenth year to the sixteenth year.

The leveling off of the growth curves at the higher levels in the present investigation matches almost perfectly the leveling off of mental growth in the upper grades. For example, the chronological age of the eighth-grade group in the present study was 165.7 months. Terman and Merrill start dropping one month in three at thirteen years of age or 156 months. It will be remembered that, for all practical purposes, growth in eye-movement efficiency had ceased by grade ten. The chronological age of the grade-ten group was 187.7 months. Terman and Merrill found that by age sixteen or 192 months, mental growth stopped. Numerous workers have found a close relationship between mental growth and growth in reading. The eye-movement scores used in this study may be regarded as measures of growth in reading. The finding

that the growth curves which were obtained for the eye-movement measures follow the course of mental growth as defined by Terman and Merrill is gratifying and adds a certain plausibility to the present study when contrasted with the results of earlier work.

As the reader may recall, the present study also involved an extension of Morse's study to higher and lower grades by using a graded passage for each grade. The object of this part of the study was to discover whether the use of graded passages would continue to show growth change in eye-movements above the point which Morse had tested. Morse found that there were significant differences in favor of seventh-grade subjects over fifth-grade subjects when each group read material for its own grade. The results in Table XII show that growth ceased to be significant at grade eight for fixation and regression frequency. A significant difference at the 5 percent level for rate of reading was revealed between grades eight and twelve. For all practical purposes, growth leveled off by the eighth grade. From grades ten to twelve there was practically no growth change.

Actually, Morse's study had nearly reached the grade limit at which significant growth ceases. It would seem, then, that the present study proves that significant growth in eye-movement efficiency does continue after the fourth grade and at least to the seventh grade, as Morse contends, but no further than grade eight or ten. This seems to be

true whether the subjects read a relatively easy passage or a passage for their own grade level.

Another question which arose from Morse's study related to possible differences in eye-movements between the easy and the graded passages. Since Morse found that fifth- and seventh-grade pupils do not differentiate in their eye-movements between materials of varied difficulty, it was not surprising to find that the subjects of the present study in grades two through eight did not differentiate between the two passages used. On the other hand, since Walker had found that good adult readers do differentiate their eye-movements on the basis of variation in difficulty of the material, the question arose as to whether such differentiation might not appear with the more mature subjects of the present study. No such differentiation appeared, though at all levels efficiency tended to favor the easier passage. The failure to obtain large differences between the two passages is probably to be attributed to the common factor of growth. Learning to differentiate between materials of varying difficulty appears to be a refinement which occurs at a later stage of development where growth no longer looms as a large factor.

The leveling off between grades four and six may be interestingly related to the pre-adolescent growth cycle. Child psychologists customarily distinguish between infancy, childhood, and adolescence. Infancy is a period of rapid growth, childhood is a period of slower growth, and

adolescence is another period of rapid growth. The leveling off between grades four and six in the present curves may be merely an indication of the last stages of late childhood when the children are getting ready to enter adolescence or a time of renewed and very rapid growth.

It is interesting that Buswell also found a leveling off at essentially the same place. Possibly workers in this field have mistaken the plateau as the end of growth in eye-movements when actually it is only a temporary slowing down.

A word should finally be said regarding the practical applications of the results of this study. It has been shown that growth in eye-movement measures in silent reading continues for a longer time than is commonly supposed. It follows that reading should continue to receive attention in the schools for a correspondingly long period. This does not mean that formal reading classes should be extended to higher levels, but it does mean that pupils should continue to receive stimulation until they have achieved their maximum growth in reading. The idea that every teacher should be a teacher of reading takes on added meaning in the light of the results of this study.

The results of this study have been presented largely in terms of averages. However, it was shown that, even with so-called average children, wide deviations from the average occur in eye-movements as measured by rate, which is a composite measure of eye-movements. With an unselect group of children, the variations may be even greater. It follows

that individuals grow at widely different rates. Thus, it becomes even more important that children receive help in reading for as long as growth continues. The large number of reading problems which surveys have revealed occur in the junior and senior high school may, in part, be due to the fact that such long term guidance has not been given.

CHAPTER V

SUMMARY AND CONCLUSIONS

A. Review of the Conditions of the Study

The present investigation has involved a study of age-grade changes in the eye-movements in the silent reading of 120 children selected from the Ypsilanti Public Schools. Eye-movement photographs were obtained for pupils from grades two, four, six, eight, ten, and twelve. Each subject read two selections before an eye-movement camera, a second-grade selection and a graded selection. The subjects were so-called average or typical children separated by two years in developmental level. The average chronological, mental, and reading ages of the groups were approximately two years apart.

An easy and a graded passage were used at each grade level. The second-grade passage was used as the easy passage for all grades. A somewhat shortened version of the second-grade passage was used with the second-grade pupils who had difficulty reading the small print of the original version. Each passage was equated for difficulty by means of one or more formulas designed for predicting readability. Formulas employed were the Lorge, Yoakum, Dale and Chall, and Flesch. All passages were semi-scientific

in nature. Each selection was about 200 words in length and was printed on two 3 X 5 cards of 100 words each. The typographical arrangement of the passages conformed to optimum standards for legibility. The Opthalmograph was used to record the eye-movements of each subject while reading the second 100 words of the test passage. Each test selection was preceded by the reading of a practice selection. Following the reading of each practice and test passage, the subjects were given a comprehension test of which they had been told in advance. The comprehension tests were standardized for comparable difficulty by trial tests on groups not included in this experiment. Each test consisted of six questions based on the text of the passage.

B. Summary of the Results

Four eye-movement measures were plotted from the films. These were (1) rate of reading in ems per minute, (2) number of fixations per em, (3) number of regressions per em, and (4) number of refixations per line. In addition, a comprehension score was obtained.

The statistical treatment of the individual data consisted first of computing the means on each measure for each group on both passages separately. These mean scores were used to plot growth curves for the various measures on the two passages. T values were computed to determine the significance of the differences between the mean scores for different grade-groups on the easy and graded passages as well as the difference between the inter-passage means for each grade-group. The problems of the study were

(1) to construct growth curves for the eye-movement measures in order to establish the pattern of growth, (2) to determine the significance of the change between various grade combinations and to discover at what grade level growth in eye-movement efficiency ceases, (3) to compare growth on the easy passage with that on the graded passages. A minor aspect of the investigation was a study of the individual differences in reading performance within grade groups.

The results may be summarized as follows:

(1) The growth curves for fixation and regression frequency and rate of reading revealed rapid growth from grades two to four, a leveling off between grades four and six, a reacceleration between grades six and eight, and, finally, a leveling off after grade eight with little growth evident after grade ten.

(2) Tests for significance of the change between grades substantiated almost wholly the over-all picture obtained from inspection of the growth curves. The differences between the means for fixation and regression frequency and rate of reading were significant at the 1 percent level between grades two and four and grades six and eight on both passages. In addition, a significant difference at the 5 percent level was found for rate of reading between grades eight and twelve on the graded passages. Significant differences were not proved for either passage between grades four and six or between grades ten and twelve for any of the above-mentioned measures.

(3) Refixation frequency followed the same general trends as the other eye-movement measures but at a much slower rate of change. For the easy passage significant differences at the 5 percent level were obtained between grades two and six and grades six and eight. For the graded passages the significance of the differences between the means was at the 5 percent level for grades two and six, grades four and eight, and grades six and ten.

(4) No significant differences were proved for the differences between the means of the two passages for any of the grade-groups on any of the eye-movement measures. However, sixteen of the twenty comparisons were in favor of the easy passage, a fact which suggests that there may have been a slight over-all difference.

(5) Growth in comprehension on the easy passage approximated the results for the eye-movement scores on this passage. T values significant at the 1 percent level were obtained for the difference between the means for grades two and four and at the 5 percent level for the difference between the means for grades four and six.

(6) Growth in comprehension on the graded passages remained at the 50 percent level except for the second-grade average which fell slightly below this figure and the twelfth-grade average which was somewhat above it. This finding more or less followed from the method used to standardize the comprehension tests on the graded passages.

(7) Wide individual differences in eye-movement behavior were found within each group on both passages as measured by rate of reading, which is a composite measure of eye-movements. Those individual differences were vastly greater than the average change from grade to grade.

C. Conclusions of the Investigation

From the specific findings of this study, the following conclusions may be drawn:

(1) Significant growth in eye-movement efficiency in silent reading continues to grade eight or ten.

(2) After grade eight or ten, growth in eye-movement efficiency definitely levels off and is no longer significant.

(3) The difficulty of the material does not significantly affect the pattern or rate of growth in measures of the eye-movements in reading.

APPENDIXES

APPENDIX A

SELECTION DATA FOR EACH GRADE

TABLE XVI

INDIVIDUAL RECORDS OF THE SEX, CHRONOLOGICAL AGE, MENTAL AGE, INTELLIGENCE QUOTIENT, READING AGE, READING QUOTIENT, AND READING GRADE FOR GRADE II

Subject	Sex	Chronological Age	Mental Age	Intelligence Quotient	Reading Age	Reading Quotient	Reading Grade
1	M	89	87	98	88	89	2.0
2	M	94	90	95	90	97	2.3
3	M	94	87	93	93	99	2.4
4	M	94	93	99	93	99	2.4
5	M	85	89	104	94	111	2.5
6	M	93	89	96	95	102	2.6
7	M	94	101	107	95	101	2.6
8	M	95	90	94	95	100	2.6
9	M	88	97	110	95	108	2.6
10	M	92	101	110	95	103	2.6
11	F	90	85	94	88	91	2.0
12	F	96	89	93	92	96	2.3
13	F	93	101	109	93	92	2.4
14	F	90	95	106	93	103	2.4
15	F	90	99	110	94	104	2.5
16	F	90	87	96	97	108	2.7
17	F	94	95	101	98	104	2.8
18	F	92	85	92	98	107	2.8
19	F	96	93	97	98	102	2.8
20	F	88	87	99	100	114	2.9

TABLE XVII

INDIVIDUAL RECORDS OF THE SEX, CHRONOLOGICAL AGE, MENTAL AGE, INTELLIGENCE QUOTIENT, READING AGE, READING QUOTIENT, AND READING GRADE FOR GRADE IV

Subject	Sex	Chronological Age	Mental Age	Intelligence Quotient	Reading Age	Reading Quotient	Reading Grade
1	M	113	104	92	117	103	4.3
2	M	121	123	102	117	96	4.3
3	M	114	123	108	119	104	4.5
4	M	115	109	95	119	103	4.5
5	M	117	118	101	123	104	4.8
6	M	128	115	90	113	89	4.0
7	M	117	120	103	118	101	4.4
8	M	113	115	101	119	105	4.5
9	M	112	121	108	119	106	4.5
10	M	108	107	99	125	115	4.9
11	F	111	110	99	115	104	4.2
12	F	118	117	99	119	101	4.5
13	F	110	121	110	120	109	4.6
14	F	118	106	90	122	103	4.7
15	F	111	121	109	124	112	4.8
16	F	111	100	90	114	102	4.1
17	F	112	105	93	118	105	4.4
18	F	115	125	109	119	103	4.5
19	F	119	109	92	121	102	4.6
20	F	115	124	108	125	109	4.9

TABLE XVIII

INDIVIDUAL RECORDS OF THE SEX, CHRONOLOGICAL AGE, MENTAL AGE, INTELLIGENCE QUOTIENT, READING AGE, READING QUOTIENT, AND READING GRADE FOR GRADE VI

Subject	Sex	Chronological Age	Mental Age	Intelligence Quotient	Reading Age	Reading Quotient	Reading Grade
1	M	135	133	99	139	102	6.0
2	M	135	139	103	143	106	6.3
3	M	134	145	108	143	107	6.3
4	M	138	141	102	145	105	6.5
5	M	142	134	95	148	104	6.7
6	M	141	148	105	140	99	6.1
7	M	141	127	90	143	103	6.3
8	M	142	129	91	145	102	6.5
9	M	140	144	103	147	105	6.6
10	M	142	153	108	151	106	6.9
11	F	125	128	102	140	112	6.1
12	F	136	149	108	144	106	6.4
13	F	134	143	107	145	108	6.5
14	F	134	134	100	145	108	6.5
15	F	140	127	91	148	106	6.7
16	F	143	138	97	139	97	6.0
17	F	138	136	99	143	104	6.3
18	F	140	133	95	144	103	6.4
19	F	137	124	91	145	106	6.5
20	F	142	137	97	145	102	6.5

TABLE XIX

INDIVIDUAL RECORDS OF THE SEX, CHRONOLOGICAL AGE, MENTAL AGE, INTELLIGENCE QUOTIENT, READING AGE, READING QUOTIENT, AND READING GRADE FOR GRADE VIII

Subject	Sex	Chronological Age	Mental Age	Intelligence Quotient	Reading Age	Reading Quotient	Reading Grade
1	M	168	173	103	180	107	9.7
2	M	167	170	102	177	105	9.4
3	M	163	163	100	154	94	7.2
4	M	164	180	110	175	106	9.2
5	M	169	152	90	157	93	7.5
6	M	163	185	114	172	105	8.9
7	M	165	168	102	170	103	8.8
8	M	165	156	95	162	98	8.0
9	M	174	187	108	180	103	9.7
10	M	177	192	109	182	102	9.9
11	F	163	166	102	174	106	9.1
12	F	157	160	102	167	106	8.5
13	F	156	171	110	167	107	8.5
14	F	168	156	93	169	100	8.7
15	F	166	161	97	170	102	8.8
16	F	163	149	92	162	99	8.0
17	F	168	156	93	166	98	8.4
18	F	169	162	96	170	100	8.8
19	F	170	175	103	174	102	9.1
20	F	165	156	95	175	106	9.2

TABLE XX

INDIVIDUAL RECORDS OF THE SEX, CHRONOLOGICAL AGE, MENTAL AGE, INTELLIGENCE QUOTIENT, READING AGE, READING QUOTIENT, AND READING GRADE FOR GRADE X

Subject	Sex	Chronological Age	Mental Age	Intelligence Quotient	Reading Age	Reading Quotient	Reading Grade
1	M	191	221	116	192	100	10.8
2	M	188	180	96	191	101	10.7
3	M	184	207	113	201	109	11.6
4	M	190	214	113	209	110	12.3
5	M	193	206	107	182	94	9.9
6	M	188	165	87	187	99	10.3
7	M	192	186	97	191	99	10.7
8	M	187	181	97	184	98	10.1
9	M	188	208	111	209	111	12.3
10	M	191	210	110	215	112	12.7
11	F	191	173	91	186	97	10.2
12	F	188	174	93	186	106	10.2
13	F	181	190	105	184	101	10.1
14	F	183	173	95	175	95	9.2
15	F	186	171	92	175	94	9.2
16	F	182	220	121	229	125	13.8
17	F	189	189	100	184	97	10.1
18	F	189	183	97	181	98	9.8
19	F	190	176	93	180	102	9.7
20	F	191	181	95	175	91	9.2

TABLE XXI

INDIVIDUAL RECORDS OF THE SEX, CHRONOLOGICAL AGE, MENTAL AGE, INTELLIGENCE QUOTIENT, READING AGE, READING QUOTIENT, AND READING GRADE FOR GRADE XII

Subject	Sex	Chronological Age	Mental Age	Intelligence Quotient	Reading Age	Reading Quotient	Reading Grade
1	M	215	182	95	210	109	12.4
2	M	216	211	110	209	109	12.3
3	M	208	211	110	208	108	12.4
4	M	215	230	120	224	117	13.4
5	M	216	186	97	191	99	10.7
6	M	214	207	108	219	114	13.1
7	M	211	230	120	218	113	12.9
8	M	210	226	118	212	110	12.5
9	M	211	184	96	208	108	12.2
10	M	210	203	106	201	105	11.6
11	F	208	201	105	228	119	13.7
12	F	210	199	104	219	114	13.0
13	F	215	215	112	197	103	11.2
14	F	217	199	104	193	100	10.9
15	F	215	178	93	199	104	11.4
16	F	212	199	104	219	114	13.0
17	F	207	211	110	208	108	12.2
18	F	212	178	93	202	105	11.7
19	F	209	188	98	200	104	11.5
20	F	215	193	101	198	103	11.3

APPENDIX B

INDIVIDUAL EYE-MOVEMENT DATA

TABLE XXII

INDIVIDUAL EYE-MOVEMENT DATA FOR GRADE II READING PASSAGE IIA

Subject	Rate in Ems per Minute	Fixations per Em	Regressions per Em	Refixations per Line	Percent Comprehension
1	128	1.09	.400	1.00	16.6
2	227	1.23	.353	.71	66.6
3	67	1.89	.653	2.00	16.6
4	132	1.06	.326	1.86	33.3
5	163	1.07	.320	.86	33.3
6	128	1.58	.466	2.57	66.6
7	162	1.00	.160	.71	50.0
8	104	1.91	.633	1.29	33.3
9	228	1.14	.300	1.14	100.0
10	99	1.66	.587	1.57	83.3
11	91	1.83	.573	2.14	50.0
12	67	2.38	.947	1.86	16.6
13	290	.66	.133	1.57	66.6
14	79	1.87	.700	.57	50.0
15	225	.86	.146	2.14	16.6
16	166	1.12	.266	1.86	16.6
17	107	.90	.260	1.00	16.6
18	314	.57	.133	1.86	33.3
19	130	1.36	.340	1.14	66.6
20	170	1.04	.266	1.86	50.0

TABLE XXIII

INDIVIDUAL EYE-MOVEMENT DATA FOR GRADE IV

Subject	Rate in Ems per Minute		Fixations per Em		Regressions per Em		Refixations per Line		Percent Comprehension	
	Passage II	Passage IV	Passage II	Passage IV	Passage II	Passage IV	Passage II	Passage IV	Passage II	Passage IV
1	224	151	.94	1.09	.270	.330	2.50	1.57	83.3	50.0
2	317	277	.66	.84	.146	.241	1.50	2.14	50.0	50.0
3	259	284	.90	.54	.238	.225	1.75	1.57	66.6	66.6
4	236	199	.73	.99	.256	.382	.75	.86	33.3	0.0
5	485	545	.42	.42	.041	.078	1.00	1.14	83.3	66.6
6	192	183	.99	1.03	.238	.246	.12	.86	100.0	50.0
7	609	627	.43	.42	.032	.020	1.00	.71	50.0	16.6
8	498	398	.43	.52	.077	.083	.87	.86	100.0	50.0
9	342	342	.56	.52	.096	.073	.62	.86	50.0	83.3
10	354	420	.59	.50	.114	.041	.87	1.14	50.0	16.6
11	233	173	1.02	1.11	.288	.382	1.62	1.29	83.3	50.0
12	385	363	.63	.62	.114	.125	1.62	1.14	16.6	50.0
13	480	503	.44	.38	.073	.068	1.75	1.86	100.0	33.3
14	192	143	.91	1.38	.256	.539	1.37	.43	100.0	66.6
15	363	277	.62	.87	.119	.204	1.75	1.86	83.3	66.6
16	211	230	.99	.92	.353	.293	1.00	1.14	100.0	66.6
17	271	301	.67	.68	.174	.193	1.25	1.29	100.0	66.6
18	161	122	1.11	1.44	.330	.461	2.62	3.15	83.3	83.3
19	335	388	.66	.58	.105	.062	1.12	.57	66.6	66.6
20	396	297	.45	.65	.064	.167	.37	.71	83.3	33.3

TABLE XXIV

INDIVIDUAL EYE-MOVEMENT DATA FOR GRADE VI

Subject	Rate in Ems per Minute		Fixations per Em		Regressions per Em		Refixations per Line		Percent Comprehension	
	Passage II	Passage VI	Passage II	Passage VI	Passage II	Passage VI	Passage II	Passage VI	Passage II	Passage VI
1	349	358	.54	.57	.045	.096	2.00	1.50	100.0	83.3
2	422	412	.60	.58	.155	.151	.87	.62	100.0	33.3
3	409	399	.48	.49	.064	.091	1.50	1.00	83.3	83.3
4	425	377	.50	.51	.100	.087	.62	.25	83.3	66.6
5	363	294	.58	.71	.132	.215	.62	1.37	100.0	83.3
6	208	246	.91	.85	.298	.229	.87	1.00	83.3	50.0
7	340	396	.48	.38	.132	.110	.87	1.37	66.6	16.6
8	321	331	.66	.66	.100	.155	1.75	1.00	83.3	50.0
9	498	422	.44	.47	.059	.059	.87	1.12	83.3	16.6
10	262	308	.78	.63	.187	.187	1.37	.87	100.0	83.3
11	569	485	.45	.49	.110	.096	.37	.75	83.3	16.6
12	308	311	.79	.72	.243	.142	1.25	2.12	100.0	66.6
13	436	396	.47	.49	.082	.110	.37	.62	100.0	66.6
14	422	415	.49	.55	.068	.105	1.25	.62	66.6	100.0
15	260	214	.86	.97	.265	.275	.87	.62	100.0	50.0
16	654	602	.33	.38	.009	.018	1.12	1.12	83.3	33.3
17	319	273	.61	.71	.187	.243	.50	.75	100.0	100.0
18	248	230	.78	.87	.142	.174	1.50	2.25	100.0	16.6
19	385	409	.68	.60	.165	.128	1.12	1.25	83.3	0.0
20	340	412	.55	.64	.114	.160	2.12	2.12	66.6	0.0

TABLE XXV

INDIVIDUAL EYE-MOVEMENT DATA FOR GRADE VIII

Subject	Rate in Ems per Minute		Fixations per Em		Regressions per Em		Refixations per Line		Percent Comprehension	
	Passage II	Passage VIII	Passage II	Passage VIII	Passage II	Passage VIII	Passage II	Passage VIII	Passage II	Passage VIII
1	545	458	.47	.61	.073	.120	1.00	1.43	100.0	66.6
2	489	440	.49	.54	.045	.068	1.50	1.00	100.0	50.0
3	415	477	.49	.39	.132	.047	.50	.86	100.0	83.3
4	609	472	.34	.47	.041	.041	.62	1.57	83.3	50.0
5	471	514	.42	.36	.068	.026	1.37	1.00	83.3	16.6
6	545	572	.38	.40	.077	.062	.62	1.00	100.0	50.0
7	494	449	.44	.51	.059	.078	.87	.43	83.3	50.0
8	805	738	.27	.29	.045	.010	1.00	1.14	83.3	50.0
9	447	572	.50	.38	.151	.094	.37	.71	100.0	66.6
10	698	619	.34	.37	.082	.068	.50	.71	83.3	33.3
11	485	498	.49	.47	.082	.062	1.25	1.14	83.3	50.0
12	476	645	.49	.42	.064	.052	.75	.86	100.0	100.0
13	447	440	.39	.41	.018	.026	.62	.43	100.0	16.6
14	451	472	.41	.39	.082	.036	.87	.71	83.3	50.0
15	432	322	.49	.61	.041	.104	1.00	1.14	66.6	33.3
16	534	487	.38	.40	.068	.073	.62	.43	83.3	33.3
17	494	416	.55	.61	.091	.089	.62	.86	100.0	33.3
18	545	636	.40	.35	.064	.020	.12	.29	66.6	16.6
19	623	636	.36	.34	.045	.026	.50	1.00	83.3	83.3
20	399	409	.52	.54	.137	.141	1.00	1.29	100.0	66.6

TABLE XXVI

INDIVIDUAL EYE-MOVEMENT DATA FOR GRADE X

Subject	Rate in Ems per Minute		Fixations per Em		Regressions per Em		Refixations per Line		Percent Comprehension	
	Passage II	Passage X	Passage II	Passage X	Passage II	Passage X	Passage II	Passage X	Passage II	Passage X
1	513	498	.41	.41	.045	.059	.75	.50	83.3	16.6
2	569	523	.44	.44	.050	.055	1.00	.87	83.3	66.6
3	654	717	.44	.40	.036	.041	.62	.75	83.3	66.6
4	534	595	.47	.45	.073	.100	.75	.75	83.3	50.0
5	436	440	.50	.49	.064	.073	.62	1.25	83.3	66.6
6	698	654	.42	.42	.055	.032	.87	.87	83.3	33.3
7	498	444	.45	.48	.050	.050	1.50	1.37	83.3	50.0
8	503	513	.42	.41	.050	.055	.50	.37	66.6	50.0
9	818	671	.32	.37	.073	.055	.37	1.00	100.0	66.6
10	588	513	.45	.47	.041	.036	.75	1.00	83.3	66.6
11	513	436	.52	.57	.055	.119	1.37	.87	100.0	16.6
12	485	391	.52	.58	.064	.123	1.62	1.12	83.3	16.6
13	680	518	.33	.38	.013	.032	.87	1.12	66.6	50.0
14	727	689	.33	.34	.036	.032	.75	.87	66.6	33.3
15	654	523	.36	.45	.041	.073	.25	.50	100.0	83.3
16	748	748	.37	.31	.045	.018	1.00	.50	83.3	66.6
17	545	436	.44	.50	.064	.087	.62	.87	100.0	83.3
18	503	455	.43	.41	.091	.041	.37	.25	100.0	50.0
19	557	459	.38	.41	.055	.064	1.25	1.25	50.0	83.3
20	654	523	.35	.37	.036	.036	.75	.37	100.0	33.3

TABLE XXVII

INDIVIDUAL EYE-MOVEMENT DATA FOR GRADE XII

Subject	Rate in Ems per Minute		Fixations per Em		Regressions per Em		Refixations per Line		Percent Comprehension	
	Passage II	Passage XII	Passage II	Passage XII	Passage II	Passage XII	Passage II	Passage XII	Passage II	Passage XII
1	638	718	.40	.36	.041	.016	1.12	1.22	100.0	83.3
2	602	710	.46	.37	.110	.061	.75	.78	66.6	83.3
3	638	765	.36	.29	.009	.016	.87	.55	50.0	33.3
4	463	508	.44	.40	.077	.077	.87	1.11	100.0	83.3
5	523	613	.47	.39	.018	.012	1.12	1.11	100.0	100.0
6	770	745	.30	.31	.004	.020	.87	.67	100.0	66.6
7	545	561	.44	.37	.032	.044	.75	1.11	83.3	33.3
8	494	508	.43	.48	.082	.110	.87	1.22	100.0	66.6
9	393	355	.57	.52	.091	.110	1.37	1.44	66.6	100.0
10	689	508	.32	.37	.000	.008	.00	.89	83.3	16.6
11	759	662	.36	.38	.045	.040	.37	.67	83.3	100.0
12	748	736	.30	.29	.013	.012	.37	.55	83.3	33.3
13	727	755	.27	.25	.027	.012	.12	.33	100.0	66.6
14	563	526	.44	.49	.077	.110	.62	.44	100.0	83.3
15	503	566	.53	.42	.123	.061	1.37	.89	100.0	100.0
16	503	415	.51	.61	.091	.162	1.00	1.67	100.0	50.0
17	476	412	.40	.43	.036	.016	1.00	1.11	100.0	16.6
18	831	669	.28	.32	.009	.008	.25	.78	83.3	66.6
19	569	654	.38	.35	.082	.057	.37	.78	100.0	16.6
20	663	535	.38	.42	.045	.073	.37	.22	100.0	33.3

APPENDIX C

COPIES OF PRACTICE AND TEST PASSAGES

GRADE IIA PRACTICE PASSAGE[1]

Plants can grow outside and inside. Boxes or cans are good to use inside to grow plants. Plants need water. Do not water them too much. Plants can get too much water. Almost all plants need light. Some plants need bright sun. Other plants live better where it is not so bright. Some plants grow in the woods. It is not very light there. Some plants must have much sun.

Sometimes plants get sick. Dark places may make them sick. The floor may be too dark. Some times people forget to water plants. When people go away they often forget to water their plants. If plants have no water or light they may die. This is how to know a plant is sick. Sick plants are not very green. They have very few leaves. They are almost white. Often sick plants can live. They often die too.

[1]For grade two subjects only.

GRADE IIA TEST PASSAGE[1]

The woods is a nice place to go. It is cool there. The fall colors are pretty to see. We can see pretty flowers there. We can hear the birds sing. We can see the little animals. It is fun to eat there. It is fun to play there. Woods are very quiet. Young trees grow there. Old trees grow there too. It takes many years until a little tree becomes big. Some day little trees will be big.

The woods have many trees. Trees that grow close together grow tall and thin. They are trying to reach the light. Trees help us. Wood is used to build houses. Wood is used to build chairs and tables too. Wood is good to burn. It can keep houses warm. It can be used to cook food. Some farmers cut all their trees down. Then they have more farm land. But good farmers keep some trees.

[1]For grade two subjects only.

GRADE IIB PRACTICE PASSAGE[1]

Plants can grow outside. They also can grow inside. Boxes or cans are good to use inside to grow plants. Many plants can grow inside. Plants need water. You must not water them too much. Too much water makes the air leave the earth. The ground needs air to grow plants. Plants can get too much water. Almost all plants need light. Some plants need bright sun. Other plants live better where it is not so bright. Some plants grow in the woods. It is not very light there. Some plants must have much sun.

Sometimes plants get sick. Dark places may make them sick. The floor may be too dark. They will not get enough light there. Sometimes people forget to water plants. When people go away they often forget to water their plants. If plants have no water or light they may die. They often do die. Sick plants can be helped. This is how to know a plant is sick. Sick plants are not very green. They have very few leaves. They are almost white. Plants get sick when they are not cared for. Often sick plants can live. They often die too.

[1]For subjects in grades 4, 6, 8, 10, and 12.

GRADE IIB TEST PASSAGE[1]

The woods is a nice place to go. It is fun to visit the woods. It is cool there. The fall colors are pretty to see. We can see pretty flowers there. We can hear the birds sing. We can see the little animals. It is fun to eat there. It is fun to play there. Woods are very quiet. Young trees grow there. Old trees grow there too. Some day the little trees will be big. It takes many years until a little tree becomes big. Some little trees are very small. Some day little trees will be tall and big around.

The woods have many trees. Different kinds grow there. Some grow fast. Some grow slow. Trees that grow close together grow tall and thin. They are trying to reach the light. Trees help us. They help city people. They help farm people too. Wood is used to build houses. Wood is used to build chairs and tables too. Wood is used to make many other things. Wood is good to burn. It can keep houses warm. It can be used to cook food. Some farmers cut all their trees down. Then they have more farm land. But good farmers keep some trees.

[1]For subjects in grades 4, 6, 8, 10 and 12.

GRADE IV PRACTICE PASSAGE

Air is not just one gas. It is several gases mixed together. About one-fifth of the air is oxygen. This is the only part of the air we use in our bodies. We breathe in all the gases of the air. We use only the oxygen part of the air in our bodies. The rest of the gases we just breathe out again. Fire uses the oxygen in the air when it burns. You can watch a burning candle use up oxygen. Light a short candle. Put it in a low candleholder. Place a large drinking glass over it.

The candle burns lower and lower and finally goes out. It does not go out until much of the oxygen in the glass is used. Besides oxygen, air has in it nitrogen and very small amounts of other gases. Suppose you make believe that an apple is air. Cut about one-fifth of it away. This part stands for the oxygen part of the air. Cut off the very thinnest piece you can. It should be about as thin as a piece of paper. This very thin piece of apple stands for several other gases that are in the air.

GRADE IV TEST PASSAGE

Levees have helped to keep rivers from flooding. But they are not the only way to keep the river waters back. Planting trees will also help to stop floods. The bed of plants and leaves and sticks which lies on the floor of the woods slows down the speed of the water. More water can sink into the ground in the woods because water is held back by the cover of plants and leaves. Not so much water runs off. Many farmers have helped to stop river floods. They are using better ways of plowing their farms.

They plow their fields so that the rows help hold back the water. High hills are being planted to grass. The water on grass covered hills does not run off so fast as it does on plowed hills. The farmers know that they must keep the fertile ground on their land. The more we do to hold back the water of each storm, the more we help to stop floods. We must help to keep more water on the fields and let it sink into the ground where it falls. Water that sinks into the ground is called underground water.

GRADE VI PRACTICE TEST

The old frontier days of plentiful rich soil are gone so that today the saving of topsoil is a problem for everybody to help to solve. Poor soil means poor food and hunger for the people. People in the United States can no longer afford to plow and plant until the soil is worn out. For a long time soil has been washing from the land faster than it has been forming. Now we must do everything possible in order to save and enrich the soil. Scattered over the United States are one hundred million acres of farmland which have become wasteland.

If this land were one big farm, it would take up as much space as California. Other pieces of land that would make as large a farm have been seriously damaged by washing away of rich ground. This bad damage can be repaired by very hard and thoughtful work. Chinese farmers have changed poor land which supported less than one hundred fifty thousand people to terraced land which feeds about forty-five million people. In the United States the Dust Bowl has grown millions of acres smaller. The government, scientists, and farmers are working with nature to save the fertility of the ground.

GRADE VI TEST PASSAGE

Most sources of light are quite hot; for example, the heat of an electric bulb will burn paper on a lamp shade if it remains touching it long enough. Not all lights, however, are hot, for if you hold in your hand a firefly while it is glowing, your hand will not be burned by it. The light of a firefly is a cold light which comes from inside the insect. Its light does not come from electricity or from the sun, but from a substance which is produced in its body. Many other kinds of animals make their own light.

If you have been on an ocean trip, you have very likely noticed glowing spots here and there on the water at night. This is called the burning of the water by some sailors though really the spots are cold lights made by tiny plants and animals in the water. Scientists believe that the light which glows at night from many larger sea animals is something like the light you see in a firefly or in its larva, the glowworm. Many kinds of fish living in the deep sea have been seen, some with five rows of lights of many colors glowing along their sides.

GRADE VIII PRACTICE PASSAGE

About eight years ago in certain sections of the United States, teletypes, machines which set type and are controlled by telegraph, suddenly began to receive messages with the letters of words in mixed order, while in other districts communication by telephone and radio was completely halted. The source of the trouble came from severe lightning storms. At this time the surface of the sun showed intense activity around many sunspots. It is thought that electricity is sent out by the sun and that it is strongest during the years with the greatest number of sunspots. Radios work best in times of few sunspots.

Astronomers are able to prove that many events on the surface of the earth are connected to activity of the sunspots. In general, in times of many sunspots the temperature is a tiny bit cooler. Plants seem to grow better during the time of sunspots. Measurements made on the annual rings of trees more than two thousand years in age indicate that the years of rapid growth correspond to the years of greater sunspot storms on the sun. In spite of these important facts, scientists feel that further testing of the idea is needed for its use in long-range forecasting of weather.

GRADE VIII TEST PASSAGE

Since chemists are able to make from raw materials fibers that rival in many ways those made by nature, man need no longer depend solely upon nature for cloth for clothing. The correct name for this group of materials is synthetics which means "put together" or "built up," and that is exactly what is done to make them. One kind of synthetic, rayon, is made in several ways from cellulose which is found in wood, straw, cotton, or stems of many other kinds of plants. In order to make it from wood, the wood is first chopped into tiny chips.

By dissolving these chips in chemicals they turn into a sirupy liquid which is then pumped through some tiny holes in a plate made of steel. It flows from the holes in the plate into another tank of chemicals where the tiny streams turn into fibers. These may be further treated to give a certain kind of finish to them or to give extra strength to them. Rayon has an advantage over silk in that it can be made into fibers of any desired length and is able to take dyes of some kinds that will not blend uniformly in silk.

GRADE X PRACTICE PASSAGE

Cancer, which twenty-five years ago ranked seventh on the list of killers and now is second only to heart disease, is not a germ disease and is therefore not communicable. Its greatest importance to high school pupils is that deaths from cancer take their highest toll in the age bracket of thirty to fifty-five and so break up many homes just at the time parents are most important to their families. Perhaps your parents are in this age group; you should talk over what you learn about cancer with your father and mother and urge them to guard against it.

Cancer is best described as a disorderly or abnormal growth of the body cells or tissues. During growth, cells multiply and organize into tissues and organs with special duties. In cancer there is an increase in the number of cells, but these do not form normal tissues and organs. These so-called wild cells go on a rampage, multiply more rapidly than usual without organization, and perhaps kill many of their own numbers at the center of the growth by starving and crowding them. They, or the poisons they make, may spread to other healthy tissues causing them to become diseased also.

GRADE X TEST PASSAGE

Many people use the word toadstool to describe poisonous fungi and the word mushroom to describe non-poisonous kinds which can be eaten, but either name may be used for the same plant. Nearly every kind of mushroom lives on decaying matter in the soil, in decaying wood or in beds of especially prepared material containing some decayed matter. When ripe, they produce spores which are carried in the air. After a spore lights in a place where much decaying matter is present and where it is moist and warm, it begins to grow and produces a lot of tiny threads.

The threads may multiply and spread in the decaying material for several years coming together in a tight mass under the surface of decaying logs or rich soil. Then some warm sunny day following a rain, cells of the threads rapidly grow longer raising a top like an umbrella or shelf which is the spore-producing stem or fruiting body. Spores are freed either from cases along its sides or between fleshy plates or gills or from tiny pores or pits beneath the umbrella. Mushrooms are grouped according to how they shed their spores, as pore, gill, sponge, and puffball mushrooms.

GRADE XII PRACTICE PASSAGE

Anyone who has gone swimming has felt the water pressing in on him from all sides and has surely noticed that the deeper he swims the greater the pressure becomes. Likewise, anyone who has ascended to high altitudes, as in an airplane, has experienced the feeling caused by reduced air pressure. It is like going high up in an elevator very fast. The physiological effects of lowered air pressure on people are of considerable importance at the altitudes attained in commercial flying; at the altitudes at which much aerial warfare is now carried on they may become definite hazards.

Water and air which exert great pressure have weight because like all bodies of material on or adjacent to the earth's surface they are pulled downward by the gravitational attraction of the earth itself. We do not ordinarily consider air as being pulled by gravity, probably because air is invisible and has little weight. Yet the fact that gases and liquids are affected by gravity and are fluid gives rise to some interesting and important characteristics of water and air. Water always runs downhill in response to gravity from which is derived the saying that water seeks its own level.

GRADE XII TEST PASSAGE

Forecasting the weather by the use of observations made at a single place gives helpful results but has several limitations. For example, one can learn little in this way of the size, rate of travel, or direction of the movement of a cyclone, or of the air masses and fronts associated with it. This knowledge can be obtained only from complete weather data gathered through a well organized network of observation stations. With the aid of such data more reliable forecasts can then be made than are possible from an analysis of pressure, temperature, winds, and clouds at one place.

The Weather Bureau maintains five hundred fifty report stations on civil airways and two hundred fifty stations scattered through the rest of the country. In addition, reports come from Canada, Mexico, Alaska, the West Indies, Central America, Europe, and eastern Asia. Reports are sent twice daily to the central Weather Bureau in Washington, D. C. The data which each of the stations sends consists of barometric pressure, temperature, dew point, direction of the wind, precipitation, maximum and minimum temperatures, barometric tendency, cloud forms, and other phenomena of special need.

APPENDIX D

COMPREHENSION TESTS FOR PRACTICE AND TEST PASSAGES

APPENDIX D

COMPREHENSION TESTS FOR PRACTICE AND TEST PASSAGES

GRADE II PRACTICE PASSAGE

Plants

1. According to the story, name two places plants can grow.
2.
3. How much light do different kinds of plants need?
4. Why is the floor often a bad place to put plants?
5. What do people sometimes forget to do when they go away?
6. What color is a plant that is well?

GRADE II TEST PASSAGE

Woods and Trees

1. According to the story, where is a nice place to go?
2. Besides the birds and trees, what else can you see in the woods?
3. According to the story, what is it fun to do in the woods?
4. What two things are made from wood that are mentioned in
5. the story?
6. What does a good farmer always have on his farm?

GRADE IV PRACTICE PASSAGE

Air

1. What gas does a fire use when it burns?
2. What part of air is oxygen?
3. Where does a fire get the gas it uses to burn?
4. What do we do with the gases of the air our body doesn't use?
5. What gas is most plentiful in the air?
6. What is a good way to show the amount of each gas in the air?

GRADE IV TEST PASSAGE

Controlling the Rivers

1. What do high banks along rivers help to do?
2. Will planting trees help to stop floods?
3. What does the bed of plants and leaves and sticks do to the speed of water?
4. What happens to water on a plowed hill?
5. What will be prevented by holding back the water after a storm?
6. What is the water that sinks into the ground called?

GRADE VI PRACTICE PASSAGE

Soil

1. When was there plenty of rich soil in this country?
2. What kind of food results from poor soil?
3. In what country is this wasteland?
4. The wasteland would make a farm equal to what place in size?
5. In what country besides the United States have farmers improved poor land?
6. What is one group that is working to save the fertility of the soil?

GRADE VI TEST PASSAGE

Light

1. Describe the temperature of most sources of light.
2. What kind of light is not hot?
3. Where does a firefly's light come from?
4. What is one likely to see on the ocean water at night?
5. What are the glowing spots in the water?
6. How many rows of lights have been seen on some ocean fish?

GRADE VIII PRACTICE PASSAGE

Sunspots

1. What was the cause of telephone and radio reception being halted in some sections of the country?
2. At the same time what was noticed on the sun's surface?
3. According to the story, what is thought to be the source of much electricity in the air?
4. When is there the most electricity in the air?
5. What scientists have observed sunspot activity?
6. How do sunspots affect growth of plants?

GRADE VIII TEST PASSAGE

Rayon

1. What fiber is this story written about?
2. What is the correct name for materials made artificially?
3. What does synthetic mean?
4. How are the wood chips turned into a sirupy liquid?
5. What method is used to make tiny streams of the liquid?
6. What is the purpose of further treatment of the rayon fibers after the first processing?

GRADE X PRACTICE PASSAGE

Cancer

1. What is the general topic of the story?
2. How has the position of cancer as a killer changed in the last twenty-five years?
3. What age group does cancer hit the hardest?
4. How can cancer best be described?
5. Why is cancer important to high school boys and girls?
6. What should you do to help your parents guard against cancer?

GRADE X TEST PASSAGE

Mushrooms and Toadstools

1. What is the misunderstanding most people have about toadstools?
2. What do mushrooms produce when they are ripe?
3. Where must spores land in order to grow?
4. For how long may the threads remain underground?
5. What may cause the cells of the threads to grow rapidly longer?
6. Where are the spore cases located?

GRADE XII PRACTICE PASSAGE

Gravity

1. What is the general topic of the story?
2. What is a good way to become conscious of the force of gravity upon one's body?
3. How does air pressure concern commercial airlines?
4. In what kind of flying may air pressure be a definite hazard?
5. What is gravity?
6. What causes water to seek its own level?

GRADE XII TEST PASSAGE

Weather Forecasting

1. To learn the rate of travel of storms, their size, and direction of movement, from where must weather data be gathered?
2. What type of weather observation has limitations?
3. How often does each weather station report to the central Weather Bureau?
4. What is one source of weather information outside the United States other than Canada?
5. Besides reporting on precipitation and wind direction,
6. what are two kinds of weather data each station reports?

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