STUDIES OF THE EYE-MOVEMENTS IN READING OF UNIVERSITY PROFESSORS AND GRADUATE STUDENTS

by

W. Robert Dixon, Jr.

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Committee in Charge:

Professor Irving H. Anderson, Chairman
Professor Paul S. Dwyer
Professor Howard Y. McClusky
Professor Donald G. Marquis
Professor Willard C. Olson
Professor Clifford Woody
Associate Professor Orlando W. Stephenson

Ann Arbor, Michigan

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W.R.D.

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CHAPTER I

INTRODUCTION

This has been an investigation of the eye-movements in reading of three groups of University of Michigan professors representing the fields of physics, history, and education. Each professor read a passage from each of these three subject-matter areas before an eye-movement camera. The passages were designed to be equal in difficulty. For comparative and control purposes, a group of teaching fellows from each of these departments was run through the same experiment.

The investigation was undertaken in an attempt to obtain answers by the eye-movement technique to the following questions:

(1) Are different types of reading induced by different kinds of subject-matter?

(2) How does familiarity with the materials of a given field affect reading performance in that field?

(3) How does specializing on the materials of a given field affect reading performance in other fields?

(4) What individual differences in reading performance exist among individuals who have chosen scholarship as a career and who may be presumed, therefore, to be among the very best of readers?

(5) What evidence may be adduced for claims which are frequently made that there are individuals who can read whole lines, or even paragraphs, in a single glance or fixation of the eyes?

(6) Do superior readers, as frequently alleged, exhibit rhythmical patterns of eye-movements which remain more or less constant from line to line?

The first and second questions constitute the primary issues of this investigation. The third question grows out of the first question. The fourth, fifth, and sixth questions are secondary in nature. In the next chapter an effort will be made to show how the two primary questions emerge from a consideration of the existing literature.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

Excellent histories of the development of techniques for recording eye-movements in reading may be found in several places in the literature. Huey (25) wrote one of the early classics on the psychology and pedagogy of reading, and his volume remains a standard source book. A more recent account of the history of eye-movement recording appears in a new book by Carmichael and Dearborn (10). In view of the fact that there already are adequate accounts of the history of eye-movement recording in the literature, it seemed unnecessary to prepare another account of this history in the present work. It should be sufficient merely to note that there are two ways of recording eye-movements currently in use. One method utilizes the principle of corneal reflection, in which a camera photographs a reflected beam of light from the cornea of the eye on a strip of moving film. The other is an electrical method, in which the changes in electrical potential resulting from the reaction of the eye muscles in reading are recorded on paper tape by means of an ink-writing device. Hoffman, Wellman, and Carmichael (23) have found that results obtained by the two methods are highly related. However, Tinker, after careful study of the advantages and disadvantages of each method, concludes that "the corneal reflection technique of photographically recording eye-movements remains the most satisfactory method for use in reading investigations."[1] Tinker bases his contention on the fact that the photographic method yields the more accurate and exact record. The photographic method was used in this investigation.

The question of the reliability and validity of eye-movement records obtained by the photographic method has also been thoroughly investigated. After a careful review of all of the evidence, Anderson and Morse (5) clearly demonstrated that eye-movement measures plotted from photographic records are both reliable and valid when reading passages of sufficient length are used. The results of their study indicate that ten lines of material are more than enough for group comparisons. The passages used in the present study comply with this requirement. In view of the fact that the reliability and validity of eye-movement measures seems to be a settled question, no special study was made of this problem either in the present investigation.

1. The Concept of Types of Reading

The idea is frequently expressed in the literature that different types of subject-matter require different types of

[1]Miles A. Tinker, "The Study of Eye Movements in Reading," Psychological Bulletin, XLIII (March, 1946), 94.

reading because of the inherent nature of the material. Adler, in the following quotation, has pointed out what to him seem to be the fundamental distinctions between history, science, and philosophy:

> History is knowledge of particular events or things which not only existed in the past but underwent a series of changes in the course of time..... The historian narrates the happenings and often colors his narrative with some comment on, or insight into, the significance of the events..... Science is not concerned with the past as such. It treats of matters that can happen at any time or place..... Philosophy is like science and differs from history in that it seeks general truths rather than an account of particular past events..... If a theoretic book refers to things which lie outside the scope of your normal, routine, daily experience, it is a scientific work..... In contrast a philosophical book appeals to no facts or observations which lie outside the experience of the ordinary man.[1]

Efforts to distinguish between various types of subject-matter constitute only one side of the problem. There is the other question of relating these differences to the method of reading. Several workers have voiced their opinion with regard to both questions. Thus, Artly first points out that "the extensive treatment of history and literature, for example, contrasts with the intensive presentation of the mathematics content."[2] And he then goes on to say that in the reading of history and literature "the reader may skim, read rapidly, or vary his rate of reading as the ideas change in importance, but in mathematics he must do a de-

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[1]Mortimer J. Adler, How to Read a Book, pp. 152-54, 156. New York: Simon and Schuster, 1940.

[2]A. Sterl Artley, "Influence of the Field Studied on the Reading Attitudes and Skills Needed," p. 41 in Improving Reading in Content Fields. Supplementary Educational Monographs, No. 62. Chicago: The University of Chicago Press, 1947.

tailed, careful, and analytical type of reading."[1] Similarly, Leary and Gray declare that "reading a literary selection is quite a different thing from reading a passage in mathematics, science, or history..... The ability to skim which is highly useful in novel reading has little application in reading the extremely compact content of science."[2]

McCaul has even gone so far as to recommend setting up an entire remedial-reading program based on the idea that different types of subject-matter call forth different types of reading. He states that data secured from reading tests usually reveal four classifications of poor readers: (1) students who understand what they read, yet read too slowly; (2) students whose comprehension is poor because they are unable to discriminate between the important and unimportant and to organize what they read; (3) students who comprehend poorly because they read too rapidly and too superficially; and (4) students whose inferior reading speed and reading comprehension result from a limited vocabulary. In suggesting training material for each of these groups, McCaul says that "English literature will furnish the materials for speeding up the slow readers; some one of the social studies, the material for increasing the pupils' ability to organize what they read; science or mathematics, the materials for developing

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[1] Ibid.

[2] Bernice E. Leary and William S. Gray, "Reading Problems in Content Fields," p. 131 in Reading in General Education. Washington: American Council on Education, 1940.

precise, accurate reading."[1]

In general, it may be said that the concept of types of reading is based on the reading rates which seem most appropriate for different kinds of material: a slow, careful rate for the detailed and compact content of science materials; a rapid, skimming rate for the story type of content; and a relatively rapid rate for the extensive and expansive content of the social studies. As will be made clear later, the present investigation was designed in terms of this concept of types of reading. A further effort will be made first, however, to define the problem in the light of the related literature. This literature will be reviewed in two parts. The first part will deal with studies of the relationship between reading performance on different types of material. These studies show that reading performance tends to be specific to the content. The second part of the review will deal with studies inquiring into the nature of this specificity.

2. Studies of the Relationship between Reading Performance on Different Types of Material

Computing correlations between the results obtained for the same group on different reading tests has been a common method of studying the relationships which exist between

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[1] Robert L. McCaul, "Economical Training in Reading at the Secondary-School Level," High School Journal, XXI (April, 1938), 118.

reading performance on different kinds of content. The idea behind this approach is that it might throw light on the issue of general versus specific reading abilities. Low correlations might point to specific reading abilities, high correlations to a general reading ability.

Thus, with reference to the way in which people read different materials, Robinson and Hall have asserted "reading in different subject fields is not highly related..... On the other hand, reading in different topics in a given field is quite consistent."[1] Robinson and Hall base this assertion on a study in which relatively low intercorrelations were found between reading scores on art, geology, fiction, and history reading tests given to 205 college students, but in which a very high correlation was found between reading scores on a test of Canadian history and one of Russian history. For example, a correlation of only .25 was found between comprehension scores on art content and geology content, whereas a correlation of .96 was found between comprehension scores on the Russian history and Canadian history tests. Similar results have been obtained by Pressey and Pressey (38), who correlated scores made on four highly reliable reading scales with the following outcome:

General 1	vs.	General 2	r = .85
General 1	vs.	Poetry	r = .38
General 1	vs.	Scientific	r = .35
General 2	vs.	Poetry	r = .31
General 2	vs.	Scientific	r = .49
Poetry	vs.	Scientific	r = .56

[1]Francis P. Robinson and Prudence Hall, "Studies of Higher-Level Reading Abilities," Journal of Educational Psychology, XXXII (April, 1941), 246-47.

Even when scores on different standardized reading tests are correlated, the correlations turn out quite low. For example, Strang (48) compared paragraph comprehension as measured by the Minnesota Reading Examination with paragraph comprehension as measured by the Iowa Silent Reading Test. She obtained a correlation of only .28 between the results on the two tests. Similarly, Gates (17) compared speed of reading on the Brown Test with speed of reading on the Courtis Test, and obtained a correlation of only .53 between the two. Results reported by Broom, Douglas, and Rudd (7) have the same significance, namely, that the correlations obtained between standard reading tests are often low. It is only when the materials of the two tests are similar that high correlations are found. Thus, Paterson and Tinker (36) correlated scores on two forms of the Chapman-Cook Speed of Reading Test and obtained a correlation of .86.

Incidentally, the same situation prevails when eye-movement measures are correlated with a paper-and-pencil criterion. Imus, Rothney, and Bear (26), Eurich (14, 15), and Litterer (31) have all found low correlations when the material read before the camera and the content of the criterion were not comparable. On the other hand, Tinker (54), by using two selections from the Chapman-Cook Speed of Reading Test as the material read before the camera and scores on the entire test as the criterion, found correlations ranging from .80 to .99 between fixation frequency and the criterion score.

The results of the studies reviewed in this section may be summarized as follows: When the materials read are comparable or are selected from the same field, high correlations between the results on different reading tests will be obtained. When the materials are not comparable or are from different fields, low correlations will be found. The literature reviewed in the next section will inquire into the nature of the specificity which results when the materials read are from different fields.

3. Studies of Eye-Movements with Reference to Different Types of Content

The idea that different types of reading are associated with different kinds of subject-matter may be traced to the pioneer work of Judd and Buswell (27). In this study, eye-movement records were made of five university students reading fiction, geography, rhetoric, easy verse, French grammar, blank verse, and algebra. Table I summarizes the results for fixation frequency, the most significant single measure of eye-movements, for the four subjects on whom data are reported in the published account of this work.

The table clearly shows that there is some variation from passage to passage and also some uniformity in the pattern of that variation from subject to subject. The notable exception is the case of CB who read algebra almost as efficiently as fiction and blank verse more efficiently than easy verse.

TABLE I

AVERAGE NUMBER OF FIXATIONS PER LINE FOR DIFFERENT TYPES OF MATERIAL

(After Judd and Buswell)

Passages	Subjects			
	GH	IM	PM	CB
Fiction	6.1	8.5	6.2	8.0
Geography	7.3	11.2	7.9	8.5
Rhetoric	8.6	11.7	7.7	8.3
Easy Verse	9.4	13.1	8.4	10.0
French Grammar	10.6	14.1	8.0	11.8
Blank Verse	11.9	16.8	8.5	9.6
Algebra	12.5	14.4	9.5	8.1

Judd and Buswell have entitled the report of their work, Silent Reading: A Study of the Various Types. They based their concept of types of reading on the finding that different kinds of subject-matter tend to be read at different rates. Apropos of this finding, Judd and Buswell have said that "the present monograph has shown that there are manifold variations in the reading process induced by changes in subject-matter."[1] Judd and Buswell have pointed out the practical application of their finding in another place in the monograph where they state that "there is need of training in methods of silent reading of science material, and there is need of a different type of training in the silent reading of literature."[2] If the differences in the nature of the content are the cause of the variations in reading performance, then there is some foundation for McCaul's plan of training, since, in general, Judd and Buswell's subjects read fiction relatively fast and algebra relatively slow.

Is the variation in the pattern of the subjects' performance, as found by Judd and Buswell, evidence that different types of material require different types of reading? The answer to this question is complicated by a number of other questions which can be raised regarding Judd and Bus-

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[1]Charles Hubbard Judd and Guy Thomas Buswell, Silent Reading: A Study of the Various Types, p. 151. Supplementary Educational Monographs, No. 23. Chicago: The University of Chicago Press, 1922.

[2]Ibid., p. 6.

well's work. First, are the differences reported in Table I significant? No statistics are presented in the report to answer this question. Second, was the pattern of variation related to the order of difficulty of the selections, as determined by the vocabulary load, sentence length, complexity of logic, and so forth? Once again we are left in doubt, since no difficulty indexes are reported for the various passages used. However, Judd and Buswell do state that there were differences in the difficulty of the passages, but the nature of these difficulties are not described and no effort was made to relate the results to such differences in difficulty as may have existed among the passages. Third, to what extent were differences in the familiarity with the materials of the different fields a factor in the variation of the reading performances? Mention has been made of the record of subject CB who read algebra almost as efficiently as fiction. This subject may have been an expert in algebra, although we cannot be sure of this in the absence of any specific information on the point.

Judd and Buswell's study really does not permit a satisfactory explanation of the variation of reading performance from passage to passage or the variation in the pattern of performance from subject to subject. However, their study was primarily exploratory in nature and could not be expected to resolve all of the questions which this review of their study has raised.

Having some of the same import as the results of Judd and Buswell are data reported by Terry (50), who recorded the eye-movements of six male graduate students reading simple arithmetic problems, numerals isolated in lines, and ordinary expository prose. He found that the prose material was read at a significantly higher rate than either the problems or the isolated numbers. This finding seems to indicate once more that mathematical material contains elements of difficulty which make for a slow rate of reading. Is that true when an individual is an expert in the field?

Tinker (51) has reported the results of a study which in many ways is an extension of Terry's experiment. Tinker photographed the eye-movements of sixteen college students reading a passage of algebra which included a few algebraic formulas. A comparison was made of the eye-movement scores on those lines in the passage which contained formulas with those lines which did not. The results show that all subjects read the lines without formulas more efficiently than the lines with formulas. The group included five subjects who had taken courses in calculus in college. The other eleven subjects had not taken any work in mathematics beyond arithmetic. It is interesting to note that the five students who had taken the more advanced work in college mathematics performed more efficiently than the eleven subjects who had not taken this advanced work. This finding implies that familiarity with the materials of the field of mathematics promotes more efficient reading, although the five subjects with the more advanced mathematical training may have also been more highly selected and for that reason turned in the better reading performance. In any case, the question still remains as to how the reading of the mathematics material would compare with the reading of prose. Tinker attempted to answer this question by including a passage of scientific prose as a part of the test material in his experiment. The subjects on the whole read the prose material more efficiently than the algebra passage, which seems to lend support to the idea that some materials by virtue of their inherent nature call for a more meticulus type of reading and hence a slower rate. However, on closer inspection one discovers that the scientific prose selection used was a description of an experiment with rats in the psychological laboratory. Since Tinker's subjects were primarily psychology students, the conclusion might well be that Tinker's study demonstrated the importance of background and familiarity rather than the existence of types of reading for different types of material, inasmuch as all the subjects may be presumed to have been more familiar with the material of psychology than with the mathematics content. A further complication is that Tinker did not equate the algebra and prose passages for objective difficulty.[1]

[1]By objective difficulty is meant the difficulty as determined by formulas for estimating the difficulty of reading material. These formulas do not take the factor of familiarity into account. Familiar material may be easy, unfamiliar material hard; but objective difficulty is another source of variation in reading performance.

A description of three more recent studies will bring this review of eye-movement studies up to date. All three have followed a pattern in which the subjects read equated passages from different subject-matter areas. Stone (47) photographed the eye-movements of 64 New York University freshmen while they read passages from mathematics, biology, English, educational psychology, a physical science, and a social science. Seibert (46) conducted a similar experiment using 60 eighth-grade students as subjects and test passages from mathematics, biography, adventure, a physical science, history, and geography. Finally, Ledbetter (30) recorded the eye-movements of 60 eleventh-grade pupils while they read equated material from high school textbooks in English, mathematics, science, and social science. In all three studies the eye-movements results varied from passage to passage. There were wide individual differences in the pattern of the variation from passage to passage. The individual differences which existed among the subjects for the same passage within each study were vastly greater than either the individual or group variation from passage to passage.

Table II presents a summary of the critical ratios which existed between the mean eye-movement and comprehension scores for various combinations of the four subject-matter areas which were common to the three studies. Nine of the critical ratios reached the 5 percent level of confidence. Four of these critical ratios involve eye-movement measures and five the comprehension scores on the passages.

TABLE II

SUMMARY OF CRITICAL RATIONS BETWEEN MEAN EYE-MOVEMENT AND COMPREHENSION SCORES FOR VARIOUS COMBINATIONS OF THE FOUR SUBJECT-MATTER AREAS COMMON TO STUDIES OF SEIBERT, LEDBETTER, AND STONE[1]

Subjects Compared	Seibert (8th grade)				Ledbetter (11th grade)				Stone (college freshmen)			
	Rate	Fixations	Regressions	Comprehension	Rate	Fixations	Regressions	Comprehension	Rate	Fixations	Regressions	Comprehension
English-Mathematics	1.71	.50	.66	2.88	1.41	1.47	1.34	.77	1.17	1.18	1.39	.43
English-Physical Science	1.12	1.24	2.42	2.62	.27	.24	1.00	1.42	1.65	.73	.03	1.03
English-Social Science	1.56	1.65	2.50	.37	.95	1.04	.30	.79	1.01	.56	.56	3.57
Physical Science-Mathematics	1.80	.75	1.90	.18	1.73	1.68	2.26	.54	----	----	----	----
Physical Science-Social Science	.42	.39	.00	2.05	1.24	1.25	1.29	.62	----	----	----	----
Social Science-Mathematics	2.23	1.16	1.96	2.27	.39	.39	1.05	.07	----	----	----	----

[1]In this and all other tables containing critical ratios, 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 results as a whole are difficult to interpret. In the first place, a comparison of the results of the three studies reveals that there was a lack of uniformity in the pattern of the results. For example, Seibert's subjects read the mathematics passage more rapidly than they read the English passage, while Ledbetter's eleventh-grade subjects reversed this relationship. To take another example, Stone's college freshmen read the physical science passage more slowly than they read the social science passage, while both Seibert's and Ledbetter's groups reversed this relationship. In the second place, although Stone, Seibert, and Ledbetter each stated that their passages were about equal in terms of sentence length and vocabulary level, they apparently did not resort to the use of formulas for estimating the difficulty of material. The present writer applied both the Flesch and Lorge formulas to the passages used in the three studies and discovered that there were differences in the difficulty of the passages in each study. Furthermore, the writer was unable to discover a uniform relationship between the difficulty of the passages and the eye-movement measures. To give an example, Seibert's mathematics passage was the easiest of the selections used in his study, and it was also the passage which was read most efficiently by his subjects. The mathematics passage happened to be the easiest in Ledbetter's study as well; yet her subjects read this passage less efficiently than any of the others which she used. A third factor which prevents confident interpretation of the results of Stone, Seibert, and Ledbetter is that in none of these studies were the subjects departmentalized so that it is impossible to ascertain just how the special interests of the subjects may have affected the variation in the reading performance. In other words, insofar as the eye-movement evidence is concerned, the questions originally raised by Judd and Buswell's study remain unanswered.

4. Summary of Review of Related Literature

On the basis of the literature reviewed in this chapter, we can say definitely that reading performance is likely to vary from one type of material to another. We cannot say for sure whether these variations are due to differences in the difficulty of the material, whether they are due to the fact that different types of material require different types of reading, whether they are due to differences in the familiarity of the material, or to what extent both types of reading and familiarity with the material may be factors in reading performance. In any case, the issue seems clearly drawn: types of reading versus familiarity with the material. The way in which the present investigation was designed to resolve that issue is described in the next chapter, where the significance of the investigation will also be discussed.

CHAPTER III

THE PROBLEM

1. General Design of the Experiment

Any experiment which seeks to answer the questions posed at the conclusion of Chapter II would seem to require the following conditions: (1) the passages to be read should be selected from different subject-matter areas; (2) these passages should be equated for objective difficulty by the best methods; (3) the subjects should have been trained in the same content fields as those from which the passages were taken; and (4) each subject should be required to read the passage from his own field, as well as those from the other fields. These conditions were met in the present study by using passages selected from the fields of education, physics, and history. The passages were equated for difficulty by means of standard formulas. Professors and graduate-students from the Physics and History Departments and the School of Education at the University of Michigan served as subjects, and each subject read all three passages before an eye-movement camera. The graduate-students were included for comparative and control purposes.

2. Relation of Primary Problem to the Design

The way in which the main question of this investigation may be related to the design of the experiment is as follows: If all of the subject groups read the physics passage at a slower average rate than any of the other passages, the inference might be that scientific material calls for a slow, meticulous, and detailed type of reading. Similarly, if all of the subject groups read the history passage at a faster average rate than any of the other passages, the inference might be that history material calls forth a rapid, fluent type of reading. If, however, all of the subject groups achieve their fastest average rate on the passage from their own field, and if significantly different average rates are not used by the education subjects in reading the physics and history passages, or by the history subjects in reading the physics and education passages, or by the physics subjects in reading the history and education passages, the ideas that a slow, careful rate of reading is associated with scientific material and a rapid rate of reading is associated with history material might be discounted and familiarity would emerge as the principal condition. Finally, however, if all of the subject groups achieve their fastest average rate on the passage from their own field, and if the education subjects read the physics and history passages at significantly different rates, and the history subjects do read the physics passage at a slower average rate than the education passage, and the physics subjects do read the history passage at a faster rate than the education passage, then both the factor of familiarity and the existence types of reading for specific content would probably need to be recognized.

Closely related to the problem of types of reading for specific content is the question of how an individual's reading performance in his special field compares with his reading in other fields. A common notion is that those persons who continually work and read in a technical field like physics become slow readers in everything. If the results show that the physics subjects read all of the passages at a slower average rate than the other groups, the notion would seem to be supported. However, in that event, another explanation which might be suggested is that physics as a content field operates to select people who are slow readers to begin with, and that training in the field may have nothing to do with their slow rate of reading. The graduate-student groups were included in the study partly to obtain a check on this possible explanation, if it did turn out that the results supported the hypothesis in question. If the physics graduate-students tend to read at a slower rate than the other graduate-student groups, the idea that physics selects slow readers would seem to gain support. If, however, the physics graduate-students tend to read at about the same speed as the other graduate-student groups, but faster than the physics professors, the results might then be interpreted to mean that long specialization in a technical field does slow down a person's reading generally. Such a finding would be particularly significant, if it was found in addition that the other two groups of professors were generally no slower than the graduate students in their departments. This additional finding would rule out the possibility that the slower performance of the physics professors was due to aging. On the other hand, familiarity can also be a factor in the reading performance of the physics subjects, that is, both the physics graduate-students and professors might be expected to read the physics passage at a more rapid average rate than the other subject groups because of their greater familiarity with the materials of the field. A comparison of the reading performance of the physics and education subjects on the history passage and of the physics and history subjects on the education passage thus becomes important. If the physics subjects read the history passage at a slower average rate than the education subjects, and if the physics subjects read the education passage at a slower average rate than the history subjects, a transfer effect might still be indicated, inasmuch as the history passage may be presumed to be relatively unfamiliar to both physics and education subjects and the education passage relatively unfamiliar to both physics and history subjects.

A similar line of reasoning may be followed with regard to the idea that specialization in the materials of history makes for transfer effects in the opposite direction. This idea would seem to be sustained if the history subjects read all of the passages at a faster average rate than the subjects from the other departments, and further, if the history professors read at a more rapid average rate than the history graduate-students. The latter finding would be important, especially if the professors in the other departments read no more rapidly than their graduate-students. Both the notions that continuous reading of technical material tends to retard reading rate and that constant reading of history material tends to promote rate would be rendered doubtful if the physics and history subjects read the education passage at about the same average rate, if the physics and education subjects read the history passage at approximately the same rate, and if the history and education subjects read the physics passage similarly.

3. The Secondary Questions Investigated

So much, then, for the primary issues. Now for the ancillary questions. The first of these concerns the individual differences in eye-movement performance which exist among the subjects used in this study. Other investigations of the eye-movements in reading uniformly have shown extreme individual variation. Morse (35), for example, in a study of the eye-movement performance of normal fifth-grade readers, discovered some children who made as many regressions per line as other children make fixations per line. It will be interesting to see what individual differences show up among a group of individuals who have chosen scholarship as a career and should, therefore, be among the best readers.

The second question of an ancillary nature involves an attempt to evaluate claims that there are individuals who can read whole lines, or even paragraphs, in a single glance or fixation of the eyes. There are numerous accounts in the literature of individuals who were supposed to be able to read that way. G. Stanley Hall, Charles Hubbard Judd, and Woodrow Wilson were professors who had that reputation. Another was one of our most illustrious presidents, Theodore Roosevelt. One of his biographers states that "he had the type of mind that can assimilate the printed page in gargantuan gulps, and he was able to retain the major part of his hasty literary meals."[1] The author of another biography of Roosevelt writes that "nothing distracts him from the book before him. It becomes for the moment the sole business of his life, and he reads so swiftly that he finishes a volume in the time that the average reader bestows on twenty pages."[2] Not to be outdone, Clifton Fadiman "boasts of his 150-page per-hour reading speed which enables him to get through what

[1]Henry Fowles Pringle, Theodore Roosevelt, p. 473. New York: Harcourt, Brace and Company, 1931.

[2]James Morgan, Theodore Roosevelt, p. 232. New York: Grosset and Dunlop, 1919.

he calls the 'jumbo-size' modern novel with an ease that flabbergasts less fortunate readers."[1] Another case is that of a child prodigy who "had the ability to see in chunks, to read not by words or phrases but by whole paragraphs at a time."[2] The writer has been unable to find anywhere, however, the report of a case in which the claim was supported by eye-movement evidence. The subjects of the present experiment contain at least one individual who has the reputation of being able to read in so-called "gargantuan gulps." The presence of this individual in the group presents an opportunity to verify the claims which frequently are made that there are people who can take in a whole line or a paragraph with one swoop.

The last of the secondary questions has to do with the idea that a good reader moves his eyes across the line in a rhythmical pattern which remains more or less constant from line to line. Dearborn seems to have been the first to propose this idea. In the report of his pioneer study of the eye-movements in reading, Dearborn has stated that "it is the writer's belief clearly indicated by the experiment that one of the essentials of natural and rapid reading is that the reader's eye should at once be able to acquire a regular and uniform motor habit of reaction for each line."[3] And

[1]John Chamberlin, "Fadiman for the Millions," The Saturday Evening Post, CXIII (January 11, 1941), 60.

[2]Amram Scheinfeld, You and Heredity, p. 283. New York: Frederick A. Stokes Company, 1939.

[3]Walter Fenno Dearborn, "The Psychology of Reading," Archives of Philosophy, Psychology and Scientific Methods, IV (March, 1906), 115.

in another place in the report he states that "the evidence would further seem to show that the acquirement of a rhythmical succession of movements is one of the means by which the fast reader attains to his greater speed in reading."[1]

Robinson has reached a similar conclusion, when he states that the eye-movements "may be defined as psycho-physiological dispositions to move the eyes during reading, in a more or less constant manner according to certain cues, mostly kinaesthetic, that act independently of the conscious act of understanding the material so long as comprehension progresses smoothly."[2]

The net result of these views has been the introduction of numerous training devices which seek to improve reading ability by means of eye-movement pacing. The Metron-O-Scope[3] and the Harvard Reading Films[4] may be cited as illustrations. The results of a study of the eye-movements in reading of a group of subjects like those used in this experiment may be helpful in evaluating these techniques.

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[1] Ibid., p. 118.

[2] Francis P. Robinson, The Role of Eye Movements in Reading with an Evaluation of Techniques for Their Improvement, p. 43. University of Iowa Studies, No. 39. Iowa City: The University of Iowa, 1933.

[3] Trade name for a triple-shutter tachistoscope developed by The American Optical Company, Southbridge, Massachusetts.

[4] A series of motion-picture films which present the reading material a phrase at a time across and down the screen in accordance with what is supposed to be the pattern of the eye-movements of the skillful reader.

4. Significance of the Investigation

A few words should be said regarding the probable significance of the investigation. If different types of reading are elicited by different kinds of subject-matter, it would seem to be both theoretically and practically sound to adopt a remedial training plan along the line of that suggested by McCaul (33). If, however, the most rapid rate is found to be associated with the most familiar material, then speed might best be promoted by the use of familiar material. Conversely, unfamiliar material, whether technical or not, might then be used to teach the art of slow reading.

The caliber of the subjects of this experiment should render the results especially interesting. A study of the eye-movements in reading has never before been made of a group like that employed in this investigation. Just how well do these subjects read? During the past few years a tremendous amount of interest has been shown in speeding up reading. Numerous articles have been written in popular magazines, and books have been published, all offering advise on how to speed your reading. A few illustrative titles are <u>The Art of Rapid Reading</u> by Walter B. Pitkin, <u>Flying the Printways</u> by Carol Hovious, and "Speed While You Read," an article by Robert Bear in the <u>American Magazine</u>. To what extent is this stress justified? It is possible that even the best readers do not read as fast as commonly supposed. In any event, the results of the present study should make it possible to evaluate the emphasis that currently is put on rapid reading.

These are merely a few suggestions as to the probable significance of the investigation. A further evaluation will be made in the discussion following the presentation of the results. This chapter has been written mainly in an effort to present an overall picture of the study.

CHAPTER IV

THE METHODS AND CONDITIONS OF THE EXPERIMENT

The specific methods and conditions which characterized the present investigation are described in detail in this chapter. The chapter is divided into four sections, dealing in order with the subjects, the passages, the camera procedure, and the eye-movement measures or scores.

1. The Subjects of the Experiment

The subjects of this experiment were selected primarily from the academic staff of the University of Michigan. A group of professors and a group of graduate-students were included from each of the following teaching units: (1) education, (2) history, and (3) physics. Only those professors with a doctorate and an academic rank of assistant professor or higher were included. The graduate-students selected had their master's degrees and were working for their doctorates. For the most part the graduate-students were teaching fellows in their departments.

It was not necessary to employ sampling techniques in the selection of subjects. There was only a limited number of professors in each department, and an effort was made to get all of them. In fact, several professors from other institutions consented to participate in the experiment when it became evident that additional records would be needed to round out each group.

After the elimination of some potential subjects because of illness, a foreign-language background, or extreme presbyopia, sixteen subjects remained in each professor group. The same number of graduate-students was used from each department. The records of these 48 professors and 48 graduate-students constitute the basic data of this study.

2. The Passages Used in the Experiment[1]

As stated previously, the passages used in the experiment were selected from the fields of education, history, and physics. Two passages were chosen from each of these fields, one of which served as a practice selection and the other as the test selection. Each passage was about 200 words in length. Because of the caliber of the individuals involved in the experiment, the reading material had to be fairly difficult in order to present any sort of a challenge to the subjects. On the other hand, the material could not contain content which would be completely beyond the reach of those subjects not working in the special field. The passages finally selected met both of these requirements. All passages were equated in terms of objective difficulty.

There have been numerous attempts to determine object-

[1]Copies of all practice and test passages are exhibited in Appendix B.

ively the difficulty level of a given reading selection by means of special formulas. But these attempts have not yielded entirely satisfactory results. One reason is that those working in the field are not in agreement as to what constitutes difficulty. In the second place, the problem of appraising the difficulty of concepts has thus far defied objective analysis. Actually, it is possible to find passages of equal objective difficulty, which undoubtedly present extreme differences in their conceptual nature. A quotation from Horn will illustrate this point:

> ... on the basis of the hypothesis that words occurring in the first twenty-five hundred of the Thorndike list should be intelligible to fourth-grade children, the following sentence should be easy to understand: The square of the sum of two numbers is equal to the square of the first added to twice the product of the first and second added to the square of the second. All of these words are among the two thousand of highest frequency in the Thorndike list. On the other hand the following sentences should be quite unintelligible: Daddy helped me with my arithmetic until bedtime. I got a bracelet, a toy dresser, and some gum for Christmas. Brother got a baseball and a sled. It is evident that the difficulty of a word in any sentence is not determined by the frequency with which the printed form of the word has been recorded but by the probability that the appropriate meaning has been associated with it by the reader.[1]

The Flesch (16) and Lorge (32) formulas were used to estimate the objective difficulty of the passages used in the present study. Of the formulas available for the purpose, it was felt that these two were most suitable. The Flesch formula relates reading difficulty to three conditions: (1) sentence length, (2) number of affixes, and (3) number of personal references. A passage becomes more difficult as the length of the sentences increases, as more affixes

[1]Ernest Horn, Methods of Instruction in the Social Studies, pp. 167-68. New York: Charles Scribner's Sons, 1937.

are included, and as personal references decrease in number. Conversely, an easy passage is characterized by short sentences, few affixes, and many personal references.

The Lorge formula gives a readability index which is dependent on four factors: (1) the number of words in the sample, (2) the number of sentences in the sample, (3) the number of prepositional phrases included, and (4) the number of hard words. The hard words in this case are words not found in the Dale list.[1]

Table III gives the level of difficulty for each practice and test passage as measured by the two formulas. The Flesch difficulty score must be translated into the proper grade level. For these passages it is sufficient to note that any score of six or more is classified by Flesch as very difficult and at the high college level. The Lorge score, on the other hand, is the actual grade level of the passage as measured by the formula. It will be noticed that the Flesch formula places all of the passages in the very difficult category, typical of scientific journals and appropriate for professional groups. The Lorge formula assigns the passages to the ninth grade. However, this formula is not as well suited for estimating the difficulty of material above grade seven. The interesting fact to note is that within the limits of each formula, the passages closely approximate each

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

TABLE III

DIFFICULTY LEVEL OF PRACTICE AND TEST SELECTIONS

Passage	Flesch	Lorge
(P) Education	7.54	9.10
(T) Education	7.41	9.93
(P) History	7.05	9.79
(T) History	7.64	9.96
(P) Physics	7.22	9.93
(T) Physics	7.48	9.28

other in difficulty.

The typographical arrangement of the passages was within the optimum limits established by Paterson and Tinker (37). These investigators spent twelve years giving 66,062 reading tests to 33,031 subjects, and they arrived at some general recommendations for the printing of any material. For the purposes of the present study, it may be noted that (1) most of the type faces in common use are included in the group of approved type faces; (2) 10 point type is recommended as the size of type printers should regard as standard; and (3) "for 10 point type leaded 2 points the limits of 'equal legibility' range from 14 to 31 picas per line."[1] In the light of this evidence, the passages used in the present study were printed in Old Style Number 7, 10 point type, leaded 2 points, with a line width of 24 picas.

3. The Camera Procedure

The instrument used in this experiment was the Opthalm-O-Graph.[2] This camera utilizes the principle of corneal reflection. Two telescopic lenses pick up the reflections which are focused on the film by means of a reflex finder. The 35 mm. film moves through the machine at a constant rate of one-half inch per second. The speed of the moving film is used to compute reading rate.

[1]Donald G. Paterson and Miles A. Tinker, How to Make Type Readable, p. 148. New York: Harper and Brothers, 1940.

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

At the outset of each recording session, every effort was made to be certain that the subject was at ease and that the instrument was adjusted properly for the comfort of the subject. Each individual was instructed to "read each passage through once as you normally would to understand the material."

Comprehension Requirement. The subject was next informed of the comprehension requirement which consisted of five Yes-No type questions on each passage.[1] The questions for each passage were scored on the basis of the answers given by the professors who had specialized in that field. A count was made of the way in which these professors had answered each question, and the answers that were given the most frequently were scored as the correct ones. A comprehension check-test was thought necessary in order to encourage a normal reading performance. The five questions on each passage were general rather than specific in nature, just enough to let the subject know that he was expected to read for meaning without, at the same time, making him hyperconscious of the comprehension requirement.

Presentation of the Passages. Including the practice and test passages, there were six separate selections to be read by each subject. Each test selection, of course, was preceded by a reading of the practice passage in the same

[1] The questions on each passage are exhibited in Appendix C.

field. The questions on the practice passage were answered, and then the test selection was presented. Since Schmidt (45) and Tinker (53) have noted a slight gain in efficiency as subjects read a series of selections before the camera, a system of presenting the passages in rotation was used within each group in order to cancel practice effects.

Securing a Representative Sample of Reading. Each passage was approximately 200 words long and was printed on two separate 3 x 5 cards composed of 100 words each. A photographic record was made of the subject's eye-movements on the second card of 100 words in each test selection.

Stone (46) and Seibert (45) have studied the problem of what portion of a passage should be considered as a representative sample of reading performance. Their evidence indicates that either the second 100 words or the third 100 words are acceptable, with the third 100 words being read slightly more efficiently than the second 100 words. In their investigations, the first 100 words were read with the least efficiency, indicating that it takes a while for the subject to hit his stride.

Introspective Commentary. The final part of the experiment was devoted to securing from each subject a commentary of his introspections during the experiment. The data thus acquired will be treated qualitatively in Chapter VI, which discusses the results of the experiment. Each subject was also asked about his own reading and study habits, and was invited to make recommendations for younger students who might be planning to specialize in his field.

Summary of the Experimental Procedure. The following brief outline summarizes the steps taken with each subject:

(1) The subject was acclimated to the camera situation.

(2) The subject was instructed to read the material as he normally would, and was told of the comprehension requirement.

(3) After a practice passage in one field had been read and the questions on that passage answered, the test passage in that same field was read and the appropriate questions answered. (This procedure was repeated for the two remaining fields.)

(4) The subject was given the opportunity to express his reaction to the experiment and also to outline any reading and study habits he employed that seemed to be most useful in mastering the subject-matter of his field.

4. The Measures Used

The eye-movement records were analyzed according to four measures: (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 was used as the

[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.

basic unit of measurement primarily because it offers a way to standardize the reporting of eye-movement records. Since the em is a fixed distance, it may be used as a standard of measurement regardless of the length of words, size of type, or length of line. Measurements in ems may be roughly translated to measurements in words by employing the constants 2.3 characters per em and six characters per word.

The comprehension requirement provided the data for the fifth measure analyzed in the present investigation. Each subject was scored in percent according to the number of questions he answered correctly on each passage.

Chapter V will outline the way in which these measures were treated, and also present the results of the study.

CHAPTER V

THE RESULTS

Before presenting the results of the experiment, it will be necessary to describe in some detail the manner in which the data were treated. This detailed presentation is required because certain aspects of the statistical procedure are new and cannot be found in the literature. The specific findings will be presented after the method of treating the data has been described.

1. Treatment of the Data

In order to determine whether the reading performances of the various groups of subjects differed significantly, their scores on each of the five measures were compared by means of the analysis of variance technique. The basic proposition in an analysis of variance is that from samples of different classifications it is possible to derive independent estimates of the population variance, one of which is based on the variance between the groups and another on the within-group variance. This fundamental proposition in turn rests on the null hypothesis which assumes that all of the groups are random samples from the same normal population.

The test of the null hypothesis is made by ascertaining through the F test whether the ratio of the two variance estimates is larger than chance would allow. If the ratio is larger than chance expectation, we should have reason to believe that the null hypothesis is false. If the ratio is smaller than chance expectation, the null hypothesis is not disproved.

The usual procedure for analyzing a simple classification of variates by means of the analysis of variance is to secure first the means of each group as well as the general mean. Next, the deviations of the individual scores, and the deviations of the group means, from the general mean are computed, squared, and summed. The estimated between-group variance is then equal to the sum of the squares of the deviations of the group means from the general mean divided by the corresponding number of degrees of freedom. In getting an unbiased estimate, it is necessary to divide through by the number of degrees of freedom. The estimated within-group variance is equal to the sum of the squares of the deviations of the individual scores from the general mean divided by the corresponding number of degrees of freedom. The ratio (F) is secured by dividing the estimated between-group variance by the estimated within-group variance. The significance of this F may be found in a table of F values. This procedure is acceptable, but it becomes quite complicated as the number of classifications increases. For the more involved situations, a quicker and more accurate calculation of F may be achieved by changing the mathematical procedure slightly in order to utilize certain features of modern calculating machines.

The steps below outline the procedure used in the analysis of variance in the present study.[1] This procedure was followed in dealing with each of the five measures derived from the eye-movement records and the comprehension test. First, the individual scores for each group were summed, and then these individual scores were squared and summed. Second, the quantity A was derived for each group by the formula $A = N\Sigma X^2 - (\Sigma X)^2$. At the same time an A for all the observations was calculated. Third, because the problem presented a threefold classification of variates (subjects from three fields of specialization, two ranks of subjects, and three different passages to be read) with replications,[2] it was necessary to set up a calculation table so that an analysis of the three main effects and their interactions could be made. Table IV is presented as an example. It shows the calculation table used in working with the comprehension scores. In one section of Table IV is the sum of the comprehension scores for each group of 16 professors on each passage read; another section presents the corresponding scores of the 16 graduate-students in each department; and the third section combines the 32 scores of the professors and graduate-

[1] The writer is indebted to Professor Paul S. Dwyer for the development of the method of statistical analysis used in treating the data.

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[1] The writer is indebted to Professor Paul S. Dwyer for the development of the method of statistical analysis used in treating the data.

[2] It is to be noted that there is some restriction on the randomness of the replications, since 96 individuals were used in obtaining 3 x 96 mea sures. Since the analysis of variance plays an exploratory role in this study, it seemed wise to use the different operators as replications and to absorb the errors due to operators in the residual error.

TABLE IV

CALCULATION TABLE DEVELOPED FOR USE WITH COMPREHENSION SCORES

Passages	Professors				Graduate-Students				Combined Groups			
	Education	Physics	History	Total	Education	Physics	History	Total	Education	Physics	History	Total
1. Education	1,120	860	1,120	3,100	1,200	1,200	1,260	3,660	2,320	2,060	2,380	6,760
2. Physics	1,320	1,440	1,280	4,040	1,360	1,460	1,260	4,080	2,680	2,900	2,540	8,120
3. History	1,240	920	1,300	3,460	1,100	1,100	1,080	3,280	2,340	2,020	2,380	6,740
Total	3,680	3,220	3,700	10,600	3,660	3,760	3,600	11,020	7,340	6,980	7,300	21,620

students.

From this table it is possible to derive the quantity A for each of the following sources (the number of degrees of freedom, calculated by conventional methods, have been inserted):

Source	Degrees of Freedom	A
Total (with replications summed)	17	478,706,480
Departments	2	233,600
Passages	2	3,754,400
Ranks	1	176,400
Department-Rank	2	1,139,600
Passage-Rank	2	4,797,200
Department-Passage	4	5,478,800

The next step is to measure the interaction. I is a quantity used to indicate the interaction. The I of a first-order interaction, for example, department-rank, is equal to the A of the dual classification less the As of the sources making up that classification. The I of a second-order interaction, department-rank-passage, is equal to the A of the total (where variates are the sums of the replications), less the sum of the As of the main effects, less the sum of the Is of the first-order interaction.

The "error term" may be regarded as a measure of chance variation. It is equal to the variation which remains after the variation due to the main effects and the interactions have been removed. It may be calculated by subtracting the A of the totals resulting from the summing of the replications from the A of all the observations.

The various Fs may be computed by using the following formula,

$$F = \frac{\frac{A_i}{DF_i}}{\frac{A_e}{DF_e}}$$

in which A_i is equal to the A of the main effect or the I of the interaction, and in which DF_i refers to the corresponding number of degrees of freedom, and also in which A_e indicates the A of the "error term" and DF_e the number of degrees of freedom in the "error term".

Table VI may be referred to as an example of the way in which this procedure may be set up in tabular form. For the convenience of those accustomed to using sums of squares (of deviations) in arriving at F, a sums of squares column has been added to each table. The sums of squares for each main effect is calculated by dividing the A of the main effect by the total number of observations (288). The sums of squares of each interaction is calculated by dividing the I of the interaction by the total number of observations. The various Fs may then be computed using the formula,

$$F = \frac{\frac{SS_i}{DF_i}}{\frac{SS_e}{DF_e}}$$

in which SS_i is equal to the sums of squares of the main effect or the interaction and DF_i to the corresponding number of degrees of freedom, and also in which SS_e is equal to the sums of squares of the "error term" and DF_e to the number of degrees of freedom in the "error term".

It was decided to study the details of those differences to which the previous analysis directed attention by means of the Student-Fisher t test. In each case only the observations necessary for making the specific test were used. With so many sources involved in the present problem, we may expect some differences significant at the 5 percent level of confidence to arise from chance alone. Hence, we have arbitrarily set the 1 percent level of confidence as the point of significance which had to be reached in any comparison before the Student-Fisher t test was applied.

2. Specific Findings

Familiarity as a Factor in Reading Performance

It will be remembered that the problem of this investigation was stated in the form of a series of questions. The specific findings will now be presented in reference to these questions. The question which will first be considered is implied in the sub-heading above: How does familiarity with the materials of a given field affect reading performance in that field? If the subjects read the material from their own field more efficiently than the materials from the other fields, it could be taken to mean that familiarity with a given field is a factor in reading performance. The results which follow with regard to this problem are presented separately for each eye-movement measure and score.

Rate of Reading. Table V presents the mean rates of reading for each group on each passage. The standard deviations of the distributions are also given. The table reveals a trend on the part of the subjects to read the materials from their own field more efficiently or rapidly than the materials from the other fields. This finding is especially apparent in the case of the professors. All groups of professors read the materials from their own field more rapidly on the average than the material from the other two fields. For example, the physics professors read the history passage at an average rate of 715 ems per minute (275 words per minute) and the education passage at an average speed of 677 ems per minute (260 words per minute), but they read the physics passage at an average rate of 938 ems per minute (360 words per minute). The graduate-students did not consistently follow the pattern set by the professors. The graduate-students in education read the physics passage faster on the average than they read the education passage, and the graduate-students in history read the education passage faster on the average than they read the history passage. However, the performance of the physics graduate-students conformed to the pattern shown by the professors. The physics graduate-students read the physics passage at an average rate of 937 ems per minute

TABLE V

MEAN RATES OF READING IN EMS PER MINUTE AND THE STANDARD DEVIATIONS OF THE DISTRIBUTIONS BY DEPARTMENTS FOR ALL PASSAGES[1]

Passages	Departments					
	Education		Physics		History	
	Professors	Graduate Students	Professors	Graduate Students	Professors	Graduate Students
1. Education	797 $\hat{\sigma}$ 219	798 $\hat{\sigma}$ 239	677 $\hat{\sigma}$ 151	695 $\hat{\sigma}$ 195	774 $\hat{\sigma}$ 240	841 $\hat{\sigma}$ 248
2. Physics	760 $\hat{\sigma}$ 271	828 $\hat{\sigma}$ 274	938 $\hat{\sigma}$ 266	937 $\hat{\sigma}$ 254	808 $\hat{\sigma}$ 237	784 $\hat{\sigma}$ 250
3. History	736 $\hat{\sigma}$ 182	767 $\hat{\sigma}$ 205	715 $\hat{\sigma}$ 188	706 $\hat{\sigma}$ 149	917 $\hat{\sigma}$ 253	824 $\hat{\sigma}$ 210

$$\hat{\sigma} = \sqrt{\frac{N\Sigma X^2 - (\Sigma X)^2}{N(N-1)}}$$

(360 words per minute), the history passage at an average rate of 706 ems per minute (270 words per minute), and the education passage at an average speed of 695 ems per minute (266 words per minute).

The trend to read material from one's own fields more rapidly than the material from the other subject-matter areas was very striking in individual cases. An example is given in Figure 1. This figure shows the eye-movement record of Case 8 among the physics professors. This individual read the history passage at 654 ems per minute (250 words per minute) and the education passage at 690 ems per minute (265 words per minute), but when he read the physics passage, he practically doubled his speed, reading it at 1,194 ems per minute (460 words per minute). Moreover, in reading the physics passage, this subject virtually eliminated regressive movements.

The question now arises as to the significance of the differences between the performances of the various groups from passage to passage. Table VI presents this statistical information in the form of an analysis of variance. It displays only one difference that is significant at the 1 percent level. This difference occurred in the department-passage interaction and is in line with the results reported in Table V, which show that the departments tended to read their own special passages most efficiently. In a negative way, Table VI demonstrates that there are no significant differences between the departments when their total rate performances on

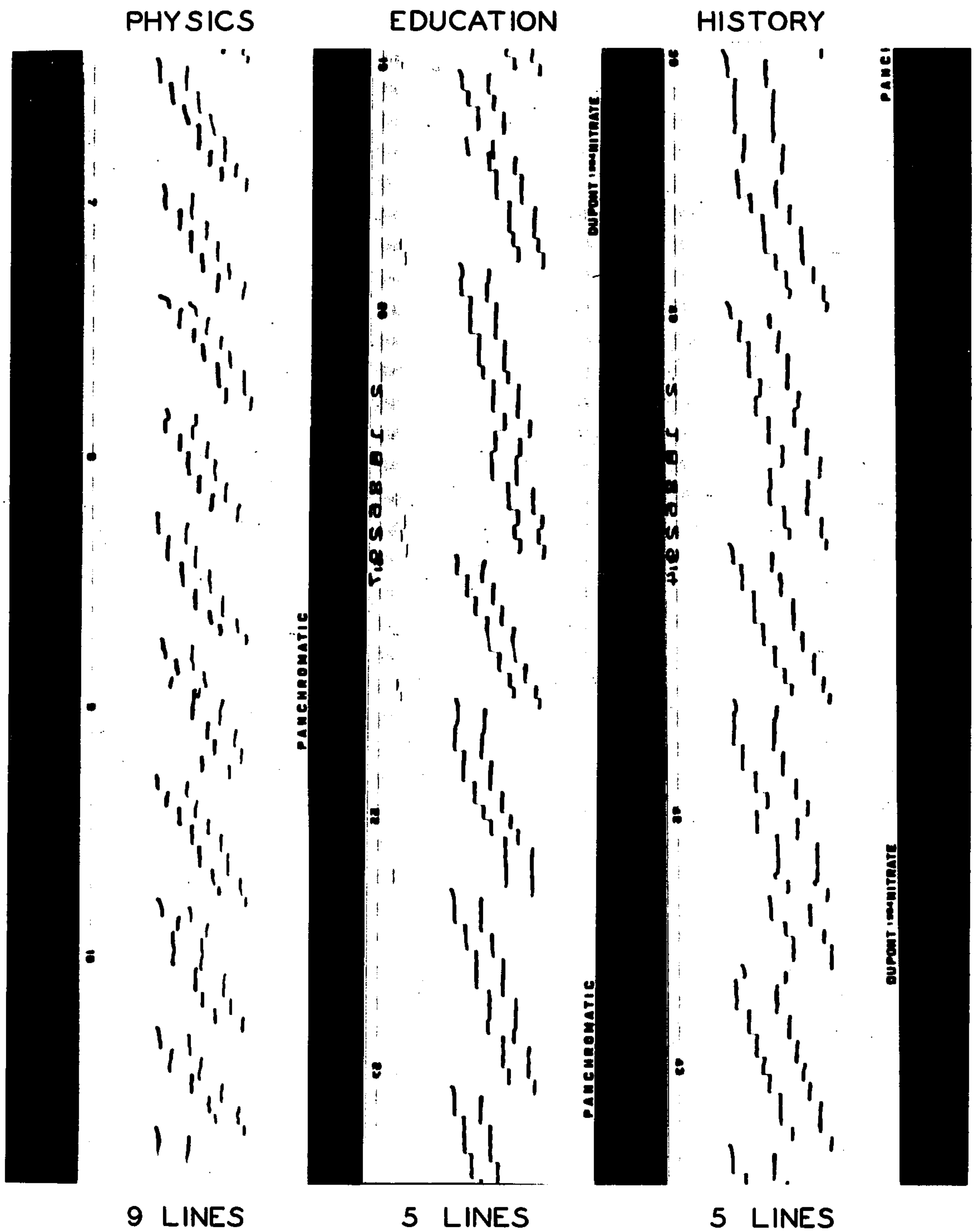


FIGURE I

SAMPLE EYE-MOVEMENT RECORDS OF A PHYSICS PROFESSOR (CASE 8) ILLUSTRATING VARIATION IN PERFORMANCE FROM FAMILIAR PASSAGE TO UNFAMILIAR PASSAGES

TABLE VI

SUMMARY OF ANALYSIS OF VARIANCE DATA FOR RATE OF READING

Source	Degrees of Freedom	A	I	Sums of Squares	A or I / D.F.	F	1 per-cent	5 per-cent
Total	287	4,360,558,976		15,140,829				
Total (with replications summed)................	17	478,706,480		1,662,175				
Departments............	2	37,114,802		128,870	18,557,401	1.29	4.71	3.04
Passages..............	2	97,770,968		339,482	48,885,484	3.40	4.71	3.04
Ranks..................	1	864,900		3,003	864,900	.06	6.76	3.89
Department-Rank........	2	46,613,348	8,633,646	29,978	4,316,823	.30	4.71	3.04
Passage-Rank...........	2	108,789,332	10,153,464	35,255	5,076,732	.35	4.71	3.04
Department-Passage.....	4	433,299,446	298,413,676	1,036,159	74,603,419	5.19	3.41	2.41
Department-Rank-Passage	4		25,755,024	89,427	6,438,756	.45	3.41	2.41
Error	270		3,881,852,496	13,478,654	14,377,231			

all passages are considered. It also discloses that there are no significant differences between the professors and graduate-students as far as rate of reading is concerned.

In view of the very significant difference that existed in the department-passage interaction, t tests were made of those combinations of passages within a department which from inspection seemed to offer the best chance of being significant. Table VII presents the t values obtained.

Only two of the t values are significant at the 1 percent level. Both of these differences involve the performances of the physics groups, and it is clear that these subjects read the familiar physics passage significantly faster than they read the unfamiliar history and education passages. None of the other departments read the various passages at rates different enough to reach the 1 percent level of confidence. It will be noticed that a t value is given for the history professors' reading of education and history. This t test was made because an inspection of Table V showed that the contrasting performance of the history graduate-students on these passages might be concealing a significant difference between the rates with which the history professors read the two passages. A t value of 1.66 was derived from this comparison, and it is significant at approximately the 10 percent level.

<u>Fixation Frequency</u>. Table VIII reveals the same trend for fixation frequency as was found for rate of reading. This

TABLE VII

SIGNIFICANCE OF THE DIFFERENCES FOR RATE OF READING BETWEEN VARIOUS COMBINATIONS OF DEPARTMENTS AND PASSAGES WITH REFERENCE TO THE EFFECT OF FAMILIARITY

Department-Passage Combination	Degrees of Freedom	t	1 per-cent	5 per-cent
Education subjects: education vs. history............	62	.95	2.66	2.00
Physics subjects: physics vs. education...............	62	5.19	2.66	2.00
Physics subjects: physics vs. history.................	62	4.12	2.66	2.00
Physics subjects: education vs. history.................	62	.58	2.66	2.00
History subjects: education vs. history.................	62	1.05	2.66	2.00
History professors: education vs. history...........	30	1.66	2.75	2.04

TABLE VIII

MEAN NUMBER OF FIXATIONS PER EM AND THE STANDARD DEVIATIONS OF THE DISTRIBUTIONS BY DEPARTMENTS FOR ALL PASSAGES

Passages	Departments					
	Education		Physics		History	
	Professors	Graduate Students	Professors	Graduate Students	Professors	Graduate Students
1. Education	.295 σ.067	.310 σ.071	.319 σ.043	.374 σ.115	.303 σ.070	.265 σ.069
2. Physics	.311 σ.060	.323 σ.091	.272 σ.078	.299 σ.033	.299 σ.071	.283 σ.054
3. History	.313 σ.069	.311 σ.067	.310 σ.054	.343 σ.081	.265 σ.055	.268 σ.048

result is to be expected, inasmuch as rate of reading and fixation frequency are correlated measures. Rate is really a composite measure of eye-movements.

All of the professor groups made their fewest fixations on the passage from their own field. For example, the physics professors averaged .319 fixations per em (9.5 fixations per line) on the education passage, .310 fixations per em (8.9 fixations per line) on the history passage, but only .272 fixations per em (7.8 fixations per line) on the physics passage. The physics graduate-students followed the same pattern as the physics professors. The graduate-students in history and education tended to depart from the pattern set by the professors in these fields, much as they did in rate of reading.

As in the case of rate of reading, the tendency to make the fewest fixations on the familiar passage stands out when individual performance is studied. A reexamination of Figure 1 will serve to illustrate this point. This subject, a physics professor, made .305 fixations per em (8.8 fixations per line) on the history passage, .266 fixations per em (7.7 fixations per line) on the education passage, but only .215 fixations per em (6.2 fixations per line) on the physics passage.

The analysis of variance data for fixation frequency are presented in Table IX. Here it is made known that two of the main effects have differences among them which are significant at the 1 percent level. The first involves a comparison

TABLE IX

SUMMARY OF ANALYSIS OF VARIANCE DATA FOR FIXATION FREQUENCY

Source	Degrees of Freedom	A	I	Sums of Squares	I / D.F.	F	1 per-cent	5 per-cent
Total	287	387.48		1.34541				
Total (with replications summed)................	17	60.78		.21104				
Departments............	2	22.92		.07958	11.46	9.47	4.71	3.04
Passages...............	2	2.49		.00864	1.24	1.02	4.71	3.04
Ranks..................	1	2.16		.00750	2.16	1.79	6.76	3.89
Department-Rank........	2	35.63	10.55	.03663	5.27	4.36	4.71	3.04
Passage-Rank...........	2	4.73	.08	.00028	.04	.03	4.71	3.04
Department-Passage.....	4	44.75	19.34	.06715	4.83	3.99	3.41	2.41
Department-Rank-Passage	4		3.24	.01125	.81	.67	3.41	2.41
Error	270		326.70	1.13437	1.21			

of the total performance, in terms of the number of fixations, among the three departments, and the other is found in the interaction of departments and passages. This second difference is similar to the difference which emerged for rate of reading. However, the difference between departmental performances is a new development. It will be discussed in a later section of the results dealing with the transfer effects of reading the materials of a special field.

In order to ascertain more particularly where the significant differences were in the department-passage interaction, t tests were made of the various combinations of the passages within a department. Table X gives the resulting t values.

Table X establishes a very significant difference between the number of fixations the physicists made on the education and physics passages. It also shows a t value approaching the 1 percent level between the performances of the physicists on the history and physics passages. Within the departments of education and history, no significant differences were found between the fixation frequency scores for any of the possible combinations of passages.

Regression Frequency. Table XI presents the average results for regression frequency together with the standard deviations of the distributions. The same trend is shown as for rate of reading and fixation frequency.

In each department the professors made their fewest re-

TABLE X

SIGNIFICANCE OF THE DIFFERENCES FOR FIXATION FREQUENCY BETWEEN VARIOUS COMBINATIONS OF DEPARTMENTS AND PASSAGES WITH REFERENCE TO THE EFFECT OF FAMILIARITY

Department-Passage Combination	Degrees of Freedom	t	1 per-cent	5 per-cent
Education subjects: education vs. physics............	62	.92	2.66	2.00
Physics subjects: education vs. physics................	62	3.05	2.66	2.00
Physics subjects: education vs. history.................	62	1.05	2.66	2.00
Physics subjects: physics vs. history.................	62	2.52	2.66	2.00
History subjects: history vs. physics.................	62	1.72	2.66	2.00
History professors: education vs. history...........	30	1.25	2.75	2.04

TABLE XI

MEAN NUMBER OF REGRESSIONS PER EM AND THE STANDARD DEVIATIONS OF THE DISTRIBUTIONS BY DEPARTMENTS FOR ALL PASSAGES

Passages	Departments					
	Education		Physics		History	
	Professors	Graduate Students	Professors	Graduate Students	Professors	Graduate Students
1. Education	.034 σ .028	.030 σ .018	.042 σ .019	.057 σ .038	.037 σ .024	.027 σ .025
2. Physics	.035 σ .019	.037 σ .025	.024 σ .017	.029 σ .021	.030 σ .022	.031 σ .022
3. History	.034 σ .026	.030 σ .019	.033 σ .019	.044 σ .023	.025 σ .021	.029 σ .024

gressions in reading the passages from their own fields. For example, the history professors averaged .037 regressions per em (1.07 regressions per line) on the education passage, .030 regressions per em (.86 regressions per line) on the physics passage, but only .025 regressions per em (.72 regressions per line) on the history passage. The performance of the physics professors for this measure was even more markedly in favor of the passage from their own field. The education professors, in terms of regression frequency, distinguished hardly at all between the three passages. Of the graduate-students, only the physics group followed the pattern set by the professors.

Once again, the variation from passage to passage was especially conspicuous in individual cases. Figure 1 remains a good example. This subject, a physics professor, made .042 regressions per em (1.21 regressions per line) on the education passage, .041 regressions per em (1.18 regressions per line) on the history passage, but only .015 regressions per em (.43 regressions per line) on the physics passage.

Although there was a general tendency on the part of the subjects to make their fewest regressions on the material from their own field, Table XII shows that none of the differences in the group performanees attained the 1 percent level of significance. It should be stated, however, that an F of 3.13 was derived for the department-passage interaction. An F of this magnitude is significant at about the 2 percent

TABLE XII

SUMMARY OF ANALYSIS OF VARIANCE DATA FOR REGRESSION FREQUENCY

Source	Degrees of Freedom	A	I	Sums of Squares	A or I / D.F.	F	1 per-cent	5 per-cent
Total	287	46.39		.16107				
Total (with replications summed)................	17	4.99		.01732				
Departments............	2	1.03		.00358	.51	3.40	4.71	3.04
Passages...............	2	.73		.00253	.36	2.40	4.71	3.04
Ranks..................	1	.09		.00031	.09	.60	6.76	3.89
Department-Rank........	2	1.87	.75	.00260	.37	2.47	4.71	3.04
Passage-Rank...........	2	.85	.03	.00010	.01	.10	4.71	3.04
Department-Passage.....	4	3.64	1.88	.00653	.47	3.13	3.41	2.41
Department-Rank-Passage	4		.48	.00166	.12	.80	3.41	2.41
Error	270		41.40	.14375	.15			

level. It is the same interaction in which an F significant at the 1 percent level was found for both rate of reading and fixation frequency. The results for regression frequency are in general agreement with the results for these other two measures. Regression frequency is also less reliable and valid than rate of reading and fixation frequency and, therefore, more subject to errors of measurement. It was not to be expected that the results for regression frequency would be as significant as for rate of reading and fixation frequency. Incidentally, fixation frequency includes regression frequency.

Refixation Frequency. The number of refixations per line is the final eye-movement measure which was used in the present study. Table XIII presents the average number of refixations made by each group on each passage.

Table XIII shows a continuation of the trend established for the other eye-movement measures. All professor groups made their fewest inaccurate return sweeps on the material in their own field. For example, the education professors averaged .40 refixations per line on the education passage, .46 refixations per line on the history passage, and .48 refixations per line on the physics passage. The trend for the two other professor groups is even more pronounced. Once again, the graduate-students in history and education deviate from the pattern established by the professors in these departments. However, the history and education graduate-students

TABLE XIII

MEAN NUMBER OF REFIXATIONS PER LINE AND THE STANDARD DEVIATIONS OF THE DISTRIBUTIONS BY DEPARTMENTS FOR ALL PASSAGES

Passages	Departments					
	Education		Physics		History	
	Professors	Graduate Students	Professors	Graduate Students	Professors	Graduate Students
1. Education	.40	.46	.45	.52	.47	.21
	σ .30	σ .29	σ .25	σ .33	σ .34	σ .20
2. Physics	.48	.44	.41	.51	.43	.30
	σ .35	σ .32	σ .35	σ .29	σ .31	σ .17
3. History	.46	.52	.63	.55	.32	.27
	σ .32	σ .30	σ .24	σ .27	σ .28	σ .20

made their fewest refixations on their most rapidly read passages, which suggests that a relationship exists between rate and refixation frequency.

Table XIV summarizes the analysis of variance data for refixation frequency. Only the F for the departmental comparison was found to be significant at the 1 percent level. This difference will be discussed in the section of the results dealing with the effect of special training on reading habits.

Comprehension Scores. Table XV gives the mean comprehension scores for each group on each passage. In keeping with the practice which has been adopted in presenting these results, the standard deviations of the distributions are also included.

It is evident from Table XV that the physics subjects made the highest as well as the lowest comprehension scores. They averaged 90.6 percent on the physics questions, but only 63.1 percent on the history questions and only 64.3 percent on the education questions. Actually, every department averaged higher in comprehension on the physics questions than on any other set of questions. The education subjects averaged 72.5 percent on the education test, 73.1 percent on the history test, and 83.7 percent on the physics test, while the history subjects averaged 74.3 percent on the education questions, 79.3 percent on the physics questions, and 74.3 percent on the history questions.

TABLE XIV

SUMMARY OF ANALYSIS OF VARIANCE DATA FOR REFIXATION FREQUENCY

Source	Degrees of Freedom	A	I	Sums of Squares	A or I / D.F.	F	1 per-cent	5 per-cent
Total	287	7078.07		24.57663				
Total (with replications summed)...............	17	861.05		2.98975				
Departments............	2	468.77		1.62767	234.38	10.18	4.71	3.04
Passages...............	2	19.07		.06621	9.53	.41	4.71	3.04
Ranks..................	1	15.53		.05392	15.53	.67	6.76	3.89
Department-Rank........	2	628.31	144.01	.50003	72.00	3.13	4.71	3.04
Passage-Rank...........	2	37.91	3.31	.01149	1.65	.07	4.71	3.04
Department-Passage.....	4	589.16	101.32	.35180	25.33	1.10	3.41	2.41
Department-Rank-Passage	4		109.04	.37861	27.52	1.19	3.41	2.41
Error	270		6217.02	21.58687	23.03			

TABLE XV

MEAN COMPREHENSION SCORES IN PERCENT AND THE STANDARD DEVIATIONS OF THE DISTRIBUTIONS BY DEPARTMENTS FOR ALL PASSAGES

Passages	Departments					
	Education		Physics		History	
	Professors	Graduate Students	Professors	Graduate Students	Professors	Graduate Students
1. Education	70.0 σ 21.9	75.0 σ 20.0	53.7 σ 15.8	75.0 σ 23.8	70.0 σ 23.8	78.7 σ 24.8
2. Physics	82.5 σ 24.1	85.0 σ 13.6	90.0 σ 14.6	91.2 σ 10.2	80.0 σ 14.5	78.7 σ 33.0
3. History	77.5 σ 21.3	68.7 σ 12.6	57.5 σ 20.4	68.7 σ 19.3	81.2 σ 15.5	67.5 σ 32.0

The tendency to score higher on the physics questions shows up in Table XVI, where the analysis of variance data for the comprehension scores are summarized. An F of 14.81 was derived when the total scores on the various tests were compared. It is the only instance to be found in this table of a difference significant at the 1 percent level. In accordance with the procedure being followed, t tests were made comparing the comprehension scores on each passage's questions. Table XVII presents the resulting t values.

The t test comparing the scores on the education and history passages resulted in a value that was not significant. However, when comprehension on the physics passage was compared with comprehension on the other two passages, differences significant at better than the 1 percent level were found. Why the subjects tended to score higher on the physics questions is not clear. It is possible that the questions on the physics passage were easier than the questions on the other passages.

A possible source of criticism are the low average comprehension scores of the physics subjects on the education and history passages. The average performances of the physics professors on the tests for these passages were hardly better than chance. The question may be raised whether they actually read the material and consequently whether the results for these passages are valid. On the other hand, it is interesting to note the relationship which existed between the comprehension scores and the eye-movement results for the physics

TABLE XVI

SUMMARY OF ANALYSIS OF VARIANCE DATA FOR COMPREHENSION SCORES

Source	Degrees of Freedom	A	I	Sums of Squares	A or I / D.F.	F	1 per-cent	5 per-cent
Total	287	41,990,000		145,798				
Total (with replications summed)...............	17	7,768,400		26,973				
Departments............	2	233,600		811	116,800	.92	4.71	3.04
Passages..............	2	3,754,400		13,306	1,877,200	14.81	4.71	3.04
Ranks.................	1	176,400		612	176,400	1.39	6.76	3.89
Department-Rank........	2	1,139,600	729,600	2,533	364,800	2.88	4.71	3.04
Passage-Rank..........	2	4,797,200	866,400	3,008	433,200	3.42	4.71	3.04
Department-Passage.....	4	5,478,800	1,490,800	5,176	372,700	2.94	3.41	2.41
Department-Rank-Passage	4		517,200	1,795	129,300	1.02	3.41	2.41
Error	270		34,221,600	118,825	126,747			

TABLE XVII

SIGNIFICANCE OF THE DIFFERENCES FOR COMPREHENSION SCORES BETWEEN THE PASSAGE COMBINATIONS

Passages Compared	Degrees of Freedom	t	1 per-cent	5 per-cent
Education vs. Physics........	190	4.57	2.60	1.97
Education vs. History........	190	.06	2.60	1.97
Physics vs. History..........	190	4.83	2.60	1.97

subjects. Table V has disclosed that this group read the physics passage more rapidly than any other group read any passage. It also shows that the physics subjects read the history and education passages at a slower rate than any other group read any passage. Turning to Table XV, we find that the physics subjects made a comprehension score on the physics passage that was the highest made by any group on any passage. Conversely, the scores of the physics subjects on the other two passages were the lowest recorded. These findings are strictly in line with the relationship which is to be expected between rate and comprehension. Previous research has shown that rapid rate and good comprehension are associated and that slow rate and poor comprehension go together. It is not so much that the physics subjects did not read the education and history passages as that they had difficulty comprehending the material. The eye-movements were affected adversely by the comprehending difficulty, which is exactly what should happen, if the reading performance is normal. When it comes to evaluating the validity of the findings of this study, these results for the physics subjects constitute one of the greatest sources of encouragement.

Summary. To summarize the results presented in this section, the following statements may be made:

(1) All of the professor groups tended to read the passage from their own field more efficiently than the passages from the other fields.

(2) Of the graduate-student groups, only the physics students followed the pattern set by the professors.

(3) The education graduate-students tended to read the physics passage slightly more efficiently than the education passage.

(4) The history graduate-students tended to read the education passage slightly more efficiently than the history passage.

(5) The differences in favor of the passage from the subjects' own field were statistically significant only in the case of the physics subjects and then only for rate of reading and fixation frequency.

(6) The differences in favor of the familiar passage approached statistical significance in the case of the history professors for rate of reading on the education versus history passage comparison and in the case of all the history subjects for fixation frequency on the history versus physics passage comparison.

These results will be evaluated in Chapter VI, which is reserved for a discussion of all of the specific findings of this research.

Types of Reading as a Factor in Reading Performance

In Chapter III it was explained how the design of this experiment permits a test of the hypothesis that different types of subject-matter elicit different types of reading.

The point was made that if all the subject groups read the physics passage at slower average rates than any other passage, it might be inferred that scientific material calls for a slow, meticulous type of reading, and that if all of the subject groups had their highest average rate on the history passage, it might be deduced that history material elicits a rapid rate of reading. The results already presented, however, have shown that no passage was consistently read slower or faster by all the subject groups. In order to make a further attempt to uncover types of reading, it becomes necessary, therefore, to resort to the other approach which was mentioned. This other approach involves specific comparisons of the performances of the various departments on unfamiliar passages. If the education subjects read the physics and history passages at significantly different rates, if the history subjects read the physics passage at a significantly slower average rate than the education passage, and if the physics subjects read the history passage at a significantly faster average rate than the education passage, it might be inferred that types of reading play at least a part in reading performance. And so, t tests were made of these comparisons for those measures which showed a significant difference in the analysis of variance.

Rate of Reading. Table XVIII presents the t values which were obtained for rate of reading. It is evident from Table XVIII that the education subjects did not read the his-

TABLE XVIII

SIGNIFICANCE OF THE DIFFERENCES FOR RATE OF READING BETWEEN VARIOUS COMBINATIONS OF DEPARTMENTS AND PASSAGES WITH REFERENCE TO TYPES OF READING

Department-Passage Combination	Degrees of Freedom	t	1 per-cent	5 per-cent
Education subjects: physics vs. history.........	62	.73	2.66	2.00
History subjects: education vs. physics.......	62	.20	2.66	2.00
Physics subjects: education vs. history.......	62	.58	2.66	2.00

tory and physics passages at significantly different rates, that the history subjects did not read the physics passage significantly slower than the education passage, and that the physics subjects did not read the history passage significantly faster than the education passage. On the basis of these results, we may state that the present study has not identified either a slow rate of reading for the physics passage or a fast rate of reading for the history passage.

Fixation Frequency. Since we have not been able to identify special types of reading in terms of the rate scores, it is not to be expected that the results for fixation frequency will be any different. Table XIX presents the t values involving the three comparisons for this measure. Nothing in these results gives encouragement to the idea that different types of material require different types of reading. The education subjects did not make a significantly different number of fixations on the history and physics passages, the history subjects did not make significantly more fixations on the physics passage than on the education passage, and the physics subjects did not make significantly fewer fixations on the history passage than on the education passage.

Regression Frequency. This is one of the eye-movement measures for which no significant F values were found in the analysis of variance. Hence, no t values were computed. The results for regression frequency may be added to the negative

TABLE XIX

SIGNIFICANCE OF THE DIFFERENCES FOR FIXATION FREQUENCY BETWEEN VARIOUS COMBINATIONS OF DEPARTMENTS AND PASSAGES WITH REFERENCE TO TYPES OF READING

Department-Passage Combination	Degrees of Freedom	t	1 per-cent	5 per-cent
Education subjects:				
history vs. physics..........	62	.57	2.66	2.00
History subjects:				
education vs. physics........	62	.42	2.66	2.00
Physics subjects:				
education vs. history........	62	.95	2.66	2.00

side of the ledger along with the results for rate of reading and fixation frequency.

Refixation Frequency. There is no evidence, either, that the number of inaccurate return sweeps an individual makes has any relation to types of reading. Table XIV shows a significant difference for this measure when the total departmental performances were compared. However, this difference is not related to the problem of types of reading. All departmental differences are taken up in the next section which deals with the effect of special training on reading habits.

Summary. The results of this section may be summarized as follows:

(1) No convincing evidence of types of reading has been obtained. The following specific findings support this statement:

(a) The education subjects did not read the physics and history passages at significantly different rates.

(b) The history subjects did not read the physics passage at a significantly slower rate than the education passage.

(c) The physics subjects did not read the history passage significantly faster than the education passage.

(2) The above statements apply not only to rate of reading but also to fixation frequency, regression frequency, and

refixation frequency.

The Effect of Training in a Special Field on Reading Performance

In relating this question to the design of the experiment, it was stated that if the physics subjects read all of the passages at a slower rate than the other groups, the interpretation might be that constant reading of technical material serves to hamper rate on all materials. It was also stated that if the history subjects read all of the passages at a faster rate than the other groups, the inference in that case might be that wide reading of history material serves to establish a rapid rate for other materials. These statements do not take into account the possibility that physics selects people who are slow readers to begin with, and perhaps that history selects individuals who are rapid readers at the beginning. The design, therefore, called for a comparison of the professors with the graduate-students in these departments, the argument being that, if there is anything to the notion that specializing on the materials of a given field can have a transfer effect, the physics graduate-students should read all of the passages at a faster rate than the physics professors and the history graduate-students should read all of the passages at a slower rate than the history professors, inasmuch as the professors have had the longer experience.

The question of training effects, however, is closely bound up with the concept of types of reading. The concept, as previously stated, is that technical material induces a slow, careful rate and that historical writing promotes a rapid rate. No clearcut evidence to support this concept of types of reading was found in the present study. The results throw into question whether the physics subjects uniformly practice a slow rate of reading on the materials of their field and whether the history subjects uniformly practice a rapid rate on the materials of their field. How can there be a special practice effect under these conditions? The problem becomes almost non-existant. The results can hardly be otherwise than negative. The evidence bears out this contention. We did not find that the physics subjects read all of the passages at a slower rate than the other subject groups. Actually, they read the physics passage at a faster rate than any other group read any passage. They also read the history and education passages at slower average rates than any other group read any passage, but the explanation previously given is that they had difficulty comprehending these materials. Conversely, we did not find that the history subjects read all of the passages faster than the other groups. Actually, as pointed out before, the physics subjects read the physics passage at a slightly faster rate than the history subjects read the history passage. Comparing the performances of the professors and graduate-students likewise failed to reveal a training effect. The physics professors did not read at a slower rate than the physics graduate-students and the history professors did not read at a faster rate than the history graduate-students.

The results do show a tendency for the history subjects to read slightly more proficiently than the other groups. Table XX presents some of the evidence in the form of t values. Two of the t values are significant, namely, those comparing the history and physics subjects for rate of reading and fixation frequency on the education passage. The difference in each instance favors the history group. Thus, there is some evidence to show that the history subjects read an unfamiliar passage at a faster rate than the physics subjects read the same unfamiliar passage. It may be possible that the difference is related to a difference in training. The only trouble with this argument is that no significant differences appeared when the physics and education subjects were compared on an unfamiliar passage and when the history and education subjects were compared on the unfamiliar passage, that is, the physics subjects did not read the history passage at a significantly slower rate than the education subjects, and the history subjects did not read the physics passage at a significantly faster rate than the education subjects.

The analysis of variance data presented earlier in Tables IX and XIV offer one more source of hope for finding a training effect. It will be noted that in each of these two tables

TABLE XX

SIGNIFICANCE OF THE DIFFERENCES FOR RATE OF READING AND FIXATION FREQUENCY BETWEEN PHYSICS SUBJECTS READING UNFAMILIAR MATERIAL AND EDUCATION AND HISTORY SUBJECTS READING UNFAMILIAR MATERIAL

Comparison	Measure	Degrees of Freedom	t	1 per-cent	5 per-cent
Education subjects vs. physics subjects reading history......	Rate	62	.91	2.66	2.00
History subjects vs. physics subjects reading education....	Rate	62	2.32	2.66	2.00
Education subjects vs. history subjects reading physics......	Rate	62	.02	2.66	2.00
Education subjects vs. physics subjects reading history......	Fixations	62	.85	2.66	2.00
History subjects vs. physics subjects reading education....	Fixations	62	3.06	2.66	2.00
Education subjects vs. history subjects reading physics......	Fixations	62	1.53	2.66	2.00

a significant F was derived for the total departmental performances. In order to study the details of the difference, t tests were applied. Table XXI presents the results. Table XXI establishes the fact that the physics subjects did not make significantly more fixations than the education subjects, but it does reveal that the history subjects made significantly fewer fixations and refixations than the other two departments. Thus, while technical material may not make for slow readers, history material may tend to produce rapid readers. The latter suggestion is based on the finding that the history subjects read an unfamiliar passage at a significantly faster rate than the physics subjects and on the further finding that, as a department, the history subjects made significantly fewer fixations and refixations than both the education and physics groups. Definite conclusions are difficult to reach. There were no significant differences between the ranks in the history department. The possibility remains that the history subjects were a select group of individuals who were rapid readers before they entered the history field.

Summary. This section of the results may be summarized as follows:

(1) No clear-cut evidence has been found that training in a special field affects reading performance in other areas. The following specific findings support this statement.

(a) The physics subjects did not read all of the

TABLE XXI

SIGNIFICANCE OF THE DIFFERENCES FOR FIXATION FREQUENCY AND REFIXATION FREQUENCY BETWEEN TOTAL DEPARTMENTAL PERFORMANCES

Comparison	Measure	Degrees of Freedom	t	1 per-cent	5 per-cent
Education subjects vs. physics subjects.......	Fixations	190	.88	2.60	1.97
Education subjects vs. history subjects.......	Fixations	190	3.13	2.60	1.97
Physics subjects vs. history subjects.......	Fixations	190	3.80	2.60	1.97
Education subjects vs. physics subjects.......	Refixations	190	.80	2.60	1.97
Education subjects vs. history subjects.......	Refixations	190	3.17	2.60	1.97
Physics subjects vs. history subjects.......	Refixations	190	4.42	2.60	1.97

passages slower than the other subject groups.

(b) The history subjects did not read all of the passages faster than the other subject groups.

(c) The physics graduate-students did not read faster than the physics professors.

(d) The history graduate-students did not read slower than the history professors.

(e) The physics subjects did not read an unfamiliar passage significantly slower than the education subjects read the same unfamiliar passage.

(f) The history subjects did not read an unfamiliar passage significantly faster than the education subjects read the same unfamiliar passage.

(2) There is a suggestion, by no means conclusive, that training in the field of history may tend to make for rapid readers. This statement seems to be supported by these specific findings:

(a) The history subjects did read an unfamiliar passage significantly faster than the physics subjects read the same unfamiliar passage.

(b) The history subjects, as a department, made significantly fewer fixations and refixations than the other two departmental groups.

<u>Individual Differences in Reading Performances</u>

The presentation of the results dealing with the three secondary questions remains. The first of these questions concerns the individual differences in eye-movement performance which exist among the present group of subjects. The results relating to this problem will be presented separately for the three measures of greatest interest: rate of reading, fixation frequency, and regression frequency.

Individual Differences in Rate of Reading. Figures 2, 3, and 4 show the distributions for rate in ems per minute separately for each group and each passage. The mean of each distribution is indicated by the broken line which runs through the figure, while one standard deviation above and below the mean is marked off by the finely dotted lines which appear on either side of the mean.

Figure 2 presents the frequency distributions for rate of reading for the education subjects. Wide individual differences exist among both the professors and graduate-students on all passages. On the education passage, for example, there was one professor who read almost three times as rapidly as the slowest reader in the group. It is obvious at a glance that the intra-passage individual variation is enormously greater than the group variation from passage to passage. For the education professors, the difference between the lowest and highest mean scores was only 61 ems per minute (23 words per minute). This may be compared with a difference of 780 ems per minute (300 words per minute) between the fastest and slowest individual rate scores for these professors on

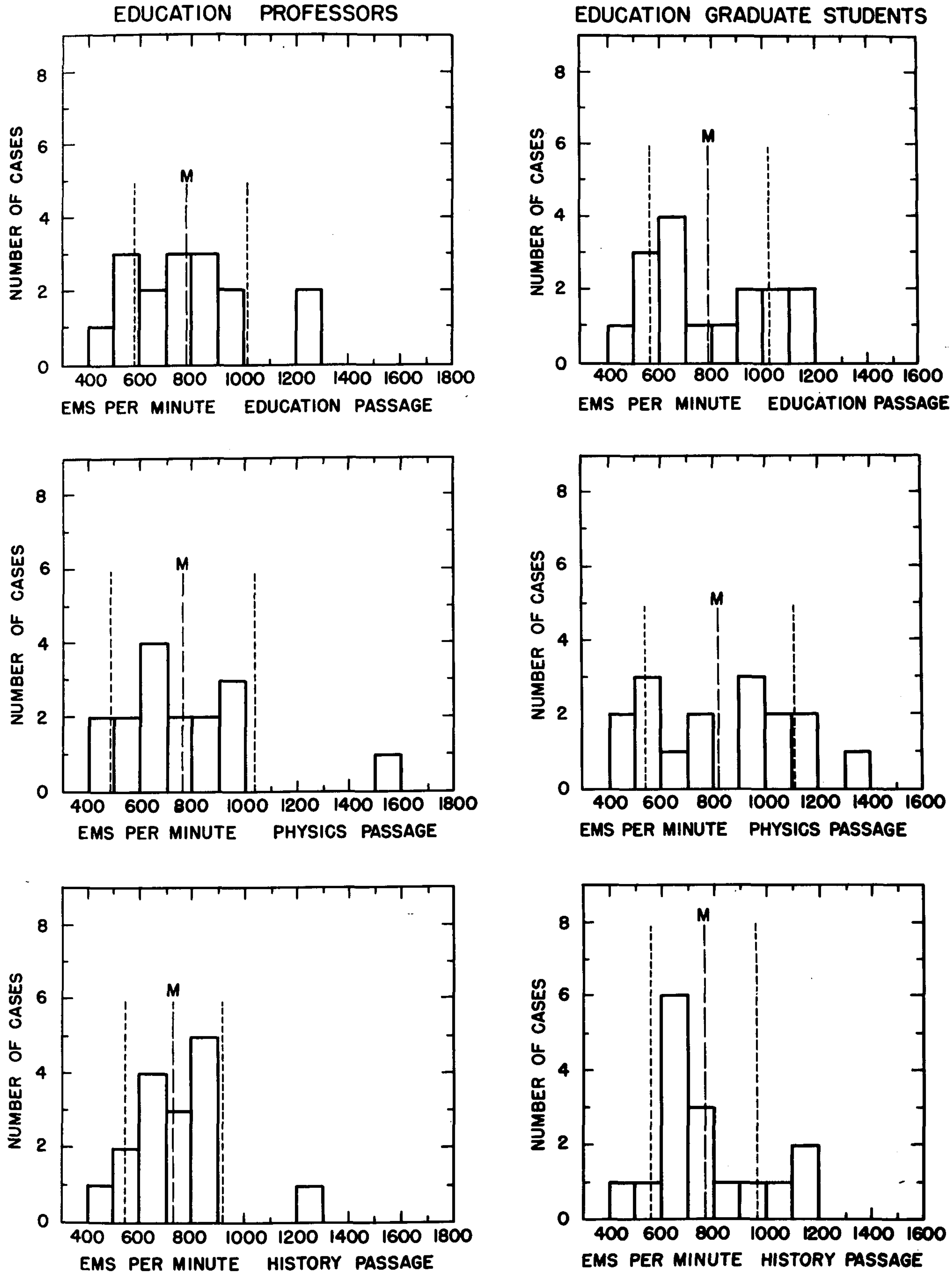


FIGURE 2

FREQUENCY DISTRIBUTIONS FOR RATE IN EMS PER MINUTE FOR EDUCATION SUBJECTS the education passage. There are no important differences in the amount of the intra-passage variation from selection to selection, and there are no important differences between the pattern of the intra-passage individual variation for the professors and graduate-students. The largest standard deviations were obtained on the physics passage for both groups, while the smallest standard deviations were obtained on the history passage.

Figure 3 shows the distributions of the rate scores for the physics subjects. Wide individual differences are again evident. On the physics passage, for example, there were some professors who more than doubled the rate of the slowest readers in the group. The intra-passage individual variation greatly exceeds the inter-passage group variation, although not as much as in the case of the education subjects, inasmuch as familiarity played a more significant part in the performance of the physics subjects than in that of either the education or history groups. The difference between the physics professors' mean rates on the passages they read the fastest and slowest was 261 ems per minute (100 words per minute). This figure can be compared with an intra-passage individual variation of 726 ems per minute (278 words per minute) for the physics professors on the physics passage. The largest standard deviations were obtained on the physics passage for both the physics professors and graduate-students, just as in the case of the history subjects. The least amount

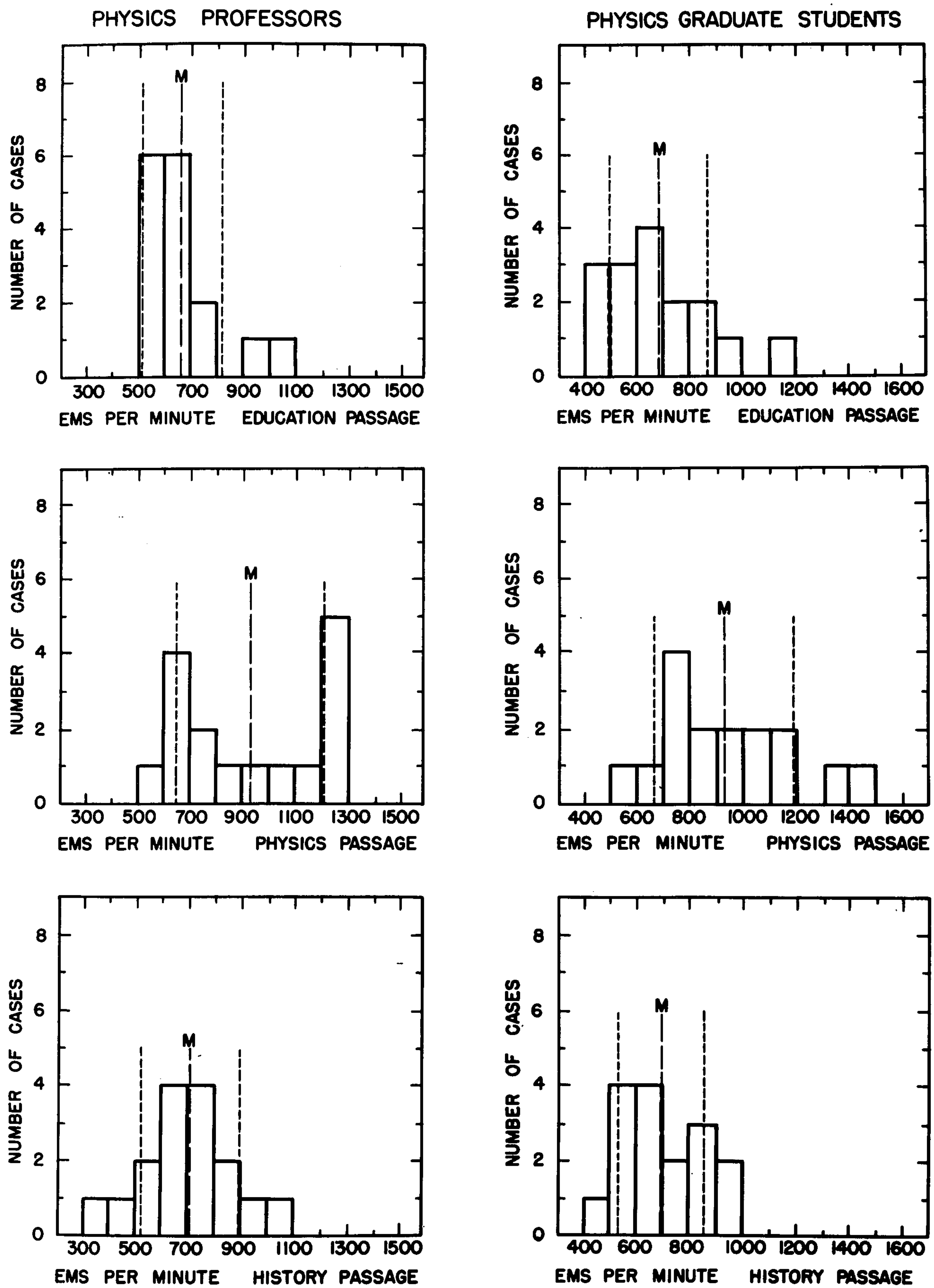


FIGURE 3

FREQUENCY DISTRIBUTIONS FOR RATE IN EMS PER MINUTE FOR PHYSICS SUBJECTS of individual variation, as measured by the standard deviations, was obtained on the education passage for the physics professors and on the history passage for the physics graduate-students.

Figure 4 displays the frequency distributions for rate of reading for the history subjects. Once again, large individual differences exist among both the professors and the graduate-students. One history professor, for example, read the education passage more than three times as fast as another history professor did. The group variation from passage to passage cannot compare in magnitude with the intra-passage individual variation. The difference between the history professors' mean rates on the passage they read the fastest and the passage they read the slowest was 143 ems per minute (59 words per minute). This may be compared with a difference of 894 ems per minute (342 words per minute) between the fastest and the slowest individual rate scores for these professors on the history passage. The amount of intra-passage individual variation among the history professors was fairly constant from passage to passage. The history graduate-students pretty much follow the pattern of the professors with regard to variability. The standard deviations for both groups are so nearly alike on all passages that there is little to be gained from making cross comparisons.

In general, there was very little difference in the variability of the rate performances between departments, unless

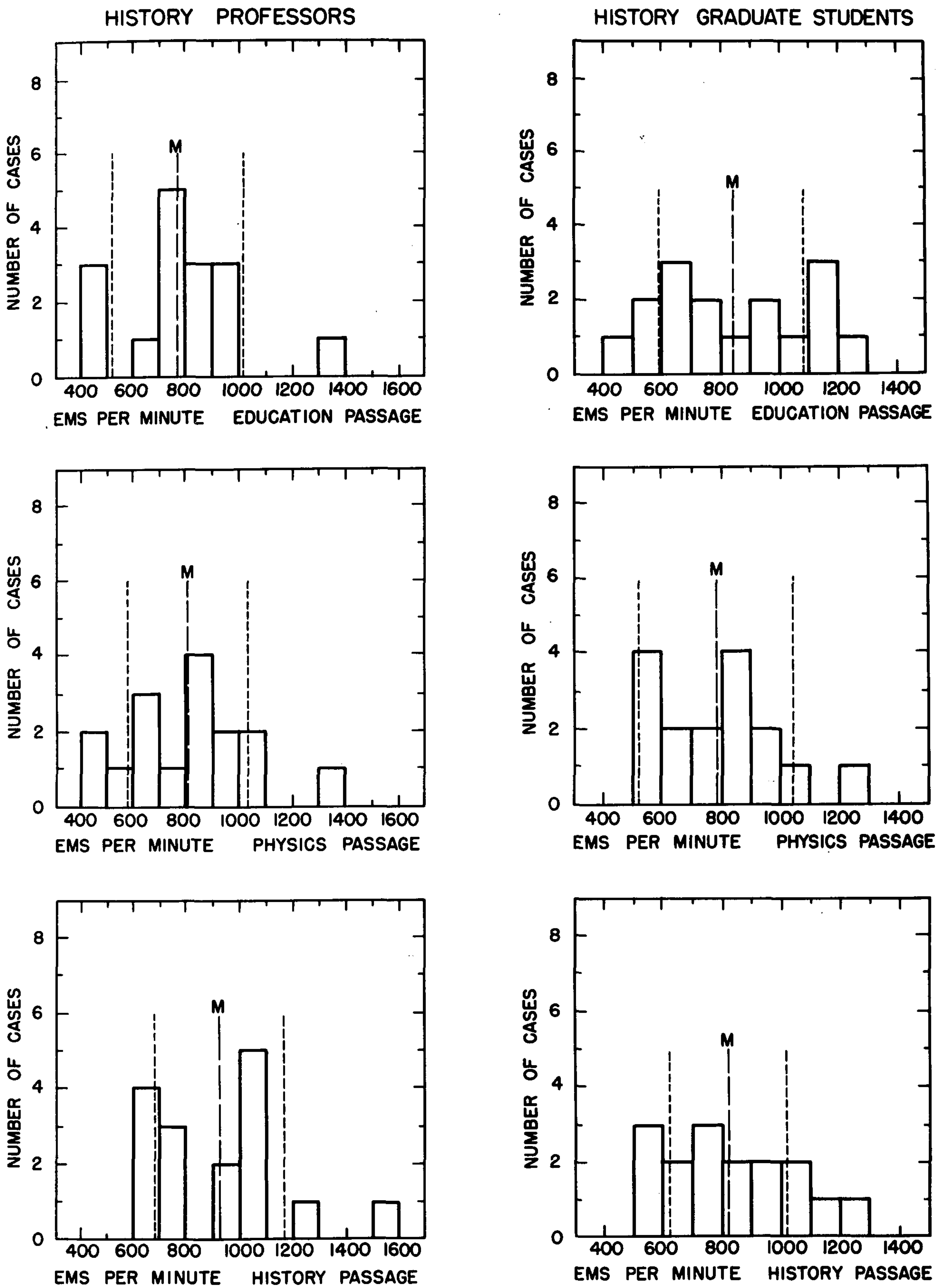


FIGURE 4

FREQUENCY DISTRIBUTIONS FOR RATE IN EMS PER MINUTE FOR HISTORY SUBJECTS it be that the physics subjects were slightly less variable on the education and history passages than were the education and history subjects.

Figures 5, 6, and 7 illustrate in terms of actual eye-movement records the intra-passage individual variations which existed among the subjects in all departments. On each figure two pairs of eye-movement records are shown. The first pair represents one of the fastest and one of the slowest readers among the professors in the department concerned; the second pair represents one of the fastest and one of the slowest readers among the graduate-students in that department. These records have been selected from the performances of the subjects on the passage for their own department.

Figure 5 illustrates the individual differences in rate of reading for the education subjects. A comparison of the two professors' records reveals that the fast reader, Case 2, read ten lines in the same time that the slow reader, Case 16, read four lines. An inspection of the other pair of records shown on this figure reveals that a similar difference existed between the two subjects representing the graduate-students in education.

Figure 6 presents the eye-movement records illustrating these differences for the physics subjects. A comparison of the records for the two professors shows that Case 15, the fast reader, read nine lines in less time than it took Case 5, the slow performer, to read four lines. The difference between

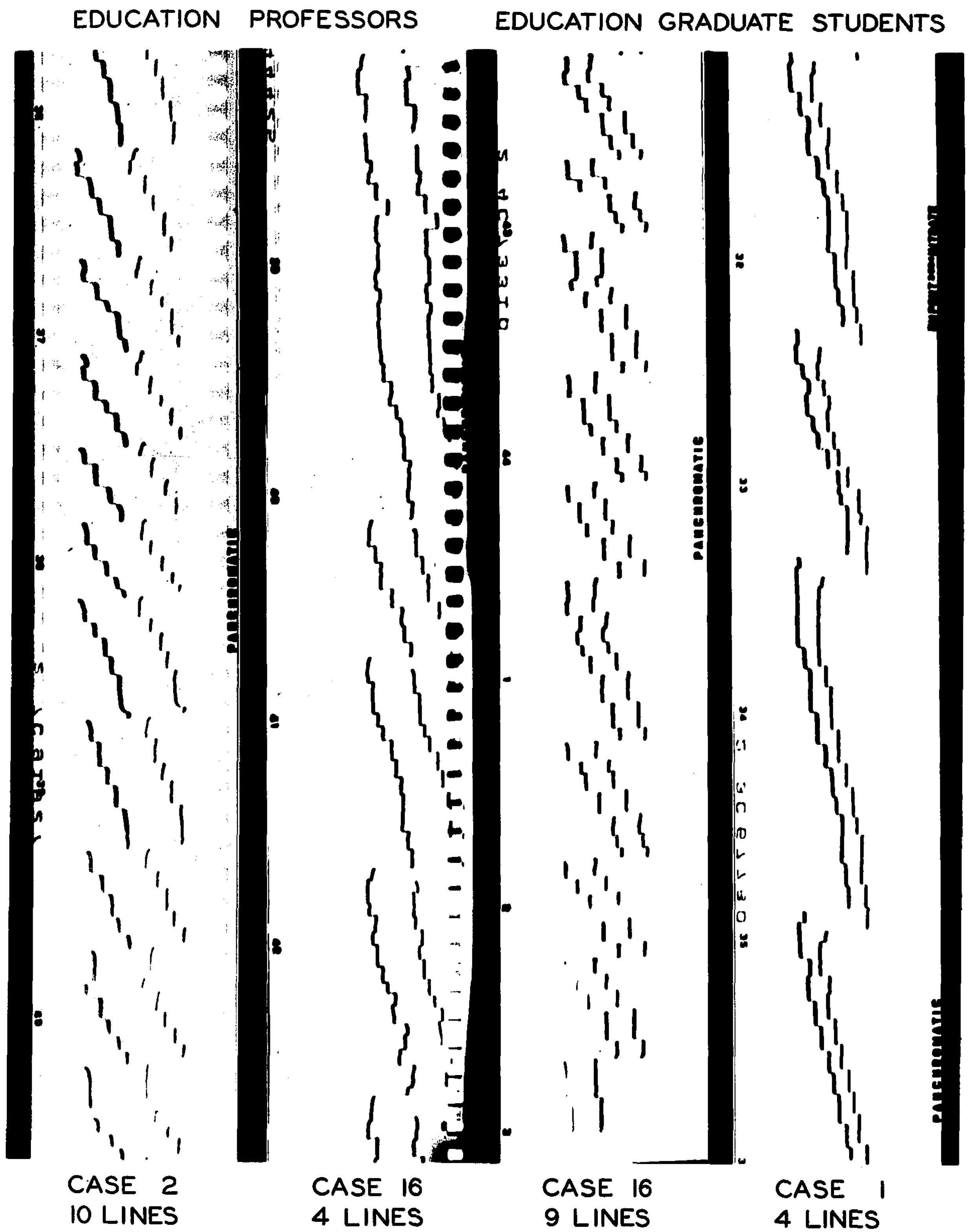


FIGURE 5

SAMPLE EYE-MOVEMENT RECORDS ILLUSTRATING INDIVIDUAL DIFFERENCES AMONG EDUCATION SUBJECTS READING THE EDUCATION PASSAGE

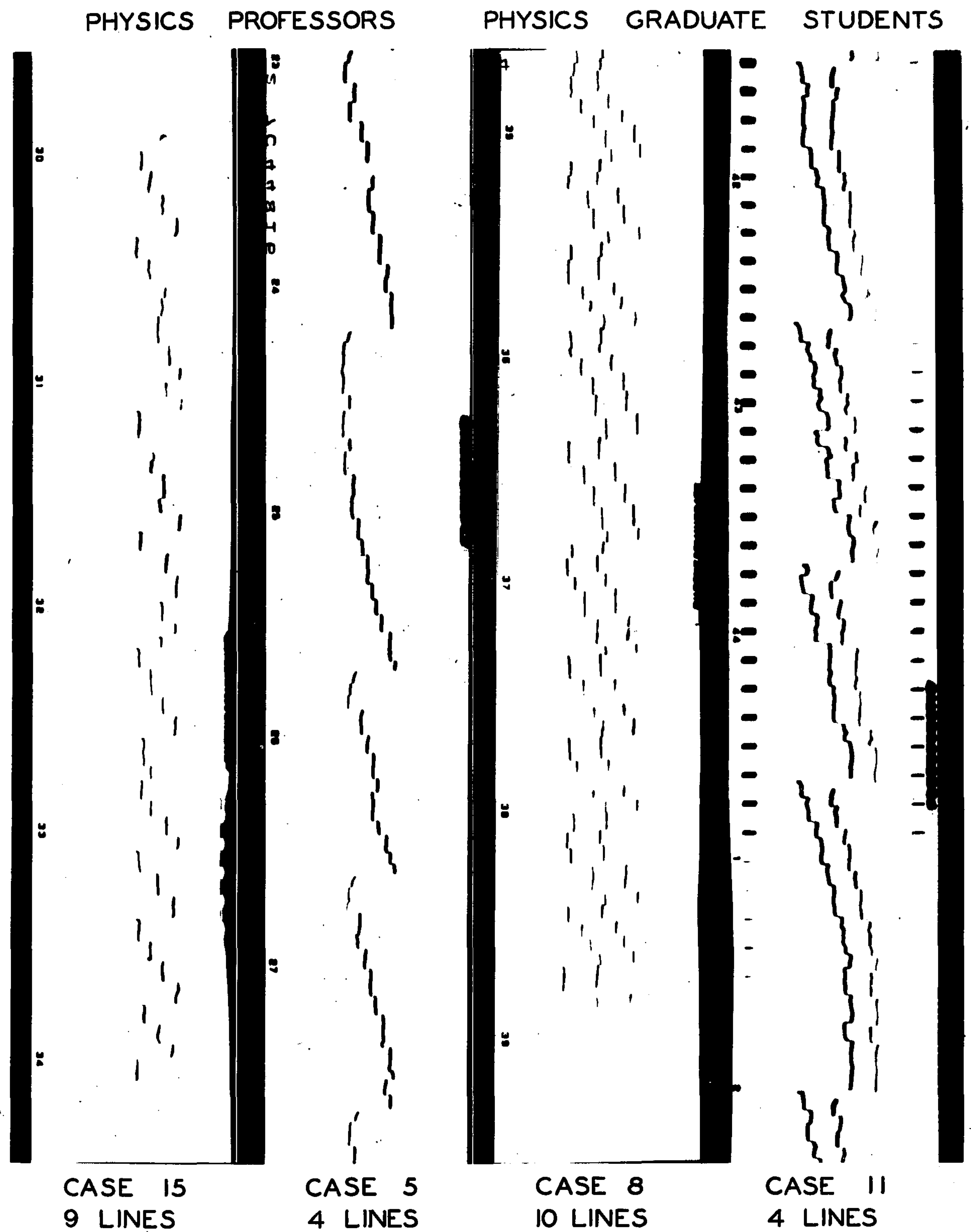


FIGURE 6

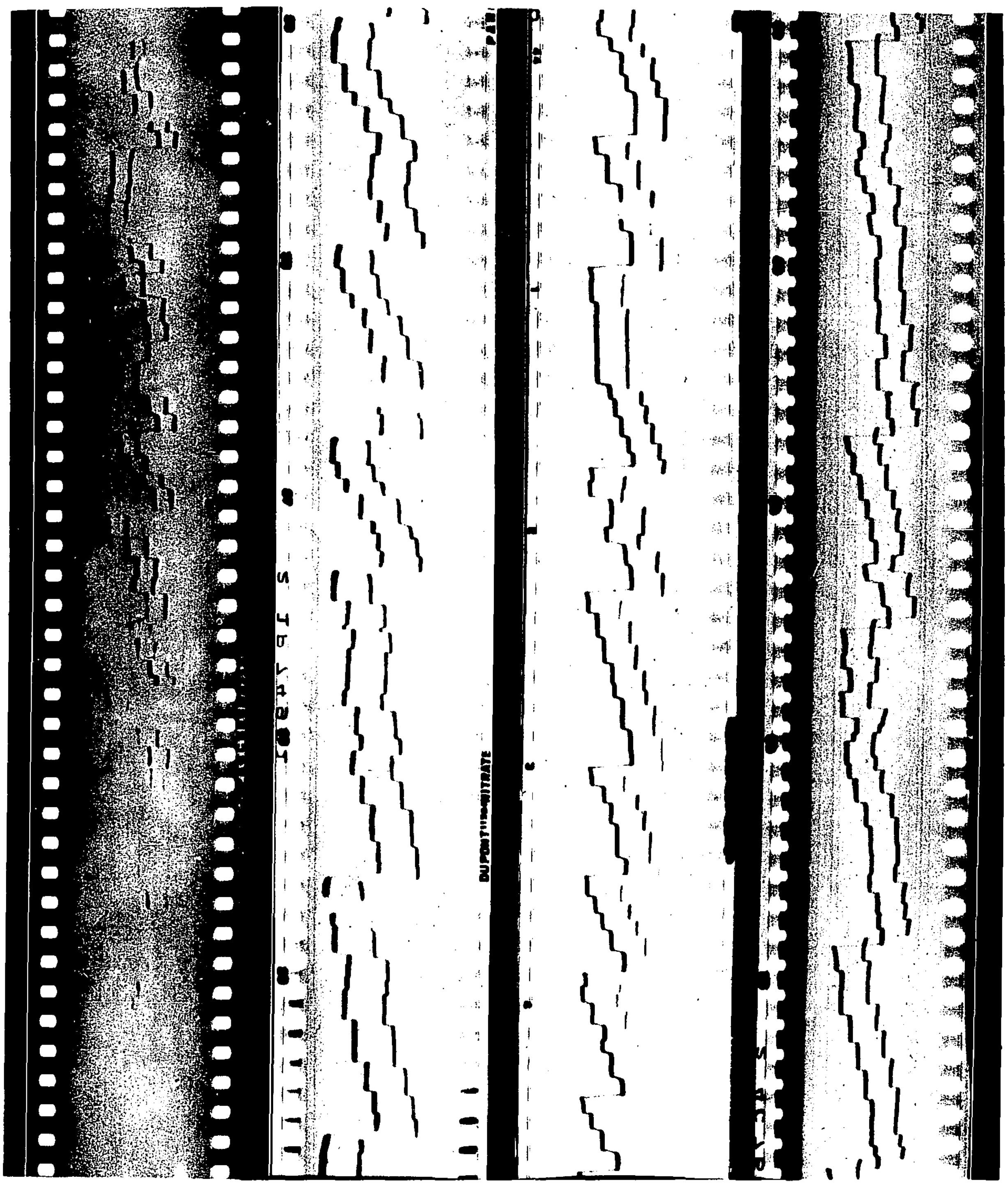
SAMPLE EYE-MOVEMENT RECORDS ILLUSTRATING INDIVIDUAL DIFFERENCES AMONG PHYSICS SUBJECTS READING THE PHYSICS PASSAGE the eye-movement records for the two graduate-students provides an equally good example of the individual differences in rate of reading which existed among the physics subjects on the physics passage.

The records shown on Figure 7 illustrate the individual differences in rate which existed among the history subjects. It will be noted that the eye-movement record for Case 13 of the history professors is somewhat faded in the lower portion of the illustration. However, it was possible to read the original record with the aid of a special light. The complete record shows that this professor read seven lines as quickly as Case 10 read four lines. A comparable difference exists between the records for the two graduate-students.

Individual Differences in Fixation Frequency. Figures 8, 9, and 10 show the distributions for fixations per em for each group on each passage. The same method of identifying the mean and standard deviation of each distribution has been followed as in the case of Figures 2, 3, and 4.

Figure 8 displays the frequency distribution for fixations per em for the education subjects. As in the case of rate of reading, large individual differences exist among both the professors and graduate-students on all passages. For example, one education professor made .189 fixations per em (5.4 fixations per line), while another professor on the same passage made .497 fixations per em (14.3 fixations per line). It is evident that the intra-passage individual

HISTORY PROFESSORS HISTORY GRADUATE STUDENTS



CASE 13 7 LINES | CASE 10 5 LINES | CASE 10 8 LINES | CASE 5 4 LINES

FIGURE 7

SAMPLE EYE-MOVEMENT RECORDS ILLUSTRATING INDIVIDUAL DIFFERENCES AMONG HISTORY SUBJECTS READING THE HISTORY PASSAGE

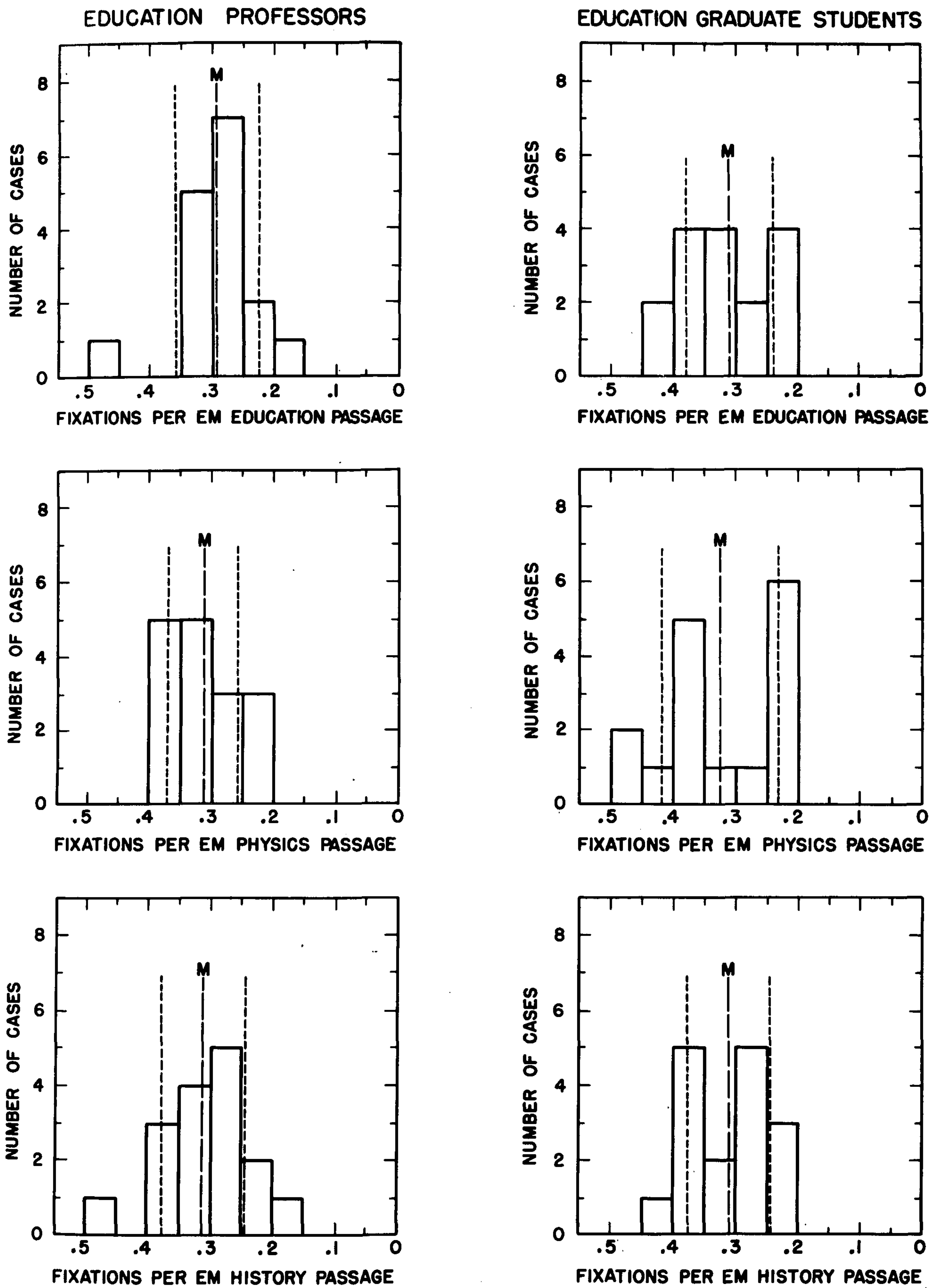


FIGURE 8

FREQUENCY DISTRIBUTIONS FOR FIXATIONS PER EM FOR EDUCATION SUBJECTS variation is vastly greater than the inter-passage group variation. The difference between the highest and lowest mean fixation scores among the professors on the education passage was .016 fixations per em (.46 fixations per line). This may be compared with a difference of .308 fixations per em (8.9 fixations per line) between the highest and lowest individual fixation scores for this group on the same passage. The intra-passage variation is fairly constant from selection to selection, and there is little difference between the intra-passage individual variation of the professors and graduate-students. The standard deviations obtained for the professors and graduate-students on each passage were very similar, except as the professors tended to be slightly less variable than the graduate-students on the physics passage.

Figure 9 presents the frequency distributions for fixations per em for the physics professors and graduate-students on each passage. Here again, large individual differences are evident. On the physics passage, for example, one of the physics professors made almost three times as many fixations as another physics professor. The intra-passage individual variation on all passages for both the professors and graduate-students is greater than the group variation from passage to passage. The difference between the physics professors' mean fixation scores on the passage they read with the fewest fixations and the passage on which they made the most fixations was .047 fixations per em (1.3 fixations

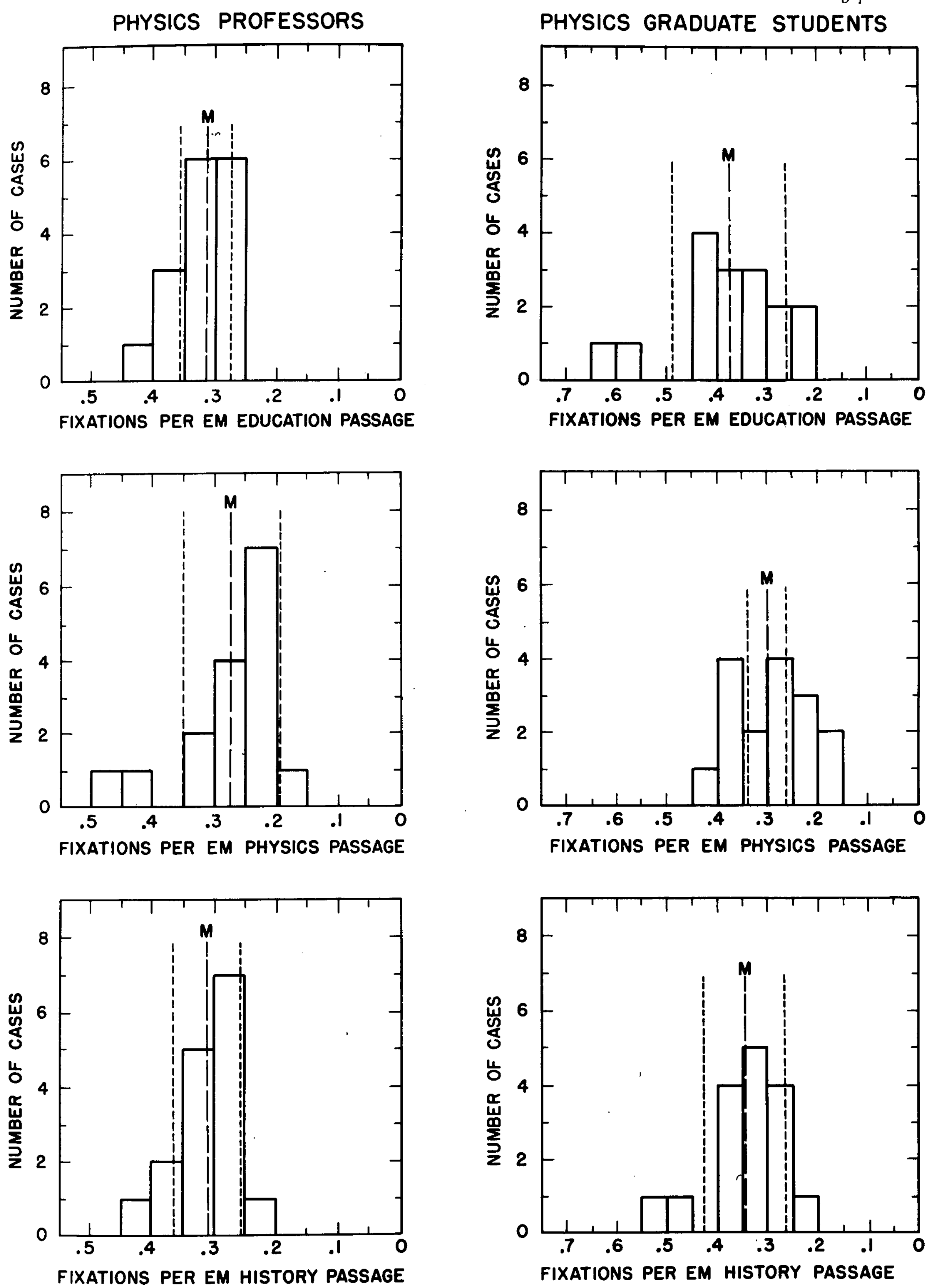


FIGURE 9

FREQUENCY DISTRIBUTIONS FOR FIXATIONS PER EM FOR PHYSICS SUBJECTS per line). This difference is much smaller than the difference of .289 fixations per em (8.3 fixations per line) that was found between the fixation scores of the physics professor who made the most fixations and the one who made the least on the physics passage. There is some fluctuation in the standard deviations from passage to passage and some difference in the standard deviations between ranks on the same passage. The small standard deviation for the physics graduate-students on the physics passage is especially conspicuous. On the education passage, however, the graduate-students were more variable than the professors. It is doubtful whether any significance can be attached to these differences in the standard deviations.

Figure 10 presents the frequency distributions for fixations **per em** for the history subjects. Once again, large individual differences occur among both the professors and the graduate-students. One history professor actually made almost three times as many fixations per em on the education passage as another did. The group variation from passage to passage does not approach a difference of this size. The difference between the history professors' mean fixation scores, on the passage they read with fewest fixations and the passage on which they made the most fixations, was .038 fixations per em (1.1 fixations per line). On the other hand, the difference between the highest and lowest individual fixation scores for the history professors on the history passage

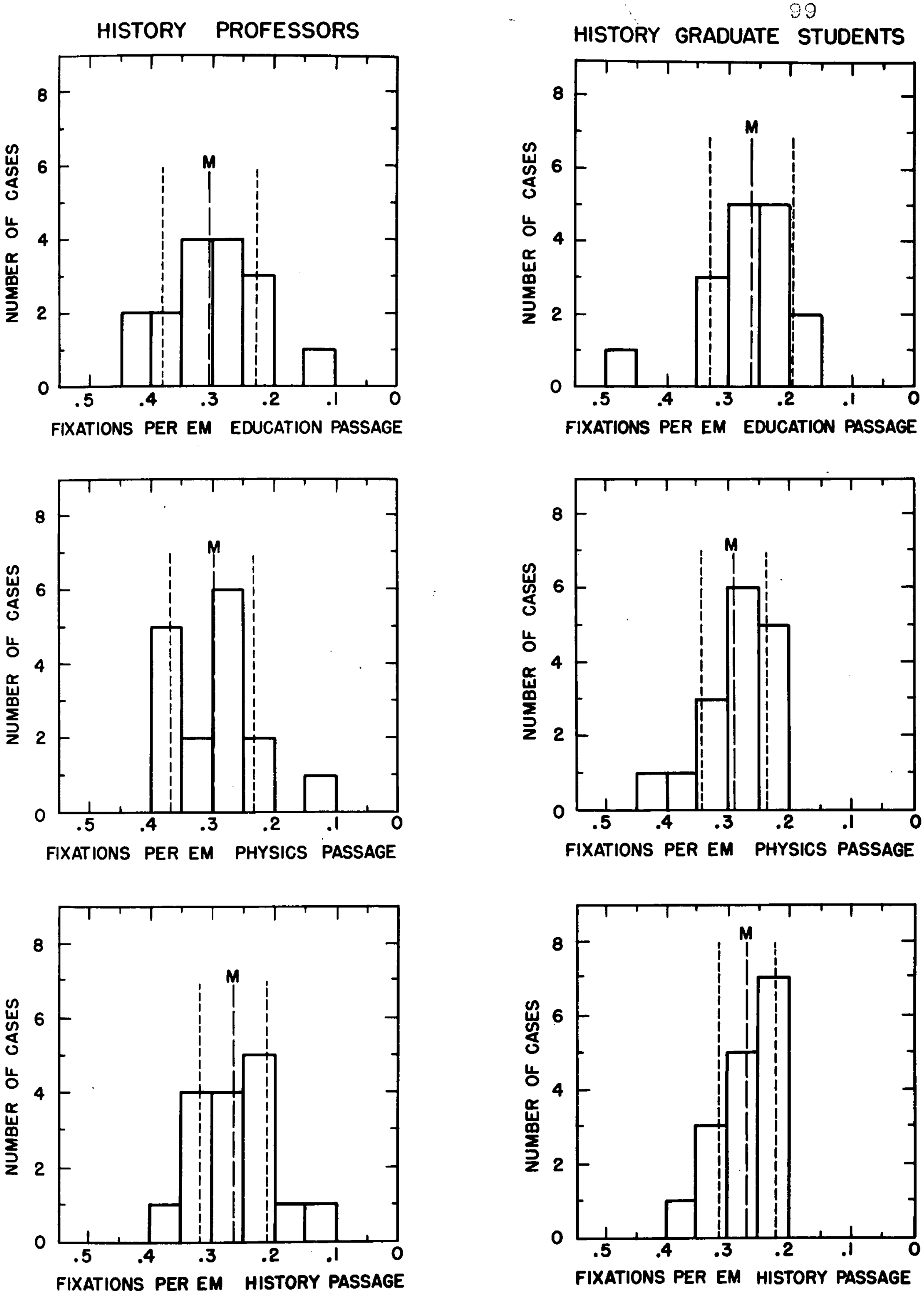


FIGURE 10

FREQUENCY DISTRIBUTIONS FOR FIXATIONS PER EM FOR HISTORY SUBJECTS was .216 fixations per em (6.2 fixations per line). There are no important differences in the intra-passage individual variation for the professors from passage to passage. The graduate-students pretty much follow suit in this case. The differences between the standard deviations from passage to passage or from professors to graduate-students on the same passage are negligible.

No important departmental differences have emerged from this analysis of the fixation frequency distributions.

Figures 5, 6, and 7 may be reexamined with reference to the intra-passage individual variation which was found for fixation frequency. A comparison of the performances of the two education professors, as illustrated on Figure 5, reveals that Case 2, the fast reader, made 49 fixations on nine lines, while Case 16, the slow reader, made 53 fixations on four lines. An analysis of the eye-movement records for the two education graduate-students shows a similar difference for this measure. A count of the fixations made by the two physics professors on the records shown on Figure 6 discloses that Case 15, the rapid performer, made 44 fixations on nine lines, while Case 5, the slow performer, made 55 fixations on four lines. The records for the two physics graduate-students divulge equally striking differences. A comparison of the two history professors' eye-movement records, as illustrated on Figure 7, show that Case 13, the rapid reader, made 28 fixations on seven lines, while Case 10, the slow performer, made 46 fixations on five lines. The eye-movement records for the two history graduate-students reveal substantially the same difference.

Individual Differences in Regression Frequency. Figures 11, 12, and 13 present the distributions for regressions per em separately for each group of subjects on each passage. The mean and the standard deviation of each distribution are indicated in the same manner as before.

Figure 11 presents the regression-frequency distributions for the education subjects. As in the case of rate and fixation frequency, wide individual differences exist among both the professors and graduate-students. Whereas one education professor made no regressions on the education passage, another professor in the group averaged 3.3 regressions per line on the same passage. The difference between the lowest and highest mean regression scores made by the professors was .001 regressions per em (.02 regressions per line). The intra-passage individual variation among the education professors on all passages eclipses the inter-passage group variation. The same points can be made regarding the distributions for the education graduate-students. The largest standard deviation was found on the education passage for the professors and on the physics passage for the graduate-students, but otherwise there is very little to choose between the ranks.

Figure 12 presents the regression scores for the physics

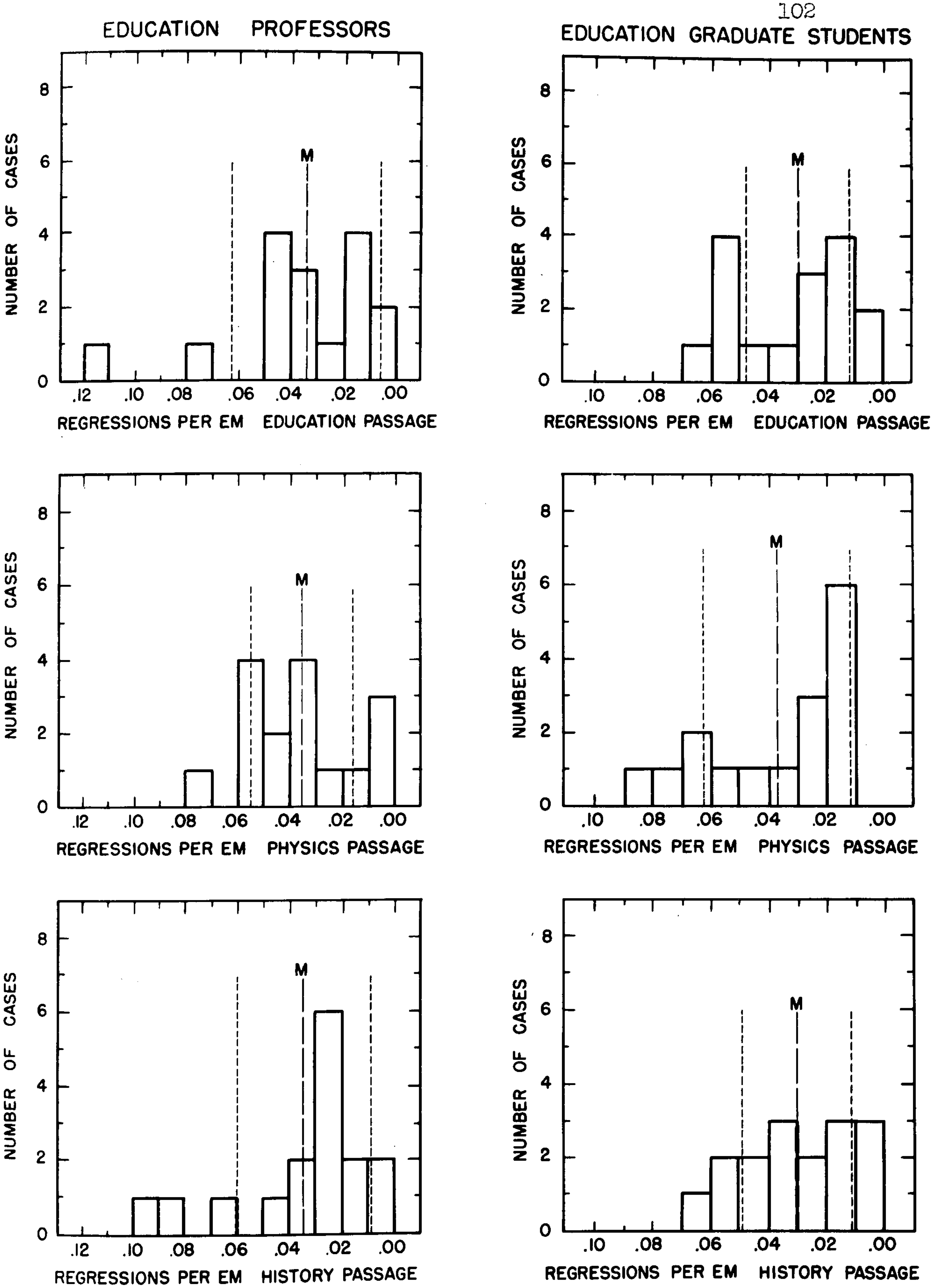


FIGURE 11

FREQUENCY DISTRIBUTIONS FOR REGRESSIONS PER EM FOR EDUCATION SUBJECTS

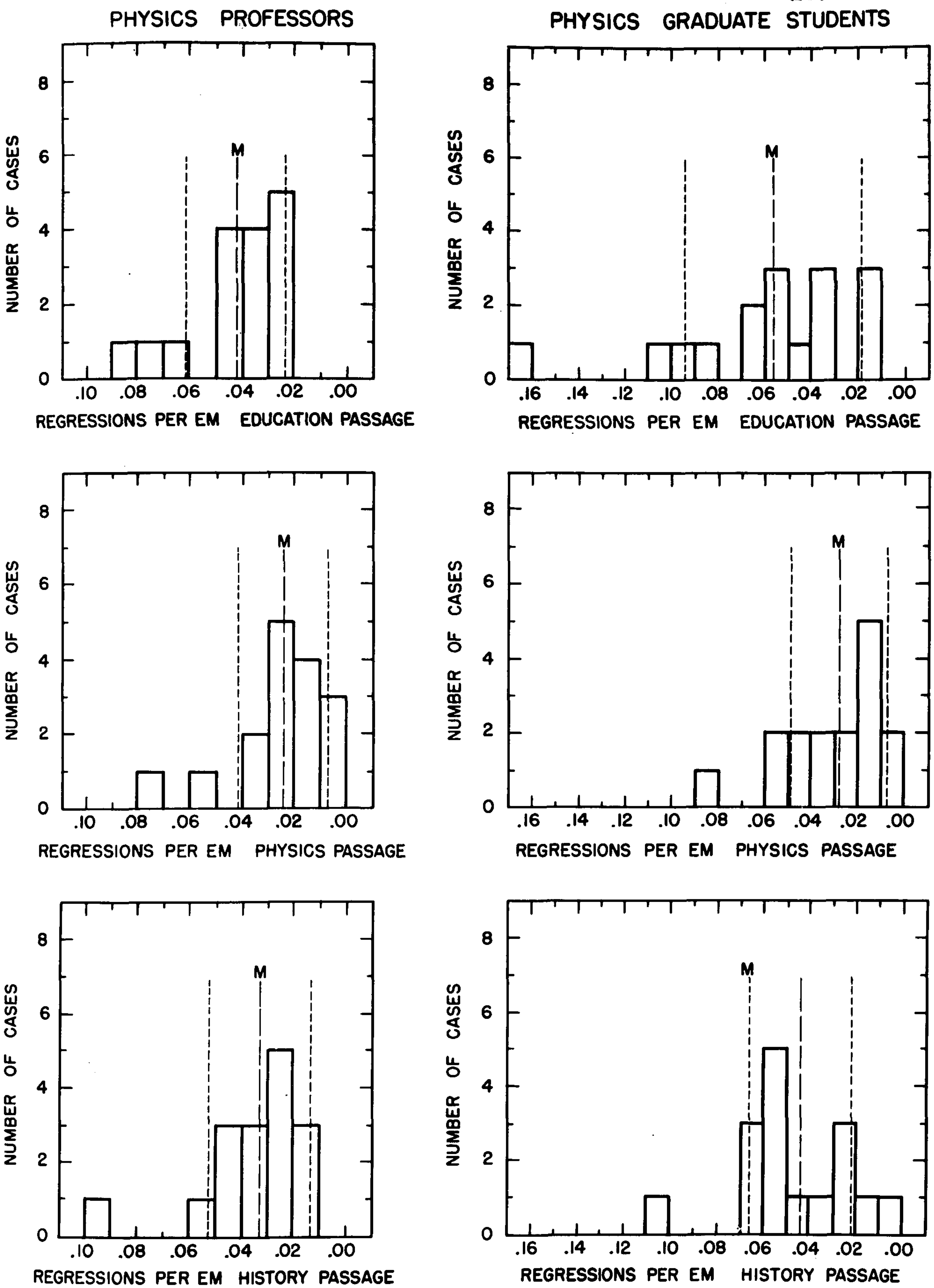


FIGURE 12

FREQUENCY DISTRIBUTIONS FOR REGRESSIONS PER EM FOR PHYSICS SUBJECTS professors and graduate-students. Once more, large individual differences are manifest among the physics subjects. One physics professor made no regressions on the physics passage, while another made 2.1 regressions per line. The difference between the lowest and highest mean regression scores for the physics professors was .018 regressions per em (.52 regressions per line). It is readily perceived that the intra-passage individual variation on all passages for both the physics professors and graduate-students is of far greater magnitude than the inter-passage group variation. The standard deviations for the professors from passage to passage are very much alike. A relatively large standard deviation was obtained for the physics graduate-students on the education passage, the reason being that one case deviated sharply from the rest of the distribution. Otherwise, there is little difference in the standard deviations for the professors and graduate-students.

Figure 13 reveals the regression-frequency distributions for the history subjects. It is the same old story of individual variation. One professor made no regressions on the history passage, while another made 1.9 regressions per line on the same passage. The difference between the highest and lowest mean regression scores for the history professors was .012 regressions per em (.34 regressions per line). Just as has been true all along, the intra-passage individual variation on all passages for both the professors and the

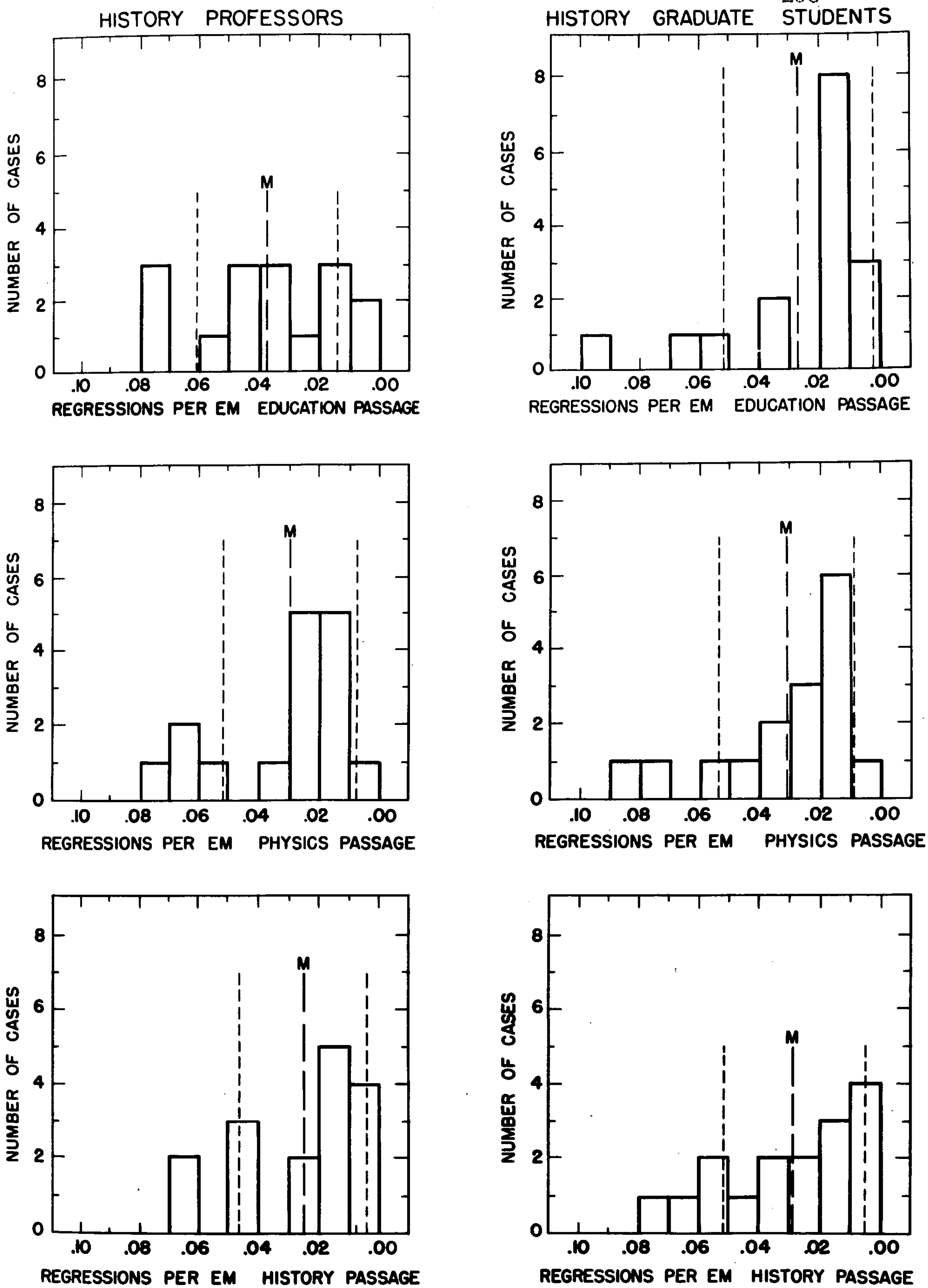


FIGURE 13

FREQUENCY DISTRIBUTIONS FOR REGRESSIONS PER EM FOR HISTORY SUBJECTS graduate-students is much larger than the inter-passage group variation. The standard deviations of the regression-frequency scores for the history subjects were generally larger than for either the education or physics subjects and highly uniform in size. The physics subjects tended to be the least variable on this measure, except for the performance of the physics graduate-students on the education passage.

To take one final look at Figures 5, 6, and 7, this time with reference to the intra-passage individual variation which was found for regression-frequency. The records for the two education professors on Figure 5 divulge that Case 2, the rapid reader, made no regressions on ten lines, while Case 16, the slow reader, made nine regressions on only four lines. The records for the two education graduate-students may be referred to as another example of the individual differences in regression-frequency which were found among the education subjects. The records for the physics subjects exhibited on Figure 6 reveal that the rapid reader of the professor pair, Case 15, made six regressions on nine lines, while Case 5, the slow reader, made nine regressions on four lines. The records for the two physics graduate-students provide another example of the same sort of individual variation. An inspection of the records for the history subjects displayed on Figure 7 shows that Case 13, the rapid reader of the professor pair made only one regression on seven lines, while Case 10, the slow reader, made seven regressions on five lines. The performances of the two history graduate-students differ in like fashion, in that the fast reader made fewer regressions on eight lines than the slow reader made on four.

Summary. The specific findings on individual differences may be summarized as follows:

(1) Wide individual variation existed within each subject group on all passages, as measured by rate, fixation frequency, and regression frequency.

(2) The intra-passage individual variation on all passages for each group was vastly greater than the inter-passage group variation.

(3) No consistent differences were found in the amount of intra-passage individual variation from passage to passage.

(4) No consistent differences emerged in the amount of intra-passage variation between the ranks.

(5) No important departmental differences were found with regard to the extent of intra-passage variability.

Studies of Omnivorous Readers

We come now to the second of the ancillary questions. As reported before, the literature contains a number of accounts of individuals who were credited with being able to read in "chunks", "sections", or "gulps". In no case were the claims supported by eye-movement evidence. The subjects of the present study include at least one individual for whom similar claims have been made. It was felt, therefore, that a study of the eye-movement records of the swiftest readers in the group might offer an opportunity to evaluate the claims which frequently are made that there are individuals who can read whole lines or even paragraphs in a single glance or fixation of the eyes.

An analysis of all the records reveals that few subjects read faster than 1300 ems per minute (500 words per minute). This rate was arbitrarily set up as the standard for selecting the swiftest readers in the group. Actually, only five subjects were found to have read this fast. Case 13 of the history professors read the history passage at 1500 ems per minute (575 words per minute), the education passage at 1380 ems per minute (530 words per minute), and the physics passage at 1350 ems per minute (520 words per minute); Case 16 of the education graduate-students read the physics passage at 1338 ems per minute (512 words per minute); Case 8 of the physics graduate-students read the physics passage at 1481 ems per minute (568 words per minute); Case 3 of the physics graduate-students read the physics passage at 1338 ems per minute (512 words per minute); and Case 11 of the education professors read the physics passage at 1554 ems per minute (596 words per minute). This is the entire list of subjects who read faster than 500 words per minute. Incidentally, the rapid readers for whom illustrative eye-movement records were shown on Figures 5, 6, and 7 include a few of the individuals listed here. These are Case 16 of the education graduate-students represented on Figure 5, Case 8 of the physics graduate-students represented on Figure 6, and Case 13 of the history professors represented on Figure 7.

Of the five cases listed, only one subject, Case 13 of the history professors, maintained a speed of 500 words per minute or better on all passages. Case 13 happens to be the individual who has the reputation on the University of Michigan campus of being able to read a line or a paragraph at a glance. One will search the record shown for this case on Figure 7 in vain for evidence of single eye-fixations per line or paragraph. The same may be said for the records of Case 16 of the education graduate-students on Figure 5 and of Case 8 of the physics graduate-students on Figure 6. One might object, however, that the passages used in the present study were too difficult to read in anything but the normal manner, and also, that the comprehension requirement operated to put the damper on speed.

In view of these objections, Case 13 was invited for further tests before the Opthalm-O-Graph. These additional tests involved material ranging in difficulty from the primary to the college level. Formal comprehension check tests were omitted and the subject was merely told to read the material as he normally would. One may search these records also without avail for single fixations per line or paragraph.

The fastest rate achieved on the supplementary tests did not exceed 600 words per minute. This is an exceptionally fast reading speed, but it is far from what we were searching for. It seems clear that this subject, while a much faster reader than most of his colleagues, nevertheless reads in the conventional manner, in that he makes several fixations per line as well as occasional regressions.

Actually, the subject who turned in the fastest single performance on the regular passages was not Case 13 of the history professors at all, but Case 11 of the education professors, who read the physics passage at 596 words per minute and made 5.8 fixations per line.

An interesting sidelight can be offered by way of an account of the reading habits of another unusual reader, Columbia University's distinguished educational psychologist, Professor Edward L. Thorndike. Professor Thorndike has been credited by Time magazine with having read the Cyclopedia of Education as bedtime reading. Professor Walter F. Dearborn, of Harvard University, has recently obtained some eye-movement records of Professor Thorndike's reading by means of the electrical-potential technique. Dr. Dearborn has given the present writer permission to use the section of Professor Thorndike's electro-oculogram[1] shown on Figure 14. The reading material in this case was a selection from Adam Smith's Wealth of Nations. A comprehension check was required. A

[1] Term used to denote eye-movement records obtained by the electrical-potential technique.

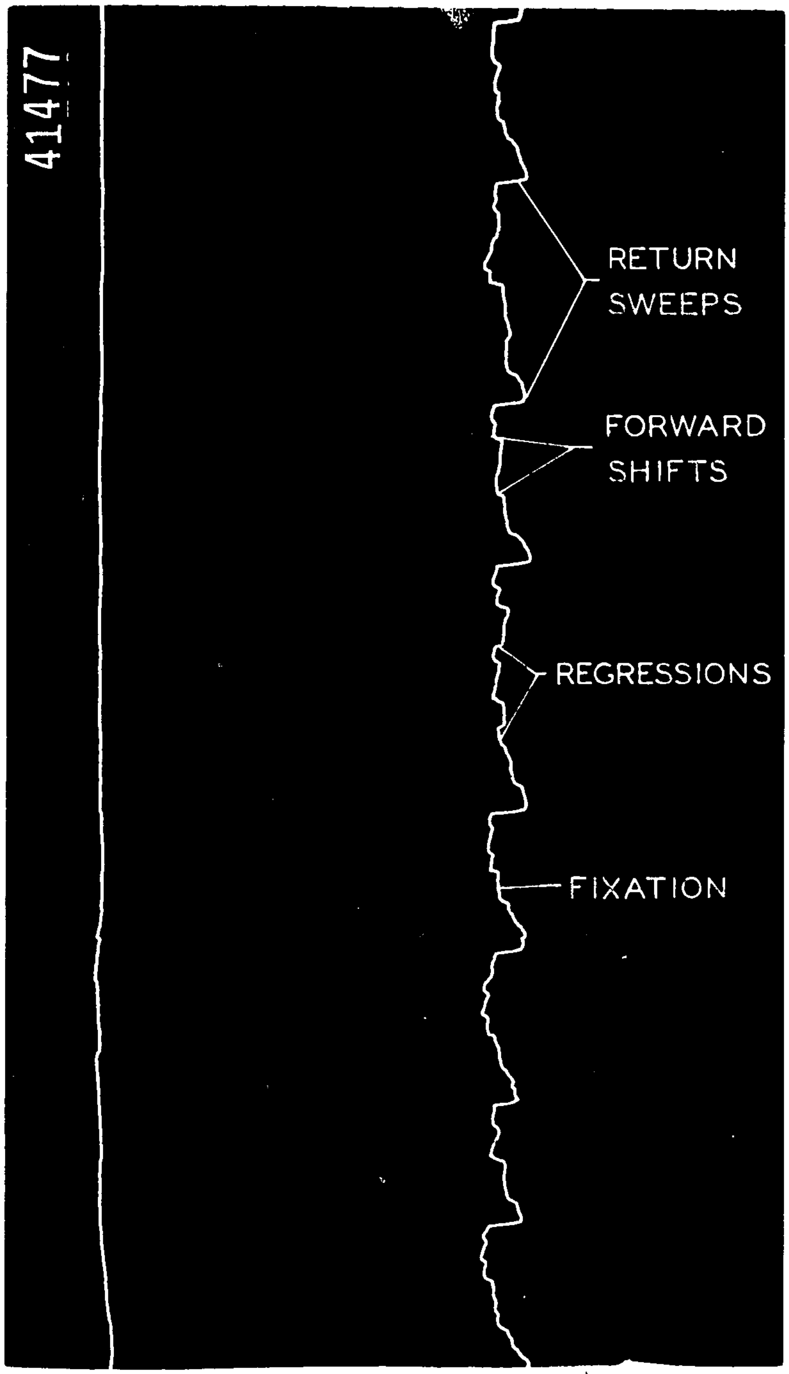


FIGURE 14

SECTION OF AN ELECTRO-OCULOGRAM
OF A SKILLED READER

rough estimate of Professor Thorndike's performance, as illustrated on Figure 14, indicates that he was reading at about 560 words per minute and making an average of six fixations per line. With Professor Thorndike's record to supplement the eye-movement records obtained from the subjects of this investigation, it seems clear that even the most omnivorous of readers do not read with the lightning rates commonly reported, especially when they are asked to make good their performance on a comprehension check test.

Summary. The following points summarize this section of the results:

(1) Among the subjects used in this investigation, no evidence was found to support the contention that there are individuals who are able to read in single fixations per line or paragraph.

(2) Only five subjects were found who read as rapidly as 500 words per minute.

(3) Only one subject read all three passages at rates as high as 500 words per minute.

(4) The fastest single performance which was achieved on any passage was 596 words per minute.

The Problem of Rhythm Reading

And so we come to the last of the secondary questions. As stated previously, several authorities, notably Dearborn (12) and Robinson (42), have declared that good readers characteristically read with a rhythmical pattern of eye-movements which remains more or less constant from line to line. Partly as a result, a number of gadgets and devices have been introduced on the market which seek to improve reading by training the poor reader in what is supposed to be the pattern of the eye-movements of the skillful reader. Actually, the evidence for the whole idea of rhythm reading is very limited. For one thing, so few studies have been made of the eye-movements of good readers. Since the subjects of the present study may be classed as good readers, it was felt that the eye-movements of a few of the most rapid readers in the group might be profitably studied with reference to the problem of rhythm reading. The records for the good readers represented on Figures 5, 6, and 7 may be used as test cases. The records for the slow readers of each pair may be employed for comparative purposes, inasmuch as slow readers are supposed to read in a less rhythmical fashion than fast readers.

We can look first at Figure 5, which presents the sample records for the education department. The record for Case 2, the rapid reader of the two professors, is rhythmical in the way that Dearborn and Robinson have described. This record shows little variation in fixation frequency from line to line. Lines 1, 2, 3, and 9 are remarkably similar in detail. The same may be said for lines 6 and 7. The record as a whole is highly regular. There are no regressions, and the four refixations on the record are a part of the repetition of the pattern of lines 1, 2, 3, and 9. The record for Case 16, the fast reader of the two education graduate-students, is not as regular in pattern as the record for Case 2. More variation in fixation frequency from line to line is shown, and occasional regressions were made. However, even on the record for Case 16, some repetition of pattern is evident. Lines 5, 8, and 9 of this record, for example, are remarkably alike in detail. No such repetition of pattern appears on the record for the slow reader of each pair. The record for the slow-reading professor is especially variable. The record for this individual on Figure 5 shows twenty fixations on the first line and only seven on the second line.

A study of the two physics professors' eye-movement records, as illustrated on Figure 6, shows that Case 15, the fast reader, read rhythmically on some lines and arhythmically on other lines. For example, lines 1, 5, and 8 were read in four evenly spaced fixations, whereas the reading of lines 2, 3, and 4 was marked by irregular eye-movements. However, the record of Case 15 is decidedly more uniform than that of Case 5, the slow reader. A glance at the two graduate-students' eye-movement records reveals that Case 8, the rapid reader, read the various lines with fairly regular eye-movements. On the other hand, the eye-movement record of Case 11, the slow reader is highly irregular.

On Figure 7, the eye-movement record for Case 13, the fast-reading history professor, does not reveal much evidence of rhythmical reading. There is some indication in the first three or four lines of this record that Case 15 may have read one line in the usual forward direction and then read the next line in a backward direction, skipping the return sweep entirely. Inspection of the two history graduate-students' eye-movement records shown on Figure 7 shows that the record for Case 10, the rapid reader, while not very rhythmical at the start, became much more regular near the end. Lines 6 and 7, for example, are very much alike in pattern. The record for Case 5, the slow-reading history graduate-student, reveals no repetition in pattern, nor does the record for Case 10, the slow-reading history professor.

One habit which did emerge was the proclivity of some individuals to make refixations on almost every line of every passage. Other individuals rarely if ever made refixations. The two records shown on Figure 15 illustrate this difference. The record for Case 12, the physics professor, contains a refixation on every line. The record for Case 5, the education professor, contains no refixations. Incidentally, Case 15 of the physics professors was a fairly rapid reader. It is interesting to observe the repetition of detail his record presents. Lines 2, 3, and 4 are very much alike in pattern. The relatively long pause which occurs at the end of every line is in nature of an individual idiosyncracy. It may be profitable sometime to reexamine all of the records collected in this study for other examples of individual habits of that sort.

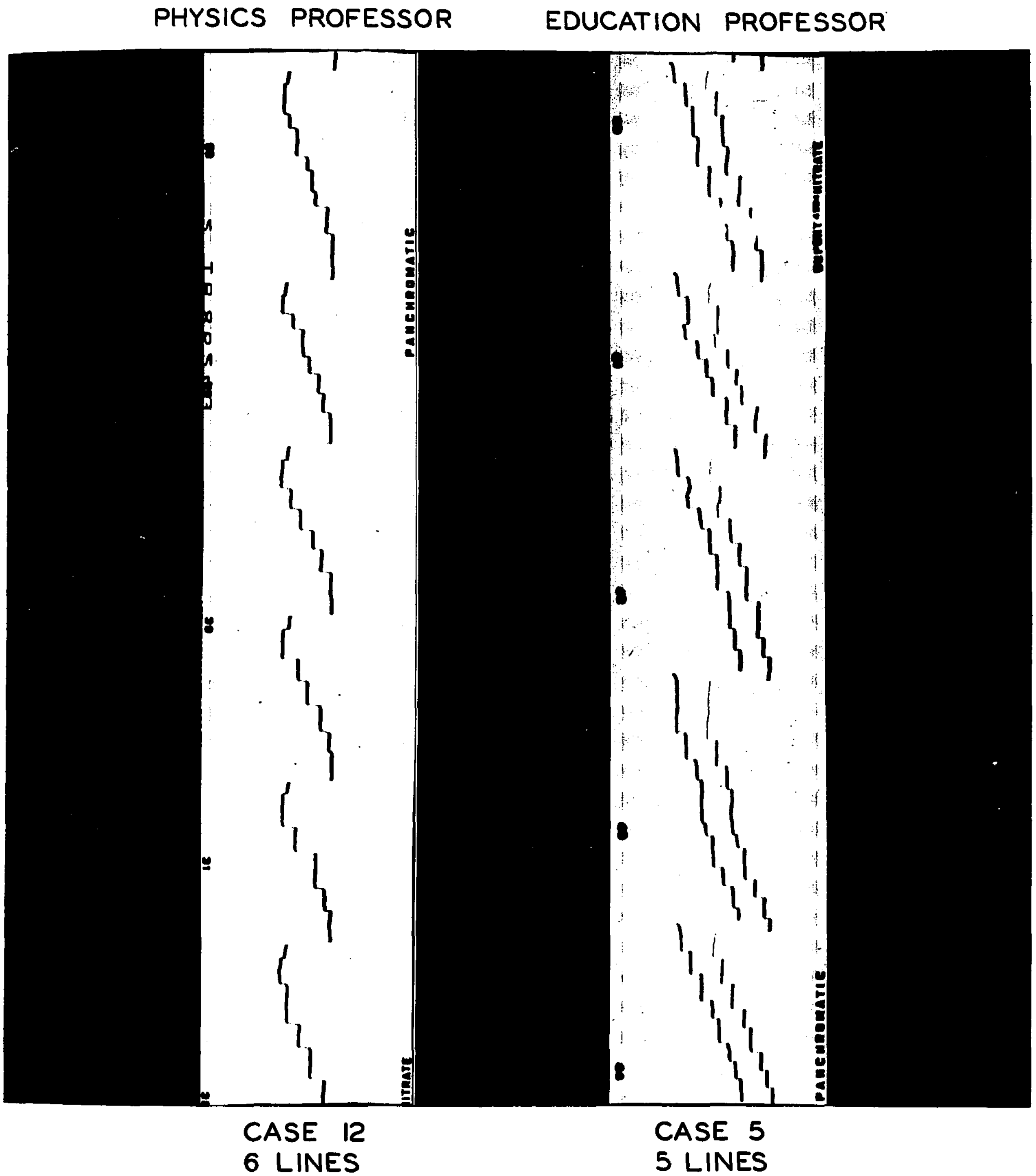


FIGURE 15

SAMPLE EYE-MOVEMENT RECORDS ILLUSTRATING INDIVIDUAL DIFFERENCES IN THE FREQUENCY OF REFIXATIONS

Summary. The following points summarize this section of the results:

(1) A comparison of the records showed that the fast readers tended to read in a more rhythmical fashion than the slow readers.

(2) The repetition of detail from line to line was rather striking in the case of a few of the records for the good readers.

(3) In a few other instances, evidence was found of arhythmical reading on the part of the good readers.

(4) One habit which emerged from the records as a whole was a tendency on the part of some readers to make refixations on almost every line of every passage.

CHAPTER VI

DISCUSSION OF THE RESULTS

As mentioned before, this chapter has been reserved for an evaluation of the general results as well as for a discussion of their implications and applications. To begin with, it may be said that familiarity has emerged as a factor in reading performance. Except for the failure of the education and history graduate-students to conform to the general pattern, all of the results presented in the first section of the specific findings add up to that end. Why significant differences were obtained only for the physics subjects is a forensic question. It is possible that the physics subjects were relatively more specialized than the other groups. Support is lent this hypothesis by the relationship which was found for the physics subjects between their rate scores on the various passages and their scores on the comprehension check tests. A corallary idea is that the education and history subjects may have been relatively less specialized. It is true that within the School of Education there are many subject-matter specialists. Some specialize in science, some in the social studies, and so forth. This condition may account in part for the failure of the education subjects to read the passage from their own field significantly more efficiently than the passages from the other two fields.

Familiarity also seemed to be less of a factor with the graduate-students than it was with the professors, if we exclude the performance of the physics graduate-students. Perhaps the professors were relatively more familiar with the passages from their own special field than were the graduate-students, and hence their performance merely reflects their longer training and experience in the field. The obvious application of these observations is that familiar materials be used to promote rapid reading and that the art of slow, careful reading be taught by means of unfamiliar material. These suggestions are contrary to the plan proposed by McCaul (33).

The evidence for types of reading was not convincing. The physics passage was not read slowly by everyone, nor was the history passage read rapidly by all the subjects. All passages were read both rapidly and slowly depending on the individual reader. Thus, encouraging students to skim over history material is questionable advice, just as it is unnecessary to tell everyone to read science material at a snail's pace.

These findings dealing with types of reading were somewhat at odds with the introspective testimony. Virtually every physics professor stated that the usual content in physics requires a slow, careful reading because the material is written in a very compact style, with important points and formulas brought up in almost every phrase. It is possible that the physics passage used in the present study was not entirely typical of the material one usually encounters in this field. Different results may have been obtained if the physics passage had contained formulas. However, Rebert (40, 41) has shown in two investigations (1) that the inclusion of numbers in a reading selection does not alter the normal reading pattern, providing the numbers are familiar, and (2) that individuals highly trained in a field such as physics or chemistry will read passages containing formulas from these fields with fewer fixations than individuals who are less specialized. Familiarity seems to be the deciding factor. A slow rate will not help if the individual is unfamiliar with the language of mathematics or science. The history subjects, as a department, tended to read more rapidly than the subjects of the other departments. This again may not be so much the materials *per se*, as it is a matter of practice. It is possible that historians are called upon to read more extensively than specialists in many other departments, and there is nothing that promotes fluency more than extensive reading of a wide variety of materials.

The evidence for the idea that training in a given field affects the individual's reading performance in other fields was also without conviction. Extremely fast, as well as very slow, readers were found in all departments. The results seem to indicate that the speed with which a person reads is an individual matter. Certainly, just as slow readers were found among the history and education subjects as among the physics subjects. When training in a technical field is given as the reason for a slow rate of reading, the individual may be stating not so much the cause of his slow reading as finding an excuse for it.

If there is one thing that this study has shown, it is that wide individual differences in reading skill existed among the subjects of all departments. Fast and slow readers were found in every department, and the over-lapping of the distributions from passage to passage was enormous.

No evidence was found for the idea that there are individuals who can read in single fixations per line or paragraph. Reports of such cases can be regarded with skepticism, unless the claims are supported by eye-movement evidence. While it is true that some individuals go through a book so rapidly that they never stop turning pages, it can also be said that they are not really reading, but rather are engaging in a masterful form of skimming. In such cases, unless the material is extremely familiar, the individual cannot stand much of a test on the material. The comprehension requirement in the present experiment was very modest, but it was enough to abolish the idea that there might have been individuals in the group who could give a passage one quick glance and absorb the material.

If anything, the subjects used in this study did not read as skillfully as might be supposed. The average rate for the three groups of professors on all passages was 303 words per minute and 8.56 fixations per line. Yet statements are frequently made in the literature that good readers average only three or four fixations per line. Such statements are careless generalizations of the facts. The notion that good readers require only three or four fixations to navigate a line stems from Buswell's early study (8). But, as Stroud (49) has pointed out, Buswell used a very short line and very easy material. When Stroud converted Buswell's data into number of fixations per 24 and 28 pica lines, he found that six or seven fixations per line would have been the expected performance, and this on the part of Buswell's best readers on second grade material. Since it is known that the number of fixations increases with the difficulty of the material, Stroud concludes that eight or ten fixations per line more nearly approaches the number of fixations the average mature reader makes. The results of the present study support Stroud's contention. And who would think of designing a pacing device involving eight or ten fixations per line?

With regard to the problem of rhythm reading, some evidence was found to support the idea that the very best of readers do occasionally adopt a set pattern of eye-movements which is repeated at least on some of the lines. These are the "short-lived motor habits"[1] of which Dearborn speaks.

[1] Dearborn, op. cit., p. 29.

There also seem to be times when fast readers resort to a pattern of eye-movements which can only be termed arhythmical. In this connection it may be appropriate to present an analysis which Dearborn has made of the eye-movement habits of Dr. Robert B. Blake, Professor of History at Harvard and formerly Director of the Harvard Library. Dr. Blake is supposed to be able to read with blazing speed. Here follows the analysis which was made of Dr. Blake's eye-movement habits and which the writer is quoting with Dearborn's permission:

> The eye-movement record of Professor Blake is characterized by a small number of fixations per line, (between four or five on the average), but a large number of regressions--in fact so frequent are the regressions that it is usually difficult to tell what is a return saccadic sweep and what is a regressive movement.
>
> The record suggests that Professor Blake follows the line of print closely for several lines then skips about through several more and then reads closely again. Thus, the record for short stretches follows the usual reading pattern, which portion is followed by haphazard patterns.
>
> There is some indication in the record that Professor Blake may read one line in the usual forward direction and the next in a backward direction thus weaving down the page.
>
> In regard to the comprehension checks: a comprehension check was taken every twenty-five pages. Since Professor Blake read over seventy-five pages in the half-hour trial, three of these internal checks were taken. These internal checks measure primarily the comprehension of the details of what has just been read. On the first check the score was 15 right out of 22; the second, 6 right out of 20; and the third, 14 right out of 20--all of which scores are below those made by the other subjects of this experiment. The final comprehension check primarily measures the comprehension of the general thought of what has been read. Professor Blake's score on this final test was 15 right out of 17 attempted.
>
> It may be concluded that Professor Blake's method of reading reduces his comprehension of details, but does not impair his comprehension of the gist of the subject matter read. The record shows definitely that the reading was not done by glanc-

ing at the page, but it is rather the result of a highly skillful skimming procedure balanced by more ordinary reading when necessary.

The suggestion that Professor Blake may read one line in a forward direction and the next in a backward direction is reminiscent of the eye-movement records for the two professors shown on Figures 6 and 7. On Figure 6, the eye-movement record for Case 15 of the physics professors gives some signs that this individual may have been reading in the manner ascribed to Dr. Blake. One may note in the third, fourth, and fifth lines of this record how the eyes seem to have been weaving back and forth across the lines rather than making a definite return sweep. On Figure 7, the eye-movement record of Case 13 of the history professors shows the same kind of performance in the second, third, and fourth lines.

CHAPTER VII

SUMMARY AND CONCLUSIONS

1. Review of the Conditions of the Study

This investigation has involved a study of the eye-movements in reading of three groups of University of Michigan professors representing the fields of education, physics, and history. The reading materials were selected from the same three fields, and each subject read the material from his own field as well as the materials from the other two fields. The professors all had their doctorates and an academic rank of assistant professor or higher. A group of graduate-students from each of the three fields was run through the same experiment. All of the graduate-students were working for their doctorates and for the most part were teaching fellows. The graduate-students were included for comparative and control purposes.

Three pairs of reading selections were used in the study. These passages were equated for difficulty by the Flesch and Lorge formulas. One passage of each pair was used as a practice selection and the other as the test selection. All the passages were 200 words in length, printed on two cards of 100 words each. The type-size and line-length were constant and conformed to optimum conditions.

The Opthalm-O-Graph was used to record each subject's eye-movements during the reading of the second 100 words of the test passage. Each test selection was preceded by a reading of the practice passage before the eye-movement camera. After each practice and test passage was read, a comprehension check test was given, consisting of five Yes-No questions. The questions were based on the main ideas in each selection.

2. Summary of the Results

Four measures were used to analyze the eye-movement records for each subject: (1) rate of reading in ems per minute, (2) number of fixations per em, (3) number of regressions per em, (4) number of refixations per line. In addition, a comprehension score was computed in terms of percent. The problems studied dealt with the effect of familiarity of material on reading performance, types of reading as a factor in reading performance, the effect of training in a special field on reading performance, individual difference among the subjects, omnivorous readers, and rhythm reading. The results may be summarized as follows:

(1) All of the professor groups, plus the physics graduate-students, read the passage from their own special field most efficiently. However, statistically reliable differences were found only in the case of the physics subjects

who read the physics passage significantly faster than they read the education or history passages, and who made significantly fewer fixations per em in reading the physics passage than they did in reading the other two passages.

(2) The science material used in the present study did not induce a special type of reading. The physics passage was not read slowly by all groups. Furthermore, the eye-movement records of the education subjects show that these individuals read the physics and history passages in about the same way, and the eye-movement records of the history subjects reveal that this group did not read the physics and education passages with significantly different eye-movements.

(3) The history material used in this investigation did not elicit a special type of reading. The history passage was not read rapidly by all groups. Also, the eye-movement records of the physics subjects show that these subjects did not read the history and education passages in a significantly different manner.

(4) The training the physics subjects have had in technical areas evidently has not served to slow down their reading in other fields. The eye-movements the physics subjects and the education subjects made on an unfamiliar selection, the history passage, were not significantly different.

(5) Some evidence was found which seems to indicate that the training of the history subjects may have operated to

speed up reading. Although the history subjects did not read an unfamiliar passage, the physics passage, significantly faster than the education subjects read the same unfamiliar passage, the history subjects did read the education passage significantly faster than the physics subjects read this same passage. Furthermore, the history subjects as a whole made significantly fewer fixations and refixations than the other two groups.

(6) The intra-passage individual variations were vastly greater than the inter-passage group variations, and tended to over-shadow any questions of types of reading and special training.

(7) No readers were found who made single fixations per line or paragraph. The average reading performance was about 300 words per minute and eight or nine fixations per line. The fastest individual performance on any paragraph was 596 words per minute, which does not approach the performance attributed to some individuals.

(8) Some evidence was found that fast readers tend to repeat the pattern of their eye-movements from line to line. Some evidence was also found that fast readers are skillful in the art of skimming, which results in arhythmical eye-movements. Refixations tended to be made habitually by some individuals.

(9) The reading of the graduate-students was found to be comparable to that of the professors. In only one instance was a significant difference found between the reading of the

two ranks and that favored the history graduate-students over the history professors in the number of refixations made.

3. Conclusions of the Investigation

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

(1) Familiarity of material may be regarded as a factor in reading performance.

(2) The idea that different types of material automatically elicit different types of reading is of doubtful validity.

(3) Training in a special academic field exerts little influence on reading habits, except as the extensive reading which history requires may serve to promote a rapid rate.

(4) The individual differences which normally exist among a population like that used in this study over-shadow all of the other sources of variation studied.

(5) Cases of individuals who are supposed to be able to read in "gulps", "chunks", or "sections" may be put down as masterful skimmers.

(6) Swift readers tend to read in a rhythmical fashion, except when they resort to skimming, and then their eye-movements become distinctly arhythmical.

All of these conclusions, of course, are subject to the conditions of the study.

APPENDICES

APPENDIX A

BASIC DATA FOR EACH GROUP

TABLE XXII

BASIC DATA FOR EDUCATION PROFESSORS

Subjects	Age	Rate in Ems per Minute			Fixations per Em			Regressions per Em			Refixations per Line			Percent Comprehension		
		Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History
1.	42	684	546	804	.277	.351	.225	.042	.058	.024	.55	.33	.30	40	100	40
2.	47	1266	936	1236	.189	.231	.196	.000	.023	.007	.44	.00	.20	60	80	100
3.	57	756	774	834	.285	.305	.278	.046	.054	.046	.33	.33	.30	100	100	100
4.	53	588	510	540	.270	.328	.312	.042	.042	.024	.33	.66	.40	60	100	80
5.	56	586	636	684	.312	.308	.285	.019	.011	.006	.00	.11	.20	40	100	80
6.	46	954	924	840	.262	.262	.295	.011	.007	.027	.11	.11	.20	80	100	40
7.	36	884	888	654	.273	.297	.385	.047	.051	.097	.22	.44	.20	80	100	100
8.	48	816	684	834	.303	.312	.290	.029	.038	.013	.28	.33	.25	80	100	60
9.	42	804	750	720	.343	.390	.361	.077	.074	.062	.33	.75	.40	60	60	100
10.	45	654	672	630	.290	.324	.315	.034	.038	.036	.22	.77	.80	40	80	100
11.	34	1218	1554	792	.228	.201	.333	.019	.007	.025	.44	.44	.50	100	20	80
12.	53	774	612	750	.316	.389	.319	.015	.030	.024	.22	.37	.30	100	100	80
13.	55	576	498	516	.344	.378	.382	.030	.030	.038	1.30	1.10	1.30	60	80	80
14.	36	756	828	666	.235	.235	.247	.030	.042	.027	.44	.00	.20	60	40	80
15.	34	954	954	822	.297	.282	.295	.003	.003	.013	.66	1.00	.90	100	80	60
16.	39	486	408	468	.497	.397	.495	.115	.054	.087	.66	.57	.70	60	80	60

TABLE XXIII

BASIC DATA FOR EDUCATION GRADUATE STUDENTS

Subjects	Age	Rate in Ems per Minute			Fixations per Em			Regressions per Em			Refixations per Line			Percent Comprehension		
		Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	Histor
1.	37	457	471	480	.401	.374	.385	.054	.027	.034	.55	.44	.50	60	100	80
2.	32	679	747	785	.368	.358	.329	.027	.010	.020	.66	.77	.40	40	100	80
3.	34	1185	928	751	.204	.246	.270	.000	.023	.017	.11	.00	.30	80	100	80
4.	27	972	972	960	.324	.312	.298	.030	.027	.031	.88	.78	1.00	80	80	60
5.	29	581	558	628	.370	.393	.368	.050	.046	.048	1.00	1.00	1.00	80	80	80
6.	32	824	499	659	.316	.462	.284	.027	.084	.006	.77	.66	.90	100	60	60
7.	30	553	518	559	.421	.467	.427	.058	.069	.052	.77	.55	.70	40	100	80
8.	34	672	560	637	.309	.432	.359	.015	.069	.038	.44	.44	.50	80	80	80
9.	28	665	723	622	.363	.378	.372	.050	.058	.059	.22	.11	.30	100	80	80
10.	29	691	1036	743	.247	.228	.292	.019	.031	.049	.22	.33	.30	80	100	60
11.	30	708	930	630	.305	.251	.278	.042	.019	.013	.11	.00	.40	100	100	60
12.	31	545	648	684	.389	.378	.361	.062	.073	.066	.44	.66	.80	80	80	60
13.	38	1054	1196	1016	.219	.212	.233	.012	.019	.007	.22	.11	.00	100	80	40
14.	36	942	1020	1188	.270	.246	.204	.027	.019	.000	.66	.78	.30	60	80	60
15.	39	1071	1110	808	.255	.247	.316	.012	.019	.028	.22	.33	.80	60	60	60
16.	32	1173	1338	1133	.216	.204	.219	.007	.012	.014	.22	.11	.20	60	80	80

TABLE XXIV

BASIC DATA FOR PHYSICS PROFESSORS

Subjects	Age	Rate in Ems per Minute			Fixations per Em			Regressions per Em			Refixations per Line			Percent Comprehension		
		Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History
1.	61	541	696	342	.405	.463	.446	.077	.073	.094	.55	.66	.57	20	100	80
2.	46	576	624	522	.312	.296	.342	.038	.026	.052	.22	.33	.25	40	60	20
3.	35	570	642	480	.339	.312	.378	.038	.023	.031	.66	1.00	.90	60	80	60
4.	66	690	888	690	.266	.235	.254	.023	.027	.010	.33	.11	.80	60	100	60
5.	52	522	570	540	.388	.412	.392	.038	.058	.039	.88	1.00	1.00	40	80	80
6.	38	630	684	648	.366	.340	.343	.023	.023	.024	.77	.33	.70	60	80	40
7.	27	690	1002	786	.328	.235	.260	.069	.019	.020	.33	.33	.50	80	100	40
8.	34	690	1194	654	.266	.215	.305	.042	.015	.041	.33	.11	.40	80	100	60
9.	40	756	1218	792	.274	.204	.264	.023	.003	.013	.55	.33	.50	60	80	20
10.	68	768	984	786	.269	.235	.267	.047	.019	.041	.12	.11	.20	40	100	60
11.	40	558	1224	882	.362	.212	.270	.081	.023	.034	.33	.22	.60	40	60	80
12.	63	606	756	666	.350	.263	.326	.027	.000	.013	.77	1.00	.90	40	100	60
13.	68	1032	1266	894	.266	.231	.284	.027	.031	.021	.00	.00	.50	60	100	40
14.	64	576	756	750	.328	.285	.306	.046	.007	.028	.77	.77	.90	60	100	60
15.	46	642	1296	1056	.303	.174	.234	.049	.031	.043	.28	.00	.62	60	100	80
16.	37	996	1218	960	.292	.254	.290	.031	.015	.029	.44	.33	.66	60	100	80

TABLE XXV

BASIC DATA FOR PHYSICS GRADUATE STUDENTS

Subjects	Age	Rate in Ems per Minute			Fixations per Em			Regressions per Em			Refixations per Line			Percent Comprehension		
		Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History
1.	32	756	888	690	.385	.293	.336	.042	.042	.062	.00	.44	.20	40	100	20
2.	28	876	870	858	.235	.243	.243	.038	.027	.024	.00	.44	.20	100	100	80
3.	24	987	1338	934	.278	.204	.260	.039	.012	.021	.55	.33	.40	100	100	60
4.	35	598	715	593	.409	.363	.400	.062	.050	.063	.77	.50	.66	40	80	60
5.	22	687	1045	720	.394	.282	.400	.062	.027	.060	.77	.88	.90	60	80	80
6.	26	696	984	774	.362	.273	.326	.054	.031	.052	.44	.33	.40	60	80	60
7.	31	1110	1196	864	.208	.189	.257	.019	.012	.045	.11	.00	.20	80	100	40
8.	26	782	1481	957	.305	.170	.255	.050	.000	.039	.55	.55	.77	100	100	100
9.	21	870	1122	870	.254	.224	.260	.019	.015	.007	.22	.22	.30	100	100	80
10.	27	471	718	658	.432	.313	.344	.100	.019	.052	.88	.66	.80	60	80	60
11.	30	474	586	614	.403	.394	.347	.082	.081	.052	.22	.22	.40	40	80	80
12.	25	606	1014	678	.628	.366	.535	.092	.046	.050	.77	.44	.80	100	100	80
13.	31	409	926	508	.594	.432	.476	.166	.058	.101	.55	.77	.80	100	100	80
14.	26	586	763	475	.340	.262	.333	.015	.008	.017	.66	.66	.50	80	80	80
15.	28	690	720	594	.336	.320	.354	.051	.038	.052	.77	.66	.60	80	100	60
16.	25	529	638	522	.436	.370	.382	.031	.012	.021	1.11	1.20	1.00	60	80	80

TABLE XXVI

BASIC DATA FOR HISTORY PROFESSORS

Subjects	Age	Rate in Ems per Minute			Fixations per Em			Regressions per Em			Refixations per Line			Percent Comprehension		
		Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History
1.	52	900	918	960	.235	.238	.241	.007	.011	.019	.22	.00	.00	60	80	100
2.	50	774	768	648	.324	.373	.355	.038	.065	.065	.22	.12	.33	80	80	100
3.	32	816	984	768	.320	.258	.321	.058	.019	.062	.55	.55	.40	40	80	80
4.	36	756	858	1092	.312	.278	.215	.048	.027	.017	.12	.22	.20	80	60	60
5.	49	438	864	912	.416	.281	.229	.073	.034	.017	.44	.22	.10	60	80	80
6.	33	888	1002	1092	.230	.204	.196	.077	.014	.017	.11	.28	.00	20	100	60
7.	54	732	678	690	.293	.348	.284	.019	.023	.027	.44	.75	.20	40	60	60
8.	39	648	588	702	.355	.386	.304	.073	.073	.041	.33	.33	.10	80	60	80
9.	54	864	864	1050	.285	.274	.256	.011	.003	.000	.55	.33	.55	80	100	100
10.	53	702	636	606	.289	.328	.339	.042	.058	.048	.33	.66	.60	100	80	80
11.	35	420	480	648	.398	.378	.305	.034	.027	.017	1.30	1.10	.80	80	80	60
12.	41	756	636	1032	.325	.374	.295	.047	.062	.047	.50	.11	.00	100	60	80
13.	55	1380	1350	1500	.147	.150	.139	.008	.011	.004	.62	.33	.42	80	100	100
14.	46	984	1068	1254	.268	.263	.242	.013	.023	.021	.50	.55	.37	80	80	80
15.	56	420	414	708	.420	.393	.291	.031	.027	.003	1.20	1.00	.90	40	80	100
16.	40	912	816	1014	.246	.267	.232	.023	.019	.007	.11	.44	.20	100	100	80

TABLE XXVII

BASIC DATA FOR HISTORY GRADUATE STUDENTS

Subjects	Age	Rate in Ems per Minute			Fixations per Em			Regressions per Em			Refixations per Line			Percent Comprehension		
		Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History	Education	Physics	History
1.	24	636	624	738	.254	.286	.239	.003	.012	.007	.44	.44	.20	80	100	80
2.	30	756	804	1212	.301	.299	.271	.054	.048	.027	.33	.50	.40	80	60	80
3.	27	762	864	1116	.296	.306	.232	.017	.030	.003	.66	.55	.60	100	80	60
4.	23	936	798	594	.214	.242	.270	.017	.017	.034	.00	.12	.20	100	100	100
5.	26	414	562	546	.479	.412	.399	.096	.081	.076	.44	.55	.20	80	60	20
6.	29	972	888	1086	.228	.246	.204	.011	.015	.000	.00	.33	.00	20	80	100
7.	34	876	1266	744	.231	.200	.281	.034	.038	.059	.22	.11	.40	100	100	40
8.	25	672	660	612	.289	.316	.267	.038	.019	.069	.00	.22	.20	100	80	100
9.	35	1152	1020	936	.224	.243	.246	.019	.023	.019	.11	.33	.20	100	100	80
10.	29	1218	756	1002	.197	.285	.211	.015	.058	.013	.00	.22	.40	60	60	40
11.	30	618	528	810	.310	.290	.246	.019	.023	.010	.11	.33	.00	80	80	100
12.	26	1110	950	956	.174	.212	.212	.003	.007	.004	.11	.11	.12	100	100	20
13.	26	1092	912	864	.254	.266	.306	.007	.011	.024	.44	.33	.30	60	100	100
14.	33	588	816	750	.305	.266	.290	.065	.027	.041	.22	.11	.77	40	80	60
15.	51	1104	546	666	.216	.363	.319	.019	.073	.052	.22	.55	.30	100	80	40
16.	26	564	552	552	.278	.316	.316	.015	.015	.030	.11	.11	.11	60	80	80

APPENDIX B

COPIES OF PRACTICE AND TEST PASSAGES

Education Practice Passage

The problem of conscience falls within the province of ethics and is concerned with the inquiry as to the origin and nature of the principles which underlie right conduct. In the growth of language, the general meaning of morals has been restricted so as to apply solely to the specific sphere of commendable customs. A radical distinction between customs right and wrong has thus become crystallized in language. The import of this is significant, for it indicates a natural trend of thought which differentiates conduct as right and wrong. The question naturally suggests itself, what is the ground for this distinction?

A reason for this classification of conduct is naturally demanded, and in the various attempts to render a satisfactory account of so evident and universal a distinction, two tendencies of thought are evident. The one would explain the recognized difference between right and wrong conduct as an immediate deliverance of consciousness, that is, knowledge which is intuitively discerned. The opposed school of thought would insist that such a distinction is obviously the outcome of experience and the gradual growth of ethical consciousness which is capable of discerning ever more clearly between right and wrong, the good and evil.

Education Test Passage

Concerning the origin of knowledge, there are two views, indicating opposite tendencies in thought, known as rationalism and empiricism. The former insists that the source of all knowledge is primarily in the mind inasmuch as there are certain fundamental principles of which the mind is immediately aware and which, therefore, modify and condition all experience. Such a view allows as primal elements of knowledge the original data given through sense perception. It only insists that such data are not the sole source of knowledge, but that the mind also furnishes its own contributing factors to the complete result.

The Empiricist holds that the mind is a *tabula rasa,* a surface smooth and clean, impressionable to the various sensory stimulations which write upon it the records of experience. The adherents of this doctrine very stoutly maintain that the so-called innate ideas, when subjected to the nearer scruitiny of a critical analysis, will be found reducible to simpler elements which are manifestly the product of experience. Our idea of causation, it is insisted, is not an intuitive possession, but it has grown with our growth through repeated observations of nature which indicate an invariability and uniformity which we unconsciously generalize into an all-embracing formula of universal causation.

Physics Practice Passage

Newton formulated three propositions which are known as Newton's Laws of Motion and which are the axioms upon which the science of dynamics is based. The first law is that every body continues in its state of rest or uniform motion in a straight line except in so far as it is compelled to change that state by force impressed upon it. This law merely states that a change of motion never occurs except as the result of force, so that if a body is at rest it will remain at rest unless some force acts upon it, or if it is in motion it will remain in motion with uniform velocity unless some force acts upon it.

Newton's second law of motion states that the time of change in the linear momentum of a body is proportional to the force acting upon the body, and the change takes place in the direction of the force. This law implies that a force will produce a change of momentum proportional to itself and in its own direction whether the body is at rest or in motion and whether or not other forces are acting upon it. For example, if a bullet were shot horizontally over a body of still water, it would strike the water at the same instant as if it were dropped vertically.

Physics Test Passage

In recent years material progress has been made in analyzing the phenomena connected with the acts of emission and absorption of light and other forms of radiant energy. Evidence shows that the emitters of light are atoms and molecules, that is, the energy alone of atoms and molecules is transformed into light energy. Thus it is not the filament of a lamp as a whole which gives out the light, but rather the individual atoms which make up the filament. Similarly, when light strikes the surface of objects and some of its energy is transformed into heat, it is only the atoms and molecules composing the bodies which act as agents for changing this energy into heat energy.

These acts of atomic and molecular emission and absorption in their many different aspects are not readily explained by the wave theory of light, but rather are more easily understood in terms of some kind of corpuscular theory. Since some of the phenomena of the propagation of light cannot yet be explained by any corpuscular theory, there is created a situation in which the propagation of light with its attending phenomena is accounted for by the wave theory, and the acts of emission and absorption, together with similar phenomena, by a corpuscular theory. The reconciliation of these opposing aspects of the theory of light is one of the major problems of present science.

History Practice Passage

In its first stage the revolution in Russia extended only to the state apparatus and the aristocracy, while in its second stage, which began with the insurrection of a group of army officers in December, 1825, the pivotal position was occupied by the intelligentsia, a product of the closer intellectual contact with western Europe after the Napoleonic Wars. By the latter half of the reign of Alexander I, the younger generation of the nobility and of the rising middle class had begun to study the idealistic philosophy of Germany and the writings of the early socialist thinkers of France.

The development of the Russian intelligentsia was conditioned by its isolation from business and public life and by its psychological make up. The members of this class, catholic in their interests and sympathies, cherished lofty ideals but remained entirely ignorant of the prosaic aspects of existence in that they demanded all or nothing, scorned gradual, concrete achievement, and were prone to fatalistic despair. The movement of the intelligentsia resembled nothing so much as a permanent discussion club, where ecstatic speeches about the magnificent future offered an escape from harsh reality. An outstanding manifestation of this utopianism was the unwarranted idealization of the masses, especially the peasants.

History Test Passage

Throughout the nineteenth century the rootless idealism of the intelligentsia was challenged only by the nihilists of the 1860's who professed extreme utilitarianism and submitted all matters to the acid test of reason. But the nihilist predisposition to a sober view of reality was soon overwhelmed by the longing of the intelligentsia to end its isolation and to bridge the gulf which separated it from the masses. The movement known as "going to the people" was particularly strong in the 1870's, however it failed to attain any concrete results largely because of the distrust and inertia of the masses.

In their desperation many of the intelligentsia then turned to terrorism, typically a weapon of the self-sacrificing idealistic individual. This form of struggle was of slight practical value, however, for the terrorist organizations were undermined by harsh governmental repression and by the corruption inherent in large scale conspiratorial operations. Whether committed to terrorist action or choosing the slower processes of underground propaganda and education, the Rüssian intelligentsia persisted in idealizing the peasantry and its communal form of agrarian organization. The latter was viewed as the survival of an early agrarian communism, a bulwark against the infiltration of western capitalism, and a basis for the future socialist organization of the land.

APPENDIX C

COMPREHENSION TESTS FOR PRACTICE AND TEST PASSAGES

APPENDIX C

COMPREHENSION TESTS FOR PRACTICE AND TEST PASSAGES

DIRECTIONS: Answer each question by underlining YES if the statement is true according to the passage, or by underlining NO if the statement is false according to the passage. These directions will apply to all passages read.

PRACTICE PHYSICS PASSAGE

YES NO 1. This passage explains two of Newton's Laws of Motion.

YES NO 2. The science of dynamics is based on Newton's Laws of Motion.

YES NO 3. Neglecting extraneous forces a body moving at a uniform velocity travels in a straight line.

YES NO 4. A body in motion will be restored to a state of rest of its own accord.

YES NO 5. A force has more effect upon a body already in motion than one at rest.

TEST PHYSICS PASSAGE

YES NO 1. This passage relates to the emission and absorption of radiant energy.

YES NO 2. The filament of a lamp as a whole gives out light.

YES NO 3. Atoms and molecules are the agents for turning light into heat energy.

YES NO 4. The corpuscular theory accounts for the propagation of light.

YES NO 5. Modern science has reconciled the corpuscular and wave theories of light.

PRACTICE HISTORY PASSAGE

YES NO 1. This passage describes three stages of the Russian Revolution.

YES NO 2. The social scientists of western Europe exerted an influence upon the younger generation of Russians.

YES NO 3. The intelligentsia were of a realistic turn of mind.

YES NO 4. The intelligentsia were composed of a frustrated clique of individuals.

YES NO 5. It may be inferred that the intelligentsia were an ineffective group of individuals.

TEST HISTORY PASSAGE

YES NO 1. This passage describes the appearance of the nihilist movement in Russia.

YES NO 2. The intelligentsia usurped the power of the nihilists in 1860.

YES NO 3. The nihilists were extremely utilitarian in viewpoint.

YES NO 4. The intelligentsia resorted to terrorism to control the masses.

YES NO 5. The intelligentsia idealized those who lived off the soil.

PRACTICE EDUCATION PASSAGE

YES NO 1. This passage discusses the development of conduct.

YES NO 2. Morality is synonymous with correct behavior.

YES NO 3. Ideas of right and wrong exist apart from language.

YES NO 4. According to one view, people naturally know the difference between right and wrong.

YES NO 5. According to the other view, ideas of right and wrong are the outcome of a conversion experience.

TEST EDUCATION PASSAGE

YES NO 1. The central idea of this passage is that experience molds the mind.

YES NO 2. The Rationalist denies the existence of innate ideas.

YES NO 3. The Empiricist accepts both innate ideas and experience.

YES NO 4. Empiricism is free of intuitive reasoning.

YES NO 5. It may be inferred that the author is a Rationalist.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Adler, Mortimer J. How to Read a Book. New York: Simon and Schuster, 1940. Pp. ix + 398.

2. Anderson, Irving H. "Studies in the Eye-Movements of Good and Poor Readers," Studies in Psychology of Reading, I, pp. 1-35. University of Iowa Studies in Psychology, No. 21. Psychological Monographs, XLVIII, No. 3. Princeton, New Jersey: Psychological Review Co., 1937.

3. ________________. "The Opthalm-O-Graph and Metron-O-Scope Evaluated in the Light of Recent Research on the Psychology of Reading," Indiana State Teachers College Journal, XII (January, 1941), 60-63.

4. Anderson, Irving H., and Dearborn, Walter F. "Reading Ability As Related to College Achievement," Journal of Psychology, XI, 387-396.

5. Anderson, Irving H., and Morse, William C. "The Place of Instrumentation in the Reading Program: I. Evaluation of the Opthalm-O-Graph," Journal of Experimental Education, XIV (March, 1946), 256-262.

6. Artley, A. Sterl. "Influence of the Field Studied on the Reading Attitudes and Skills Needed," pp. 39-42 in Improving Reading in Content Fields. Supplementary Educational Monographs, No. 62. Chicago: The University of Chicago Press, 1947. Pp. viii + 240.

7. Broom, M. Eustace; Douglas, Josephine; and Rudd, Marion. "On the Validity of Silent Reading Tests," Journal of Applied Psychology, XV, No. 1, 35-38.

8. Buswell, Guy Thomas. Fundamental Reading Habits: A Study of Their Development. Supplementary Educational Monographs, No. 21. Chicago: The University of Chicago Press, 1922. Pp. xiv + 150.

9. ________________. How Adults Read. Supplementary Educational Monographs, No. 45. Chicago: The University of Chicago Press, 1937. Pp. xiii + 158.

10. Carmichael, Leonard, and Dearborn, Walter F. Reading and Visual Fatigue. Boston: Houghton Mifflin Company, 1947. Pp. xiv + 483.

11. Chamberlin, John. "Fadiman for the Millions," Saturday Evening Post, CXIII (January 11, 1941), 27, 58-61.

12. Dearborn, Walter Fenno. "The Psychology of Reading," Archives of Philosophy, Psychology and Scientific Methods, IV (March, 1906), 7-132.

13. Dearborn, Walter F.; Anderson, Irving H.; and Brewster, James R. "Controlled Reading by Means of a Motion Picture Technique," Psychological Record, II (May, 1938), 219-227.

14. Eurich, Alvin C. "The Reliability and Validity of Photographic Eye-Movement Records," Journal of Educational Psychology, XXIV (February, 1933), 118-122.

15. ______________. "Additional Data on the Reliability and Validity of Photographic Eye-Movement Records," Journal of Educational Psychology, XXIV (May, 1933), 380-384.

16. Flesch, Rudolph. The Art of Plain Talk. New York: Harper and Brothers, 1946. Pp. xiii + 210.

17. Gates, Arthur I. "An Experimental and Statistical Study of Reading and Reading Tests," Journal of Educational Psychology, XII (September, 1921), 303-14, 378-91, 445-464.

18. ______________. "Diagnosis and Remediation in Reading," Elementary English Review, XIX (December, 1942), 289-290.

19. Gilbert, Luther C., and Gilbert, Doris Wilcox. "Reading before the Eye-Movement Camera Versus Reading away from It," Elementary School Journal, XLII (February, 1942), 443-447.

20. Gould, George M. "Reading a Book-Page Instantaneously," Scientific American Supplement, LXXIV (September 14, 1912), 175.

21. Gray, William S. "The Nature and Types of Reading," pp. 23-38 in The Teaching of Reading: A Second Report, thirty-sixth yearbook of the National Society for the Study of Education, Part I. Bloomington, Illinois: Public School Publishing Company, 1937. Pp. vii + 422.

22. Gray, William S., et al. Reading in General Education. Washington: American Council of Education, 1940. Pp. xiii + 464.

23. Hoffman, A. C.; Wellman, B.; and Carmichael, L. "A Quantitative Comparison of the Electrical and Photographic Techniques of Eye-Movement Recording," Journal of Experimental Psychology, XXIV (January, 1939), 40-53.

24. Horn, Ernest. Methods of Instruction in the Social Studies. New York: Scribner's, 1937. Pp. xix + 523.

25. Huey, Edmund Burke. The Psychology and Pedagogy of Reading. New York: The Macmillan Company, 1913. Pp. xvi + 469.

26. Imus, Henry A.; Rothney, John W. M.; and Bear, Robert M. An Evaluation of Visual Factors in Reading. Hanover, New Hampshire: Dartmouth College Publications, 1938. Pp. 144.

27. Judd, Charles Hubbard, and Buswell, Guy Thomas. Silent Reading: A Study of the Various Types. Supplementary Educational Monographs, No. 23. Chicago: The University of Chicago Press, 1922. Pp. xiv + 160.

28. Leary, Bernice E. "The Role of Reading in the Content Fields," pp. 10-13 in Improving Reading in Content Fields. Supplementary Educational Monographs, No. 62. Chicago: The University of Chicago Press, 1947. Pp. viii + 240.

29. Leary, Bernice E., and Gray, William S. "Reading Problems in Content Fields," pp. 113-185 in Reading in General Education. Washington: American Council on Education, 1940. Pp. xiii + 464.

30. Ledbetter, Frances Gresham. Reading Reactions for Varied Types of Subject Matter: An Analytical Study of the Eye Movements of Eleventh Grade Pupils. Unpublished doctor's dissertation, New York University, 1945. Pp. xiii + 255.

31. Litterer, Oscar F. "An Experimental Analysis of Reading Performance," Journal of Experimental Education, I (September, 1932), 28-33.

32. Lorge, Irving. "Predicting Readability," Teachers College Record, XLV (March, 1944), 404-419.

33. McCaul, Robert L. "Economical Training in Reading at the Secondary-School Level," High School Journal, XXI (April, 1938), 117-125.

34. Morgan, James. Theodore Roosevelt. New York: Grosset and Dunlap, 1919. Pp. xii + 324.

35. Morse, William C. A Comparison of the Eye-Movements of Average Fifth and Seventh-Grade Pupils Reading Materials of Corresponding Difficulty. Unpublished doctor's dissertation, University of Michigan, 1947. Pp. vii + 156.

36. Paterson, D. G., and Tinker, M. A. "Time Limit vs. Work Limit Methods," American Journal of Psychology, XLII (January, 1930), 101-104.

37. Paterson, Donald G., and Tinker, Miles A. How to Make Type Readable. New York: Harper and Brothers, 1940. Pp. xix + 209.

38. Pressey, L. W., and Pressey, S. L. "A Critical Study of the Concept of Silent Reading Ability," Journal of Educational Psychology, XII (January, 1921), 25-31.

39. Pringle, Henry Fowles. Theodore Roosevelt. New York: Harcourt, Brace and Company, 1931. Pp. x + 627.

40. Rebert, G. Nevin. "A Laboratory Study of the Reading of Familiar Formulas," Journal of Educational Psychology, XXIII (March, 1932), 192-203.

41. ________________. "A Laboratory Study of the Reading of Familiar Numerals," Journal of Educational Psychology, XXIII (January, 1932), 35-45.

42. Robinson, Francis P. The Role of Eye Movements in Reading with an Evaluation of Techniques for Their Improvement. University of Iowa Studies, No. 39. Iowa City: University of Iowa, 1933. Pp. 52.

43. Robinson, Francis P., and Hall, Prudence. "Studies of Higher-Level Reading Abilities," Journal of Educational Psychology, XXXII (April, 1941), 241-252.

44. Scheinfeld, Amram. You and Heredity. New York: Frederick A. Stokes Company, 1939. Pp. xvii + 434.

45. Schmidt, William Anton. An Experimental Study in the Psychology of Reading. Supplementary Educational Monographs, No. 2. Chicago: The University of Chicago Press, 1917. Pp. iv + 126.

46. Seibert, Earl William. Reading Reactions for Varied Types of Subject Matter: An Analytical Study of the Eye Movements of Eighth Grade Pupils. Unpublished doctor's dissertation, New York University, 1943. Pp. xiv + 238.

47. Stone, Lewis Gordon. Reading Reactions for Varied Types of Subject Matter: An Analytical Study of the Eye-Movements of College Freshmen. Unpublished doctor's dissertation, New York University, 1941. Pp. xiv + 273.

48. Strang, Ruth. Problems in the Improvement of Reading in High School and College. Lancaster, Pa.: The Science Press Printing Co., 1940. Pp. 423.

49. Stroud, J. B. "A Critical Note on Reading," Psychological Bulletin, XXXIX (March, 1942), 173-178.

50. Terry, Paul Washington. How Numerals Are Read. Supplementary Educational Monographs, No. 18. Chicago: The University of Chicago Press, 1922. Pp. xii + 109.

51. Tinker, Miles A. "A Photographic Study of Eye Movements in Reading Formulae," Genetic Psychology Monographs, III, No. 2 (February, 1928), 69-182.

52. ______________. "The Role of Eye-Movements in Diagnostic and Remedial Reading," School and Society, XXXIX (February, 1934), 147-148.

53. ______________. "Eye-Movements in Reading," Journal of Educational Research, XXX (December, 1936), 241-277.

54. ______________. "Reliability and Validity of Eye-Movement Measures of Reading," Journal of Experimental Psychology, XIX (December, 1936), 732-746.

55. ______________. "The Study of Eye Movements in Reading," Psychological Bulletin, XLIII (March, 1946), 93-120.

56. Traxler, Arthur E., "Value of Controlled Reading: Summary of Opinion and Research," Journal of Experimental Education, XI (June, 1943), 280-292.

57. Walker, Robert Y. "The Eye-Movements of Good Readers," University of Iowa Studies in Psychology, No. 17, Psychological Monographs, XLIV, No. 3 (1933), 95-117.