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A STUDY IN THE MECHANICS OF READING

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A Study in the Mechanics of Reading

THIS study was undertaken with the purpose of finding out what factors in the mechanical phase of the reading act are most likely to arrest the child's progress in learning how to read. The general plan of procedure may be divided into four principal parts. In the first part an attempt was made to derive by means of a theoretical analysis the main mental processes involved in the mechanical aspect of reading. In the second the efficiency of these mental processes was tested for every child who served as a subject for the experiments. In the third part the reading ability of every child was either determined by means of a test or obtained from the teacher of the children. The fourth part consisted in calculating the coefficients of correlation for the children's reading ability and their efficiency in every one of the mental processes tested. Those efficiencies which gave the highest degrees of correlation with reading ability were assumed to be the most important in learning how to read.

The analysis of the mechanical phase of the reading act yielded the following principal factors: the visual perception span; the recognition of unfamiliar visual words; speed in the recognition of familiar visual words or their elements; speed in the recognition of familiar visual words and the reproduction of their oral equivalents combined; the association of familiar and unfamiliar oral words with unfamiliar visual words; the phonetic analysis and synthesis of words. It was also thought to be worth while to test visual and auditory reproduction, because the recognition of an impression is dependent upon its power to reproduce its former associates, especially those of visual and auditory nature in the case of reading. On the fifth of these items, that pertaining to the association of familiar oral words with unfamiliar visual words, no experiments were made because the necessary materials could not be prepared and the experiments be performed before the close of the school year.

The data of the study were obtained from two sets of experiments, the first of which was carried on in the winter of 1915 and the second in the spring of 1918. The subjects of the first set were sixteen school children of the sixth grade. There were eight boys and eight girls. Their age-differences were very small. Taking their ages at the nearest birthday, twelve were twelve years old, three were eleven, and one was fifteen. For the second set of experiments the subjects were fifteen sixth grade children of the

B division, six girls and nine boys. All of these children were beyond twelve years of age but only two were beyond fourteen.

In reading ability the sixth grade children of the B division were ranked by their teacher, who had worked with most of them for several years and who therefore knew their relative abilities very well. With but a few exceptions the differences in reading ability were so marked that the ranking could be easily made. The reading abilities of the sixth grade children were determined upon the basis of the time required to read a passage of thirty-five lines from a fourth reader. Five seconds were added to the reading time for every error. The amount of time added for every error was chosen somewhat arbitrarily but this addition had practically no effect upon the reading rank of this group of children, because those who read the most fluently also made the fewest errors, the coefficient of correlation for speed and errors being .87. Only mispronunciations and the inability to give a pronunciation were recognized as errors. For all of the children but one, who required ten minutes to read the passage, the reading time ranged from one minute and a half to five minutes. The errors ranged from two to forty-two.

As almost all of the sixth grade children had the same chronological age and as all but four of them did not vary more than a year in mental age, they were thought to constitute a good group for calculating the amount of correlation between their reading abilities and their grades of intelligence. If those children who have the highest mental ages are assumed to be the most intelligent, then the coefficient for reading ability and intelligence is .06; but if those children whose mental ages exceeded their chronological ages the most be considered the most intelligent, then the coefficient is .56. However, if the group of children had been larger these coefficients might have been very different.

In calculating the above coefficients Pearson's method adapted to rank differences was used, the formula being: $r=1-\frac{6\,\Sigma\,D^2}{n(n^2-1)}$ Unless otherwise specified this formula was used for working out all of the other coefficients given in this study. For those who are not familiar with methods of correlation I am making a brief general statement of the meaning of the coefficient of correlation. For this purpose I shall use reading ability and general intelligence as the factors to be correlated. If the child who is the best reader also has the best intelligence, the one who is next best reader has the next best intelligence and so on for the whole group, then the correlation for reading ability and intelligence will be expressed by the coefficient 1. If, however, the best reader has the poorest intelligence, the next best reader the next lowest intelligence and so on, then the coefficient of correlation will be

—1. Again, if there is no connection between reading ability and intelligence beyond a chance relationship, then the coefficient will be 0.

For the experiments on the relation between the visual perception span and reading ability the sixth grade children of the B division served as subjects. The words which were used to vary the demands upon the span are given in the following list of five groups:

1	2	3	4	5
play	there	pretty	pennies	football
come	happy	coming	bonnets	straight
like	going	garden	grandma	overalls
rain	stand	crying	morning	leapfrog
have	thing	babies	strings	marching

The words of these groups, which vary in length from four letters in the first group to eight letters in the eighth, were cut from the Sun Bonnet Primer and pasted on a white card of the size required by the tachistoscope, but the type deficiencies of these words were such as to make it impossible to use them. They had to be exposed very often before the children could recognize them and the number of expositions varied considerably from word to word. The letters of the words were too small and the ink was too pale for ready recognition. While considerable improvement has been made within recent years in the size and nature of the type used for primers, it is still very deficient. The type face is too small, the width of the stroke is insufficient or the whites and blacks are poorly balanced and the long ceriphs obscure the forms of the letters and words.

On account of type deficiencies and the shortness of the printed words, the words were finally printed on white cards with a stub pen and heavy black ink. While this resulted in considerable variation in the size of the letters and the lengths of the words, it gave us words which could easily be recognized. No capitals were used because the object was to make words in their general form look as nearly as possible like words of ordinary text. The length of each word in millimeters is given in Table II and the approximate size and spacing of the letters is given in the following table:

TABLE I

Approximate size and spacing of the letters.

	mm		mm
Height of tall letters	13	Width of stroke	1.25
Height of small letters	7	Spacing of letters	2 to 3
Width of small letters	6		

The words were exposed by means of Whipple's portable tachistoscope. This is a very convenient form of tachistoscope.

By its use the exposition time can be varied from one-thousandth to one-tenth of a second. Its most serious short-comings appear to be a lack of accuracy in the exposition times and the absence of a fixation point. The former, however, did not interfere with the attainment of our purposes. The tachistoscope was placed squarely in front of the child at a distance of eighteen inches from the eyes. It was tilted at such an angle that the line of sight made angles with the plane of the card containing the word.

The words were exposed in the order in which they appear in the above list, every exposition being preceded by the preparatory signal *now*. If the child recognized a word correctly on its first exposition, the next word was shown; but if he failed, the same word was shown repeatedly until the child succeeded or the word had been shown twelve times. The exposition times for the first four trials were one-three hundred and fiftieth, one-one hundred and tenth, one-fortieth, and one-tenth of a second respectively. For additional expositions these times were repeated in the same order until either recognition occurred or twelve expositions had been made. As there were fifteen children and twenty-five words, three hundred and seventy-five expositions would have been required had every child succeeded on the first trial. Out of these three hundred and seventy-five cases there were only thirteen for which twelve expositions were insufficient. Moreover, out of the three hundred and seventy-five cases only one hundred and ten required more than a single exposition for correct recognition. Most of the repeated expositions occurred on the word groups, four and five.

Those children who averaged the smallest number of expositions were assumed to have the widest perception span. This assumption may seem to be unwarranted because word recognition depends upon the degree of familiarity as well as upon the perception span. As all of the words were taken from a primer it was thought that there certainly could be no large differences in the degree of familiarity. Ease of recognition may also vary somewhat with the form of the word, but as a variety of forms appeared in the groups with the shorter as well as in those with the longer words, this factor was kept fairly constant and does therefore not enter into the problem. At any rate whether some word forms are recognized more easily than others has not been very satisfactorily determined. More work has been done on the recognizability of letter-forms, but even here there is poor agreement.

How the number of expositions increased with the length of the word is shown in the following table in which are given the length of each word in millimeters, the number of expositions per word and other results which will be referred to later:

TABLE II

Showing the words exposed, their lengths in millimeters, the number of expositions required for recognition, the total response times on each word and the response times for all but the poorest subject.

Words	Length in mm.	Total Number of Exposures	Total Response Times in Fifths of a Second	Response Times with one Case Omitted
play	27	24	88	78
come	34	23	72	67
like	25	17	86	79
rain	26	41	119	94
have	30	15	82	71
Averages	28	24	89	78
there	34	15	84	68
happy	41	17	121	76
going	36	16	90	75
stand	36	16	96	80
thing	32	17	99	84
Averages	36	16	98	77
pretty	43	21	97	91
coming	45	16	82	72
garden	48	21	123	80
crying	42	19	140	104
babies	41	28	136	105
Averages	44	21	116	90
pennies	52	76	125	100
bonnets	54	86	149	124
grandma	62	87	155	147
morning	55	23	114	80
strings	49	31	139	119
Averages	54	61	136	114
football	45	37	144	104
straight	45	25	130	105
overalls	47	35	135	100
leapfrog	50	41	155	130
marching	57	22	126	116
Averages	49	32	138	111

The words of the first and second groups appear to have fallen well within the limits of the children's perception spans. The whole number of children required, for the correct recognition of every word in the second group, only six more than the smallest possible number of expositions. On the first group they required, for correct recognition, forty-five more than the smallest number of expositions, but this was probably not due to the narrowness of the perception span. Twenty of the forty-five extra expositions were made by two children on the word rain, which was poorly printed, the letters i and n having been very poorly spaced. This resulted in such readings as ram and ran. Seventeen of the extra expositions were made on the first and second words. This may be ascribed to a lack of sufficient preliminary practice, only two words having been exposed for this purpose.

Even for the third group only twenty extra expositions were required for the correct recognition of every word. As thirteen of these were made on the word babies, which was the shortest word, the perception span was undoubtedly wide enough to recognize the words of this group. Twelve of the extra repetitions on babies were required by two children. It is perhaps worthy of note that the words ending in *ing*, *coming* and *crying* in this group, required the smallest number of expositions. *Morning* in the fourth group and *marching* in the fifth group also required the smallest number of expositions in their respective groups, even though they were the second and third longest words of the whole list. If this is due to the fact that the syllable *ing* is so frequently repeated as the final syllable of words, then it appears that the possibility of improving the recognition of words by means of practice is almost without a limit.

The words of group five required only about one-half as many expositions as those of group four. This fact may be attributed to differences in word familiarity, the number of letters in each word, word form and word length. If there is any difference between the groups in word familiarity it is probably in favor of group four. The words of group four also have the smallest number of letters. Which group of words contains the forms most favorable to easy recognition it is probably impossible to say. There are two plural endings in group four and only one in group five, but the children did not make any errors on these phases of the words. Moreover, *grandma* is not a plural form, and yet required the most expositions.

The only remaining difference is that of length, and this is very much greater for the words of group four than for those of group five, the average difference in length being five millimeters. If the individual words of group four and five, excepting *morning* and *marching*, be compared, it will be found that the words of fifty millimeters and above required without exception a larger number of expositions than the shorter words. Again, if we disregard the first group and compare the remaining groups with respect to length and number of expositions, it appears that the number of expositions increases quite regularly with the length of the word. These facts appear to justify the statement that those children who required the smallest number of expositions for correct recognition have the largest perception span. If it can also be shown that these children are the best readers, then there must be some connection between the ability to read and the visual perception span. Either the ability to read depends upon the perception span or both depend upon the same ability. There is, however, the possibility that the best readers increased their perception spans by doing much more reading than the poorer readers. On this point there is no evidence for a decision, and if there were it would not interfere with what we are trying to show: i. e., that the best readers have the widest perception spans.

In the preceding paragraph I attempted to show that under the conditions of our experiments, the ranking of the children based upon the widths of the perception spans was the same as the ranking based upon the number of expositions required for correct recognition. Now, as the coefficient of correlation for reading ability and the number of expositions is .68, this is also the coefficient for reading ability and the visual perception span. I also calculated the coefficient of correlation for reading ability and the number of expositions on each of the last two groups of words in the above list. In each case the coefficient was found to be .69. For the remaining word-groups no coefficients could be calculated, because very many children had the same number of expositions for every one of these groups.

Having shown that reading ability and width of perception spans have a high coefficient, I shall venture to make a few practical suggestions in regard to the perception span in the teaching of reading. The high coefficient shows that it is one of the important factors involved in the act of reading. This fact, in connection with the further fact that the young child's perception span is narrow but increases considerably with age, constitutes a strong argument against the early teaching of reading. If the learning of reading were postponed until a later age, the child would, on account of a wider perception span and greater maturity in other capacities involved in reading, learn reading far more easily and very probably more perfectly. The width of the visual perception span increases not only with age but also with training. The conditions under which the child learns how to read should therefore be such as to impel him to make an effort to increase his perception span and to build up larger and larger perception units. I believe that the development of large perception units should receive the careful attention of the teacher and should not be permitted to develop incidentally in connection with ordinary reading. Of course, this and most of the other practical deductions made in this study should be taken as suggestive only until tried out by carefully conducted experiments in the teaching of reading.

The time required for the recognition of familiar visual words and the reproduction of their oral equivalents combined, is another factor involved in reading which I attempted to measure. This was done in connection with the experiments on the perception span by measuring the time which elapsed between the exposition of a word and its pronunciation by the child. As soon as the word appeared in the tachistoscope, the experimenter started a stop-watch and when the child gave the name of the word the experimenter stopped the watch. This would be a very crude method for getting the absolute response time of a child but as interest here was only in the relative response times the method was thought to be sufficiently reliable.

Only the response times for correct recognition were recorded, because the times for incorrect recognitions varied so much as to be valueless—from three-fifths of a second to fifteen seconds. Moreover, in some cases there was no response until a correct one could be given. As stated before, in thirteen cases no responses occurred by the twelfth exposition. For these cases a time value was assigned. This was the child's average time on all words which required more than one exposition. Correct recognition occurred on the first exposition for two hundred and sixty-five of the three hundred and seventy-five cases.

The response times on every word for the whole number of children is given in Table II in fifths of a second. If the results of the poorest subject are omitted the increase in response times from group to group is very slight. The average time for the last group of words is less than one and one-half times that for the first group. The difference in the response times between the first and last groups can be diminished to one-half this amount by omitting the response times for the words which required more than a single exposition for recognition.

Our main interest in the response time however is in the relation which it bears to reading ability. Are the children with the shortest response times the best readers and those with the longest response times the poorest readers? A number of different bases were used for the purpose of ranking the children in the speed of their responses. The first of these was the child's average response time for all the words which required only one exposition. Upon this basis the coefficient of correlation for speed of response and reading ability is .81. The second basis was the child's average response time for all of the words regardless of the number of expositions required for recognition; the third was the average response time for all the words of group three; the fourth, for all the words of group four; and the fifth, for all the words of group five. The coefficients for reading ability and the speed of response, with the rankings made upon the bases just described, are .80, .85, .80 and .80, respectively.

These high coefficients indicate that the ability to make a quick oral response to the printed word is an essential factor in the mechanical aspect of reading. But this response is a complex. It involves a number of factors, every one of which requires some time. For example, there is the time for pronouncing the word after it has appeared in consciousness; the time for reproducing and recognizing the auditory and speech-motor images which precede the pronunciation; and the time involved in the arousal and recognition of the visual impression. Every one of these factors might still be further analyzed. Recognition in itself is a complex process. I have, however, gone far enough in the analysis for my purpose. The mere pronunciation of a word after its auditory motor forms have already appeared in consciousness does not appear to be a serious cause of delay in the act of reading, for children have no difficulty with repeating a familiar word after having heard it. The rate of recognizing familiar words may undoubtedly be a serious cause of delay. Experiments on the speed of recognizing familiar verbal elements and on the recognition of strange words will be described in the following pages.

The arousal in consciousness of the auditory-motor forms of the word by the visual impression after this has been recognized, I believe to be an important factor in lengthening the total response time. The time for the reproduction of the auditory-motor forms of the word is dependent upon the intimacy of the connections between these forms on the one hand and the visual form on the other. If the connections are very intimate then the auditory-motor forms are reproduced easily and quickly, but if the connections are imperfectly and loosely formed reproduction is apt to be delayed. It is probable that for practiced readers an imperfect connection between the visual and auditory-motor phases of the word is a more serious cause of poor reading than faulty visual recognition, especially as the latter may depend partly upon the former. It is more difficult for the child to recall the name of a word after he has seen and recognized it than it is for him to recognize a word, just as adults find it more difficult to recall the names than to recognize the faces of people.

If this opinion is correct then the formation of intimate connections between the visual and auditory-motor phases of the word should be stressed most in developing the mechanical side of reading. How this may be done most effectively it may be impossible to say, but I shall nevertheless venture to discuss the problem. I believe that the most intimate connection between one complex and another is made by analyzing each complex into its elements and associating the corresponding parts, the size or nature of the elements to be determined by the degree of their familiarity. As these associations are being formed they should be connected with other similar associations until the associated parts become intimately united with one another. Thus, in reading, the visual word should be analyzed into letters or syllables and the oral word should be analyzed into sounds or syllables, the parts of the one being meanwhile associated with the corresponding parts of the other. These associated parts should then be connected with other associated parts. In this way the visual word becomes better known, the auditory-motor word becomes better known, and the two are unified by many intimate associative connections so that when the one is in consciousness the other can be readily reproduced. Care however must be taken to avoid the continuance of this procedure beyond the limits of necessity. The goal of this procedure is to develop the ability to recognize the visual word as a whole quickly and accurately and to supplement the visual word quickly and accurately with its total oral equivalent. The teacher of reading is apt to either over-do the analytic-synthetic work or neglect it altogether. One teacher relies mainly upon teaching the elements of the word, another upon deriving these elements through word-analysis, a third upon combining the elements into word wholes, a fourth upon the recognition of words and phrases as a whole, a fifth upon thought anticipation and so on. Every one of these factors has its place in reading; none of them should be neglected, but none of them should be overemphasized. The kind and amount of emphasis required will vary with the individual and the stage of development in reading ability.

Another series of experiments was undertaken with the B division of the sixth grade in order to determine to what extent their reading ability correlated with the ability to learn the recognition of strange forms. These forms consisted of Greek words. The children under controlled conditions attempted to learn the recognition of ten of these words. Sixteen more of these words were used in connection with the ten to test the success of the children's efforts. The whole list follows:

ἠρζάμην	εὐτυχέω	βελτίων	μάχαιρα	ἀγοράζω
δεχόμαι	ἀδελφός	ἰςάζω	λοχᾱγίᾱ	κτάομαι
δῠνᾰτός	αθροίζω	ἱππυκός	πρέσβυς	κεφαλήν
ἠγάσθην	ἀριθμός	θέμενος	οἴχομαι	λανθάνω
ἐκκλίνω	βάλανος	θορῠβος	πολέμιος	μελανίᾱ
				ὀρυκτός

Every one of the foregoing words was printed in Greek letters on a separate card about the size of a visiting card. The first ten words in the list were shown to the children in a constant order at the rate of one in two seconds. The time was controlled by means of a metronome. The child was asked to look at the words carefully so that he would be able to find them when mixed with Greek words which he had not seen. After the child had been told what he was expected to do, the experimenter placed the first card directly before him and after two seconds placed the second card on top of the first so as to cover up the first word. This procedure was continued until all of the ten words had been placed before the child. The ten cards were then shuffled with the remaining sixteen, about twenty seconds being required for this purpose. The whole pack of cards was now placed before the child and he was asked to separate them into two piles, the one containing those words which he had seen before and the other those words which he had not seen. The whole procedure of learning and testing was repeated four times, making five trials in all. In separating the cards the child was allowed as much time as he desired.

For the pile containing the words which the child thought he had seen before, the wrongs and rights of the five trials were averaged and the accuracy of recognition was calculated as indicated by the following formula: $r = \frac{R - 5/8\,W}{C}$. In this formula r represents the accuracy of recognition; R the number of cards placed correctly; W the number of cards wrongly placed; and C the number of cards, in this case ten, which the child might have placed correctly. As the ten words which the child had seen were mixed with sixteen which he had not seen, he got by chance more wrong than right in making the separation. To equalize the chances for placing words rightly and wrongly, W is multiplied by $5/8$. The percentage of accuracy as found by this formula varied from 7 to 63, the fourth poorest reader making the best score.

The ability to learn the recognition of strange forms as represented by our subjects was now correlated with their reading ability. The coefficient for these abilities is —.11, an amount which is much more than covered by the probable error (see Table IV). According to this coefficient learning to recognize forms is none of the factors which is responsible for the prevalent poor reading among the children of the upper grades. Learning to recognize strange word-forms may be a difficult task for the beginner in reading but it does not appear to be so difficult as to interfere seriously with the development of his subsequent reading ability. The ability to learn the recognition of strange forms should be kept distinct from that of recognizing familiar forms quickly, a problem which will be considered presently. Perhaps these two abilities are intimately related but at present no evidence of this appears to be at hand.

In connection with these experiments an interesting fact on the method of recognizing strange words was brought out. The children were asked whether they depended upon the appearance of the word as a whole or on parts of the word for recognition. The following represent the variety of replies to this question: "Some of the funny letters"; "The different marks over the letters"; "The first two or three letters"; "The first and last letters". All of the children relied upon the appearance of letters for word recognition and only three said that they also tried to remember the appearance of the word as a whole. The percentage of accuracy for one of these three was the lowest of the whole group and for another it was a fair average. The best subject depended upon the first two or three letters. The child who had the second best record said that he depended upon two letters somewhere within the word. The child with the second poorest record depended upon the appearance of the word as a whole, together with the appearance of some of the letters within the word.

I think we may fairly assume that beginners in reading use similar methods in attempting to recognize words. On this assumption the question arises whether the children should be allowed to use their own methods or whether they should be encouraged to depend upon total word form for recognition. I shall try to answer this question by examining the probable consequences of allowing the child to use his own methods, those of recognizing words upon the basis of one or a few of their letters. If the child recognizes words upon the basis of such simple signs as one or two of their letters, then as his visual vocabulary increases these signs of recognition will appear in many other words with the result that the new and the old can no longer be distinguished without considerable confusion. To avoid this the child must develop a recognition which is based upon the total appearance of the word. In this connection the further question arises whether the child should be permitted to develop this kind of recognition by his own methods or whether the teacher should direct and help him. Undoubtedly the end will be attained more quickly if the teacher will give the child some intelligent assistance. The whole task of the recognition of complex word-forms would become very much easier for the child if reading were postponed until a later age.

There are some teachers of reading who assert that the child will learn to recognize the long word just as quickly as or often more quickly than the short one. When this is the case it must not be assumed that the child had become just as familiar with the long as with the short word, for he recognizes the long word upon the basis of only one or more of its ear-marks such as its greater length or an odd first letter. This is his method of recognizing the short word also but, as the short word has fewer characteristics than the long one, it is more completely known when only a few of its characteristics are recognized.

The next series of experiments represents an attempt to determine whether good readers have a higher speed in visual recognition than poor readers. The children of the sixth grade served as the subjects. For the materials of these experiments I intended to use short sentences composed of familiar words, the sentences to be exposed for such periods of time as would permit of eye-movements yet tax the child's fluency in reading. But as no apparatus for making such expositions was available, I used the following one-syllabled German words in place of the sentences:

Gruss	Stein	Turm	Berg	Kunst	Krug
Raum	Kreuz	Werk	Hand	Strauch	Welt
Uhr	Fass	Schiff	Stern	Frucht	Jahr
Zeit	Blatt	Glas	Hof	Schrift	Feld
Netz	Weg	Baum	Korb	Wald	Bild

These words were exposed in the above order and form by means of a Wirth memory apparatus. The exposition time, which was controlled by means of a metronome with electrical connections, was three-quarters of a second. As the time was long enough to permit eye-movements and as the words were short, this was not a test of the visual perception span but of the speed in recognizing a series of well-known letters, letters whose forms were well known and whose names were well possessed.

Preliminary practice consisted of only one exposition. The children were placed in a comfortable position directly in front of the apparatus and at an easy reading distance. At their right side was a table with pencil and paper. The children were instructed to get the spelling of a word and then write it on the paper prepared for the purpose. Every word was written by the child directly after its exposition, as much time being allowed for this as the child required. Letter errors were counted. They consisted of additions, omissions, inversions and transportations. The number of errors made on every word by all of the children is given in the following table:

TABLE III

Words Exposed	Total No. of Errors	Whole Word Missed
Uhr	5	1
Weg	1	0
Hof	0	0
	—	
Average	2	
Raum	11	1
Zeit	7	0
Netz	8	1
Fass	6	1
Turm	8	0
Werk	1	0
Glas	5	0
Baum	6	0
Berg	0	0
Hand	0	0
Korb	6	0
Wald	0	0
Krug	8	0
Welt	2	0
Jahr	7	0
Feld	2	0
Bild	0	0
	—	
Average	4.5	

Words Exposed	Total No. of Errors	Whole Word Missed
Gruss	10	0
Stein	6	0
Kreuz	32	1
Blatt	8	0
Stern	3	0
Kunst	16	0
	—	
Average	12.5	
Schiff	14	0
Frucht	34	1
	—	
Average	24	
Strauch	31	0
Schrift	36	0
	—	
Average	33.5	

The above word-groups are composed of words of different lengths, the shortest having only three letters and the longest seven. The number of errors varies considerably with the group, the groups with three, four, five, six and seven-letter words averaging 2, 4.5, 12.5, 24 and 33.5 errors per word respectively. If the number of errors per word be taken as a measure of the task of recognition, it appears that this task under the conditions of our experiments increases far more rapidly than the number of letters in the successive groups. Thus twice as many errors are made on the four-letter group as on the three-letter group and three times as many errors on the five as on the four-letter group.

Most of the errors were made on letters composing the middle part of the word. There were 249 errors excluding those due to missing whole words. Of these 153 were made on middle-letters and only 96 on end-letters. Only the first and last letters were taken as end letters, excepting the last group in which the first two and the last two were taken as end-letters. For the second word-group in which there are just as many letters in the middle of the word as at the ends, there are 42 middle-letter errors and

23 end-letter errors. The letters at the ends had the advantage of both position and form, the first letters being capitals and many of the last letters being tall.

There were large individual differences in the number of errors. The best subject made only one error while the poorest made twenty-three. It was assumed that those children who made the most errors had in general the slowest rate of recognition, an assumption which is perhaps unwarranted. If it be accepted, however, then the coefficient of correlation for speed of recognition and reading ability is .87. The speed of recognizing very familiar visual materials may depend largely upon the excitability of the retina. In some children the retina may be so inert as to make it difficult for them to become fluent readers. While native excitability of the retina can evidently not be improved, there is no reason to doubt that its excitability can be improved for the same stimulus by much and intense practice.

With the sixth grade children acting as subjects, another series of experiments was performed to determine whether the ability to reproduce series of visual and auditory impressions would show any correlation with reading ability. For the visual series the materials consisted of the following nonsense syllables: xon, ger, lah, bir, tex, lur, sen, bef, zif. These materials were presented six times in succession and in the same order at the rate of one in three-quarters of a second by means of a Wirth memory apparatus. The time was regulated by a metronome with electrical connections. Directly after the materials had been presented for the sixth time the child wrote what he remembered. Credit was given for all of the syllables which were reproduced correctly, regardless of the order. The ability to reproduce such visual material does not appear to be any better for the good than for the poor readers. The coefficient of correlation is —.03; this is more than covered by the probable error.

The following nonsense syllables were used to test the child's ability to reproduce a series of auditory impressions: gur, tus, ner, lab, daw, tac, sot, rix, nas. These also were presented six times in succession. The experimenter pronounced them at the rate of one in three-quarters of a second, the time being controlled by means of a metronome. Directly after the sixth presentation the child was asked to reproduce the syllables orally. In both this and the preceding experiment no letter errors were counted. The poor readers succeeded just as well in the reproduction of these syllables as the good readers. The coefficient is —.05. An effort was made to have a recall after twenty-four hours but some special work in the training school interfered with this.

The form of this experiment can be much improved. In its present form it does not test the kind of reproduction involved in learning how to read. The ability to be tested is the reproduction of a familiar oral word in response to a strange visual word. This can be tested by exposing Greek words on the Wirth memory apparatus and telling the child at the same time the names of their English equivalents. After the list of words has been repeated a number of times in this way, the child's ability to reproduce the English names of the Greek words may be tested by showing the Greek words once more on the memory apparatus and asking the child to name them. The speed of naming them would test the intimacy of the connections between the strange visual and familiar oral words, while the accuracy of the reproductions would test the retention of the connections.

The results of these experiments were also tabulated for the purpose of showing whether the children learned nonsense syllables best when presented to the eye or to the ear. In this connection it must be remembered that the child's response to visual presentation was in writing and to auditory presentation oral. No difference in the two methods of learning was discovered from the standpoint of group ability. The total number of correct reproductions for auditory presentation was 103 and for visual presentation 101. However, a comparison of individual results shows that those who excelled by the visual method did not also excel by the auditory method. The coefficient of correlation for the two series of results is —.39. Pearson's product-moments method was also used for calculating the coefficient. By this method the coefficient is —.35. These negative correlations show that those children who learned the materials best when presented to the eye were the ones who learned them poorest when presented to the ear, and vice versa. There appears to be a tendency toward specialization in using the senses for learning verbal material.

In the last series of experiments an effort was made to measure the children's relative ability in making phonetic analyses and syntheses of strange words with the visual word to serve as an aid to the analytic-synthetic activity. The sixth grade children of the B division served as subjects. The materials consisted of the following nonsense words:

ĕmblĭskū́tăs	**dēvĭshquā́gō**	**thrēlīmŏt́zō**
plāŏnĕx́terĭf	**hāpōlĭ́frŏn**	

These words were typewritten and appeared on separate cards in the above form.

The experiments were preceded by some preliminary work. The children were reviewed on the long and short sounds of all the vowels. Any deficiencies in this work were eliminated by means of training. Only two of the children required training on one or more of the sounds. The children were also given some preliminary practice in the pronunciation of strange words. For this purpose five Greek words, somewhat shorter than those of the above list, were used. They were asked to pronounce these words and if they failed they were asked to pronounce the syllables, which were pointed out for them. Then they were asked to pronounce the syllables in rapid succession until they succeeded in pronouncing the words as wholes. They were also given instruction in the correct pronunciation of syllables and in placing the accent.

It was a difficult matter to conduct the experiment in such a way as to keep the conditions uniform for all of the children, but in spite of this handicap I feel that their relative ability for this task was fairly well determined. The first word of the list was placed before the child with the direction to pronounce it. If he failed to get started or if his attempts were futile by the close of a one-minute period, the experimenter pointed to the first syllable and asked him to pronounce it. Usually the child succeeded in doing this, but if he failed the experimenter assisted him. The remaining syllables of the word were gone over in a similar manner. The child was then asked to pronounce all of the syllables in succession. If he failed he was again assisted in the manner just described. In this way the syllables were gone over until the child could pronounce them in rapid succession and finally succeed in pronouncing the word as a whole with a high degree of accuracy. The children had very little difficulty in giving the sounds of letters and naming the syllables, but many children were very deficient in breaking the word into syllables and in recombining them. After the experimenter began to assist the child he gave in each case the best assistance he could offer within the limits described, but as the less capable children required so much more help than the more capable ones, it took them much longer to give a correct pronunciation.

The average amount of time which the child with the aid of the experimenter required to give a correct pronunciation of the five words was taken as a measure of his ability to pronounce strange words by means of analysis and synthesis. To work out the pronunciations of the whole list of words the best child required an average of forty-five seconds per word and the poorest child required seven hundred and nineteen seconds. The ability for this kind of work gave a high correlation with reading ability, the coefficient being .85. Almost all of the best readers therefore surpass the poorest in the ability to break up words into smaller units and to re-combine them. This is precisely the way in which adults get at the pronunciation of words which are strange or not entirely familiar. Moreover, in reading a text with very familiar words it is not improbable that the reader who has the ability to see out parts of words and to re-combine them readily can increase the extent of his average reading range and select the fixation points at more regular intervals, factors which very much enhance the reading act. I believe therefore that some of our instruction in reading should be devoted to making the children familiar with the parts of words and to the development of the ability to re-combine these parts into larger or word units.

A similar series of experiments on analysis and synthesis was made with the sixth grade children acting as subjects. In these experiments the children's ability to divide words into syllables was tested by asking them to name the parts of familiar English words and their synthetic ability was tested by having them pronounce syllabized Greek words. Although these tests were not very well controlled and the children did not show such marked differences in reading ability as the sixth grade children of the B division, the coefficient of correlation for this work and reading ability was .65.

I finally calculated the coefficient for a combination rank and the rank in reading ability. For making the combination rank I selected the rankings of the sixth grade children of the B division in the perception span, in the speed of making an oral response to the visual word and in analytic and synthetic ability. These ranks were combined by finding the averages for every child. Upon the basis of these averages a new ranking was made. The coefficient for this rank and the rank in reading ability is .88. This coefficient is .03 higher than the highest coefficient of the individual ranks and .20 higher than the lowest coefficient of the individual ranks.

I thought it might also be worth while to point out some of the marked sex differences even though the sex groups were very small and at least in the sixth grade, B division, very uneven in general intelligence, the girls testing much higher than the boys. In the sixth grade, B division, the girls, as was to be expected, surpassed the boys by large amounts in the width of the perception span, in the speed of their responses and in analysis and synthesis, but the boys, in spite of their intellectual inferiority, surpassed the girls slightly in form recognition. In the sixth grade the girls made only about one-half as many errors as the boys in recognizing the letters of the German words. In this grade the sexes were well balanced in general intelligence. The girls therefore appear to surpass the boys very considerably in the speed of recognizing familiar visual materials, but are far surpassed by the boys in learning to recognize strange visual forms of verbal character.

For the sake of making convenient a comparison of the various coefficients I have brought out all of them together in Table IV. This table gives the number of children or subjects for every experiment; the grade to which the children belonged; the nature of the abilities correlated; the coefficients of correlation and the probable error for every coefficient.

TABLE IV

Coefficients of Correlation

No. of Children	School Grade	First Series of Rankings	Second Series of Rankings	Co-efficients	Probable Errors
15	6B	Perception span	Reading ability..	0.68	.0938
15	6B	Response time	" " ..	0.81	.0601
15	6B	Analysis and synthesis	" " ..	0.85	.0545
		Combined ranks	" " ..	0.88	.0394
15	6B	Form recognition	" " ..	–0.11	.1725
16	6	Speed in recognition	" " ..	0.87	.0410
16	6	Analysis and synthesis	" " ..	0.65	.0974
16	6	Intelligence	" " ..	0.56	.1157
16	6	Visual learning	" " ..	–0.03	.1685
16	6	Auditory learning	" " ..	–0.05	.1684
16	6	Auditory learning	Visual learning..	–0.39	.1430
16	6	Speed in reading	Errors in reading	0.87	.0410

The phases of mental activity which give high coefficients with reading ability are the perception span, the speed of the oral response, analytic and synthetic ability, the speed of visual recognition and general intelligence. Probably no serious effort should be made to teach reading to those children who have a very low degree of intelligence. Even though they succeed fairly well with the mechanical aspect of reading, they are said to get very little meaning from the printed page. In regard to the other factors I may say that none of them should be neglected in the teaching of reading. The most helpful and intelligent instruction in reading cannot be given without knowing which of these factors in general require the most attention and which of them in a particular case are very poorly developed. This is the only way in which trial and error methods in the teaching of reading can be eliminated and instruction in the subject raised to a professional rank.