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The effects of context upon speed of reading, eye movements and eye-voice span

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THE EFFECTS OF CONTEXT UPON SPEED OF READING, EYE MOVEMENTS AND EYE-VOICE SPAN

BY

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Subjects read aloud 200-word passages of statistical approximations up to the 8th order. Their eye-movements were recorded together with a trace of the speech output. Speed of reading, using the syllable as the unit of measurement, increased up to the 5th order for slow readers. Fast readers, on the other hand, further increased their speed to the 6th order. This result had been predicted from a hypothesis that fast readers use contextual cues more efficiently.

Measures of the material in the eye-voice span showed an increase up to the 8th order. Fast readers had a larger material span than slow readers beyond the 5th order, a result paralleling the differences in speed increase. It is suggested that the eye-voice span measured in time is dependent upon the chosen reading speed and the material span.

From the eye-movement records there was no variation of the mean duration of fixation between passages, or between fast and slow readers. The average value was about 240 millisec. The number of both forward and regressive eye movements decreased with increase in contextual constraint up to the 5th or 6th order, i.e. with increase in speed of reading. Fast readers were superior to slow readers in both these respects. The effect of decreasing contextual constraint was to produce more regressive movements together with a slightly smaller mean saccade.

Introduction

It is known that the reading efficiency of most literate adults can be improved without training. All that is necessary, in many cases, is that the person reads "more actively" and increases concentration (Morton, 1959, 1961). This implies the existence of some potential relevant to the processes of reading which is normally not fully utilized in the untrained adult. The hypothesis is put forward that this potential is related to our knowledge of the statistical properties of the language. If we utilized this knowledge more completely while reading, then the immediate stimulus would become more predictable. It has been shown (Morton, 1964*a*) that the visual duration threshold for a word in a sentence context is an inverse function of the probability of the word in the context. Thus, increasing the probability of a stimulus would make the stimulus more easy to perceive, and, if this were a limiting factor in reading, would result in an increase in reading speed, with no comprehension loss.

The suggested increase in the ease of perception might be utilized either by spending less time on each fixation or by making fewer fixations per line. In the latter case, words could be recognized in spite of being on the periphery of vision.

An alternative formulation of the hypothesis would be: assuming that most individuals do use contextual cues to a certain extent in reading, then the effect of increasing the amount of contextual constraint in a passage would be to increase the individual's speed of reading. If then we have a series of passages with increasing amounts of constraint, the speed of reading should increase up to the passage which has the amount of constraint normally used by the reader. In addition, if faster readers normally use more context, the effect will have its limit for them at a higher order of statistical approximation to English than for the slow readers.

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Sumby and Pollack (1954) found that speed in typing, and speed, errors and mean number of glances per word in reading aloud were all related to the order of approximation to English of the passages used. The present experiment is in part a replication of this work and in part an extension.

Materials

The passages used in the experiment were 200-word statistical approximations to English. These were constructed by the method due to Shannon (1951) and Miller (Miller and Selfridge, 1950) and typed on quarto paper in pica. The passages used were the Zero, 1st to 6th and 8th order passages. The first hundred words in the 2nd, 4th, 6th and 8th order lists are due to Taylor and Moray (1960) and were used by their kind permission. The subjects who generated the remaining words were undergraduate and senior members of Reading University.

Apparatus

In addition to examining the relation between the order of approximation of a passage and the speed of reading for that passage, changes in eye-movements during the reading were studied. What was required was to discover whether the change that took place in the eye-movements as the speed increased consisted of a change in the number of fixations or regressions, or a change in the duration of fixations.

Eye-movements were recorded by the technique of electro-oculography, described by Shackel and his co-workers (Shackel, Sloan and Warr, 1958; Shackel, 1960) among others. This technique utilizes the presence of a standing potential difference between the front and back of the eye-ball. The field from this dipole moves as the eye-ball rotates, and electrodes placed on the skin surface will detect the resulting change in d.c. potential which is then amplified and recorded on paper as a continuous record of the position of the eyes. The electrodes used were of the suction type (Shackel, 1958).

The electrical system is shown in schematic form in Figure 1. The preamplifier was

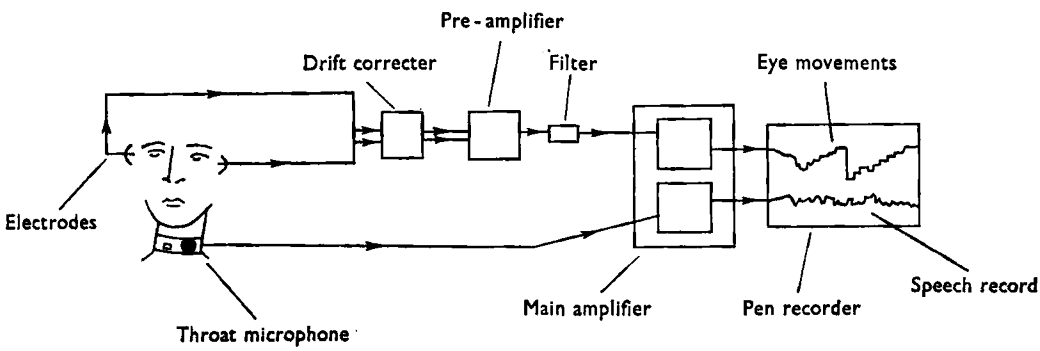


FIGURE 1

Apparatus.

a balanced chopper d.c. preamplifier, designed by Dr. E. R. F. W. Crossman; the main amplifier was a Southern Instruments No. 357 and the two-channel pen recorder a Southern Instruments Pen Oscillograph. The filter was a simple three-stage cascade filter made by the writer and optimized empirically to cut down interference without having too long a time-constant. Only the horizontal eye-movements were recorded; the other channel of the pen recorder was used to record the impulses from a throat microphone, so that the time relationship between eye and voice might be studied. In addition the subject's voice was recorded on a Stenorette recorder so that all errors could be noted.

The subject's forehead rested on a padded, rigid bar, with his eyes 35 cm. away from the text, the position of which was adjusted so that it could be read with comfort. The subject's head was not otherwise fixed, since the apparatus in its existing state was prone to drift in any case (this varied with the subject, the electrodes and the experimenter's competence). Any attempt to plot precisely the fixation points would have been at the expense of making the subject more uncomfortable, and the reliability of such assignments would have been low. Head movements were rare and could easily be discriminated from eye-movements on the record.

Thirty-two male subjects were used, senior and student members of the university.

Procedure

The electrodes and throat microphone were fitted to the subject, who was made as comfortable as possible in the reading position. The subject then fixated a card on the reading stand and the apparatus was adjusted so that fixations at the edge of the card, equivalent to the length of line of the passage, caused the pen to cover about three quarters of the width of the recording paper. To accustom the subject to the apparatus, and vice versa, he was asked to read aloud a 450-word passage from the Pelican *Economics of Everyday Life*. Then the passages of approximation were presented, according to four 8 × 8 Latin Square designs, with instructions to read them "as quickly as possible, minimizing errors." The subject first fixated three calibration points at the top of the paper, then he read the heading before going straight on to the passage.

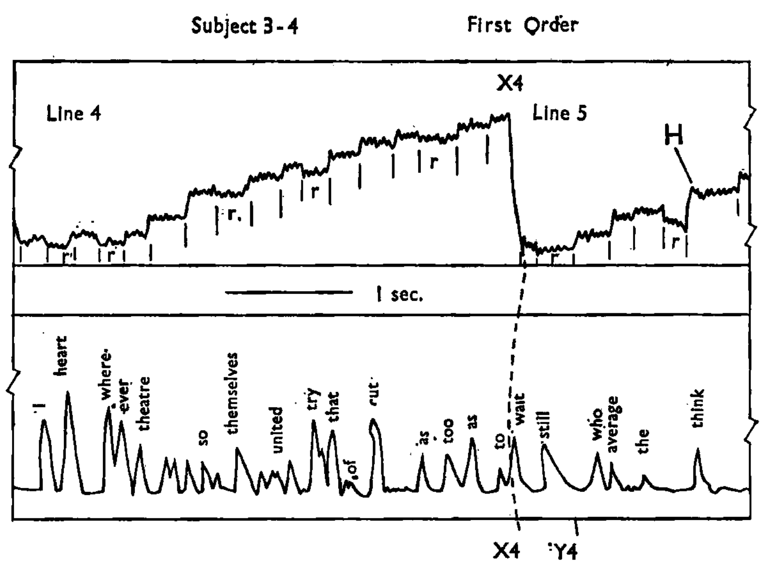
Subjects were told to read the passages without trying to give them any meaning, and were warned that they were all nonsense passages. After the eight lists had been read, a further text from the same book was presented, 444 words long, with instructions to read it, as far as possible, without regard to punctuation or meaning. Many of the subjects found this instruction hard to obey.

The experiment took anything from 20 min. to an hour, depending on the speed of reading, and on whether the apparatus functioned smoothly.

Results and Discussion

Sample records are shown in Figure 2. Eye-movements could be distinguished on the records, and the precise time at which separate words were spoken could be seen from the second channel. The clarity of these records varied considerably from subject to subject. Although apparatus noise was low, there was interference due to brain rhythms and especially to impulses in the speech muscles (compare the silent and oral reading records). Thus a certain amount of visual filtering had to be done to discriminate between noise and eye movements. In fact many of the records had to be rejected because of the low degree of confidence with which the eye movements could be distinguished from interference.

(*a*)



(b)

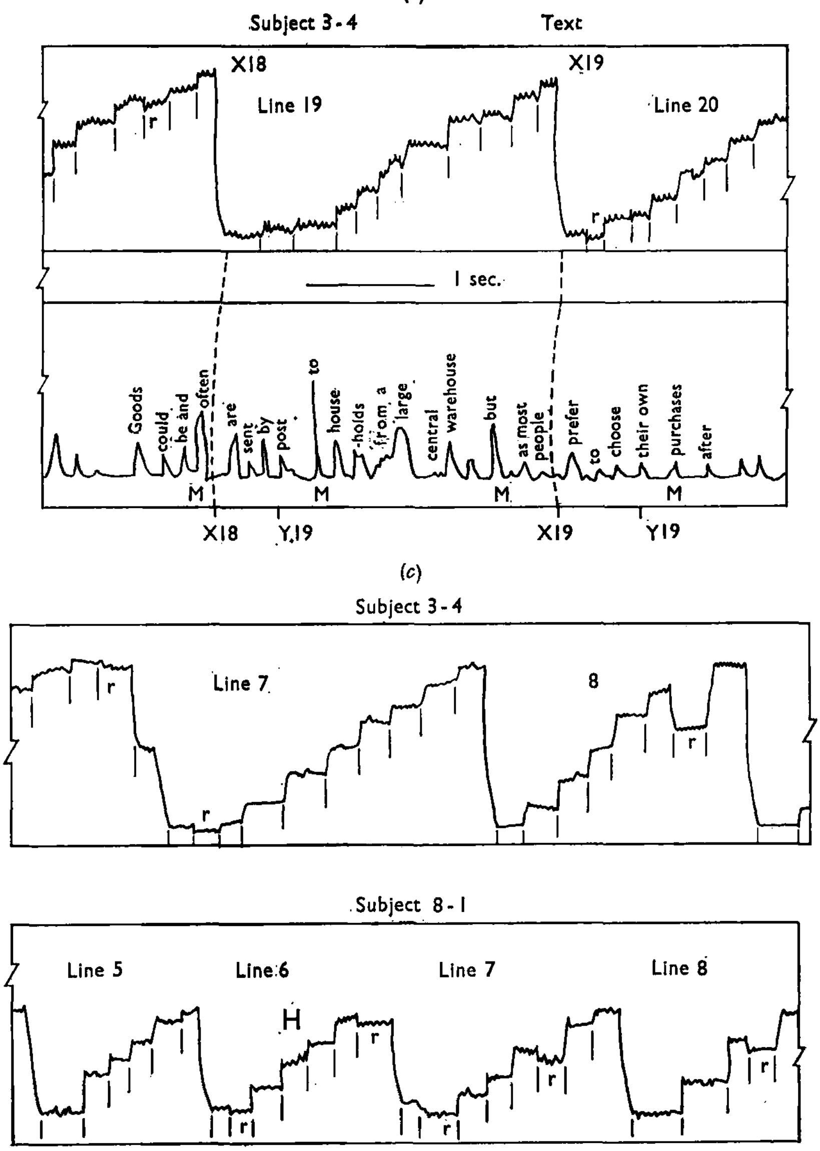


FIGURE 2

Sample records for eye movements. (*a*) and (*b*) Oral Reading; (*c*) Silent Reading.

Notes

1. r = regression. H = Head movement.
2. For both subjects there are fewer fixations per line in silent reading, and they are of shorter duration than those in oral reading.
3. A comparison of the records of subject 3–4 on silent and oral reading shows the interference due to the speech organs.
4. On the oral reading records, "M" represents a place marked on the record at the time the word was spoken.
5. "X" represents the time when the eye leaves the end of a line.
   "Y" is the time when the last word on the line has been spoken.
   "XY" is the eye-voice span.

The assigning of the positions of the words on the record was facilitated by noting the positions of the pauses on the tape recording, and also by marking (on the record) the position of key words as they were spoken. Only three records of the speech had to be rejected.

1. *Speed of reading*

The time taken to read the passages was measured from the record on the second channel. Since the effect of the order of presentation of the passages was negligible, the results for each order of approximation and for the text were pooled across subjects. Since there are differences between the passages with regard to the mean number of syllables and letters per word (these figures are given in Table I), the speed was calculated for all the measures separately. The mean times per passage, and the mean times in sec. per word, syllable and letterspace are given in Table II.

TABLE I

MEAN NUMBER OF SYLLABLES AND LETTERS PER WORD

	Zero	*First*	*Second*	*Third*	*Fourth*	*Fifth*	*Sixth*	*Eighth*	*Text*
Syllables ..	2·615	1·490	1·415	1·345	1·410	1·430	1·520	1·515	1·540
Letters ..	7·850	4·675	4·335	4·280	4·410	4·285	4·695	4·685	4·707

TABLE II

SPEEDS OF READING AND TIME FOR READING

Passages	*No. of words*	*Mean time in sec.*	*Mean speed of reading*		
			sec./word	*sec./syll.*	*millisec./letter-space*
Zero ..	200	140·38	0·702	0·268	80·22
First ..	200	71·57	0·385	0·240	63·80
Second ..	200	58·07	0·290	0·205	55·20
Third ..	200	53·37	0·267	0·198	51·17
Fourth ..	200	52·53	0·263	0·186	49·23
Fifth ..	200	51·28	0·256	0·179	49·17
Sixth ..	200	54·07	0·270	0·178	48·10
Eighth ..	200	54·44	0·272	0·180	48·48
Text ..	444	115·54	0·260	0·169	46·21

The time for reading the whole passage decreases significantly only to the 3rd order, as in the Sumby and Pollack (1954) experiment. (All stated differences are significant at $p = 0{\cdot}05$ at least.) There is also a significant increase in time between the 5th and 6th order. This latter finding, which is unexpected from a simple informational viewpoint may be partly explained by considering the differences between the passages in the mean word length previously mentioned.

Time per unit is used as a metric since this measure is more normally distributed. For linguistic convenience the term "speed" will be used hereafter instead of its inverse. The mean speed of reading by sec. per syllable increases up to the 5th order, and the speed for the text is greater than that for any of the approximations. The results using sec. per letter-space are substantially the same.

Differences between fast and slow readers. The original hypothesis was that fast readers use context more effectively than slow readers and presumably use more context. Thus we would expect the fast readers to increase their reading speed up to higher orders of approximation than the slow readers. In order to test this prediction the 32 subjects were divided into two groups of 16 according to their mean speed of reading, as measured by sec. per syllable, over all the passages. The mean speeds of the two groups on the different passages are shown in Figure 3.

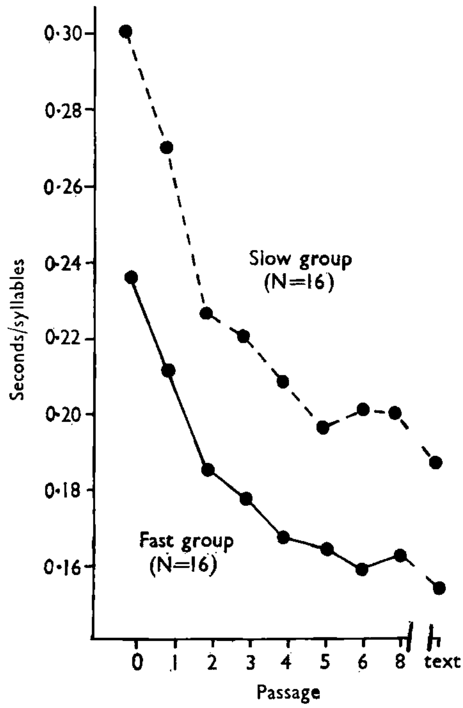


FIGURE 3
Comparison of speeds of fast and slow readers.

In all the graphs the passages are treated as if the successive orders of approximation were equidistant points in a continuum indicated by the abscissae, and the points on the graphs have been joined together. There is no justification for this procedure apart from that of convenience of presentation.

Since the slow group increases its speed only to the 5th order, we would predict a further increase in speed for the fast group between the 5th and 6th orders. A comparison of the mean changes in speed between the 5th and the 6th order approximations for fast and slow readers showed that the two groups differ; the fast readers increasing their speed significantly ($p < 0{\cdot}025$, Wilcoxon Test). There was no difference in speed between the 6th and 8th order passages for either group. Thus the faster readers may be said to be able to utilize the additional constraints found in the sixth order whereas the slow reader is limited in his use of contextual constraint to those found in the fifth order passage. This confirms the secondary hypothesis, and is compatible with the original hypothesis.

Individual differences. There was a wide range of reading speeds among the group. Thus, the times for reading the O-order passage ranged from 103 to 182 sec., and for the 8th order passage from 40 to 71 sec. Product-moment correlations for reading times were calculated between all pairs of passages and between all the passages and the mean time per subject. All the correlations were significant beyond the $p = 0{\cdot}001$ level, half of them being greater than $r = 0{\cdot}87$, and the lowest correlation, $r = 0{\cdot}727$, being between the times for the zero order passage and the text. The size of even this correlation might in part be due to differences in motivation or interpretation of instructions, but probably also indicates the presence of general oral reading skills which apply both to disconnected, often unfamiliar polysyllabic words and to connected prose. Since Morton (1959) found a relationship between amount of leisure reading and reading efficiency (defined as the product of (silent) reading speed and comprehension) a likely explanation is that people who read more, both develop more efficient ways of using contextual constraint, and also have more experience of dealing with unfamiliar words. In this way they would be superior on all passages, and, as shown above, would be able to utilize additional contextual constraints.

"Meaning" and the approximations. In the present experiment the performance on the text is significantly better ($p < 0{\cdot}01$) than that on the approximations. This was in spite of the fact that many of the subjects observed punctuation and meaning pauses, which added an average of about 12 sec. to the time of reading or 0·013 sec. per syllable. Miller and Selfridge (1950) however, in an experiment on immediate memory, found no equivalent increase in recall on their prose passages and concluded that "meaning" is not important in recall. This presupposes that there is nothing "meaningful" about the approximation passages. However, several of the present subjects reported that they were assisted in their reading of the fourth or fifth and higher order passages by treating sections of the passage as meaningful units. In addition, in the Miller and Selfridge experiment, the words were read out "slowly and distinctly in a near monotone with a short pause between words" (pp. 180–1). It seems probably that additional meaningfulness of the text would be obscured by such a procedure. Under different conditions of presentation it might well be found that "meaning" aids recall as well as assisting in reading. It might also be noted that if the Miller and Selfridge results are recalculated on the basis of a syllable unit (using estimates from the passages they quote on pp. 184–5 and the graph on p. 181) the amount of textual material recalled rises above that for the approximations.

2. *Errors*

The mean number of errors decreased to the 5th order. Assuming that errors are caused by excessive speed of reading, the differences in speed up to that point may be less than they would have been with error-free performance. There was no relationship between a subject's mean speed of reading and the number of uncorrected errors.

It might be noted that many errors were made and corrected, and no allowance was made for this waste of time in calculating the speed of reading. The effect of error-correction was to introduce a random element into the individual speeds, but it was assumed that this would average out for the group results. The total number of corrected errors was about the same for all passages.

The nature of the corrected and uncorrected errors is discussed elsewhere (Morton, 1961, 1964*b*).

3. *Eye-voice span*

The eye-voice span is a measure of the amount of material or time by which the voice lags behind the eyes in oral reading. Fairbanks (1937) has shown how the size of the material-span varies during reading. His results show that the span falls during regressions and refixations (i.e. a regression immediately following the first fixation on a line) and at the end of a sentence. Any pause in the speech which is unaccompanied by a regression resulted in the span lengthening, but at times, when a regression accompanied the correction of an error, the span would fall to nothing.

In order to measure the span, it is necessary to know precisely the fixation point of the eyes. In the present experiment, the position of the eyes could be told for certain only at the end of a line. On the record, the span on any line is the distance between the point where the eye begins the return sweep to the beginning of the next line and the point when the last word on the line had been spoken. This is illustrated on the sample records shown in Figure 2. The span was measured in two ways:

(*a*) *Material* (words, syllables, letter-spaces). These represent the amount of material which is no longer seen but has not yet been spoken at the instant the eye starts the return sweep.

(*b*) *Time*. This is the interval between the instant when the last word in the line was no longer being fixated and the instant it had been spoken.

As has been noted, a pause in the speech or a corrected error can alter the span considerably, and the relative effects of these upon time span and material span varied with the circumstances. Where such phenomena occurred within the measured span, that line was rejected if the pause was greater than 600 millisec., or if the error caused a regression back from the beginning of the next line. The levels of the material and time spans on the text would be reduced, relative to the other passages, by the tendency to observe meaning and punctuation pauses, and are so not strictly comparable.

Results (see Table III).

TABLE III

MEAN MEASURES OF EYE-VOICE SPAN

Passage	Time span in millisec.	Material span		
		In words	In syllables	In letter-spaces
Zero	621	1·17	2·70	9·06
First ..	617	1·99	2·71	10·71
Second ..	618	1·99	3·34	11·25
Third ..	616	2·58	3·56	12·54
Fourth ..	636	2·93	3·30	13·04
Fifth	615	3·00	3·93	13·88
Sixth ..	673	2·61	4·23	13·86
Eighth ..	708	2·01	4·99	15·46
Text	641	2·78	4·14	15·27

The results, shown in this table and Figures 5–6, represent the means of measurements taken on the last five lines of legible record on each passage for each of 29 subjects. (Three of the speech records were undecipherable.)

(*a*) *Material span*. The mean number of words in the span increases to the 5th order and then falls. The drop appears to be related to differences in word length. When measured by syllables or letter-spaces, the material in the span increases, with some irregularities, up to the 8th order. This is true for both fast and slow readers (Fig. 4). Fast readers have the larger span, but the difference is not significant until the 6th order passage, by either syllables or letter-spaces. Thus the fast group appear to use that additional constraint between 5th and 6th order, not available to the slow group, which was deduced from their reading speeds.

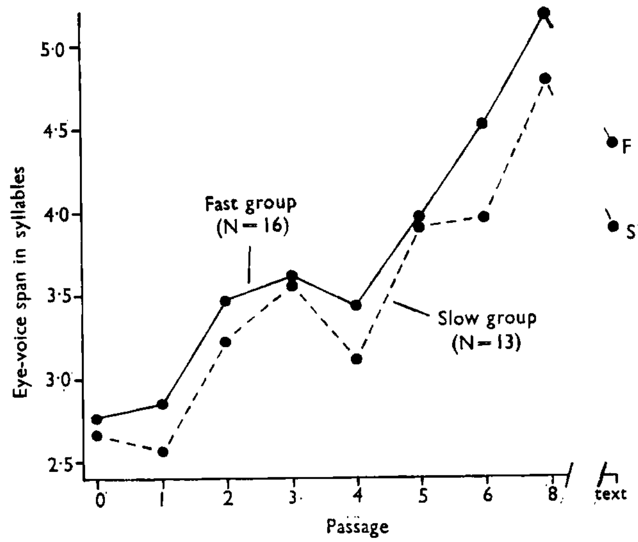


FIGURE 4
Eye-voice span in syllables for fast and slow readers.

(*b*) *Time span.* The time span remains approximately constant up to the 5th order and then increases to the 8th order. For all approximations the slow group has a larger mean time span (Fig. 5), but the difference is only significant for the 8th order ($p < 0{\cdot}05$, two-tailed: Mann-Whitney test). The average speed and the average time span for the approximations are related with $\tau = -0{\cdot}249$ ($p = 0{\cdot}026$).

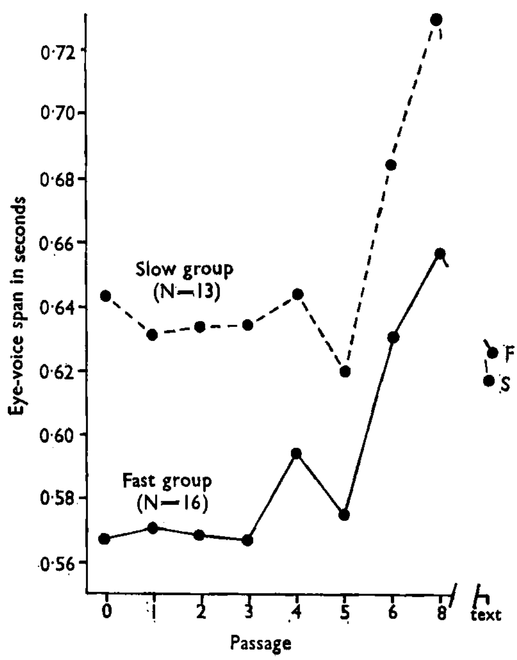


FIGURE 5
Eye-voice span in millisec. for fast and slow readers.

Fairbanks (1937) and Buswell (1920) also found that good readers had a higher material span than poor readers. However, in addition they reported a higher time span for good readers, a result not replicated in the present study. This might be due to differences in reading speeds between the studies.

Dependence of time span upon material span and speed. The two measures of material and time span are often treated as if they were in some way equivalent and independent of any other variable. Thus Fairbanks (1937) in referring to the concept of span remarks: "It is felt that 'lead' is more descriptive of the kind of eye-voice relation as it usually obtains," implying that 'lead' had the same significance in any unit; and Woodworth and Schlosberg (1954) say: "With experienced readers the span is as long as eight words, 2 seconds or a line of print, depending on which unit of measurement one prefers to consider" (p. 507).

However, it is clear that the rate of reading equals the material span divided by the time span (which we will write as $R = M/T$). At any speed of reading, either of the two measures can, theoretically, take any value, and the value of the other measure is then determined. With increasing constraint up to the 5th order, M rises roughly proportional to R while T remains roughly constant. It seems likely then that T is a variable dependent upon the values of R and M.

Tendency to speed up at end of lines. The equation $R = M/T$ can be used to estimate the speed of reading at the ends of the lines (where the span was measured). This speed measure was compared with the measured speed (S) for the passage. Apart from the 4th order, R is greater than S for both fast and slow readers. In general then, the reading speed is faster than average at the ends of lines. From Fairbank's (1937) result, that the material span at the ends of lines is approximately equal to the average for the passage, then the present measures of time span must be underestimates of the average value.

4. *Eye-movements*

Two eye-movement measures were taken on each of six lines for each passage, i.e. about half the record:

(*a*) *The mean duration of fixation.* For each line this was taken as the time between the beginning of the first fixation and the end of the last fixation on that line divided by the total number of fixations for that line. The measure included the time taken by the actual moves from one fixation point to the next, and accordingly all the times quoted are about 15 millisec. (Tinker, 1947) in excess of the true duration for a fixation.

(*b*) *The mean number of forward saccadic movements and regressive movements per line.* Sample records are presented in Figure 2.

The results are the average scores for the 18 subjects whose records could be interpreted with confidence. No more than six lines could be taken without reducing the number of subjects whose records could be included.

It should be noted that there is a variation in the eye movements from line to line in any one passage. For example, more regressive movements occur in those lines where reading errors are made and corrected. In addition the length of the saccadic movements and the duration of individual fixations have a wide range. The duration of individual fixations ranges from 180 to 350 millisec. on most passages for most subjects.

Results

(*a*) *Duration of fixation* (fixation time). The mean fixation times for the different passages are given in Table IV. Each figure is the mean of from 80 to 120 fixations averaged over nine subjects for each of the sub-groups. The longer mean fixation time on the Zero order passage could be due to the fact that some eye movements on that passage were too small to be recorded; these might have occurred when a particularly unusual word was being carefully examined. Apart from this there appears to be no difference in fixation time among the various passages.

TABLE IV

MEAN DURATION OF FIXATION. FAST VS. SLOW READERS (measures in millisec.)

Passage	*Fast group* ($n = 9$)	*Slow group* ($n = 9$)	*Difference*
Zero	260	252	8
First	244	241	3
Second	238	243	−5
Third	238	247	−9
Fourth	234	242	−8
Fifth	235	236	−1
Sixth	243	235	8
Eighth	243	243	0
Text	245	238	7

An analysis of variance, from which the Zero order results were omitted, was carried out on the individual's scores, and is summarized in Table V. There are relatively large inter-subject differences and negligible intra-subject variations between passages. The "Group" source concerns the division between fast and slow readers referred to below. The individual mean fixation times ranged from 219 to 281 millisec.

TABLE V

ANALYSIS OF VARIANCE OF THE FIXATION TIMES

Source	*D.F.*	*S.S.*	*M.S.*	*F*
Between groups (G) ..	1	14·40	14·40	< 1
Between subjects ..	16	32333·60	2020·80	15·432 ($p < 0·01$)
Between passages (P) ..	7	891·22	127·32	< 1
P × G	7	1290·60	184·37	1·408
Residue	112	14666·70	130·95	
Total	143	49196·52		

The stability of the average fixation time has been noted previously by Buswell (1922), Robinson (1933) and Stone (1941) who measured eye-movements of subjects reading passages of varying difficulty. Whereas there were differences between the passages in the number of fixations, the duration remained constant. Tinker (1951) however, did find differences in mean fixation time between easy prose (220 millisec.) and scientific material (236 millisec.). Such a difference would be found if the eye made a number of undetectibly small fixations on unusual words, thus biasing the mean, as seemed to happen on the Zero order passage in the present experiment. Tinker gives no information which might help to settle that point.

The problem arises as to what determines the duration of a fixation. Tinker (1958) considers perception time, thinking time and reaction time to "eccentric stimulation" (p. 218) as being included in the total fixation time. However he regards 100 millisec. (an adequate tachistoscopic exposure "for a well cleared up perception"; p. 218) as suitable for the perception time, and quotes several figures for reaction time, centering on about 170 millisec. (the same order of magnitude found by the writer in his own rather crude check). The average fixation time in the present study is less than 250 millisec. for oral reading, and individual fixations, especially in silent reading, were as brief as 170 millisec. Thus the notion that eye-movements are triggered after analysis of the immediate stimulus is clearly inadequate as a general rule, since there is no time, or less than no time, available for either the initial clearing-up process, or the comprehension time. It often happens that an individual word will be fixated for an extended period, when the sequence described may take place, but in rapid reading some other mechanism clearly operates.

Carmichael (1957) goes even further than Tinker, and says: "... the measurement of fixation times after regressive movements must be related to complex brain activity and ... it is associated with an identifiable *segment or unit of thought.* This technique demonstrates that this total *complex cognitive time* may be as short as one fifth of a second or less" (p. 7: present writer's italics). Carmichael seems to be making the mistake of supposing that all the comprehension processes relevant to an immediate stimulus must be completed before the eye can move on. There seems however to be no *a priori* reason to suppose that the visual and comprehension analyses (wherever and however they take place) could not function simultaneously on different material. Indeed the very existence of regressive movements indicates that the eyes move on before the material fixated has been adequately processed.

It seems then that the signal for the eyes to move can be given before the immediate stimulus has been analysed, and since the mean duration of regressions is the same as that of forward fixations, one need construct no special theories nor make special deductions regarding them.

(*b*) *Number of fixations and regressions.* The mean number of forward and regressive eye movements per line, and also the difference between these two measures, are given in Table VI. The total number of fixations decreased to the 5th order. This is a necessary concomitant of the invariance of the mean fixation time and the increase in speed to the fifth order. Of more interest is the small change in the difference measures. Up to two-thirds of the difference in the total number of forward movements could be contributed by the necessity of returning the eyes to the pre-regression fixation point and hence they are a direct result of the regression.

TABLE VI

MEAN NUMBER OF EYE MOVEMENTS PER LINE

Passage	*Forward movements (F)**	*Regressive movements (M)***	*Difference (F–M)****
Zero	16·31	6·04	10·27
First	14·58	4·58	10·00
Second	13·36	3·74	9·62
Third	12·22	3·36	8·86
Fourth	12·39	2·99	9·40
Fifth	10·77	2·88	7·89
Sixth	10·84	3·09	7·75
Eighth	11·38	2·89	8·49
Text	11·26	2·99	8·27

These differences are significant with a t-test $p < 0.025$ on the Wilcoxon test.

* 0 > 1 > 2 > 3, 4 > 5, 6, 8, text

** 0 > 1 > 2 > 3 > 4, 5, 8
2 > 6

*** 0, 1, 2, 4 > 5, 6, 8, text
1 > 3 > 5, 6
8 > 6

In some cases the post-regression movement takes the eye beyond the pre-regression fixation point, but not always. It was not possible to obtain precise data from the present records.

Cherry (1957) discusses the possibility of applying the concept of "feed-back" to the reading situation, and wonders whether "the point to which the vision is shifted, in any one saccade, may be the result of a prediction based on previous perception" (p. 286). The implication is that more difficult passages would require shorter movements, and to some extent his idea is confirmed. However, the increase in the number of those regressive movements unconnected with errors as the order of approximation decreases indicates that the regulation of the saccade size is inadequate to compensate completely for the differences in difficulty of the passages.

In summary, it can be said that the mean duration of fixation in an oral reading task is independent of the redundancy of the passage and that the main effect upon eye movements is that there are more regressions in the less constrained passages, with the addition of a slightly smaller mean size of saccade.

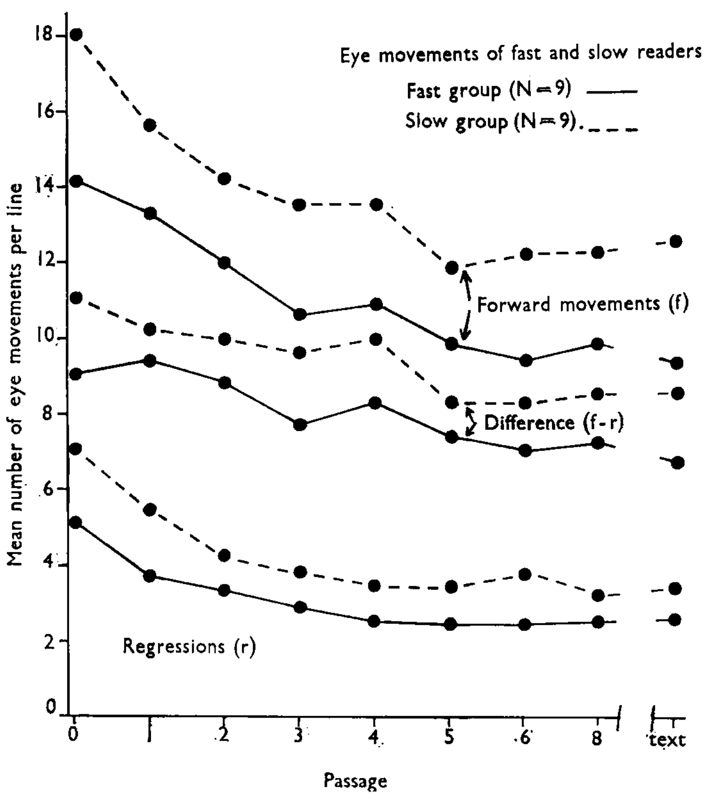


FIGURE 6
Eye movements for fast and slow readers.

The results are in agreement with those of Anderson and Swanson (1937), in as much as the superiority of the good readers in oral reading takes the form of fewer eye movements.

(*c*) *The correction of errors.* The eye-movement and speech records were examined to see if there was any relationship between the correction of an error and regressive movements. A corrected error, in this context, includes a word partially spoken correctly, and then repeated. Inadequacy of the records prevented examination of more than 33 corrections, a quarter of the total, but the results seem sufficient for certain general conclusions to be drawn.

(1) Only 23 of the 33 examples studied were accompanied by regressions. There was, furthermore, no relationship between the category (Omission, Substitution, Transposition, etc.) of an error and whether it had been accompanied by a regression or not.

(2) When a regression did occur, it occurred anywhere from 600 millisec. before the voice had paused after an error, to 600 millisec. after the pause. In other words, sometimes the regression enables the error to be noted, and sometimes a regression would be made because the error had been made and noted, perhaps via auditory feed-back.

(3) The correct word was spoken from between 250 and 600 millisec. after the start of the regression fixation.

Conclusions

The amount of contextual constraint in a passage affects directly the speed of reading, the amount of material in the eye-voice span and the mean number of fixations and regressions per line. Comparisons of changes in reading speed and the size of the span show that fast readers can utilize more contextual constraint than slow readers. The eye-voice span measured in time units can be shown to be dependent upon the material in the span and the speed of reading. The mean duration of fixation remains unchanged on different passages.

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