Eye movements of children during reading

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EYE MOVEMENTS OF CHILDREN DURING READING

Abstract

The present study was designed to produce a table of norms of fixations, regressions and rates of reading, expressed as lengths of film in inches. While other eye-movements measures, such as span of recognition, are included in various studies, these are not given in the present investigation. The reason for this is that such measures are calculated from the measures used here, and secondly the use of these other measures make assumptions regarding their authenticity which are not always verified by investigations. Fixations, regressions and reading time are fully objective and require no hypothesis of central thought processes to explain their supposed function.

The instrument used was the Ophthalmograph manufactured by the American Optical Co. The eye-movements are recorded by the corneal reflex method on a moving strip of film which moves through the camera at a constant speed of .327 inches per second. The reading cards were 5 in. x 3 in., the largest size of card usable with this apparatus.

The text of the Test Card is an adaptation from "Claudius the Bee" by J. F. Leeming.

Three hundred children attending schools in Durham County were tested, there being fifty children in each of the age groups from eight to thirteen years inclusive. Every child tested was required to read the Burt Graded Vocabulary Scale to their chronological age level before being accepted for testing.

The means of the eye-movement measures for each age group are shown in the tables together with the highest and lowest score in each year group, and also the range. All measures are for twelve lines of reading. The graphs show the averages for each eye-measure for all the age groups.

The measures obtained are also calculated to produce norms of eye movements, according to reading age, and also according to reading age within each chronological age group.

An evaluation is made of the eye-movement camera as a clinical tool and future lines of research suggested.

"EYE MOVEMENTS OF CHILDREN DURING READING".

by

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CHAPTER 1.

OUTLINE OF THE RESEARCH.

There has been a large body of opinion in America, much of it centred in reading clinics attached to Education departments and University research departments, which has refused to accept the opinion that eye movements are merely indications of reading maturity. They have acted upon the assumption that students will not necessarily develop eye-movement techniques of the maximum efficiency allowed by their level of reading maturity unless they are given training directed to such improvement. The body of results showing the greater efficiency attained by students given eye-movement training is becoming too large to be ignored. The evidence available has encouraged at least one business organisation in this country, namely The Imperial Chemical Industry, to organise reading clinics for its executives in order to increase their reading efficiency. Here again the results have been most encouraging to those who are proponents of eye-training techniques. In view of these developments it would appear that the time is ripe for a new evaluation, to be undertaken in this country, of eye-movement training techniques and the use of the eye-movement camera as a clinical tool. The present study is presented as an initial step toward this new evaluation.

As there exists no table of norms of eye movements for children or adults in Britain it is proposed to produce a text, suitable to be read by children from the ages of eight to thirteen, for use with the eye-movement camera. It is then proposed to produce a table of norms for fixations, regressions and reading time as measured by length of film in inches for 50 children in each age group. As a subsidiary aim it is hoped to analyse the results obtained to ascertain whether any conclusion can be reached regarding the factors which cause variation in eye-movement measures.

It was decided that it was necessary for each age group to read the same text in order to avoid variation in eye movements due to differing text, print size and typographical factors. In order to maximise the reliability of the eye-movement measures the passage read was made of maximum length, i.e. 14 lines, this being the largest amount capable of being read with the eye-movement camera used in this study. In obtaining the norms it was only possible to score the record from twelve lines, it being necessary to omit the record obtained from the first and last lines as these have been shown by many authorities to be atypical of the normal reading pattern. Each child read a practice passage in order to ensure adaptation to the eye-photography procedure. Only the records of children giving satisfactory comprehension were included in the table of norms.

It was found that few children over the age of eight were unable to adapt quickly to eye-movement photography conditions and few records were spoiled due to nervousness.

A considerable number of records were spoiled, especially in the younger age groups, by the children's inability to read without head movements. This resulted in the corneal reflection not reaching the film strip and thus producing an incomplete record. It was not possible to include such children in the results since having read part of the passage before head movement, any subsequent record would not be typical of those eye movements made when reading a new passage. It would appear that these factors which limit the representative nature of the sample used in producing these norms are inseparable from eye-movement photography techniques. The measures obtained indicate that the anticipated decrease in the number of fixations, regressions and reading time, here expressed as length of film, does occur with the increasing maturity and reading ability of the reader. There is a cessation of improvement in respect of fixations and regressions in the twelfth year. Whether this is a temporary plateau or represents a normal adult level of reading attainment will require further investigation. In the present study the speed of reading has not ceased to improve in the thirteenth year. The most striking feature of the results is the wide degree of variation, in all the measures used, between individuals of similar age and equated reading ability. This points to the existence of a widely differing personal factor in the ability to develop eye movements commensurate with the individuals reading maturity in the absence of techniques designed to improve reading speed and eye movements. Analysis of the results, in which individuals are equated for age and word recognition ability, does not confirm the hypothesis that eye movements are merely symptons of the reading process.

STATEMENT OF THE PROBLEM.

In undertaking any investigations of eye movements of children while reading it is necessary to establish a preliminary table of norms of eye movements, against which the performance of individuals can be assessed, to determine their relative efficiency in this aspect of the reading process. It was not possible in the present study to follow the normal procedure of testing a representative sample of children of each age group, as certain difficulties peculiar to eye-movement measures had to be surmounted. In the case of cognitive tests, the least able child of any age group can be included by simplifying the test items until some score is obtainable. With eye-movement photography some basal criterion of reading ability must be established independently since the eye movements of non or marginal readers are so numerous and various as to be unscoreable. In the present investigation this basal level was taken as the reading age to the nearest year, as measured by the Burt Graded Vocabulary Test, which corresponded with the chronological age of the child tested. Thus a child of eight years had to read to an eight year minimum standard of reading before being accepted for testing.

A further departure from customary procedure was the raising of this basal level for each year group. Thus the basal level of the eight year group was a reading age of eight years but the basal level of the ten year group was a reading age of ten years. This step was taken for the following reasons. It has already been established by Judd and Buswell (27) that the complexity of the material read will influence the degree of disorganisation of the regular eye-movement habits, and introduce random eye movements.

It is obvious that one feature of complexity of a passage for a reader will be the difficulty he has in recognising the words of that passage. To include a ten year old child who is reading to a seven year level in the ten year norms will certainly increase the scatter of the eye-movement measures within that group, but will not increase the efficiency of the norms. These norms are not therefore representative of the children of any particular age group in the population but they are typical of the eye movements of children of that chronological age who can also read to an equivalent standard on the Burt test.

In the present investigation an attempt is made to restrict the variation in each age group in one direction by eliminating from the norms all those individuals who cannot attain a defined basal level of word recognition. Whilst this is not the only method of producing such a table of norms, it is claimed that this is a valid method of comparing the reading performance of children. It is especially suitable for future investigations of the problem of why such large variations in eye-movement measures are found amongst children who are capable of meeting this basic criterion. The representative nature of the sample of children who contributed to the norms established in this investigation is further restricted by the necessity of ensuring that every child had adequately comprehended the passage he had read before the camera. This precaution was necessary in order to ensure that the norms obtained were not falsely decreased by children who had the facility of skimming a passage with apparently perfect eye movements but who, as a result of such skimming, had insufficient comprehension of the material they had read. Whilst it may be felt that these restrictions upon the representative nature of the sample contributing to the norms established limit their usefulness it should be pointed out that, in fact, the norms obtained are adequate for the purpose envisaged. This is because they are representative of the eye-movement measures made by children with the aforementioned characteristics and they can only properly be used for comparison purposes with children who must fulfil the same basic requirements as those children who established the norms, if any comparisons made or conclusions drawn are to be valid.

CHAPTER 2.

REVIEW OF THE PERTINENT LITERATURE.

The study of eye movements has long engaged the attention of psychologists, as a means of studying the operation of the physiological mechanism of the eye, and to determine how this mechanism varies to meet changing demands in the reading situation. A comprehensive account of the history of eye-movement research and techniques up to 1936 is to be found in the work of Tinker (54). Carmichael and Dearborn (9) provide an excellent survey of developments from 1917 to the present time. To summarise the methods employed in studying eye movements, an example of each of the various procedures follows.

AFTER-IMAGE.

This method was based on the knowledge that an object fixated for a period left an after image. The subject, on reading immediately after fixation, could trace the after-image at successive fixations along the line of print. Such a method was highly subjective and could not be used with children.

OBSERVATION.

By cutting a small hole in the centre of the page being read by the subject, Miles (33) counted the eye movements and showed that with practice an observer could attain a high degree of efficiency, provided that only one aspect of the observed movements was recorded at a time. Tinker (54) has shown that approximately one fifth of such movements are missed by the observer. The method is however useful for revealing gross abnormalities and is also effective with slow readers with a long duration pause. It can be used by teachers as a method of checking eye movements on a qualitative basis without the employment of expensive equipment. Both of the foregoing methods have the common disadvantages of large errors, subjective judgement and the fact that no record can be obtained to allow for later analysis.

MECHANICAL.

Prior to the use of photography, many ingenious methods were devised of attaching objects to the eye. Some experimenters fixed the apparatus to the reading eye whilst others required the subject to read with one eye only, the measuring apparatus being attached to the closed eyelid of the non-reading eye, the movements being recorded on a kymograph. Such mechanical methods have many disadvantages. The extra work which the eye does in operating such mechanism may well make the records atypical. The reading was generally monocular, the record being taken from the non-reading eye on the assumption that the eyes work in conjunction. Thus the reading situation was itself abnormal and the results were further complicated by visual defects such as muscular imbalance, divergence and convergence errors.

PHOTOGRAPHIC.

Photographic records were obtained by fixing reflectors to the eye, the photographing of white paint spots placed on the eye and later, by the corneal reflex method. This last method, being the one used in this research, will be fully described later. It most nearly meets the requirements laid down by Dodge (15) as necessary to allow for adequate and reliable recording and analysis of eye movements. He says:- (1) "It must operate under conditions of normal binocular vision; (2) Be capable of registering both eyes simultaneously; (3) Be timeable; (4) Registering medium must have neither momentation nor inertia; (5) The eye must perform no extra work or be subjected to unusual conditions; (6) Apparatus must be able to record the movements of large numbers without serious inconvenience, either during, or after the experiments".

ELECTRICAL.

The latest method of recording eye movements has been dependent for its development upon the advances in the field of electronics, making possible the detection and amplification of minute changes in electrical potential. It was first anticipated that such electronic techniques would make possible the measurement of electrical impulses conveyed by the cranial nerves to the eye muscles but this has not, to the present, been developed to such a degree as to make recording by this technique a practical possibility. Electrical recording has been developed and used extensively by Carmichael and Dearborn (9). This latter technique utilises the fact that the electrical potential of the eyeball varies from front to rear; being positive in the front and negative in the rear. By placing one electrode on the skin of the face at the external canthus of each eye, one attached to the bony ridge above the right eyebrow and another on the ridge beneath the right eye, it is possible to pick up changes in potential as the eyeball swivels in its socket and these differing potentials can then be amplified and recorded.

The superiority of this method over that of photographic recording is that it allows the subject freedom of movement.

Provided sufficiently long leads are attached to the electrodes, the subject can change his position and sit naturally without interfering in any way with the record. Also the subject quickly becomes adapted to the placing of the electrodes and ceases to be aware of them so that the reading situation more nearly approaches normal. These advantages are the more essential as the reading period increases in length, for the photographic method requiring absolute stillness on the part of the subject is not one which can be used for long periods. For these reasons Carmichael and Dearborn (9) in their study of visual fatigue which required six hours continuous reading, found the electrical method essential. For the purposes of the present research it would not appear that the corneal reflex method using photography, has any disadvantages which render its use inadvisable.

CORNEAL REFLEX METHOD.

In the corneal reflex method of photographing eye movements, a beam of light is directed into each eye. The reflections of this light are focussed by adjustable lens holders on to the moving film. Due to the fact that the eye is not a perfect sphere any movement of the eye is accompanied by a shift of the reflected beam in the same direction as the eye movement. This lack of symetry of the cornea of the eye which makes possible the corneal reflexion method also raises problems as to the extent to which such records accurately portray the eye movements. Dodge (15) states "Somewhat unfortunately for the purposes of photographic registration the radius of the curvature of the cornea increases slightly from its apex to its periphery". It follows:-

1. That no use of the corneal reflection is permissable which involves the use of the extreme peripheral and irregular portions of the cornea.

2. That all records produced by eccentric portions of the cornea will be forshortened in direct proportion as the virtual image seems to approach the edge of the cornea.

Karslake (28) finds that undistorted reflection occurs only from the centre third of the cornea, so that the angular field of view through which eye movement is possible for photographic purposes may be no more than 15 to 20 degrees. These limitations, are not such as to affect the measures usually extracted from a reading graph, namely number of fixations, regressions, and pause duration, nor will they significantly affect eye-movement records made by a 100 mm line at 13" to 14" distance, subtending an angle of 18° (approx.) at the eye. Such limitations do, however, point to the danger of diagnosing eye abnormalities, such as muscular imbalance, over convergence and divergence from these records, except on a very provisional basis. This is especially so since a difference of curvature of the cornea may exist between the two eyes. The Bureau of Visual Science (7) discussing the Ophthalmograph, state that "In general, it may be said that the amplitude of the corneal reflection is approximately half that of the actual displacement of the cornea and is always in the same direction".

A further fact which might be expected to affect the accuracy of the shift of the reflected beam, is that the centre of axis of rotation of the eye is not a single hypothetical point within the eyeball. Instead it tends to shift slightly and to vary with the degree of movement. Barnes (1) shows that this shift of centre of axis of rotation is related to the tortion phenomena whereby the eye moves not only in a horizontal or vertical direction but also rotates slightly about its sagittal axis, in addition to the general movement or shift in the line of fixation. The result of this as observed by Smith (46) is that divergent movements of the eyes are accompanied by an upward movement. As will be shown later when discussing the eye movements of reading, such divergent movements can quite frequently occur due to the muscleature of the eye. If this movement was a significant amount it could adversely affect the photographic records. Concerning this torsion phenomena Carmichael and Dearborn (9) consider that for the very small degrees of excursions required for reading movements the effect is negligible as far as the interpretation of records is concerned.

READING SITUATION DURING PHOTOGRAPHY.

Whilst the record of eye movements is being photographed it is necessary to keep to an absolute minimum the number and extent of head movements which occur constantly during normal reading without appearing to impair the reading efficiency. Such head movements during photography superimpose upon the record movements which require careful and lengthy analysis in order to distinguish them from the interfixation movements or the corrective movements of the eyes, taken to overcome faulty first fixations. There is also the further risk that the reflected beam will fail to remain in focus and will thus result in a spoiled record due to even slight involuntary movement. For this reason all photographic studies have included some method of keeping the head still by means of teeth pads, rests, brow pads and adjustable fittings all of which differentiate reading before the camera from the normal reading situation. Karslake (28) considers this to be a disadvantage inherent in the corneal reflex method. In addition, he finds the reader is distracted by the presence of the lights lying within the peripheral field of vision which are necessary to obtain the corneal reflex. He questions whether under such conditions the general awkwardness of the situation, and the difficulties involved in being properly placed in preparation for the photography the record obtained can be considered a record of typical reading. This is an important question, for whilst it is true that eye photography would still have many uses even if it did differ significantly from the normal reading situation, its use as an interpretive and diagnostic tool will be greatly increased if it can be shown to duplicate, within reasonable limits, normal reading habits. Part of the answer to this problem lies within the findings regarding the reliability and validity of the reading graph which will be dealt with later. Gilbert and Gilbert (21) have also reported an investigation bearing directly upon this question. They tested 47 children of age range 11 to 15 years who read material, firstly at a table and then under corneal reflex photography conditions. Using the criteria of reading time and comprehension score they found that the measures did not differ significantly in the two situations. When questioned there were almost as many subjectswho stated that they preferred to read at the camera as there were subjects who preferred to read at the table. Buswell, (8) who has used the apparatus extensively, remarks "Judging from the behaviour of the children, they did read in a normal manner and showed no confusion due to the apparatus". Contrary to expectations he found the first grade pupils, 6 year olds, almost as easy to photograph as the older pupils.

Schmidt (42) has also shown that children adapt so quickly to the experimental situation that the first reading graph obtained by the corneal reflex method may be accepted as a fairly reliable index of an individuals average accomplishment. In comparing the average number of fixations, average duration pause, average fixation time per line and average number of regressions made on the first reading, with the averages obtained from three, four and six readings, no significant differences in these measures were found. A study of the validity of eye-movement measures by investigating adaptation to the artificial laboratory situation is reported by Tinker (53). This study is particularly valuable because standardised material was used and the comparison was made strictly on the basis of the scoring procedure adopted when the test was used under ordinary reading conditions. Fifty-seven freshmen were tested on the Chapman-Cook Speed of Reading Test Form A whilst sitting at a table, the normal testing procedure. Each subject was then seated before the camera, the normal adjustments for focussing and keeping the head stationary were made and the procedure explained to the subject. The motor was then switched on and under normal operating conditions and believing that a record of their eye movements was being made, the subjects read the Chapman-Cook Speed of Reading Test Form B, an equivalent form of the test. In fact, during the latter test there was no film in the camera and each test was scored for one and three quarter minutes reading time. The average score for the group whilst reading at the table was 16.08, the average score for reading before the camera was 16.13. Tinker states "The average scores show that the subjects read as well before the camera as when reading normally". The group as a whole gave an entirely typical performance in the photographic situation. Thus all the investigators agree that adaptation to the experimental situation is made rapidly and easily by the majority of subjects.

It is however essential to differentiate between what is true for a group and what may apply only to individuals within the group. When discussing the reliability co-efficients Tinker (53) remarks "Evidently most readers, after the experimenter has given an explanation of how the apparatus works, settle quickly into consistent and typical reading. Observation revealed certain subjects who were disturbed, by the light shining in their eyes and by rigid confinement in the head rest. They need practice as well as explanation to bring adequate adaptation. It is probably best to give all subjects a practice trial to promote adaptation to the set up". The correctness of this advice is confirmed by a study of the reliability co-efficients obtained in his investigation. It can be seen that the paragraph preceded by the most practice, tends to be slightly more typical of performance in general. Thus, the reliability co-efficient for fixation frequency, of paragraphs of easy prose read at the same sitting is:-

Practice para. of 8 lines read with no practice correlated with Paras. A.B.C. of 23 lines - .85

Para. A of 5 lines read after 8 practice lines correlated with Paras. A.B.C. of 23 lines - .85 - .87.

Para. B of 10 lines read after 13 practice lines correlated with Paras. A.B.C. of 23 lines - .91

Para. C. of 8 lines read after 23 practice lines correlated with Paras. A.B.C. of 23 lines - .93

It will be seen that the evidence, as taken from group averages of performance, indicates that adaptation is rapid in the majority of cases. Both observation and the study of increase of reliability after practice, indicate that adaptation is by no means complete at the first experience of the photographic apparatus. We may conclude that records for the establishment of norms of performance and individual records for diagnostic use will be improved if the subject is given reasonable practice at the camera, as well as explanation before being photographed. A study of the correlations given on page 19 will show that for perception time and fixation frequency, the most valid of the eye movement measures, a reliability of over .9 is obtained when reading a paragraph of 10 lines length after having read 13 practice lines. A practice text of 15 lines should therefore be more than adequate to ensure that adaptation to the experimental situation has taken place before photography commences.

RELIABILITY OF EYE-MOVEMENT MEASURES.

The measures which are available from eye-movement records are fixation frequency, duration of fixation, perception time, and regression frequency. The significance of these scores will be discussed later. Any survey of the photographic technique must consider the data available concerning the reliability and the validity of these commonly used scores, and this is the purpose of the present chapter. All studies agree that the reliability of the scores obtained from eye-movement records is high. The first studies in this field calculated reliability by the split-half or by the odd-even method. Typical of such investigations is that of Eurich (18). He reports reliabilities obtained from the reading of three paragraphs by one hundred school children. He first calculated the reliabilities between paragraphs 1 and 2, paragraphs 1 and 3 and paragraphs 2 and 3. The results were :-

FIXATIONS range from .70 for first two paras. to .87 for last two paras.

REGRESSIONS range from .68 for first two paras. to .87 for last two paras.

DURATION OF FIXATION range from .69 for first two paras. to .86 for last two paras.

Using all three paragraphs by the split-half method the results were :-

FIXATIONS .91 REGRESSIONS .91 DURATION OF FIXATION .86

Litterer (31) reports a study of reliability co-efficients obtained by the split-half method on easy prose for fixation and perception times. His correlations were :-

FIXATION FREQUENCY .92

PERCEPTION TIME .91

Tinker (53) investigated the reliability co-efficient by the test-retest method. This method of assessing reliability raises methodological problems which do not arise in the studies previously mentioned. As will be explained more fully later, eye movements tend to alter according to the difficulty of the material read, the interest of the textual matter, and also the varying typographical factors of the print. For this reason any test-retest method of calculating reliability must ensure that these factors are kept constant. This requirement has been met by Tinker (53) who tested college students reading equated paragraphs at the same sitting and at a second sitting The complete table of correlations obtained is given below. It will be observed that the results show an increase in reliability after practice, a tendency also revealed by the study reported by Eurich. Summarising the results obtained by Tinker we observe that the end of session reliabilities are:-

FIXATIONS	para	C	(8 lines)	with	paras	A-C	(23 lines)	at same sitting is .93
	"	C	"	"	"	D-F	"	at second sitting is .81
PERCEPTION TIME	"	C	"	"	"	A-C	"	at same sitting is .92
	"	C	"	"	"	D-F	"	at second sitting is .77
REGRESSIONS	"	C	"	"	"	A-C	"	at same sitting is .84
	"	C	"	"	"	D-F	"	at second sitting is .76
DURATION OF FIXATION	"	C	"	"	"	A-C	"	at same sitting is .94
	"	C	"	"	"	D-F	"	at second sitting is .78

For convenience of reference the results of Litterer, Eurich and Tinker are tabulated below.

Reliability Co-efficients for Eye-Movement Measures.

STUDY	FIXATIONS	REGRESSIONS	TIME	FIXATION/DURATION
Litterer	.92	--	.91	--
Eurich	.91	.91	--	.86
Tinker	.88	.80	.82	.82

The findings of Tinker are lower than the reliability co-efficients obtained by other investigators. A study of the full table of correlations given by Tinker reveals that the reliabilities obtained at the same sitting are higher than those obtained at the second sitting, and that the first sitting correlations are more nearly similar to those obtained by the other investigators. Part of this difference may be attributed to errors in equivalence of the two texts used in the test-retest method. It would appear however that the reliability co-efficients obtained by Tinker are the minimum standards, and as such they confirm the conclusion of all investigators that eye movements have satisfactory reliability as measures of reading performance. This is true of even very small samples (5 lines) where group comparisons are made. Tinker considers that where individual diagnosis is needed it is necessary for the subject to read more material. He suggests that selections should be at least 15 lines in length to be adequate for purposes of individual diagnosis.

VALIDITY OF EYE-MOVEMENT MEASURES.

The research findings concerning the validity of eye-movement measures are much less unanimous than it is regarding reliability. Litterer (31) correlated the measures obtained from eye-movement photography with achievement scores on standardised reading tests and obtained validities ranging from - .27 to - .51. The negative correlations indicate that the reading score on standardised tests increased as fixation frequency, regression frequency, and perception time decreased. Eurich (19) found validity co-efficients for adults ranging from -.02 to -.24, and for children from -.11 to -.55 when validating eye-movement measure against the scores obtained on speed of reading and comprehension tests. He concluded from his investigations that "While the validity of photographic eye movements for Elementary School pupils, as determined by various reading and intelligence tests, is somewhat higher than for College students, it is not sufficiently so as a measure of rate or comprehension in reading, to be regarded as highly satisfactory for diagnostic purposes". It would be a mistake to infer that such low validity co-efficients make eye-movement measures a poor diagnostic tool. As has been mentioned previously, eye movements which are reflections of reading procedure, tend to vary according to the peculiarities of textual matter, interest factors, and typographical considerations. Any investigation into validity which does not equate the test material with the material used as a validity criterion is introducing into the investigation a factor which will tend to lower the validities under consideration.

Before being able to judge the significance of the validities so far mentioned, it will be pertinent to ask what validity co-efficients are found between two normal standardised reading tests. Tinker (52) has investigated this problem and his findings are revealing. He states "When the scores on one reading test are correlated with scores on another reading test, composed of material which is not strictly comparable to that in the first, irrespective of whether speed is correlated with speed, comprehension with comprehension, or comprehension with speed, the highest correlation to be expected is approximately .60 but it may be considerably lower. Co-efficients between .25 and .45 are quite representative of these correlations. Therefore, when eye-movement records are correlated with scores on standardised tests (of different textual material) a co-efficient of .25 to .4 should indicate fairly high validity, and a co-efficient of .45 to .55 excellent validity. Tinker (53 investigated the validity of eye-movement measures by computing validity co-efficients:-

(a) With scores on standardised reading tests as criteria, and

(b) With performance on strictly comparable material as criteria.

The co-efficients from (a) were:-

Perception time and speed test, or vocabulary test, or comprehension.	Range from -.23 to -.64 for easy prose. Median co-efficient -.44
Fixation Frequency and other tests	Range from -.22 to -.61 for easy prose. Median co-efficient -.43
Regression Frequency and other tests.	Range from -.06 to -.39 for easy prose. Median co-efficient -.28
Duration of Fixation and other tests.	Range from .02 to -.25 for easy prose. Median co-efficient -.17

He concludes "Adaptation to the reading situation (Material and Method) yields more valid performance. None of the validity co-efficients are large. Regression frequency and duration of Fixation are less valid measures".

It will be seen from the foregoing results that using dissimilar material and accepting the criteria of validity stated by Tinker for such cases, many of the validity co-efficients obtained for perception time and fixation frequency, especially in those cases preceded by adequate practice, fall into the excellent validity class. The median co-efficients for these two measures indicate fairly high validity. Despite this, Tinker considers that the method of estimating validity from material of different textual content is hazardous.

In part (b) of his validity investigation he used performance on strictly comparable material as a criteria. The procedure in this case was for each subject to read a selection from the Chapman-Cook Speed of Reading Test CC 1 before the camera at the first sitting after 23 lines of practice reading. Another selection of the same test C.C.2 was read before the camera after 23 practice lines at the second sitting and the scores obtained were compared with scores obtained on the Chapman-Cook Speed of Reading Test read normally. Results were:-

Test Performance and CC1	Fixations	- .69
" " " CC2	"	- .56
" " " CC1 and CC2	"	- .71
" " " CC1	Perception Time	- .65
" " " CC2	" "	- .64
" " " CC1 and CC2	" "	- .71
" " " CC1	Fixation Duration	- .08
" " " CC2	" "	- .24
" " " CC1 and CC2	" "	- .14

He concludes that fixation frequency and perception time are highly valid measures of reading performance. In another study by Tinker and Frandsen (55) seeking to establish the significance of each of the four measures of eye-movement records they conclude that both perception time and fixation frequency are closely related to each other and are highly satisfactory measures of reading ability. Regression frequency is moderately correlated with speed and hence is only a fair measure of reading ability. Duration of Fixation, because of variable correlation with speed, is in general, a poor measure of reading ability, particularly in special reading situations. This latter conclusion is confirmed by Eurich (18) who states "The evidence is uniform and clear in pointing to the fact that the average duration of fixations is a different measure from either regressions or fixations". He disagrees with the findings of Tinker regarding regressions. He gives correlations between numbers of fixations and numbers of regressions ranging from .84 to ,91 and recommends that since the number of regressions is so much smaller than the number of fixations, it would be an economy to use the former measure. This latter finding, although attractive as a means of speeding analysis of the reading graph, has not been sufficiently substantiated by other investigators to be accepted at present.

The experimental evidence would appear to be unanimous in finding that eye-movement measures are, with adequate measurement techniques, reliable measures. Regarding validity, Tinkers' investigations with dissimilar criteria agree closely with other investigators and compare favourably with validity co-efficients obtained from two standardised dissimilar tests. When comparable material is used so that the disturbing factor (dissimilar material) is removed from the situation, the eye-movement measures, fixation frequency and perception time are shown to have high validity, whilst the simultaneously obtained measures, duration of fixation and regression frequency, are of great diagnostic value as will be shown later.

EYE-MOVEMENTS.

Much research has been directed to the oculomotor behaviour of the eye and the accompanying psychological processes which together constitute the reading method. In order to fully understand the analysis of the eye movement record, it will be useful to study individually the eye movements and the associated measures derived from them.

FIXATIONS.

Perception takes place in reading when the eyes are stationary and fixated upon some part of the text. To all intents and purposes the eye is perfectly still during such fixation periods but McAllister (32) has shown that even during a single fixation, the absolute point of fixation is not maintained for more than 100 milliseconds. This movement is not of sufficient magnitude to be registered by the photographic technique used in this study. A further movement which often occurs during the normal fixation period, is due to the fact that each individual tends to fixate a point primarily with the dominant eye. The non-dominant eye is often not accurately fixated upon the same spot as the dominant eye immediately following the interfixation movement. On occasion the corrective movement of the non-dominant eye is of sufficiently large magnitude to show on the photographic record.

PERCEPTION TIME.

Since perception takes place during fixations, the sum of all fixation durations will equal total perception time. The percentage of the reading time which is devoted to perception has been studied by Tinker (54); Shen (43) and Walker (57). For comparison these results are tabulated below.

Percentage of Reading Time on Fixation and Movement.

STUDY	Perception Time as percentage of Reading Time	Interfixation Time as percentage of Reading Time
TINKER	94.1%	5.9%
SHEN (reading Chinese)	96%	4%
WALKER	97%	3%

Approximately 95% of the reading time is devoted to fixations. In the analysis of the reading graphs the total reading time is taken as perception time; thus an error is introduced into the record. The error appears however to be a very constant factor for all subjects and ignoring it, allows a much quicker and simpler analysis of the reading graph. By enlargement against a time scale the measurement of the actual perception time would be possible. Even with complicated apparatus it is probable that subjective error would introduce a highly variable error into calculations of perception time. Thus there would be little improvement in the accuracy of the result from that achieved by the acceptance of the 5% of movement time in the calculations of the perception time.

DURATION OF FIXATION.

All investigators agree that the variation in the duration of fixations between individuals is large. Carmichael and Dearborn (9) point out that fixations could be as short as 50 to 100 milliseconds and under strong illumination even shorter. Thus the duration of fixations must be dependant upon central thought processes and investigations have shown that fixations are rather constant in duration but vary much more in frequency. Vernon (56) suggests that it is personal and established individual peculiarity to read either with a large number of short pauses or a small number of long pauses. The data on which this suggestion was based was derived from tests with ten adults. Much more extensive investigation with all types of material, and a large number of subjects, would be necessary before this hypothesis could be accepted as a typological finding of the reading process. O'Brien (35) offers supporting evidence of the relative stability of duration of fixation. After conducting training designed to develop speed of reading with children, he showed that as a result of training the number of fixations and regressions were reduced to a marked degree, but that duration of fixation did not alter appreciably or uniformly with the subjects tested. He suggests that with fewer fixations the duration of fixation may increase slightly, although the aggregate duration of fixations per line is much less, due to reduction in frequency of fixations. Frandsen (20) conducting a study on the influence of varying types of questions upon fixations, also remarked upon the very slight change in duration of fixation despite the large variation in frequency of fixation produced by the differing materials. Tinker (51) found a small positive correlation between the extent of eye movement in interfixation movements and duration of fixation. This finding is corroberated by Eurich (19) who found correlations ranging from .1 to .41 between the number of regressions and the average duration of fixation. He concludes that the evidence is uniform and clear in pointing to the fact that the average duration of fixations is a different measure from either regressions or fixations. Buswell (8) has shown in his grade medians for eye-movement measures that the average duration of fixation decreases with increasing maturity varying from 432 milliseconds for grade 1 children (6 years old) to 236 milliseconds for grade 6 (12 year olds) at which level it appears to remain for all higher grades. Because of the relative stablity of duration of fixation the intercorrelations with other measures of speed are low, and this measure is, as a result, a poor criterion of reading ability. It would appear, however, that further research, with adequate numbers of subjects, could usefully be devoted to this aspect of eye movements to ascertain whether the suggestion of Vernon that individuals appear to read either with a long duration of fixation and few pauses or short duration of fixation and many fixations can be verified.

FIXATION FREQUENCY.

This is a very variable measure which has a high intercorrelation with speed and is a very good measure of reading ability. Fixation frequency is affected by the reading attitude of the individual, the difficulty or degree of familiarity of the material and the typographical factors of the material used. As the conclusions regarding typography will be discussed later when considering the material for the present investigation, it will not be discussed further in this chapter.

EFFECT OF ATTITUDE AND MATERIAL.

Judd and Buswell (27) found that the number of fixations increased with the difficulty and unfamiliarity of the material read. Subjects read passages of fiction, geography, rhetoric, easy verse, blank verse and algebra. They found fewer fixations when reading the fiction, and marked individual adaptation, as reflected by increases in the number of fixations, to the different types of material. They concluded that familiarity and interest which was not constant for all subjects with the other materials facilitated adaptation. They also found changes in frequency of fixations were caused by changes in attention, when subjects were required to answer questions, and when reading analytically. Dearborn (12) has suggested that when reading a portion of printed matter, the reader develops "Short lived motor habits" so that a rhythm of fixation is developed suitable to the text read. Judd and Buswell (27) compared students reading English, French and Latin, and found that the reading of French was much more laboured compared with reading English, whereas the reading of Latin, which subject the students did not take, showed such irregular and confused eye movements and numerous regressions that it appeared to be aimless wandering.

In studying the effect of different types of examination questions on eye fixations Frandsen found that in every case averages of fixations for easy prose were exceeded by the corresponding averages for the questions. Tinker (51) has shown by plotting fixation points on the text read that such increase in frequency of fixation is not caused entirely by more numerous fixations within the same area of eye movement, although these did increase. Comparing records obtained from 32 subjects reading prose, algebra, Chemistry and formulae, he determined the average amount of line length covered by the eyes in reading. His results are tabulated below:-

Percentage of Length of Line covered by Eye Movements.

	Prose	Algebra	Chemistry	Formulae
High School Group	87%		89%	
University Group	84%	89%		99%

General averages for the High School group indicate that the first and last fixations in lines of prose are 6 mm from the end, whilst in reading Chemistry the average is 4 mm from ends of lines. The University group fixate, on the average, 7 mm from the end of lines with prose and practically at the ends of lines when reading Formulae. He observes that the increased number of fixations and regressions where formulae are involved indicates that ordinary reading habits are abandoned and that the reading becomes more careful and analytical. Schmidt (42) remarks that the distinction between normal and careful reading is undoubtedly a fundamental one and he attributes some of the contradictory results obtained in reading researches, in part at least, to the fact that the experimenters overlooked this distinction. Despite the wide range of individual variation in the number of fixations per line, Schmidt (42) reports a range of from 4.1 per line to 10.8 per line, Buswell (8) in plotting what he refers to as normal growth curves, has shown that the average number of fixations per line decreases with the increasing maturity of the reader. His figures indicate that the normal adult stage of reading is reached by the fifth grade, that is by an eleven year old child. Tinker (54) has pointed out that Buswell's findings, although verified by other investigators, cannot be correctly called growth curves, since by using school grades as his steps, each grade group after the first is more and more highly selected by the school system. Also these norms are produced under prevailing educational conditions.

Since the saccadic interfixation movement seems largely physiologically determined and in any case represents only 5% of the reading time, and as the average duration of fixation is found to be fairly constant, it follows that any increase in reading speed must be accompanied by a reduction in the number of fixations.

DECREASE IN NUMBER OF FIXATIONS WITH TRAINING.

O'Brien (35) has shown experimentally that training directed specifically toward increasing the speed of reading, results in a decrease in the average number of fixations per line. Using a control group equated for reading ability and intelligence, he trained 401 children to read with speed, whilst the controls continued normal reading instructions. At the end of the experiment there was no significant difference in the level of comprehension between the experimental and control groups but the experimental group had gained an average of 30% superiority in speed over the control group and their fixations per line had decreased from an average of 8.3 before training to 6 per line after training. Peters (40) showed that speed training resulted in an average increase of 18.7% in speed of reading without injuring quality in any way and this fact is also confirmed by Gray (22). It will therefore be seen that the growth curves of Buswell in no way reflect some physiological limit imposed upon the reading habit, but rather the standard attained through certain teaching methods. It would appear that a majority of individuals without special training read at a speed well below that of which they are capable with special training. Gray, (23) having conducted a survey of relevant research, concludes that the size of the unit recognised in reading may be increased through appropriate training. This improvement occurs largely in the first four grades (i.e. 6 years to 10 years) but it may also occur as a result of training in the upper grades and even in the case of adults.

INTERFIXATION MOVEMENTS.

The movements made between fixations when reading are named interfixation movements or saccadic movements, and as has been mentioned previously, these movements occupy approximately 5% of the total reading time. Dodge and Cline (17) have measured by photographic technique the speed of the saccadic movement between two points and the angular velocity of the eye as calculated by them is given overleaf.

Speed of Saccadic Movement over Varying Arc.

For 5^{o}	of arc	28.8	milliseconds	for 20^{o}	of arc	54.8	milliseconds
" 10	"	38.8	"	" 30	"	80.4	"
" 15	"	48.2	"	" 40	"	99.9	"

They consider that such movements between fixation points are not materially different qualitatively or quantitatively from the eye movements used in reading, It will be observed that the duration of eye movement does not increase in direct proportion to the arc of movement. The explanation of this fact is offered by Miles (34). He states that the saccadic movement consists, at first, of a period of rapid and quickly accomplished acceleration, a rather large arc of movement that is executed at a uniform maximum speed, and then a longer period of deceleration as the eye draws near the new fixation point. Carmichael and Dearborn (9) have also observed that as the extent of the saccadic movement increases the magnitude of the increment in duration of movement decreases. They also report that for the same individual and the same extent of movement the duration of movement is nearly, though not perfectly, constant. They observe that a reader cannot voluntarily control the speed of the saccadic movement even though he can make a saccadic movement at will by looking from one object to another. Miles (34) has also commented upon this lack of voluntary control of the speed of interfixation movements once the decision to shift to a second point has been made. He points out that due to the speed of the saccadic movement, approximately 30 milliseconds for 5° of arc, the period of movement is too brief to include a conscious reaction interval. Where the reading is at all analytical the arc of movement will be considerably less. Tinker (51) gives 1 degree 22 seconds for High School students reading Chemistry with Formulae in which case the duration of movement will then be shorter than 30 milliseconds. We may therefore conclude that control of such eye-movement speed is beyond the power of the individual, once the movement is initiated, since the subject cannot be aware of the motion early enough to do anything toward directing it voluntarily until after the movement has come to an end.

PERCEPTION DURING MOVEMENT.

Woodworth (58) considers that the question as to whether we see during the saccadic movement divides, in fact, into two questions. Firstly, whether we derive from the stimulation received by the retina during saccadic movement, any data that are used in perception; and secondly, whether any sensation at all results from the stimulation received by the retina during saccadic movement. Holt (24) had concluded from the fact that he could find no evidence of perception during voluntary saccadic eye movements that the answer to both questions must be a negative. He had suggested that this lack of perception might be due to a central visual anaesthesia during eye movements.

Dodge (14) denies this suggestion on the grounds that clear vision is possible when following a moving object (pursuit movement). Objects fixated when the head moves cause compensatory eye movements and clear vision results. He concludes that the undifferentiated effects of adequate stimulation during eye movements is falsely localised at the point of ultimate fixation. There, like the more familiar obstructions to clear vision due to binocular incoordination and accommodation, with which it is so easily confused, it is simply ignored. Dodge (16) also points out that the stimulation during eye movement scarcely covers the duration of the most pronounced after effects of the stimulation of the preceeding fixation pause, whilst the more intense stimulation of the succeeding fixation would make the faint stimulation hardly perceptible. Woodworth (58) concludes "We can see what the retina has to show during saccadic movements, but there is usually very little to see. Since such stimulation is of no practical interest it is habitually disregarded and over-looked".

EXTENT OF INTERFIXATION MOVEMENTS.

Dearborn (12) has suggested that a reader develops short-lived motor habits suitable to the type of material read and to the varying reading attitude of the reader. Tinker (51) has found the extent of the interfixation movement decreases with the difficulty of the material and with the reading maturity of the subject. In the research previously referred to he found the average length of eye movements as follows:-

	PROSE	CHEMISTRY	CHEMISTRY WITH FORMULAE
HIGH SCHOOL STUDENTS	1° 35'	1° 36'	1° 22'
UNIVERSITY STUDENTS	2° 3'	1° 54'	1° 31'

It will be observed from the figures that the High School students as a group appeared to be using the same movements to read prose as to read chemistry, indicating that both materials were approximately the same degree of difficulty to them, whilst the formulae needed more analytical reading. The University students show a definite decrease of eye movement with the more complex material indicating that the interfixation movement has become adapted to the need for more analytical reading. Tinker calculates that the average length of eye movement in reading scientific prose corresponds approximately to the rod-free area of the retina, whilst in reading formulae the eye movement corresponds to the area of the foca centralis.

DIVERGENCE DURING EYE MOVEMENT.

Schmidt (42) has pointed out the interfixation movements of the eye are clearly accompanied by divergence, the degree of such divergence varying almost directly with the speed and extent of the movements in question. Such divergence involves an upward and outward movement of the eye, the former movement being due to the torsion phenomena whereby the eye rotates about its sagittal axis. Miles (34) has shown that quite independantly of the subjects' desires or efforts, the abductive or outward saccadic movements are usually found to be more rapid than the associated adductive or inward saccadic movements. Thus, there is present in the occulomotor structure of the eye, a mechanism which tends to obstruct the simultaneous fixation of the two eyes upon the same spot following any interfixation movement. In the degree of movement normally used for reading it does not appear that this irregularity is, in the absence of abnormal muscular imbalance, of such a degree as to affect materially the reading process.

RETURN SWEEP.

The return sweep is the saccadic movement from the end of one line to the beginning of the following line. Dodge and Cline (17) have calculated that the moves to the left are much longer in duration, usually two to three times the duration of the moves to the right. It has been suggested that an indented margin on the left would enable the return sweep to be made with less missing of lines and decrease the number of faulty first fixations. Vernon (56) found that readers did occasionally jump or recede one line in returning from the end of one line to the beginning of the next, though this occurred, on the average, only once or twice in ten pages of reading. She suggests that there is perhaps insufficient evidence of the need for such a change. Such indentation would also interfere with the development of the "short lived motor habit" hypothesised by Dearborn (12).

REGRESSIONS.

Regressions are those saccadic movements made within a line of print in which the eye moves from right to left in opposition to the normal progression from left to right. Tinker (51) differentiates the regression into two types:-

Type 1 - are regressions to correct inaccuracies in the location of the first fixation in a line.

Type 2 - all other regressions than those occurring at the extreme left of the line.

Buswell (8) classified regressions in the following manner:-

1. The most common - where the return sweep fails to carry the fixation back to the first word. This type of regression persists into the mature reading stage.

2. Regressions caused by the fact that mature readers read with a relatively small number of fixations. In their effort to grasp a larger unit in a single fixation they occasionally over-reach their maximum span and find it necessary to make a regressive movement to clarify the meaning. Such regressions are few and occur only with mature readers.

3. Regressions due to lack of word knowledge, which occur with children and adults when difficulties are encountered.

4. Regressions included in movements characterized by random oscillation of the eye, with no apparent plan on the part of the reader. This occurs when the reader fails to get a clear perception of the meaning, and sets up a series of eye fixations over the area of difficulty.

Buswell found the grade medians for regressions decreased from the first grade (age 6) at which time the average number of regressions was 4 per line, to the college level (age 17) when regressions averaged .5 per line. It would appear that the attainment of maturity with respect to regressions takes longer than is the case with perception time and fixation frequency. O'Brien (35) has shown that training in directional attack on words and speed training helps to reduce the number of regressions made during reading. He shows an average decrease of .7 regressions per line (approximately 50%)

attributable to training. Tinker and Frandsen (55) found that regression frequency correlated only moderately with speed, ranging from .59 for easy narrative to .62 for scientific prose, and Tinker (48) considers that regression frequency is only a fair measure of reading performance.

In an investigation showing the effect of material of varying difficulty upon eye movements Frandsen (20) found that the frequency of regressions showed the largest extent of variation of the measures recorded. Judd (26) found that the records of eye movements whilst the subject is reading the first line show an abnormal number of pauses because they usually include at the beginning of the first line a series of regression movements. It has also been noticed that the duration of fixation during the reading of the first line tends to be longer than the average. For this reason, he states, that it is not safe to base generalisations on the results obtained in records of the first line. Many of the investigators have accepted the unreliability of the first line record. The American Optical Co. (7), the makers of the instrument used in the present investigation, recommend that the first and last lines of the record be ignored when analysing it and their own reading cards are so printed that twenty-five or fifty words are read by the subject between the beginning of the second line and the end of the penultimate line.

The fact that regressions are, on occasions, necessary parts of the reading process, especially in analytical reading is shown by Bayle (2). She made an analytical study of regressions and found that such movements tended to fall into one of six categories. To test the validity of her findings she produced reading selections which she anticipated should cause regressions of a certain type and her expectations were fulfilled. Her six patterns of regressions were:-

1. Regressions after the first fixation in a line.
2. Adjustment within a line, when span of vision is over-reached.
3. Regressions for verification.
4. Regressions during word analysis.
5. Regressions for phrase analysis.
6. Regressions for re-examination of a whole line.

Tinker (50) quoting Bayle's work states "Recognition of the fact that regressions are legitimate and essential in certain kinds of reading would avoid some of the misconceptions involved in training eye movements.

SPAN OF RECOGNITION.

The Bureau of Visual Science, (7) discussing the analysis of the reading graph, give as one of the measures obtained the "average span of recognition". They state:- "Thus it is seen that in order to compute the span of recognition used in reading, it is necessary to know two things:- (1) The number of words in the selection read and (2) The number of fixations made in reading that selection. This is the <u>only</u> way to obtain some knowledge of the extent of the span <u>actually used in reading</u>".

This measure will not be used in the present investigation because in the opinion of the author such a term as "span of recognition" is misleading and offers no new measure. It is obvious that in reading any selection of known length, the fewer the fixations the greater the number of words seen at one fixation and the more numerous the fixations, the fewer words will appear to have been recognised at each fixation. Thus the "span of recognition" as used here is no more than an interpretation derived from the number of fixations. Since the number of fixations will include regressions, the measure is obviously not entirely accurate since it is conceivable that some words recognised in the regression have already been recognised in the previous fixation. Further, such a term is misleading if it is regarded as in any way relating to the perceptual span, or is even accepted as what the reader aims at recognising during each fixation.

Buswell (8) has shown that an excessive number of fixations may occur in one or more places in a record and be attributable to a confusion which is primarily related to lack of word knowledge or failure to grasp meaning. Such temporary manifestations included in the number of fixations would decrease the "span of recognition" and present a false picture of the subject's reading maturity, Dockeray (13) found that span of distinct vision at 35 cms was from 20-22 mms on either side of the fixation point. The distance between fixations, with very few exceptions, lies within the limen of distinct vision, and he concludes that probably the fields of distinct vision overlap in successive fixations.

Stromberg (47) has questioned the validity of the method of plotting fixation points by projecting the photographic record onto the printed selection read. As part of his investigation he shows that whilst one eye is fixated at one point on the record, plotting of the fixation point of the other eye indicated that at the beginning of the line it was twelve letter spaces away from the simultaneous fixation point of the first eye, and yet, nine fixations later, both eyes were fixated within the same four letter word. Until more experimentation can be done to determine the effect of such large coverage of the line by the two eyes at the same fixation, and the differential effect of occluding either eye, it would be unwise to accept such a measure as the "Average span of recognition" as indicative of the amount actually recognised at each fixation during reading. For these reasons it is not considered advisable to include this measure in the present investigation.

EFFECT OF CONTENT UPON EYE MOVEMENT.

Any study which is concerned with the measurement of eye movement must take account of the fact that eye movement whilst reading is affected both by the content of the material read, the attitude such material induces in the subject and the purpose for which the subject is reading such material. Schmidt (42) has pointed out that the difference between normal and careful reading is undoubtedly a most fundamental one, whilst Tinker (49) has shown that skimming a passage involves an entirely different form of eye movement from that used when adopting a study attitude. He found a correlation of .46 between reading performance when reading easy narrative and when reading easy prose. Frandsen (20) conducted an investigation into eye movements whilst subjects were reading examination questions differing in type and by measured amounts of difficulty. He found variations in all measures with varying types of questions and in all cases the means obtained for fixation, regressions and perception time exceeded the averages obtained whilst reading easy prose. Average duration of fixation varied only slightly from one type of material to the other. Judd and Buswell (27) found in comparing the reading of fiction, geography, rhetoric, easy prose, French grammar, blank verse, and algebra, that all measures varied with the difficulty and unfamiliarity of the material read, whilst a comparison of English, French and Latin, the latter subject not being taken by the subjects, revealed that reading of matter which is completely unfamiliar results in random eye movement and disorganisation of the regular eye-movement habits.

It may therefore be concluded that eye-movement measures are valid only for the particular type of material read whilst under test, and will be valid for other material only in so far as it can be shown to the the same kind and of the same degree of familiarity.

EFFECT OF TYPOGRAPHY UPON EYE MOVEMENTS.

A printed page varies in respect of the following characteristics:-

TYPE. Types are divided into families, each family being the creation of a particular designer who evolved that style of type.

SIZE. The measurement of print is made by the point system, each point being .013837 of an inch. This measure refers to the length of the type face but bears no constant relationship to the size of the large or small letters within that type face. This is due to the fact that each large letter on a type face has to have sufficient space (beard) beneath it to allow for the letters with tails. The proportion of the face occupied by the large and small letters and therefore the actual size of the letters, is an individual characteristic of the originator of that type. One is therefore unable to assume that two type families of the same print size will possess letters of identical size and in considering the size of print suitable for children it is often necessary to ascertain the size of letter required and then relate the size to the particular type in order to ascertain what point size yeilds letters of that calibre.

BOLDNESS.

This refers to the thickness of the line composing the letter and is usually available in all types and sizes, the grades being light, medium, bold, extra bold and italics.

LENGTH OF LINE. This measure is self explanatory.

DISTANCE BETWEEN LINES (INTERLINEAGE)

Type may be SET SOLID, in which case the space between the lines is supplied by the beard of the type face only.

LEADING.

Type is referred to as with "Points leading" when a stated number of points of lead is placed between the lines. Thus 2 points leading indicates that the type face is separated by 2 points distance when assembling, thereby increasing the distance between the lines of print.

Buckingham (6) criticising some of the earlier investigations into optimum sizes for reading has pointed out that the attempt to set up "standards" in any one of the above measures by separating individual items will yield results both impractical and meaningless. It is the relationship between these items which makes for an ideal and optimal typography. In the following survey of investigations concerning typography some of these items will be considered in isolation but the conclusions drawn should be made within the framework of Buckingham's dictum. In quoting sizes, all measures will be given in millimetres irrespective of the measure used by the author quoted, in order to make possible comparison within this study.

TYPE.

Paterson and Tinker (37) studied the speed of reading of the eight most commonly used types in the United States - CASLON OLD STYLE, SCOTCH ROMAN, GARAMONT, OLD STYLE BODONI, CHELTENHAM, ANTIQUE, and KABEL lite, set in 10 pt, 80 mm line set solid. They found no important difference in the rate of reading of any of these types, although comparison with less used types showed that the commoner types were read appreciably faster. They conclude that type faces in common use are equally legible. They note that the conclusion is not surprising in view of the fact that such type faces survived in competition with thousands of other type faces which have been put on the market. The British Association Report (4) also found themselves unable to make any recommendation concerning type faces, provided that the minimum standards recommended by them for size of letters were met. Pyke (41) measuring the relative legibility of eight type faces also concludes that differences in type faces must be very radical indeed in order to bring about appreciable differences in speed of reading.

SIZE.

The British Association (4) Report of 1913 investigated the minimum standards of size of print required for children and their results are listed below.

Under 7 years	height	of	short	letters	3.5	mm
7 to 8 years	"	"	"	"	2.5	mm
8 to 9 "	"	"	"	"	2.0	mm
9 to 12 "	"	"	"	"	1.8	mm
Over 12 "	"	"	"	"	1.58	mm

J. Kerr (29) considered as a result of enquiries and unspecified experimental tests that for ordinary school purposes the following size type was needed.

Below 7 years	small	letter	size	2.8 mm
7 to 9 years	"	"	"	1.75 mm
9 plus	"	"	"	1.5 mm

Buckingham (6) conducted an extensive investigation with two thousand children of 8 years of age and over, using 18 different combinations of type sizes; 18 point, 14 point, and 12 point, varying lengths of line and interlinear spacing. His conclusions were that 12 point type, of the monotype number 8 series (small letter size 2 mm) was read faster, with more comprehension, and was superior when both these measures were combined. Blackhurst (3) found that the optimum sizes of print were:-

AGE		
6	24 point	(small letter size for Times Roman Type 3.2 mm)
7 and 8	18-24 point	(small letter size for Times Roman Type 2.5 mm - 3.2 mm)
9	18 point	(small letter size for Times Roman Type 2.5 mm)

The results obtained by the various authors are tabulated below. It will be seen that there is much difference of opinion concerning the optimum size of print for children.

Recommended Print Size for Varying Ages.

AGE	6	7	8	9	10	11	12
Brit. Ass.	3.5mm(24pt)	2.5mm(18pt)	2mm(14pt)	1.8mm(12pt)	1.8(12pt)	1.8(12pt)	1.58(10pt)
Kerr.	2.8(18pt)	1.75(12pt)	1.74(12pt)	1.75(12pt)	1.5(10pt)	1.5(10pt)	1.5(10pt)
Buckingham.	--	--	1.8(12pt)	1.8(12pt)	1.8(12pt)	1.8(12pt)	1.8(12pt)
Blackhurst.	3.2(24pt)	3.2(18-24pt)	3.2(18-24pt)	2.5(18pt)	2.5(18pt)	2.5(18pt)	2.5(18pt)

In the above table point sizes of the commonest English types have been inserted where not given by authors, and actual size of small letters of the type specified have been inserted where point size only was given.

Concerning the size of print for ages above 12 years, Patterson and Tinker (38) who have conducted extensive investigations into typography, stated that 10 point Scotch Roman Type (1.5mm) is read much faster than smaller sized print, and print as small as 6 point, results in a definite decrease in reading speed. Judd (26) has shown that a change in print size from 11 point to 22 point causes very little difference to the adult reader. It would appear therefore that Vernon's (56) conclusion that type which is suitable for children will hold no difficulties for adults, may be accepted. We may therefore assume when considering the material to be used in this research that there is no need to produce cards of different type size for the over 12 age groups or for adults. Carmichael and Dearborn (9) have suggested that the confusion concerning optimal size of print for reading resulting from experimental investigations, may be due to the very short printed passages used as sample texts when comparing various print sizes. Differences in the results obtained by the various investigators may be accounted for, at least in part, by the variation in the individual ability to adapt quickly to a new typographical format, after having just briefly read another. Long periods of continuous reading with a number of subjects are required if conclusions in this field are to be fully satisfactory.

It may be said that the investigation of Buckingham most nearly approaches this ideal. Obviously, however, the policy of publishers must affect this question of optimum print size, since familiarity with certain print sizes will be a contributing factor to reading speed with children. Before any decision concerning size of print can be made it will be necessary to establish what size of print is actually being published for children, and what they read in schools.

PUBLISHERS INFORMATION.

Enquiry of four of the most prominent publishers of childrens' books in this country has revealed a high degree of unanimity regarding the size of print which is considered suitable for children. 18 point Baskerville Type (2.8 mm small letter) is commonly used for children aged from 6 to 9 years. 14 point (2 mm) and 12 point (1.8 mm) are intended for children aged 9 to 12 years, whilst 12 point (1.8 mm) is the commonest size for children aged 12 to 15 years. A survey of the books actually used in 100 Durham schools was carried out by the author to ascertain how far the publishers intentions were in fact being carried out. By far the commonest type used in books read in these schools is Baskerville, whilst Times Roman, Imprint, Chippendale, Bodini, Cushing and Garamond are also used. The majority of the print is of the medium or bold thickness to give clarity. The percentage frequency with which the various type sizes are encountered in the different age groups, as revealed by the books examined in this survey, are tabulated below.

Point Rating.	Small Letter Size	Age 6-7	7-8	8-9	9-10	10-11	11-12
24	3.2mm	28%	12%	-	-	-	-
18	2.8mm	56%	38%	6%	4%	5%	2%
14	2mm	14%	31%	33%	8%	10%	8%
12	1.8mm	2%	19%	44%	54%	35%	40%
10	1.5mm	-	-	17%	34%	50%	50%

From the table it will be seen that children of all ages meet a wide range of print in their normal school reading. 18 point print, according to the above figures, has the higher degree of familiarity for the younger ages of children and 14 point print would seem a safe size to use for all ages since it shows less fluctuation in usage throughout the age ranges studied and will therefore be approximately familiar to all.

LENGTH OF LINE.

It will be necessary when considering the optimum length of line to consider also marginal indentation, since this is a related factor. Buckingham (6) considered that line lengths of 61.5mm to 89 mm where optimum lengths for children. Blackhurst (3) found that lines between 60 and 100mm could be read with equal ease. The British Association Report (4), making their recommendations, suggest lines of maximum length of 100 mm for the 7-8 age group, presumably because of the larger size of print needed at this level. They recommend a maximum of 93 mm for the remaining groups. Paterson and Tinker (39) surveying eleven studies completed by them in which the line width was considered, conclude that line widths can be varied to a surprising degree without any appreciable effect on speed. That is, a definite range of optimal line widths exists. However, lines shorter or longer than the optimal range, definitely retard reading speed. From this study it would seem, although this is not explicity stated, that a line of 80.2mm is the median length of the optimal range, whilst 38 mm is so short as to be outside the lower limit of this range and 181 mm is outside the upper limit of the optimal range. It appears that the decreased efficiency with which a very short line is read is due to the readers inability to make maximum use of horizontal peripheral clues. In reading extremely long lines the reader appears to have difficulty in locating the beginning of successive lines and of making correct first fixations, these difficulties causing an increased frequency of regressions. The majority of investigators would therefore accept a line of approximately 90 mm as meeting the optimal requirements for normal reading purposes. In the books used in the schools investigated there would appear to be considerable variation in line length within the one book. This arises because of the practice of providing pictorial illustrations on almost every page of early reading books which restricts the length of line possible. Once the amount of illustration has decreased, the length of line found in the popular readers would seem to be within the range 95 to 115 mms. These lengths fall within the limits established by investigation as necessary for optimal reading conditions.

Concerning marginal indentation, it can be established that normal printing procedure results in the majority of individuals being required to read material with regular margins.

Dearborn (12) has suggested that the formation of regular "short lived habits" of eye movement are fostered by the regularity of the printed material and will be adversely affected by irregularities such as marginal indentation. Even if one does not accept the existence of these "short lived motor habits", it does not appear that any experimental evidence has been produced which would indicate that regular margins are a handicap to efficient reading. Nor does it appear that marginal indentation produces benefits of such significance as to make any alteration in normal printing procedure justifiable.

DISTANCE BETWEEN LINES (INTERLINEAGE).

All authorities agree that type set solid, that is with the distance between lines made up of the beards of two adjoining type faces, does not provide sufficient space for the print to be read with maximum efficiency by children or college students. Buckingham (6) has studied this problem with children and his results indicate that leading of three points, or four points, results in more efficient reading than is procured by comparable type size and line length using 5 point leading. Paterson and Tinker (36) studied the relative efficiency of students reading ten point Scotch Roman Type of 80.2 mm line length set solid, and with 1 point 2 point and

4 point leading. Their results showed that 1 point of leading does not facilitate speed of reading, but 2 point and 4 point leading definitely increases the speed of reading. The increase was significant for both amounts of leading, with a slight advantage in favour of 2 point leading. The material with 2 point leading was read 7.5% faster than the material set solid whilst the four point leading was read 5% faster. Although some other investigators have suggested that one point of leading is as effective as larger amounts, the majority agree that 2 points to 4 points of leading is most effective.

A survey of the books used in the 100 schools investigated revealed no reading books in common use which were set solid, the amount of interlineage ranging from one point of leading to 4 points of leading. Enquiry did not reveal that any particular books were considered as too difficult for a group due to insufficient spacing between the lines.

EVALUATION OF OPHTHALMOGRAPH CARDS.

The American Optical Co., the makers of the instrument used in the present study, supply a set of reading cards with selections printed in various sizes of type and graded for the different age levels of the children tested. These cards are so designed that 25 words on the junior cards and

50 words on the Senior cards lie between the beginning of the second line and the end of the last line but one. This arrangement allows for the reading of 25 or 50 words whilst ignoring the record obtained from the first and last lines. These cards have parallel forms so that practice can be given on one card and the record taken on another. Imus Rothney and Bear (25) used these cards in an investigation into the reliability of the ophthalmograph and found that with selections of this length the reliability co-efficients ranged from .59 to .72. They concluded that these figures were not high enough for the purpose of individual diagnosis and suggested that higher reliabilities would be obtained if the length of the reading selection were increased from five to seven times the present amount.

Broom (5) investigating the same problem with 192 children found reliability co-efficients of a somewhat higher order than the previous investigators, but pointed out that the co-efficients obtained were of doubtful value. He suggested that true reliabilities would not be obtained until the same card was used in test and retest, or until adequately standardised and equivalent card selections were available. Tinker (53) has pointed out that the reliability of the photographic record is increased if the length of the passage read is increased from 5 lines to 15 lines. The ophthalmograph reading cards would appear to have been produced to enable reading measures to be easily calculated for units of 100 words. This method has, however, resulted in very short reading passages particularly for the younger age groups where the number of words read is only 25.

All of these investigations indicate deficiencies in the makers reading cards which render them unsuitable for the present investigation, and for these reasons they will not be used in this study.

EVALUATION OF EYE-MOVEMENT RECORDS IN CLINICAL SITUATIONS.

There exists a wide divergence of opinion as to the value of the eye-movement camera as a clinical tool for the diagnosis of reading ability. Many of the investigators agree with Tinker (54) that eye movements are the effects and not the causes of reading difficulties and that the eye-movement camera is a research instrument of little clinical value. He also feels that any emphasis upon the peripheral and mechanical factors in reading by the use of eye-movement records may result in neglect of the more important central factors of comprehension and assimilation. The opposing view stressing the value of eye-movement records in the clinical situation is held by Kurtz (30) who claims that the importance of the objective permanent record of eye movements offered by the ophthalmograph in clinical diagnosis cannot be over-emphasised. This estimation of the role of eye-movement records in clinical practice is supported by Clarke (11) who considers that eye-movement photography serves as a valuable objective auxiliary to other techniques.

It is unfortunate that the evaluation of eye-movement records has been caught up, and in many cases submerged, by the discussion as to the value of controlled reading techniques, i.e. methods of training eye movements by mechanical and somewhat artificial reading programmes. The proponents of this latter type of training have sought to show that such training has resulted in more efficient reading, and in the subjects making eye movements more comparable with those of efficient readers. Having, to their satisfaction, shown that such improvement is obtained as the result of training, their support for ophthalmographic analysis in the clinic rests upon the value of this instrument for revealing atypical movements before training, and improved records of eye movements after training. The opponents of the clinical use of the ophthalmograph have attempted to meet the arguments of the eye-training theorists, by showing, either that eye training does not improve reading, or that it improves reading only as much as more natural techniques. They also fear that such mechanistic methods stress the peripheral elements of reading to the neglect of the more important central factors in the reading situation. They tend to condemn the eye-movement record together with all such mechanistic devices as unnecessary and often harmful.

O'Brien (35) conducted an investigation with 401 pairs of pupils, matched for initial reading ability in grades IV to VIII, The experimental group were trained in methods of reading designed to increase speed, whilst the control group continued normal reading lessons. At the end of a period of 39 days the experimental group showed an average gain of 31% over the control group, and showed a noticeable difference in the number of fixations and regressions. A somewhat similar result is reported by Peters (40). His group, trained in reading for speed, gained 18.7% in speed without any injurious affect upon the quality of the reading. The suggestion is made that these results point to the advisability of giving speed drills as part of the teaching of reading. Grey (22) also concludes that positive results are obtained from training in speed. Unfortunately these results fail to be conclusive, since no experimenter has shown that the results obtained from so called speed training, with its emphasis on correct eye movements, is not, in fact, obtained by the increased motivation, individual attention and greater interest in reading aroused by such training techniques. Sisson (45) found that adult readers, reading with intent to improve, made as great a gain in speed as adults trained with eye-movement training techniques. A similar conclusion is reached by Cason (10). Simpson (44) contradicts these findings and states that unless students deliberately attempt to improve their eye movements by appropriate techniques they will not do so by reading ordinary printed matter. All experimenters appear to have ignored the possibility that whilst improvement of comparable magnitude may result from eye-movement training, or from central process training, a greater improvement may result from the use of both techniques.

Due to the inconclusive nature of the evidence, no final evaluation of the eye-movement record can be made which depends upon evidence of eye movements as causal factors in reading disability. It is possible, without excluding eye movements as a causal factor in reading disability, to accept the statement of Tinker (50) that changes in eye-movement patterns occur when difficulties of comprehension arise; with variations in reading purpose; and changes in the central processes of apprehension and assimilation. It is now well established that occulor motor reactions are exceedingly flexible and quickly reflect any variation in the central processes of perception, apprehension and assimilation. An adequate evaluation of the place of the eye-movement record as obtained by the ophthalmograph will only be possible when research has produced answer to the following questions:-

1. Will the eye-movement record differentiate more adequately than other techniques those readers whose effective reading is hampered by too much, or too little analysis?

2. Can valid conclusions be drawn from the eye-movement record as to the type of difficulty encountered by the reader?

3. Will specific difficulties in perception, apprehension and assimilation yield typical patterns of eye movements?

   The work of Bayle (2) on regressions would indicate that such is a possibility.

4. Will the eye-movement camera allow a study of silent reading as it in fact occurs and not as it is assumed to occur from conclusions which must perforce, at present, be drawn from oral reading?

5. Can the eye movement record reveal those adult readers who are unable to read effectively because they maintain immature reading habits, and are unable to switch to more flexible reading procedures, when needed, for varying reading purposes? The large amount of work carried out in University reading clinics on the backward reading habits of undergraduates would indicate a need for such a diagnostic tool.

It is hoped that the establishment of norms applicable to English children, which is the purpose of the present study, will be a starting point for such investigations and will stimulate research in this country in order to provide answers to the foregoing questions so that the true value of eye-movement photography may be ascertained.

SUMMARY OF CONCLUSIONS.

1. The corneal reflex method of eye movement photography, despite the imperfections of the eye and the strangeness of the experimental situation, is found to yield a record which is typical of normal reading.

2. The eye-movement measures derived from the photographic records have satisfactory reliability and validity.

3. It has been found advantageous to allow the subject practice in reading in the experimental situation before the final reading record is obtained.

4. If records are to be used for individual diagnosis a reading selection of at least 15 lines is desirable.

5. Due to the difficulty of providing equivalent forms for group testing and individual diagnosis, it would appear advisable that the material used for establishing norms should be the same as that to be used for individual diagnosis.

6. The reading cards supplied by the American Optical Co. are unsuitable due to the lack of equivalence between the graded cards and also to the shortness of the reading selection.

7. One card for reading by subjects of all ages will avoid changes in eye-movement measures due to varying typographical and contextual factors.

8. Comprehension will need to be tested after the reading of the material to ensure that the selection has been adequately read.

9. The test card used in the present investigation will need to be a compromise between conflicting requirements. Optimal print size, optimal length of line and optimal length of selection will tend to enlarge the size of the test card. Opposed to these requirements are factors which limit the size of the selection. These are, the size of the film strip, the maximum size of card capable of being read under photographic conditions with this instrument and the necessity of avoiding peripheral corneal reflections.

CHAPTER 3.

DESIGN OF THE PRESENT STUDY.

The present Study was designed to produce a table of norms, of fixations, regressions and rates of reading, expressed as lengths of film in inches, against which the performance of individuals can be assessed to determine their relative efficiency in this aspect of the reading process. Other eye-movement measures, such as span of recognition, are included in various studies but these are not given in the present investigation. The reason for this is that such measures are calculated from the measures used here and therefore contribute no new data regarding eye movement. Secondly, in the use of these other measures assumptions are made regarding their authenticity which are not always verified by investigations. Fixations, regressions and reading time are fully objective and require no hypothesis of central thought processes to explain their supposed function. It was not possible in the present study to follow the normal procedure of testing a representative sample of children of each age group, as certain difficulties peculiar to eye-movement measures had to be surmounted. In the case of cognative tests, the least able child of any group can be included by simplifying the test items until some score is obtainable. With eye-movement photography some basal criterion of reading ability must be independently established, since the eye movements of non or marginal readers are so numerous and various as to be unscoreable. In the present investigation, this basal level was taken as the reading age to the nearest year, as measured by the Burt Graded Vocabulary Test, which corresponded with the chronological age of the child tested. Thus a child of 8 years had to read to an eight year minimum standard of reading before being accepted for testing.

A further departure from customary procedure was the raising of this basal level for each "year" group. Thus the basal level of the "8 year" group was a reading age of 8 years but the basal level of the "10 year" group was a reading age of 10 years. This step was taken for the following reasons. It has already been established by Judd and Buswell (27) that the complexity of the material read will influence the degree of disorganisation of the regular eye-movement habits, and introduce random eye movements. It is obvious that one feature of complexity of a passage for a reader will be the difficulty he has in recognising the words of that passage. To include a 10 year old child who is reading to a 7 year level in the 10 year norms will certainly increase the scatter of the eye-movement measures within that group, but will not increase the efficiency of the norms.

In the present investigation an attempt is made to restrict this variation in one direction by eliminating from the norms all those individuals who cannot attain a defined basal level of word recognition appropriate for their age. While this is not the only method of producing such a table of norms, it is claimed that this is a valid method of comparing the reading performance of children, and is especially so for future investigations of the problem of why such large variations in eye-movement measures are found amongst children who are capable of meeting this basic criterion. The norms obtained in this investigation can therefore be taken as typical of children of the indicated chronological age, reading this particular test passage, who are further capable of reading to a reading age the same as, or greater than, their own chronological age, and who can show adequate comprehension of the material read. One further criterion also served to restrict the universality of the children whose eye-movement scores contribute to the final averages obtained. Any child who moved his head during the photography, to such an extent that the movement was observable to the experimenter, spoilt his record. The reflection from their cornea failed to enter the focussing tubes and therefore did not reach the film strip.

With regard to such spoiled records, two courses of action were possible. The spoiled records could be included in the norms by scoring them to the end of the last complete line appearing on the record. The average for fixations, regressions and reading time could then be calculated for the number of lines read and this figure then used to ascertain the number of such movements which would have been made by the subject if he had read the complete card without movement. It was not considered that the averages obtained from any number of lines short of the full number was practicable for the following reasons. Investigation of the records obtained reveals that although there is a tendency for the eye movements to show a consistent distribution along each line, which may be taken as typical of the individual's reading habit, certain lines seemed to occasion more difficulty than others. This is reflected in an increase in fixation, regressions or reading time for that line. To accept the average obtained from, say three lines, and apply it to the full text would only be accurate if it could be shown that each line was equivalent in every factor that might affect eye movements. As this equivalence was not present in the test cards used in this study, such interpolation was not considered satisfactory. Theoretically it should be possible to produce a text in which this equivalence between lines is present, but it is doubtful whether, in practice, such a text could be produced in a simple narrative form. One should also bear in mind that the reliability of the measures obtained increases with the length of the passage read, so that it is unlikely that such a procedure would result in increased accuracy.

It should also be noted that it was not possible to allow the child who had spoiled a record to start the test again, since, by virtue of having previously read some part of the card, it was probable that the eye-movements would have been atypical because of the child's tendency to skim the portion of the card previously read. For these reasons no spoilt record was used in the calculation of the norms and no child who had spoiled a record could be included in the sample of children contributing the records. The incidence of spoilt records, due to head movement producing incomplete records, is given in the following table.

Percentage of Spoilt Records for Each Age Group.

AGES	8	9	10	11	12	13
Percentage spoilt	28%	24%	18%	9%	3%	2%

It will be noted that the percentage of spoiled records declines with the increasing reading maturity and muscular control of the children.

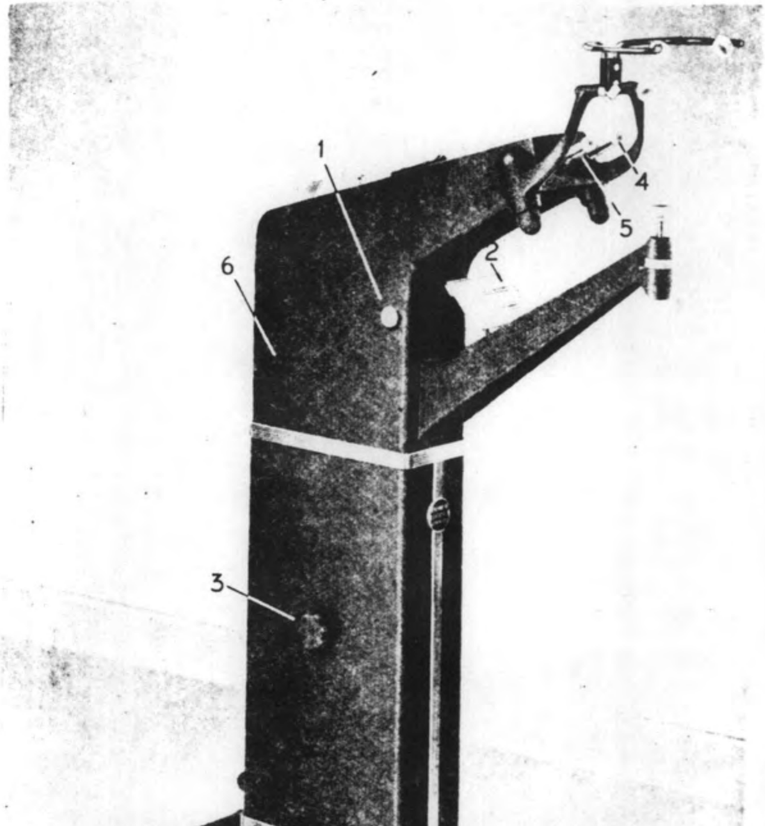
The norms obtained from this study may appear, at first sight, to have such limited applicability as to be unrepresentative. It must be stressed, however, that no satisfactory eye-movement record can be obtained from any child which is capable of being compared with these or any other norms of eye movement, unless the child can read before the camera satisfactorily and can show that he has comprehended the passage read. Thus, it may be claimed that these norms are, in fact, representative of the eye movements of those children who are capable of producing eye-movement records for comparison against these norms.

Description of the Measurement Techniques.

THE INSTRUMENT.

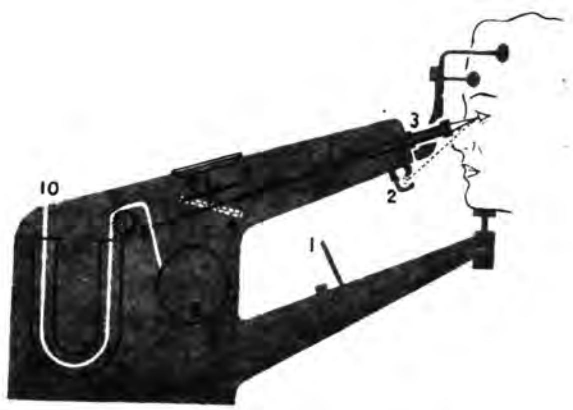
The Ophthalmograph, the instrument used for the photography of the eye movements during this investigation, is a portable binocular eye-movement camera. It is made by the American

plate I



Optical Company and was developed by the combined efforts of the Eastman Kodak Co., and the Bureau of Visual Science. The Camera is capable of photographing the movements of both eyes simultaneously and can be operated in a normally lighted room. (Plate I). Small lights in adjustable shields throw a beam into each eye, the same lights being used to illuminate the passage being read. The cornea reflects the beam into the adjustable lens tubes and these reflections appear as tiny beads of light in the camera reflex-finder. The movement of the light beads corresponds with the movement of the eyes. After the reflex beams have been correctly focussed, the lowering of the cover over the reflex-finder enables the corneal reflexions to be thrown onto the film once the machine is operating. The film is driven by a small synchronous electric motor designed to operate on 110 volt AC, 60 cycle, single phase current and is constructed to maintain constant speed with negligible variation for ordinary changes in line voltage. Testing has shown that the use of this machine with a suitable transformer on 250 volt AC current does not affect the constancy of the speed but the rate of film movement is slower. Under the operating conditions for which the machine was designed the film moves through the camera at a speed of ½ inch per second. Used on 250 volt mains the

plate 2



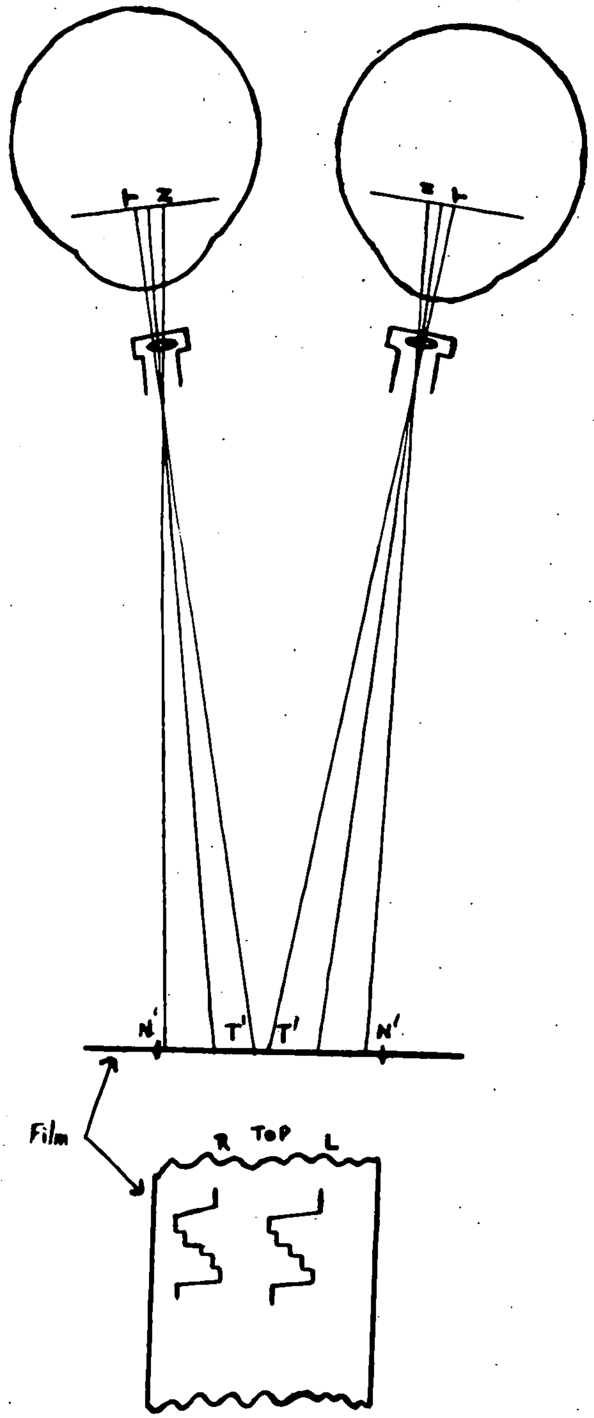
1. Adjustable reading card. 2. Lamp housing. 3. Telescoping lens tube. 4. Mirror in focusing position. 5. Focus point of image on film. 6. Ground glass reflex finder. 7. Mirror position during operation. 8. Film supply chamber. 9. Film developing tank. 10. Developed film exit.

film speed is .327 inches per second. The starting switch for operating the electric motor embodies a two-way control which allows the machine to operate continuously or to cease operation when 18 inches of film has been exposed. Where subjects take longer to read the selection than the 55 secs. running time needed to expose 18 inches of film, the switch is left in the continuous position until the subject is nearing the end of his reading. Throwing the switch to the intermittent position then causes the machine to complete its cycle and switch off automatically. Identification of each film strip is made possible by inserting, in a special slide in the camera, an index card on which has been printed the name of the subject. This is automatically photographed onto the film strip.

ILLUSTRATION OF THE PHOTOGRAPHIC PRINCIPAL OF THE OPHTHALMOGRAPH (Plate 2).

The light from the lamp (2) strikes the cornea of the subject's eye. The reflection of this light is intercepted by the lens in the lens tube (3) and reflected from mirror (4) to reflex-finder (6) where the light rays of the two corneas can be observed and brought into focus. When the hinge cover of the reflex-finder is closed and the motor control switched on, the mirror automatically swings out of

plate 3

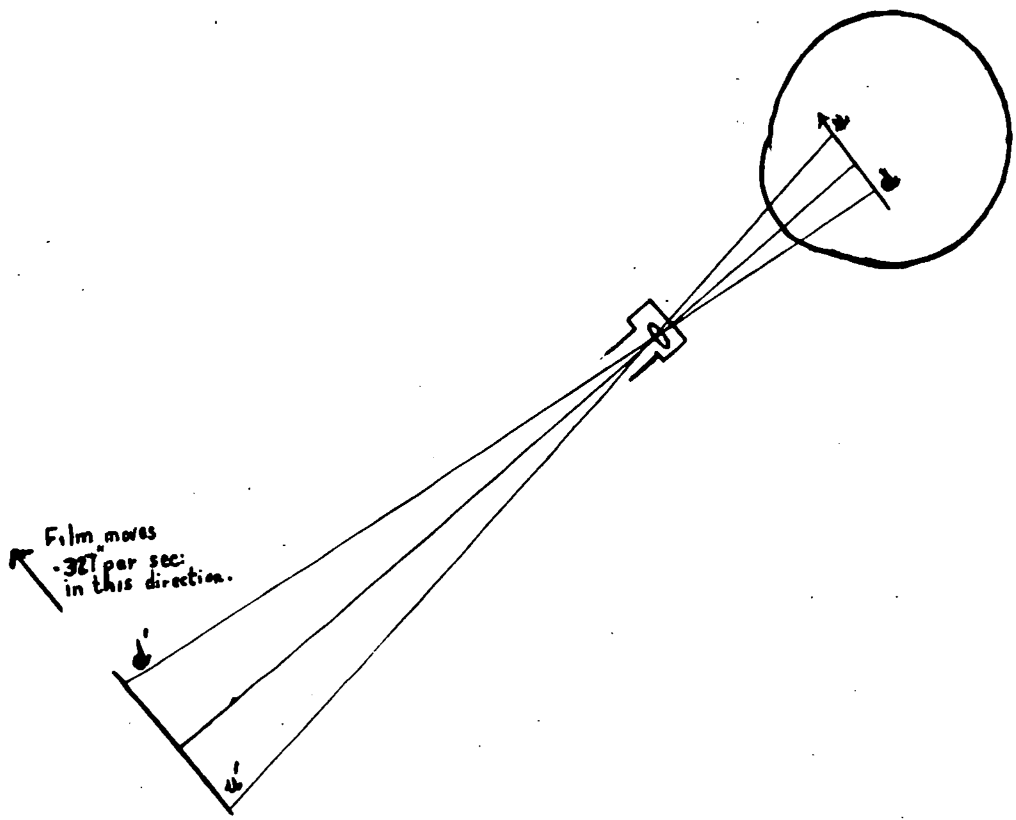


position and allows the light rays to be focussed onto the surface of the film.

The film in the camera travels upward at the constant speed of .327 inches per second with the emulsion side towards the subject. The focussing for the reflex images by means of the telescopes and finder is done in such a way that the reflex from the subject's left cornea appears on the right side of the view finder (right side of operator who is facing subject) and vice versa, the reflex from the subjects right cornea appears on the left side of the finder. It is from this setting of the focussed corneal reflexes that the recording on the film is made.

Plate 3 illustrates the plan of eye-movement photography. From this diagram it is obvious that when the eyes turn to the right, the focussed corneal reflexes, on the emulsion side of the film, move in an opposite direction, i.e. to the left. When the eyes are rotated to the left the focused corneal reflexes move to the right. In order to understand the record on the film strip and to make the recordings comparable to our own eye movements, the developed film is held with the first line on top and emulsion side away from the observer. Under these conditions the right stairway of the film strip (right side of the observer) will picture the movements of the left eye of the subject and the left

plate 4

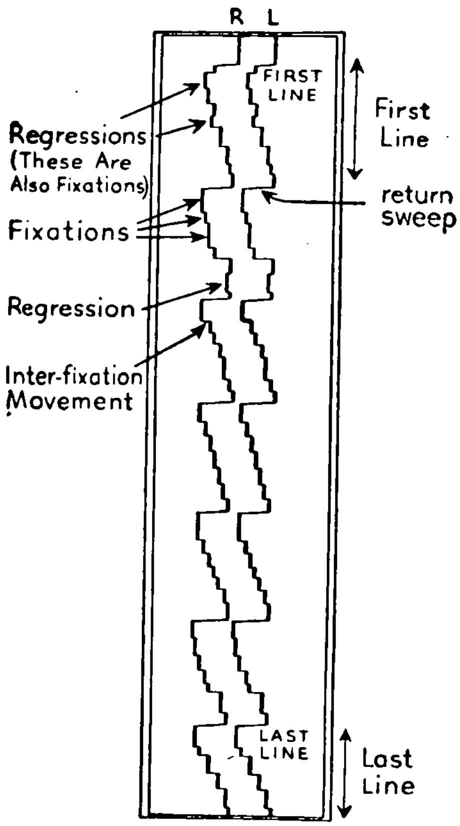


stairway (left side of observer) will depict the movements of the right eye of the subject in the correct sequence of the lines on the test card.

Plate 4 represents a diagramatic elevation of the photographic arrangement. From this plan it is evident that when the eye movement is upwards it will be recorded on the film in an opposite direction. A downward movement of the eye will be recorded in an upward direction on the film strip because the eyes usually move faster than the film. At this point it is necessary to remember that the film is moving in an upward direction past the recording space at a constant speed. Combining these two motions, film and eye, it is clear that an eye adjustment downwards will shorten the vertical fixation line, while an upward eye movement will lengthen the vertical line.

Plate 5 is a diagramatic representation of the reading graph as it appears to the observer when the developed film is held with the first line on top and the emulsion side away from the observer. The lines are then shown in correct sequence and the successive fixations are shown progressing to the right as the eyes move along the line of print. The traces made by the respective eye movements are indicated in the diagram.

plate 5



The Reading Graph

READING CARDS.

The American Optical Co. supply reading cards with the Ophthalmograph. These were not considered suitable for use in the present investigation due to:-

1. National characteristics of the context being unsuitable for British children.
2. The cards were graduated in print, material and length for different grade levels.
3. The length of material was too short to be used for both establishing norms and individual diagnostic purposes.

New cards had therefore to be prepared for the present investigation. In order that the readihg passage might be made as long as possible, a card 5 inches by 3 1/10 inches was used, this being the maximum size card which could be used with this instrument. This card permitted the printing of 14 lines of 14 point Times Roman lower case type with one point of leading. Length of line was 112 mms. Prior investigation had shown that 14 point type was read by all the age groups tested in this investigation and it was considered that changes in eye-movement records due to differing typography should be eliminated by using one print size for all ages.

For similar reasons it was considered inadvisable to have different contextual material for the various age levels as prior investigation had shown that eye movements may be altered by differing materials, length of meaningful units, and interest of material. Since it would have been unlikely that different texts could be devised for the different age levels which would be exactly parallel in all these respects, it was considered preferable to have one text to be read by all groups. The piece selected is an amended version of a passage from "Claudius the Bee" by J.F. Leeming, a fairy story for children with underlying satirical observation on human behaviour.

SAMPLING.

The records of 300 children attending schools in Durham County were used, there being 50 children in each of the age groups from 8 to 13 years inclusive. Every child tested was required to read the Burt graded Vocabulary Scale to their chronological age level before being accepted for testing. They were then required to read Card 2, containing instructions concerning the test, while sitting before the camera under normal operating conditions. At the conclusion of the reading, comprehension was tested. In order to pass the comprehension test which was not quantitatively scored, the children had either to repeat the salient features of what they had read, or to answer correctly four out of six questions upon the material they had read. Any child unable to pass the comprehension test on the practice card, or the test card, was not included. The test of comprehension ensured that the photographs obtained would not include records of children who had skimmed the card.

It was decided that no more than 10 pupils in each age range should be drawn from any one school. Pupils in each school where selected from those available by taking every fourth child in the register until the required number of children had been obtained from that school. Owing to spoiled records the number of children actually tested to obtain 10 records varied from school to school. This procedure was followed in every school with the exception that in the final school, where the children comprised the last 10 of the 50 children tested in any age group, selection was on age in order to bring the average age for each group to the mid year level, i.e. 9 yrs. 6 months, 10 yrs. 6 months etc. Ages of the children were calculated to the nearest complete month at the date of testing and photographing. The assumption was made that in the 8 to 10 year groups tested, there would be the normal percentage of Grammar School children. It was therefore necessary to ensure that an equal percentage of these children should be included in the 11 to 13 year groups. As the percentage of Grammar School provision in the county at this period was approximately 20%, ten children in the later age groups were taken from Grammar Schools.

PROCEDURE.

Every child tested was required to read the Burt Vocabulary Test and only those children who were able to read to their chronological age level were accepted for eye photography. All children who succeeded in reading to this level were then seen individually in a separate room, and the following procedure was adopted:-

1. The child was shown the camera and told that it was an instrument for photographing the eyes whilst reading. The need for remaining still and avoiding head movements was stressed and it was explained that the chin rest, brow pads and head clamps were to assist them to keep still.
2. The child then sat in position before the camera and was told that the first card to be read was for practice.
3. The child was then told "Read the card silently, read it only once and close your eyes when you have finished reading. Read it so that afterwards you can tell me about what you have read".

4. The child then read the card under normal operating conditions, with the exception that the film-drive motor was not switched on.

5. On completion of the reading the child gave an account of what had been read, or if unable to do this, was required to answer correctly four of the following questions.

(a) What does it tell you about your head?

(b) What do you do if you feel uncomfortable?

(c) How should you read the card?

(d) Why should you read it carefully?

(e) What do you do when you have finished reading?

Children who passed satisfactorily this practice portion of the test then continued to the next part as follows:-

1. The focusing card was placed in position.

2. The child was told "Underneath this card is the one you are to read. It is a bee speaking, telling you something of the way they live".

3. The child then resumed the reading position before the camera and was told "Keep very still and look at the "X" on the card".

4. The reflexes were then focused.

5. The child was told "Keep you head still, read silently, close your eyes when you have finished".

6. The camera motor was then started, the focusing card lowered and the child commenced reading.

7. On completion of the reading, the child gave an account of what he had read, or if unable to do so was required to answer correctly four of the following questions.

(a) Do bees like light or gloomy homes?

(b) How do bees get their light?

(c) For how long do the worms glow at one time?

(d) Do the glow-worms like helping the bees?

(e) What do the glow-worms receive in return for their help?

(f) What does the bee say about the houses of human beings?

The record of any child whose comprehension of the passage read did not meet the required standard was rejected.

The cards mentioned in the above procedure will be found in Appendix A.

Card 1 .... The focusing card.

Card 2 .... The practice card.

Card 3 .... The test passage.

CHAPTER 4.

RESULTS.

The full tabulation of results will be found in Appendix B.

The means of the eye-movement measures for each age group are tabulated below, together with the highest and lowest score in each year group and also the range. All measures are for twelve lines of reading.

Means and Ranges of Eye-Movement Measures for Each Age Group.

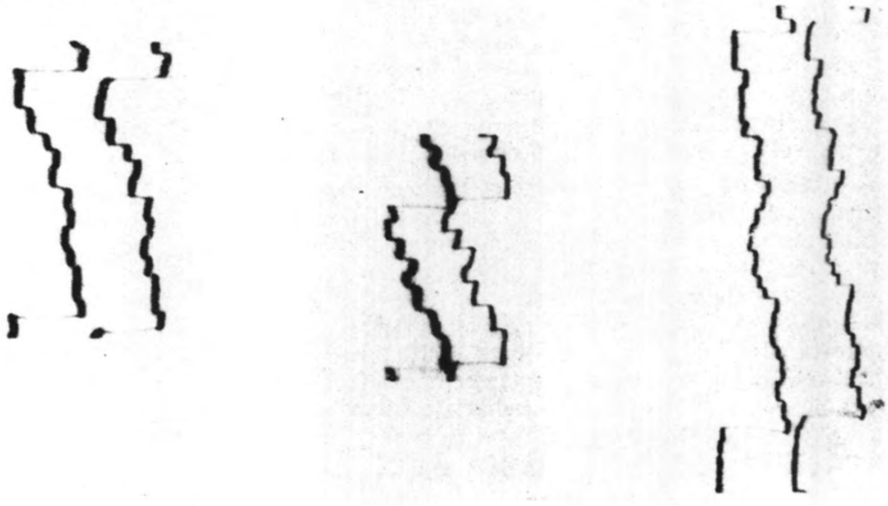
	Fixations				Regressions				Length			
Age	Average	Lowest	Highest	Range	Average	Lowest	Highest	Range	Average	Lowest	Highest	Range
8	173.4	94	250	156	40.9	11	75	64	18.3"	6.85"	29.1"	22.25"
9	165.8	114	255	141	44.1	14	98	84	15.1"	8.55"	28.5"	19.9"
10	145.9	85	255	170	37.1	12	103	91	13.11"	7.75"	25.85"	18.1"
11	145.1	86	199	113	34.8	11	67	56	13.3"	7.2"	21.1"	13.9"
12	135	99	196	97	30.8	7	61	54	12.4"	8.6"	20.5"	11.9"
13	135.1	91	178	87	30.6	14	54	40	11.5"	8.25"	16.7"	8.45"

plate 6

DIAGRAM I
10 YEAR AVERAGE

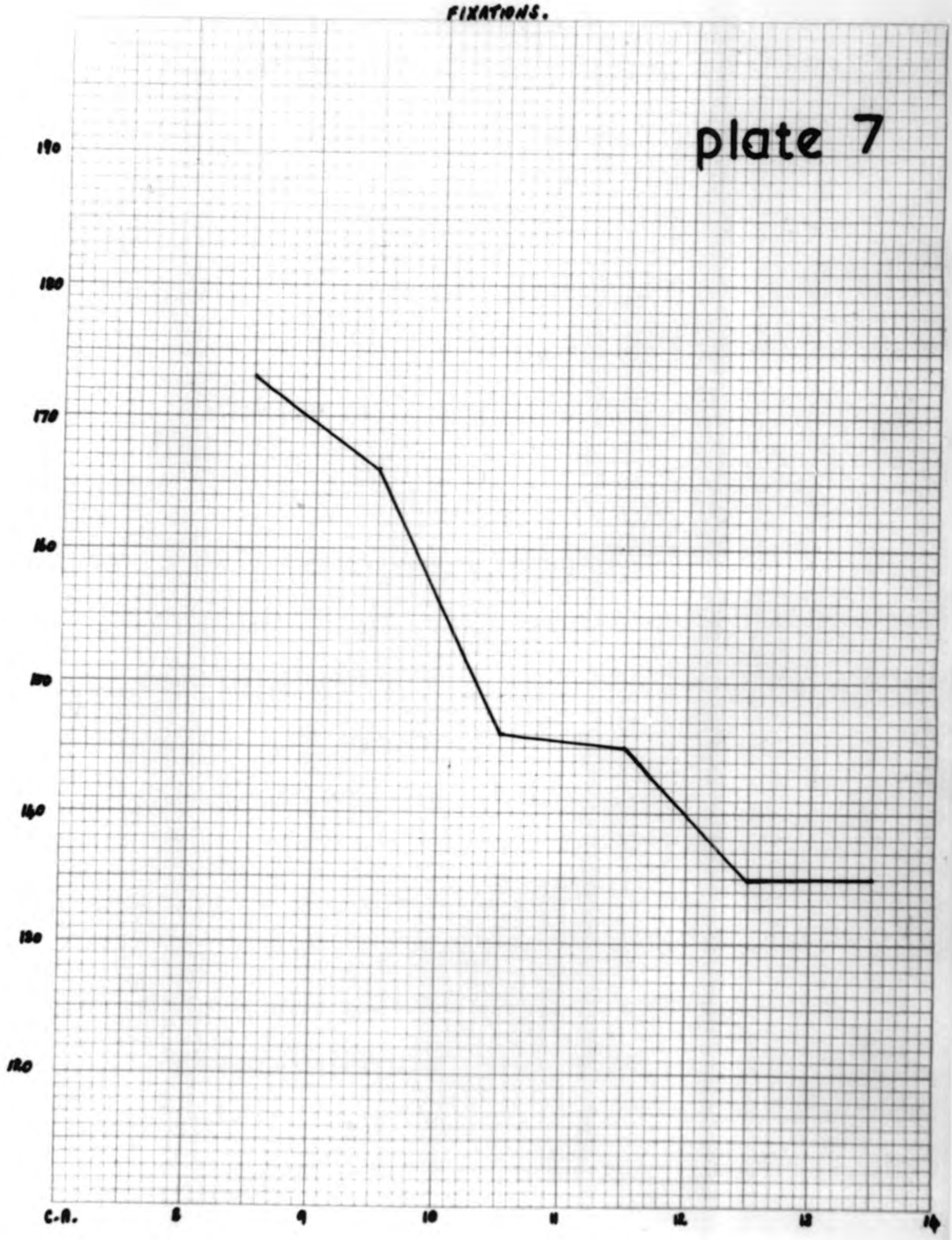
DIAGRAM II
BEST

DIAGRAM III
WORST



The Graphs on Plates, 7, 8, 9 and 10 show the averages for each eye measure for all the age groups. It will be observed that with the increasing maturity of the reader the anticipated decrease in the number of fixations, regressions and reading time (here expressed as the length of film) does occur. There is a cessation of improvement in respect of fixations and regressions at the twelfth year.

For purposes of illustration, a copy of the film records is given in Plate 6. Diagram 1 shows the eye-movement trace made by a ten year old child whose eye-movement score was the same as the average for the 10 year group. Diagram 2 shows the eye-movement trace made by the best reader in that group. Diagram 3 shows the eye-movement trace made by the worst reader in that group. On Plate 11 is shown, for purposes of comparison, the fixations and regressions made by 10 year old children. Slanting lines denote regressions and vertical lines denote fixations. The top section shows the fixations and regressions made by a child whose score for these measures falls at the average for the 10 year group. The second section shows the fixations and regressions made by the 10 year reader with the lowest score in these measures, i.e., the best reader. The bottom section indicates the fixations and regressions made by the ten year reader with the highest score in these measures, i.e. the worst reader.


FIXATIONS.
plate 7
190
180
170
160
150
140
130
120
C.A.
8
9
10
11
12
13
14

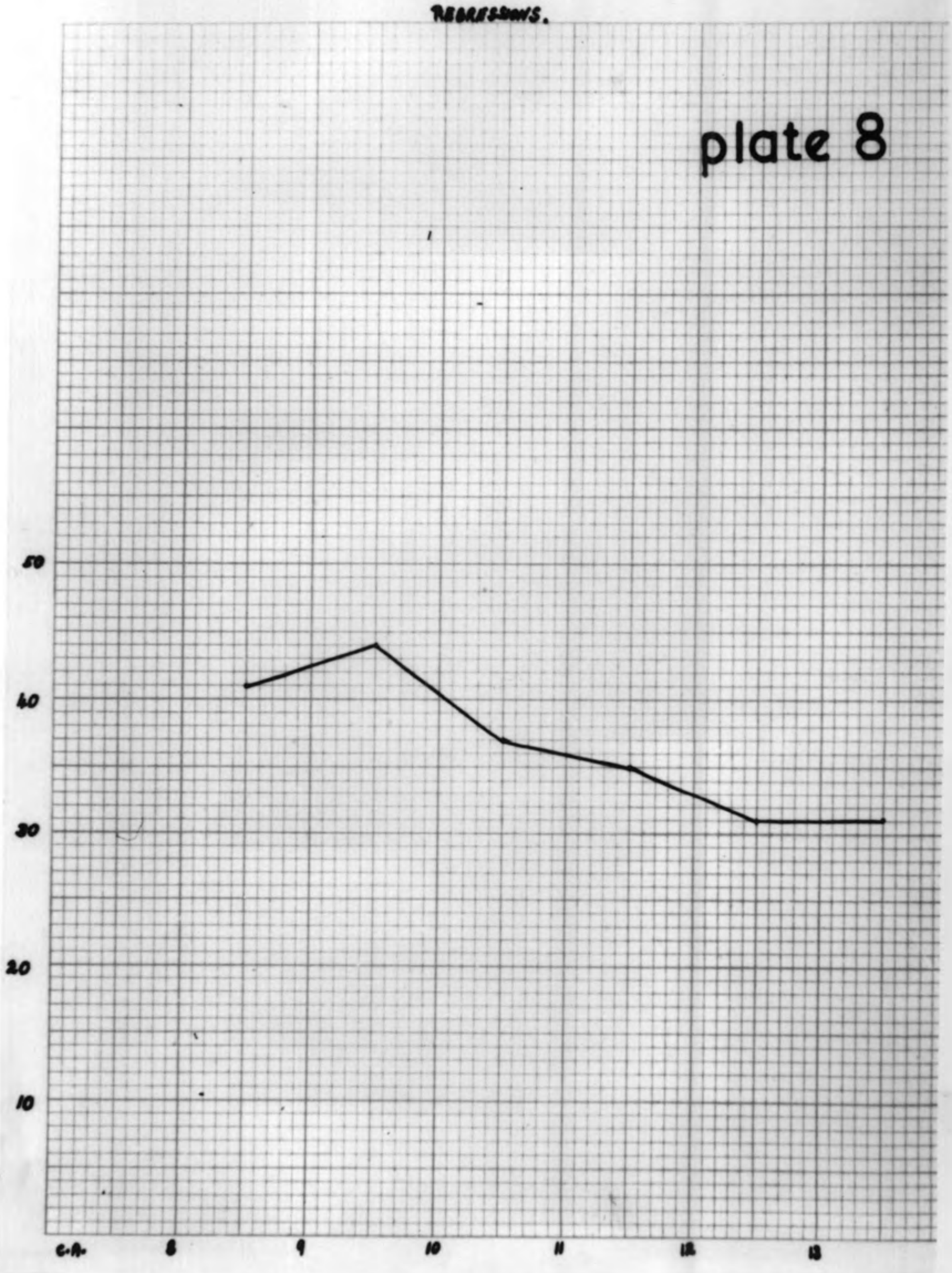
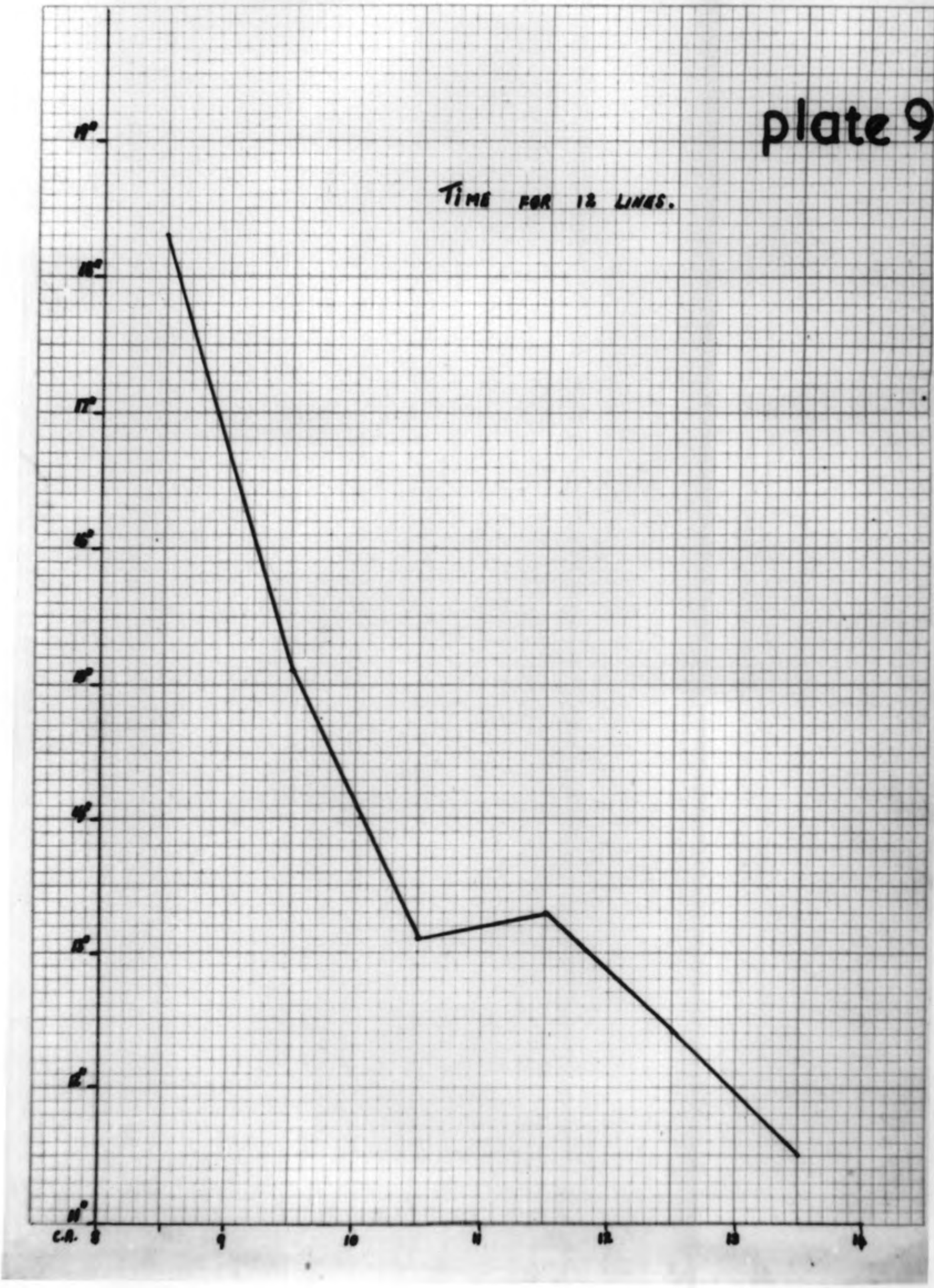

REGRESSIONS.
plate 8
50
40
30
20
10
C.A.
8
9
10
11
12
13

plate 9



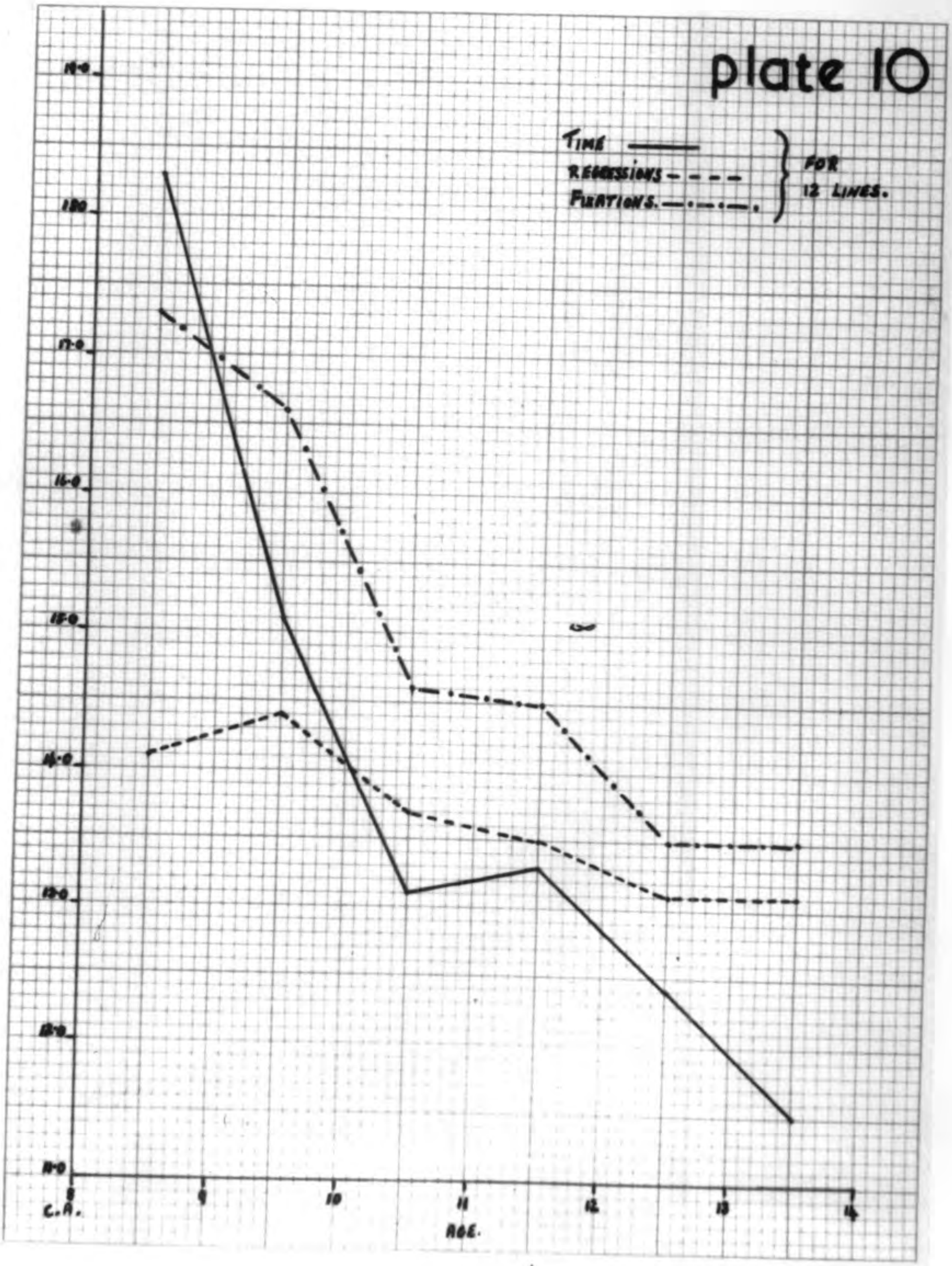


plate 10
TIME
REGRESSIONS
FIXATIONS
FOR 12 LINES.
19·0
18·0
17·0
16·0
15·0
14·0
13·0
12·0
11·0
8
9
10
11
12
13
14
C.A.
AGE.

This example illustrates the wide variation in eye movements which exist among children of the same age. This is even more surprising when it is found among children of 10 years of age with the same basal reading level; and further, when it is realised that this passage is well within the capacity of every child capable of reading, with comprehension, to a basal 10 year level.

The average results given in the foregoing section may not be considered sufficiently discriminatory owing to the fact that although the children are of the same chronological age and of the same basal reading level within each group, they have varying reading ages. This difference in reading ages among children of the same chronological age group arose because it was found that few children who could read to the same level as their chronological age were unable to continue reading some of the words in the higher age levels of the test.

As the standard form of administering the Burt Graded Reading Vocabulary was followed in the present study, a reading age for each of the children tested was obtained. It is therefore possible to rearrange the data obtained to give averages for fixations, regressions and reading time for every reading age within each chronological age group. Results tabulated in this manner are given in Table 1.

plate II

Card IV

We feel that lots of light helps to make happy bees. Gloom of any kind we do not like. We get our light in a very simple way. Those tubes which you can see are just glow worms. We have large farms of worms attached to each nest, and of course the glow worms are glad to help us. They have all they want, good food, comfort, warmth, and a good home—a far better life than they would have outside. They are trained to go to their place and to glow for an hour at a time. You will see them coming out of the farms to go on duty. The bees live in those houses. We feel that bees living in nice homes are gentle bees. Now I often ask why you humans let people put up ugly homes. It must be bad for one to live with ugly things.

TABLE 1.

Averages of eye movement measures tabulated according to the reading age of children within each of the year groups measured.

C.A.	8	9	10	11	12	13	Total Average
Aver.R.A.	8.7						8.7
Cases	8						8
Fixations	181.6						181.6
Regressions	43.9						43.9
Time	21.4						21.4
Aver.R.A.	9.3	9.7					9.5
Cases	11	6					17
Fixations	170.7	171.3					170.9
Regressions	39.5	46.5					42
Time	17.5	16.4					17.1
Aver.R.A.	10.5	10.3	10.4				10.4
Cases	13	12	8				33
Fixations	183.3	167.6	177.5				176.2
Regressions	44.3	41.2	53.4				45.4
Time	18.5	16	15.9				17
Aver.R.A.	11.2	11.4	11.4	11.3			11.3
Cases	14	16	12	14			56
Fixations	164.5	164.2	153.4	156.3			160
Regressions	39.2	44.2	37.7	36.7			39.7
Time	18.2	14.5	13.7	14.7			15.3
Aver.R.A.	12.1	12.4	12.4	12.3	12.7		12.4
Cases	3	11	14	9	15		52
Fixations	178.3	163.6	144.5	144.1	153.7		153
Regressions	50	41	34.5	33.1	38.4		37.6
Time	14.9	13.9	13.3	12.6	14.9		13.9
Aver.R.A.		13.3	13.4	13.4	13.4	13.5	13.4
Cases		5	13	19	22	25	84
Fixations		164.6	122.9	147.8	122.1	132.6	133.7
Regressions		54.2	29.8	37.9	25.6	28.9	31.7
Time		15.4	10.9	13.5	11.1	11.2	11.9
Aver.R.A.	14		14.1	14.2	14.2	14.2	14.1
Cases	1		3	8	13	25	50
Fixations	116		137.3	120	135.6	137.6	133.8
Regressions	14		35.7	25	30.8	32.4	30.6
Time	10.6		11.6	11.	11.8	11.9	11.7

plate 12

AVERAGE FIXATIONS.

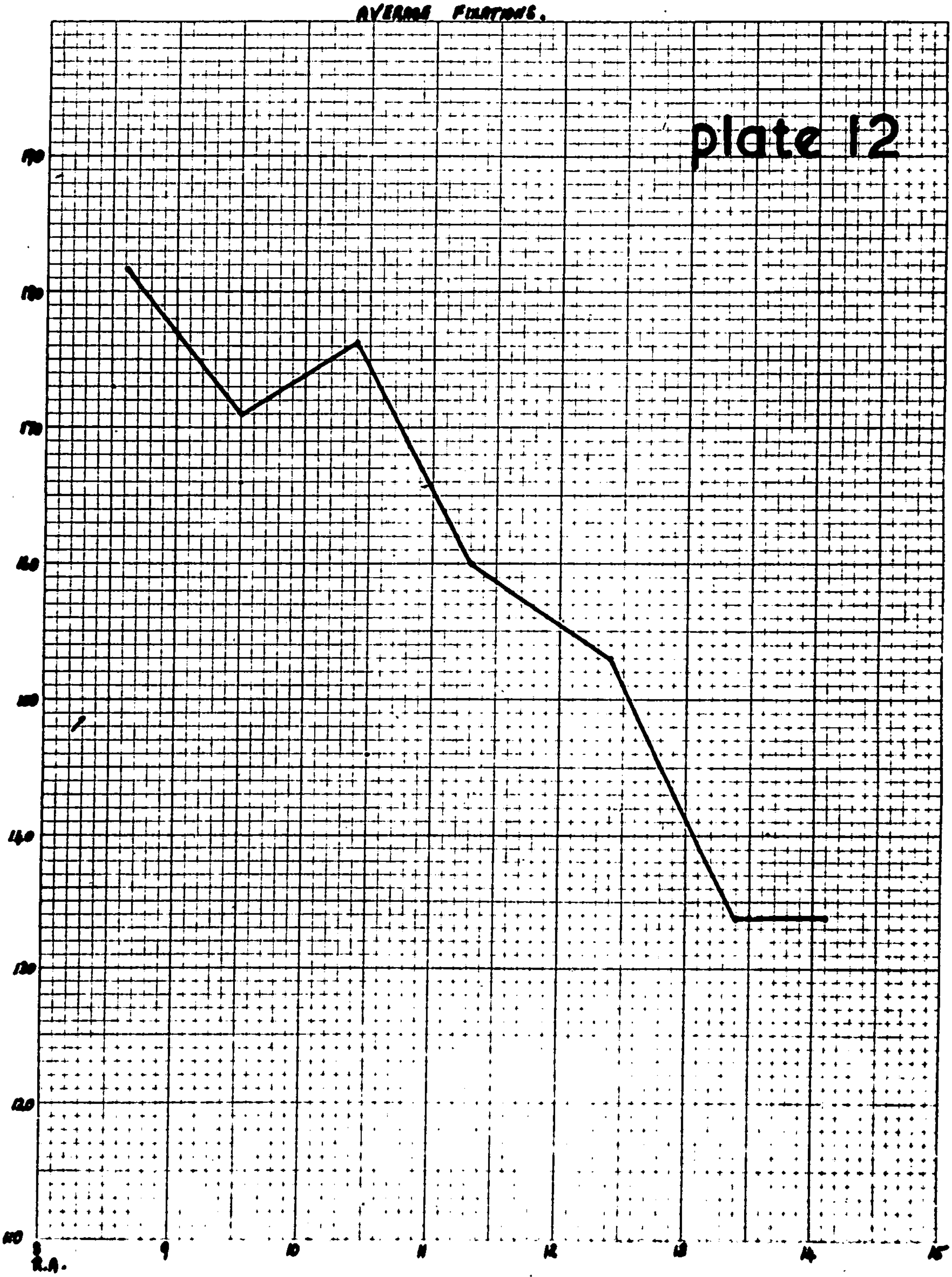
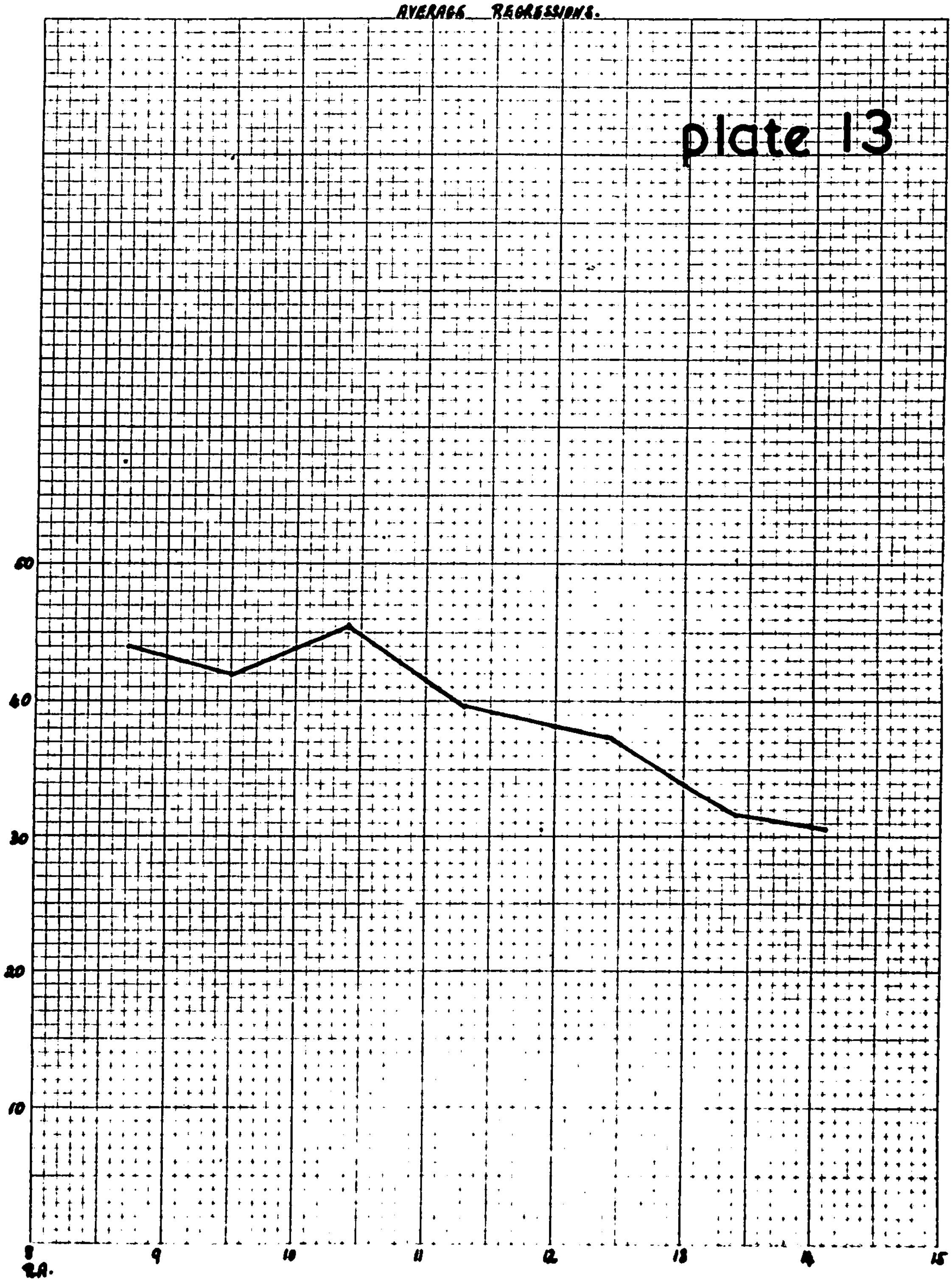


plate 13



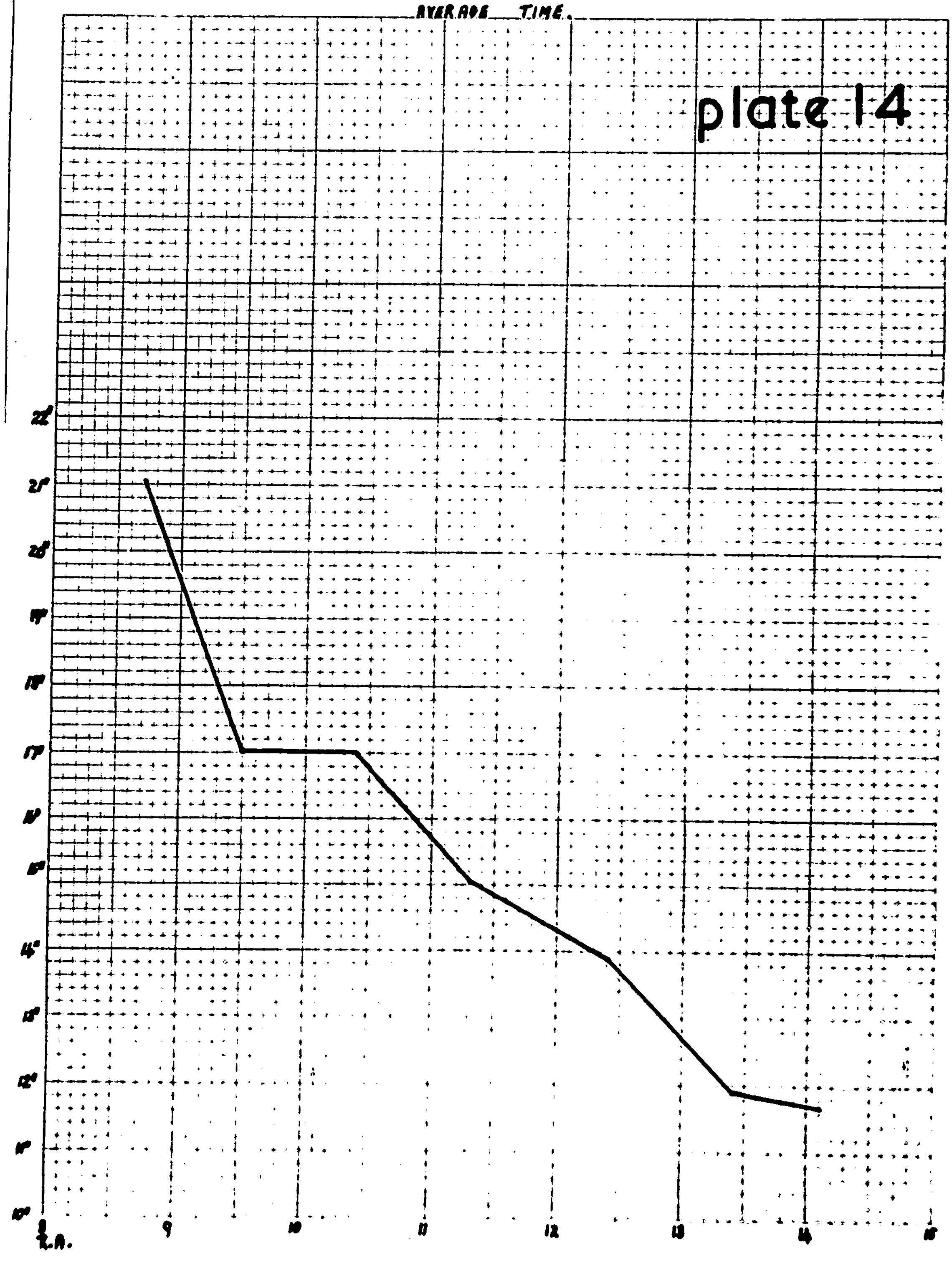
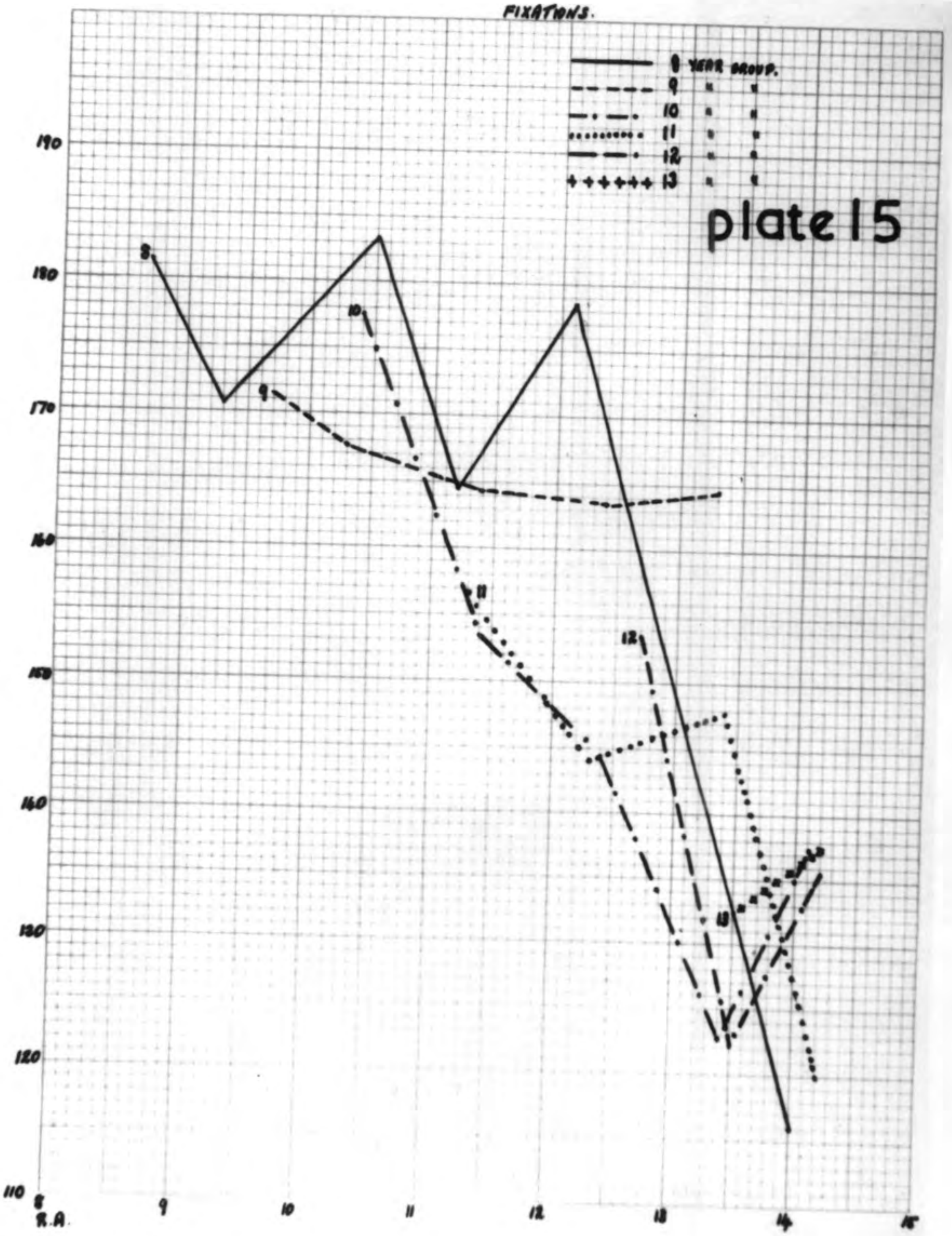

AVERAGE TIME.
22°
21°
20°
19°
18°
17°
16°
15°
14°
13°
12°
11°
10°
8
R.A.
9
10
11
12
13
14
15

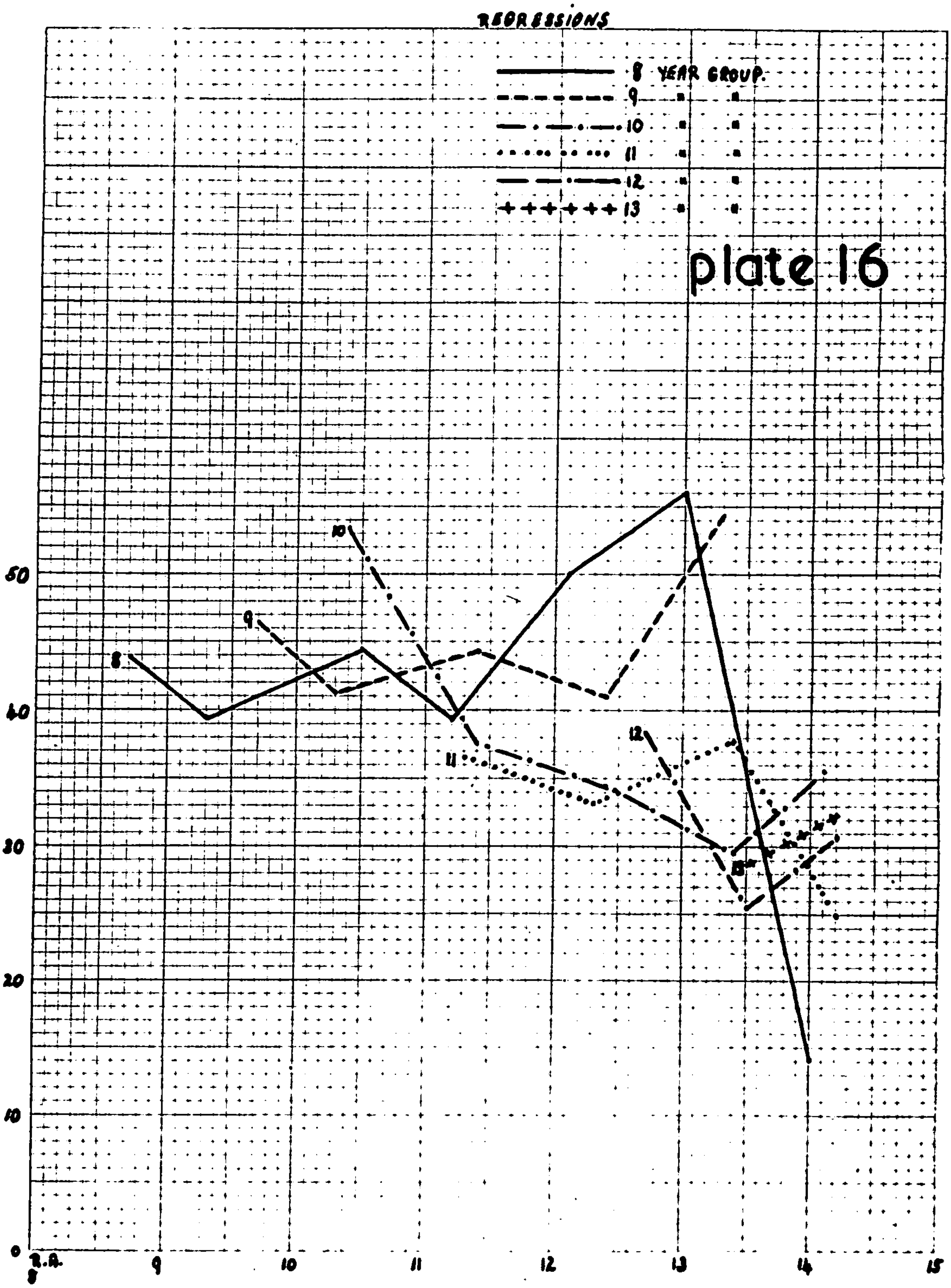
plate 14

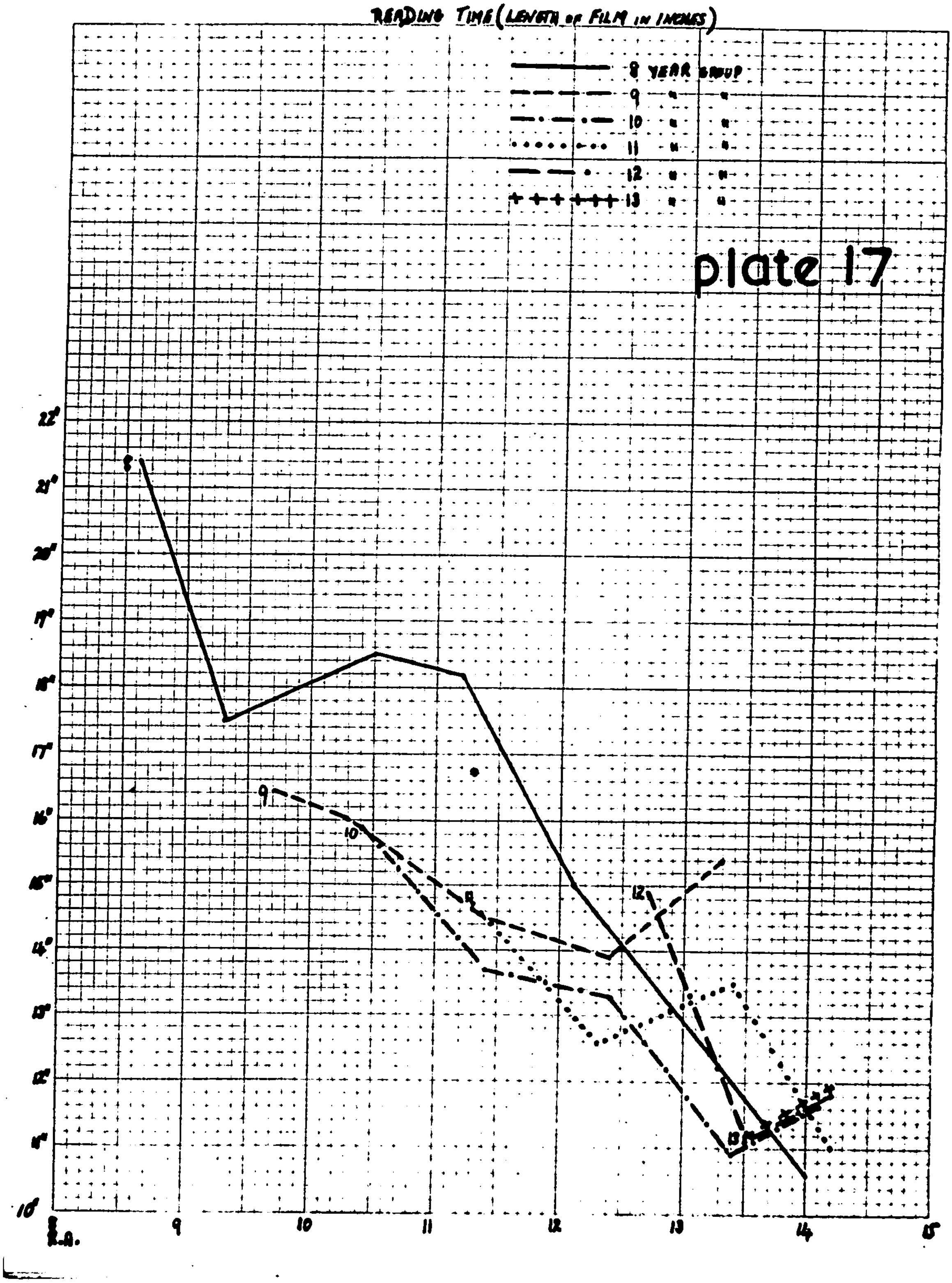
The averages as indicated in the last column of the above Table are plotted graphically on Plates 12, 13 and 14. A study of these last three graphs will indicate that there is a consistent tendency for the fixations, regressions and reading time to decrease with the increasing reading maturity of the individual.

The data tabulated in Table 1 has also been shown in graphical form for each measure on Plates 15, 16 and 17.

As is indicated by Plates 15, 16 and 17 the variation in eye-movement measures between individuals of the same level of reading ability and differing chronological age is very wide. There is also great variation between the eye-movement measures of individuals of the same chronological age but varying levels of reading ability. These results would therefore appear to indicate that there is no consistent relationship between reading ability as measured by the Burt Graded Reading Vocabulary Test and eye-movement measures. Nor can it be assumed from this study that this is due to any varying difficulty for individuals in the ability to comprehend the material read, since the wide variation in measures is equally evident in the 10, 11, 12 and 13 year age groups despite the fact that the level of the material read is well within the scope of all the children in these year groups.


FIXATIONS.
8 YEAR GROUP.
9 " "
10 " "
11 " "
12 " "
13 " "
plate 15
190
180
170
160
150
140
130
120
110
8
R.A.
9
10
11
12
13
14
15


REGRESSIONS
8 YEAR GROUP.
9 " "
10 " "
11 " "
12 " "
13 " "
plate 16
50
40
30
20
10
0
R.A. 8
9
10
11
12
13
14
15



READING TIME (LENGTH OF FILM IN INCHES)
8 YEAR GROUP
9 " "
10 " "
11 " "
12 " "
13 " "
plate 17
22"
21"
20"
19"
18"
17"
16"
15"
14"
13"
12"
11"
10"
8 R.A.
9
10
11
12
13
14
15

For purposes of comparison the eye movements of four teachers and twelve University students were photographed during the course of this study. These adults read the same material as the children under similar operating conditions. The averages obtained are tabulated below.

Means and Ranges of Eye-Movement Measures for Adults

	Fixations				Regressions				Length			
	Average	Lowest	Highest	Range	Average	Lowest	Highest	Range	Average	Lowest	Highest	Range
Adults	106	66	126	60	18.9	5	33	28	8.8"	5.25"	13.55"	8.3"

It will be observed that the averages for fixations, regressions and reading time for the adults tested are below those obtained for the 13 year age groups. It should be noted, however, that these adults are by no means a representative sample of the adult population, since, they may be expected to fall within the high intelligence group and are, in addition, those adults who would be expected to do a large amount of reading in the course of their daily work.

It is therefore particularly striking that the range between the best and the worst of the adult readers remains so large.

Table 2 shows the score for fixations, regressions and reading time of the best and the worst reader for each reading age group within each chronological age group.

TABLE 2.

C.A.	R.A.	FIXATIONS			REGRESSIONS			TIME		
		Best	Worst	Range	Best	Worst	Range	Best	Worst	Range
8	8	140	240	100	28	70	42	12.9	29	16.1
	9	94	218	124	11	74	63	6.8	29.1	22.3
	10	140	231	91	24	70	46	12	24.8	12.8
	11	99	250	151	15	66	51	8.25	28	19.75
	12	144	199	55	26	75	49	11.55	17.55	6
9	9	139	255	116	32	98	66	12.3	28.5	16.2
	10	123	240	117	24	80	56	10	23.7	13.7
	11	114	234	120	28	70	42	8.55	24.8	15.25
	12	116	191	75	14	54	40	10.6	18.45	7.85
	13	128	198	70	42	77	35	10.6	18.65	8.05
10	10	126	255	129	35	103	68	11.35	25.85	14.5
	11	101	213	112	20	57	37	8.5	21.2	12.7
	12	110	188	78	20	56	36	8.2	17.75	9.55
	13	85	154	69	12	44	32	7.75	16	8.25
	14	126	143	17	31	41	10	10	12.6	2.6
11	11	114	183	69	20	54	34	9.9	19.7	9.8
	12	114	177	63	19	48	29	10.3	17.7	7.4
	13	96	199	103	11	67	56	7.2	21.1	13.9
	14	86	171	85	15	42	27	9	13.1	4.1
12	12	108	196	88	17	60	43	10.45	20.5	10.05
	13	103	158	55	7	61	54	8.4	14.3	5.9
	14	99	159	60	18	50	32	7.75	16.2	8.45
13	13	104	155	51	14	52	38	7.65	16.1	8.45
	14	91	178	87	14	54	40	8.35	16.7	8.35
Range		49	62		14	16		4.55	12.3	

It will be observed from Table 2 that the range between the best and the worst reader for fixations for every reading age group in every chronological age group is, with only one exception, greater than the difference between the best reader of eight years old who has a reading age of eight and the best thirteen year old who has a reading age of fourteen. Likewise the range for fixations between the worst reader with a chronological age of eight and a reading age of eight and the worst reader with a chronological age of thirteen and a reading age of fourteen is 62. On the other hand, the range between the best and the worst readers of identical age and identical reading age vary between 151 and 51 with the exception of one group, ten year olds, reading to a reading age of 14 where the range for fixations is 17. In fact, in only five groups out of 24 does the range between readers of equated reading ability and chronological age, appear less than the range between the worst eight year old reader with a reading age of eight and the worst 13 year old reader with a reading age of 14. If the comparison is made between the best readers, then in 23 cases out of 24, the range of fixations between readers of equated ability is greater than the range between the best eight year old reader with a reading age of eight and the best 13 year old reader with a reading age of 14.

Turning to regressions, it will be observed that the range between the best eight year old child reading to a reading age of eight and the best thirteen year old reading to a reading age of 14 is 14. The range between the worst eight year old reading to a reading level of eight and the worst 13 year old reading to a level of 14 is 16. In 23 groups out of 24 these figures are exceeded by the range between the best and the worst readers of equated chronological age and reading ability.

Examining the reading time, a somewhat similar position is found. The range between the best eight year old reading to a reading age of eight and the best thirteen year old reading to a reading age of fourteen is 4.55". This range is exceeded in 22 cases out of 24 by the ranges found between the best and the worst readers of equated chronological age and reading age. The range between the worst reader at the eight year chronological and reading age level and the worst reader at the thirteen year chronological age and 14 year reading age level is 12.3". This is exceeded in 10 cases out of 24 by the range between the best and the worst readers of equated chronological age and reading age. It would, therefore, appear that the evidence given in this table indicates that the difference in eye movements between readers separated by five years of chronological age and five years of reading ability is less than that usually found between the best and the worst readers of similar chronological age and reading level. This is the reverse result from that which would be expected if eye movements were merely symptons of the level of reading ability. In this latter case one would anticipate that the range between the best and worst readers of equated reading ability would be less than that found between readers of different reading levels. The results given in Table 2 would indicate that the ability of individuals, despite satisfactory comprehension of the material they read, to acquire efficient eye movements without specific training directed to that end, is very different. This difference in ability to acquire correct eye movements may be expected to cause a wider range of eye movements between individuals of equated reading ability than is found between those individuals who have similar ability to acquire efficient eye movements without training and yet are separated by five years in reading ability. All these facts point to the conclusion that correct eye movements are not automatically acquired and that there is a need to ascertain whether this varying ability to acquire efficient eye movements is a factor of the individual's personality and further to establish how far within the limits imposed by the personality these aspects of the reading process are amenable to training by techniques designed specifically for their improvement.

CHAPTER 5.

INTERPRETATION AND DISCUSSION OF RESULTS.

The anticipated decrease in the number of fixations, regressions and reading time (expressed as length of film) with the increasing maturity of the reader is found in this investigation. There is a cessation of improvement in respect of fixations and regressions at the twelfth year. Whether this is, in fact, a temporary plateau or represents the normal adult level of reading attainment will require further investigation. This question is not settled by the fact that the adult results given in this study are lower than those indicated on the graph by this plateau, since, in this case the University students and teachers tested cannot be considered a representative sample of the adult population. Buswell (8) has indicated that the normal adult stage of reading is reached by American children at the fifth grade level (at 11 years of age). In the present study the speed of reading has not ceased to improve at the thirteen year level. It should not be concluded from this that English children are slower in reaching reading maturity since such results will depend upon the difficulty of the passage read. Even the use of the same passage as read by the

American children would not necessarily produce comparable results as familiarity with the subject matter, national idiom and expression, might render the text more difficult for one group of the children. The improvements shown in the graphs are those which occur even when no specific training is given to the subjects in order to increase their reading speed. The photographic record obtained is a permanent record, not only of the reading speed of the subject, but also reveals the reading habits of the individual with regard to fixations and regressions.

The eye movement camera is an expensive addition to a reading clinic and the developing of the film will add to the expense of each case. It may fairly be asked therefore, whether the possibilities of improvement in reading ability, as a result of using this apparatus, will warrant the expense involved. Despite the high correlation of the photographic record with speed of reading tests, and satisfactory reliability, it does not appear that a process as lengthy or as expensive as eye-movement photography would be justifiable as a clinical tool if its only value were as an alternative to a quickly administered speed of reading test. Any evaluation of the eye-movement photography technique must depend in the last resort upon any evidence which will help to settle the question as to whether eye movements are merely the symptoms of reading maturity which is itself governed by word recognition and comprehension ability.

It has been suggested by Vernon (56) that eye movements, even with equivalence of comprehension ability, may be a reflection of an individual's personality, and that it is a personality characteristic to read either with a large number of quick fixations or a smaller number of long fixations. Even if this were accepted, it would still be possible for the number of fixations, regressions and total reading time to be far in excess of that required for adequate reading. The work of O'Brien in training pupils to read with greater speed showed an average decrease for number of fixations per line of nearly 25% and his results indicate that all the 401 subjects tested showed some reduction in eye movements. This would show that the personality factor even if it is associated with some type of reading habit, does not ensure that an individual's reading procedure is the most efficient possible within the limits imposed by the personality type.

Consideration of the results contained in this study would appear to confirm such a hypothesis. It can be observed in the Table on Page 88 that the range for fixations at year eight is 156 and that with the exception of year ten there is a gradual reduction in the range of fixations until the year thirteen when the figure is 87. As these figures are obtained for twelve lines, this means that at the 13 year level the worst reader needs just over seven fixations per line more than the best reader, to read identical material. The wide variation within each age group for fixations, regressions and reading time might be no more than an indication of the wide differences in reading ability found amongst readers of the same chronological age. In Table 2, however, the groups are divided not only into chronological age groups but are further sub-divided into reading age groups. Once again we find that readers equated both for reading ability and chronological age show such variation that the difference between the best and the worst readers is almost invariably greater than between readers of widely differing reading ability. These results suggest that the varying ability of individuals to develop efficient eye movements without specific training for this purpose is a greater cause of variation in eye movements than is reading ability. Acceptance of these facts would indicate the need for eye-training procedures at some stage in the reading programme. Recognition of this need would establish the use of the eye-movement camera as a necessary clinical tool for the diagnosis of faulty eye movements.

LINES OF FUTURE INVESTIGATION.

Before the hypothesis as to the amount of improvement rendered possible by measures which reduced the number of fixations could be accepted, the relative stability of the personal factor known as duration of fixation would have to be established. If the stability of the duration of fixation can be established it should be possible to investigate some of the possible determinants of its length for any one individual. It will be pertinent to establish whether or not it is connected with intelligence or some perceptual element which bears no relationship to the individuals ability as measured by intelligence tests. In the present study no attempt was made to discover the relationship between the intelligence of the pupils and the eye measures obtained from them. It may be found that the fixations or frequency of regressions or reading time is related to the intellectual level of the child. It will also be necessary to establish at which period of the reading programme training directed specifically to improving eye movements can be introduced without impairing other developing aspects of the reading process. When these investigations have been undertaken it will be far easier to establish the value of eye-movement photography. If we accept eye movements as causal factors in reading difficulty then this technique is a valuable method for diagnosis and a means of checking remedial treatment. The present norms were achieved by children of the same chronoligical age who were also capable of reading to the same minimum level appropriate to their age. It is hoped that the use of the same text for each age group will have eliminated variation which could be attributed to typographical factors, and length of meaningful phrases, which have been shown to cause variations in the measures used. Accordingly these norms should be suitable for further investigation of the questions raised here.

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LOOK AT THE CROSS IN THE CENTRE OF THIS CARD

X

This is a test piece to get you used to reading in front of the camera. You will see that it is not hard. Try not to move your head whilst you are reading. Read the cards with care, as when you have finished, you will be asked questions on what you have read. This is to make sure that you have read it properly. If you feel awkward or uncomfortable let me know as I want to be sure that you feel quite at ease before you read the next card. Start reading the next card as soon as it is shown to you and when you have read it close your eyes and keep them closed until told to open them again. Do not forget read carefully, close your eyes when you have finished and try hard not to move your head.

We feel that lots of light helps to make happy bees. Gloom of any kind we do not like. We get our light in a very simple way. Those tubes which you can see are just glow worms. We have large farms of worms attached to each nest, and of course the glow worms are glad to help us. They have all they want, good food, comfort, warmth, and a good home—a far better life than they would have outside. They are trained to go to their place and to glow for an hour at a time. You will see them coming out of the farms to go on duty. The bees live in those houses. We feel that bees living in nice homes are gentle bees. Now I often ask why you humans let people put up ugly homes. It must be bad for one to live with ugly things.

APPENDIX B.

AGE GROUP FOR 12 LINES.

AGE GROUP	NAME	FIXATIONS	REGRESSIONS	TIME
8 9/12	J.B.	182	27	22.55
9/12	R.L.	219	70	24.8
4/12	J.W.	147	32	14.2
11/12	C.A.	116	14	10.6
4/12	I.B.	196	37	28.3
9/12	J.B.	218	52	24.75
5/12	D.H.	164	31	13.25
3/12	A.F.	182	49	21.35
8/12	N.T.	173	37	18.
8/12	J.McL.	195	40	25.6
8/12	M.M.	213	46	29.1
11/12	D.B.	199	49	17.5
6/12	M.L.	199	46	18.9
6/12	P.J.	230	69	18.6
11/12	J.H.	250	66	37.9
6/12	J.W.	174	40	17.3
11/12	M.T.	142	28	13.55
4/12	G.L.	237	53	28.
3/12	D.J.	181	29	14.45

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{7}{12}$ W.M.	160	46	19.7
$\frac{11}{12}$ P.B.	144	26	11.55
$\frac{5}{12}$ D.R.	161	53	17.8
$\frac{11}{12}$ D.B.	211	74	17.95
$\frac{1}{12}$ G.Y.	240	70	27.3
$\frac{11}{12}$ A.E.	176	29	15.65
$\frac{7}{12}$ E.W.	149	38	13.65
$\frac{11}{12}$ S.B.	136	26	16.0
$\frac{1}{12}$ A.H.	94	21	6.85
$\frac{6}{12}$ J.J.	124	28	14.85
$\frac{5}{12}$ C.P.	137	33	12.8
$\frac{9}{12}$ B.B.	134	11	13.0
$\frac{9}{12}$ A.P.	140	41	12.9
$\frac{8}{12}$ P.W.	192	75	15.75
$\frac{6}{12}$ N.G.	142	37	13.8
$\frac{8}{12}$ M.B.	145	24	13.75
8 I.F.	99	15	8.25
$\frac{8}{12}$ J.L.	169	43	21.15
$\frac{2}{12}$ M.T.	182	45	20.4
$\frac{4}{12}$ A.H.	138	26	12.3

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{1}{12}$ V.A.	149	19	14.
$\frac{5}{12}$ I.P.	236	53	27.75
$\frac{4}{12}$ S.M.	196	47	28.4
$\frac{8}{12}$ T.H.	140	28	12.
8 B.C.	177	38	16.9
$\frac{1}{12}$ G.J.	149	44	14
$\frac{2}{12}$ A.E.	231	68	23.9
$\frac{5}{12}$ E.S.	188	45	17.85
8 L.W.	180	49	14.65
$\frac{1}{12}$ C.A.	214	44	29
$\frac{10}{12}$ D.R.	118	34	10.55
303	8668	2045	913.1

Av: Age $8\frac{6}{12}$

Av: Fix. 173.4

Av: Reg. 40.9

Av: Time 18.262"

AGE GROUP FOR 12 LINES.

NAME	FIXATIONS	REGRESSIONS	TIME
9 $\frac{1}{12}$ J.M.	141	27	10.6"
$\frac{10}{12}$ D.M.	188	54	16.05"
$\frac{8}{12}$ R.W.	208	51	23.7"
$\frac{7}{12}$ C.P.	191	54	11.65
$\frac{6}{12}$ E.C.	240	80	23.45
$\frac{5}{12}$ D.C.	169	48	12.75
$\frac{4}{12}$ S.V.	157	40	13.25
$\frac{3}{12}$ E.J.	155	45	11.2
$\frac{9}{12}$ N.H.	140	36	12.3
$\frac{10}{12}$ N.H.	154	33	8.55
$\frac{6}{12}$ L.L.	255	98	28.5
$\frac{1}{12}$ F.R.	230	52	18.9
$\frac{2}{12}$ M.T.	180	37	14.6
$\frac{5}{12}$ D.McW.	164	36	16.9
$\frac{6}{12}$ D.T.	183	46	18.45
$\frac{10}{12}$ D.W.	170	43	18.3
$\frac{8}{12}$ E.L.	186	43	15.5
$\frac{11}{12}$ J.D.	139	32	12.9
$\frac{1}{12}$ E.E.	114	33	8.85

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{2}{12}$ N.C.	161	30	16.9
$\frac{2}{12}$ S.R.	162	44	15.9
$\frac{9}{12}$ J.M.	146	40	15.75
$\frac{9}{12}$ M.W.	131	37	13.05
$\frac{3}{12}$ W.J.	183	47	13.8
$\frac{11}{12}$ M.M.	121	28	11.7
$\frac{6}{12}$ J.A.	170	36	14.4
$\frac{11}{12}$ P.O.	178	46	18.65
$\frac{11}{12}$ M.L.	163	54	12.05
$\frac{9}{12}$ V.A.	163	29	19.05
$\frac{7}{12}$ D.E.	177	46	18.05
$\frac{11}{12}$ Y.B.	153	51	12.6
$\frac{5}{12}$ J.T.	133	37	11.5
$\frac{11}{12}$ M.B.	116	14	12.5
$\frac{8}{12}$ R.E.	127	31	10.
$\frac{6}{12}$ M.P.	164	41	15.6
$\frac{8}{12}$ J.R.	123	37	11.2
$\frac{6}{12}$ W.A.	172	56	19.8
$\frac{6}{12}$ A.W.	139	32	13.4

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{5}{12}$ C.L.	125	25	12.1
9 P.H.	198	63	17.6
$\frac{8}{12}$ D.W.	137	42	12.7
$\frac{7}{12}$ M.N.	128	43	10.6
$\frac{7}{12}$ F.R.	218	57	20.45
$\frac{7}{12}$ V.S.	144	35	13.5
$\frac{4}{12}$ J.F.	182	77	17.6
9 B.P.	178	37	14.35
9 P.W.	195	52	13.2
$\frac{2}{12}$ D.W.	125	24	10
$\frac{1}{12}$ I.S.	234	70	24.8
$\frac{3}{12}$ M.A.	179	54	13.95
299	8289	2203	753.15

Av: Age = $9\frac{6}{12}$

Av: Fix. = 165.8

Av: Reg. = 44.1

Av: Time = 15.063"

AGE GROUP FOR 12 LINES.

NAME	FIXATIONS	REGRESSIONS	TIME
$10\frac{8}{12}$ M.O.	89	21	7.75"
$\frac{10}{12}$ R.B.	146	37	16.0"
$\frac{8}{12}$ A.H.	110	31	9.35"
$\frac{10}{12}$ M.L.	116	37	8.95"
$\frac{11}{12}$ S.L.	108	21	8.1"
$\frac{10}{12}$ J.W.	169	41	13.4"
$\frac{3}{12}$ K.N.	139	42	12.3"
$\frac{5}{12}$ T.H.	154	34	14.5"
$\frac{8}{12}$ P.R.	171	36	13.7"
$\frac{8}{12}$ T.S.	177	47	16.6"
$\frac{10}{12}$ H.G.	144	33	14.65"
$\frac{3}{12}$ A.B.	105	21	8.5"
$\frac{4}{12}$ S.T.	141	27	14.35"
$\frac{4}{12}$ M.H.	112	29	8.2"
$\frac{5}{12}$ S.V.	138	30	13.75"
$\frac{8}{12}$ L.C.	174	41	15.5"

AGE GROUP FOR 12 LINES (Contd.)

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{8}{12}$ M.L.	148	42	12.45
$\frac{7}{12}$ W.B.	188	57	17.2
$\frac{7}{12}$ J.D.	116	21	12.65
$\frac{4}{12}$ A.D.	188	45	17.75
$\frac{1}{12}$ J.W.	150	36	13.4
10 J.W.	177	50	15.5
$\frac{1}{12}$ R.H.	171	51	15.
$\frac{1}{12}$ D.C.	177	56	15.2
$\frac{5}{12}$ N.B.	164	42	13.4
$\frac{2}{12}$ M.L.	129	21	13.15
$\frac{1}{12}$ P.J.	130	25	9.3
$\frac{2}{12}$ O.G.	197	69	13.2
$\frac{7}{12}$ M.W.	154	43	14.65
$\frac{5}{12}$ J.T.	144	35	11.8
$\frac{6}{12}$ D.J.	147	35	11.9
$\frac{7}{12}$ L.R.	159	41	16.55
$\frac{7}{12}$ J.B.	213	55	21.2
$\frac{3}{12}$ M.B.	173	36	17.9
$\frac{2}{12}$ J.S.	255	103	25.85

AGE GROUP FOR 12 LINES (Contd).

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{4}{12}$ I.K.	112	21	8.3
$\frac{4}{12}$ R.B.	170	53	15.45
$\frac{2}{10}$ D.M.	119	24	10.6
$\frac{3}{12}$ P.B.	143	31	12.6
$\frac{3}{12}$ M.H.	114	20	8.5
$\frac{2}{12}$ P.E.	101	21	8.5
$\frac{10}{12}$ P.R.	143	44	14.9
$\frac{10}{12}$ A.L.	85	12	8.05
$\frac{10}{12}$ M.M.	120	43	10.0
$\frac{11}{12}$ U.W.	126	36	11.35
$\frac{11}{12}$ D.W.	169	31	15.85
$\frac{10}{12}$ N.O.	130	33	14.05
$\frac{11}{12}$ V.J.	120	20	11.45
$\frac{11}{12}$ B.G.	143	35	10.0
$\frac{8}{12}$ F.T.	126	41	12.35
301	7294	1856	655.6

Av: Age $10\frac{6}{12}$
Av: Fix. 145.9
Av: Reg. 37.1
Av: Time 13.11

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$11\frac{2}{12}$ D.C.	104	18	10.5
$\frac{1}{12}$ F.Y.	121	24	12.2
$11\frac{10}{12}$ J.H.	119	26	10.45
$\frac{1}{12}$ B.H.	96	11	7.2
$\frac{1}{12}$ D.L.	122	33	8.85
$\frac{10}{12}$ B.W.	110	21	10.3
$11\frac{11}{12}$ R.T.	100	15	11.7
$\frac{2}{12}$ E.H.	141	36	12.6
$\frac{2}{12}$ W.G.	183	50	16.0
11 M.L.	130	20	10.15
$\frac{1}{12}$ D.K.	173	47	16.5
$\frac{1}{12}$ L.B.	154	35	12.75
$\frac{9}{12}$ E.T.	146	31	10.3
$\frac{11}{12}$ E.W.	151	40	11.45
$\frac{9}{12}$ A.L.	177	41	19.7
$\frac{3}{12}$ E.P.	146	38	11.4
$\frac{4}{12}$ J.W.	183	54	18.6
$\frac{7}{12}$ N.P.	160	43	16.6

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{7}{12}$ C.M.	106	19	10.55
$\frac{11}{12}$ M.D.	176	54	18.05
$\frac{8}{12}$ A.H.	164	58	14.1
$\frac{8}{12}$ K.T.	199	67	18.15
$\frac{4}{12}$ K.D.	171	33	13.1
$\frac{5}{12}$ B.E.	155	30	15.75
$\frac{10}{12}$ C.L.	154	30	12.9
$\frac{4}{12}$ D.H.	167	40	15.5
11 K.W.	155	54	13.85
$\frac{3}{12}$ L.C.	114	21	10.05
11 I.W.	127	31	10.3
$\frac{4}{12}$ A.M.	165	34	17.45
$11\frac{10}{12}$ A.B.	86	17	9
11 R.G.	178	52	18.45
$\frac{1}{12}$ K.J.	140	29	10.2
$\frac{10}{12}$ W.S.	121	20	11.3
$\frac{9}{12}$ J.G.	133	24	12.55
$\frac{8}{12}$ J.D.	114	19	10.45
$\frac{6}{12}$ K.H.	131	42	9.4

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{5}{12}$ M.P.	135	21	11.7
$\frac{5}{12}$ J.V.	151	35	14.05
$\frac{10}{12}$ B.H.	135	32	12
$\frac{9}{12}$ I.M.	114	26	10.5
$\frac{9}{12}$ A.McA.	174	43	21.1
$\frac{8}{12}$ J.S.	147	39	17.7
$\frac{7}{12}$ J.N.	167	46	16.35
$\frac{9}{12}$ E.C.	169	37	16.7
$\frac{11}{12}$ A.T.	177	48	13.5
$\frac{10}{12}$ D.W.	167	38	17
$\frac{9}{12}$ J.H.	147	45	11.8
$\frac{8}{12}$ G.M.	144	27	9.9
$\frac{4}{12}$ F.C.	155	50	12.45
297	7254	1744	663.10

Av: Age = $11\frac{6}{12}$

Av:Fix. = 145.1

Av:Reg. = 34.8

Av:Time = 13.3"

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$12\frac{2}{12}$ H.B.	161	42	13.75
$\frac{1}{12}$ P.J.	180	45	18.45
$\frac{1}{12}$ J.McC.	144	23	11.
$\frac{2}{12}$ J.B.	155	50	11.2
$\frac{1}{12}$ C.S.	138	36	12.
$\frac{11}{12}$ D.O.	144	31	13.4
$\frac{8}{12}$ P.B.	108	17	11.2
$\frac{11}{12}$ M.L.	137	35	14.3
$\frac{4}{12}$ B.T.	118	17	8.65
$\frac{9}{12}$ A.W.	114	13	11.4
$\frac{2}{12}$ D.B.	119	34	13.3
12 B.C.	122	18	11.5
$\frac{11}{12}$ J.R.	106	10	9.65
$\frac{5}{12}$ A.B.	159	44	15.95
$\frac{4}{12}$ K.D.	105	7	8.65
$\frac{4}{12}$ M.B.	123	28	12.7
$\frac{3}{12}$ G.H.	138	29	12.3
$\frac{7}{12}$ W.B.	139	34	13.4
$\frac{5}{12}$ E.C.	104	32	8.6
$\frac{5}{12}$ J.H.	120	21	11.5

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{3}{12}$ E.H.	104	30	11.5
$\frac{1}{12}$ M.E.	103	18	8.85
$\frac{4}{12}$ J.G.	151	23	14.2
$\frac{4}{12}$ A.M.	138	38	12.2
$\frac{4}{12}$ E.W.	117	31	12.1
$\frac{4}{12}$ E.O.	99	18	7.75
$\frac{11}{12}$ D.B.	194	45	18.75
12 G.R.	151	31	11.
$\frac{4}{12}$ A.B.	159	29	16.2
$\frac{2}{12}$ M.H.	127	43	9.9
$\frac{11}{12}$ R.O.B.	150	38	12.2
$\frac{8}{12}$ C.S.	140	41	12.2
$\frac{8}{12}$ L.T.	111	20	10.7
$\frac{8}{12}$ A.S.	166	45	20.5
$\frac{6}{12}$ C.C.	174	36	14.8
$\frac{11}{12}$ A.B.	196	60	19.
$\frac{9}{12}$ P.G.	158	61	12.6
$\frac{10}{12}$ D.R.	106	17	9.25
12 W.L.	126	35	10.2
$\frac{4}{12}$ R.J.	121	19	10.6

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{6}{12}$ A.W.	136	39	12.15
$\frac{7}{12}$ J.R.	128	31	13.1
$\frac{10}{12}$ D.S.	147	38	13.7
$\frac{10}{12}$ M.L.	151	31	17.2
$\frac{11}{12}$ A.S.	115	16	12.05
$\frac{7}{12}$ C.S.	134	30	11.45
$\frac{9}{12}$ M.C.	134	28	11.
$\frac{10}{12}$ J.M.	133	24	10.45
$\frac{8}{12}$ E.G.	113	23	8.4
$\frac{8}{12}$ K.S.	136	35	13.45
294	6752	1539	620.35

Av: Age $12\frac{6}{12}$

Av: Fix. 135.0

Av: Reg. 30.8

Av: Time 12.4

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
13 6/12 J.L.	173	45	15.25
9/12 G.R.	117	14	9.9
13 V.M.	138	28	14.05
4/12 H.H.	122	27	10.3
2/12 S.L.	127	19	8.95
3/12 G.R.	129	25	10.2
3/12 A.F.	127	25	8.75
2/12 E.W.	135	35	12.3
1/12 J.W.	151	54	15.1
4/12 J.C.	140	40	12.6
4/12 T.M.	153	36	11.25
3/12 A.F.	113	30	9.5
2/12 M.B.	105	29	8.7
3/12 V.W.	136	23	8.65
3/12 D.F.	99	14	9.5
1/12 J.G.	178	44	15.6
1/12 E.M.	152	40	16.1
11/12 B.T.	155	52	12.9
9/12 A.K.	140	24	11.75

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{8}{12}$ R.C.	120	25	9.6
$\frac{2}{12}$ M.O.	134	23	10.05
$\frac{11}{12}$ F.M.	176	47	16.7
$\frac{11}{12}$ K.W.	149	26	13.05
$\frac{6}{12}$ R.A.	91	15	8.35
$\frac{11}{12}$ T.W.	130	36	12.2
$\frac{11}{12}$ M.S.	136	33	12.6
$\frac{7}{12}$ V.S.	152	44	14.95
$\frac{11}{12}$ F.A.	136	24	12.4
$\frac{8}{12}$ T.D.	174	35	13.6
$\frac{10}{12}$ K.S.	151	31	13.05
$\frac{10}{12}$ A.H.	116	35	8.5
$\frac{4}{12}$ I.C.	138	26	13.4
$\frac{9}{12}$ B.D.	146	44	13.35
$\frac{3}{12}$ J.C.	134	32	12.0
$\frac{9}{12}$ B.B.	173	50	15.95
$\frac{8}{12}$ G.L.	142	31	11.2
$\frac{3}{12}$ N.D.	153	32	12.6
13 A.McK.	135	27	11.8
$\frac{4}{12}$ J.L.	144	17	13.

AGE GROUP

NAME	FIXATIONS	REGRESSIONS	TIME
$\frac{3}{12}$ H.G.	140	39	11.8
$\frac{5}{12}$ M.B.	128	35	10.6
$\frac{6}{12}$ E.G.	122	22	10.4
$\frac{11}{12}$ D.W.	137	23	10.3
$\frac{10}{12}$ R.H.	122	29	10.2
$\frac{9}{12}$ T.N.	133	26	10.
$\frac{9}{12}$ G.A.	120	20	8.25
$\frac{5}{12}$ J.D.	95	25	8.6
$\frac{10}{12}$ M.S.	104	19	7.65
13 P.R.	108	27	9.8
$\frac{10}{12}$ K.L.	126	30	10.15
294	6755	1532	577.45

Av: Age $13\frac{6}{12}$

Av: Fix. 135.1

Av: Reg. 30.6

Av: Time 11.5