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COMPARISON OF SACCADIC EYE MOVEMENTS DURING FIXATION AND READING

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MICROSACCADES (very small high velocity eye movements) are the main means by which a subject keeps the retinal image of a visual target in some "preferred" foveal locus when he is asked to "fixate" (CORNSWEET, 1956; NACHMIAS, 1959, 1961; FIORENTINI and ERCOLES, 1966; BOYCE, 1967). Recently it has been shown that these movements, which are very common during "fixation", are not essential for position control of the target image. STEINMAN, CUNITZ, TIMBERLAKE and HERMAN (1967) reported that microsaccade rates were markedly reduced when subjects were explicitly instructed to "hold" their eyes in position rather than to "fixate". Under this "hold" instruction, microsaccades were not only very infrequent, but the variability of the eye about its mean position was essentially the same as variability during "fixation" when saccades occurred about twice each sec (standard deviations were about 3 min arc for 10 sec periods under both instructions). Thus, it seems that the frequency of small high velocity eye movements is subject to voluntary control and, furthermore, that "fixation" microsaccades are not *required* for the control of retinal image position over appreciable periods of time.[2] Why, then, do subjects typically make microsaccades when they are asked to "fixate"?

One possibility is that these small saccadic eye movements serve to improve visibility during "fixation". This seems unlikely, however, because large saccades have been shown to elevate thresholds (VOLKMANN, 1962; LATOUR, 1962; VOLKMANN, SCHICK and RIGGS, 1968) and there is some evidence for a similar elevation when small high velocity movements are made during "fixation" (DITCHBURN, 1955; BEELER, 1967). Although there is still some doubt about the detrimental effect of microsaccades on vision (KRAUSKOPF, GRAF and GAARDER, 1966), there is no good evidence that they enhance or are essential for target visibility. Frequently it is taught that "fixation" microsaccades aid vision because they prevent target-fading. At first blush this seems reasonable because it is well known that "stabilized" retinal images do disappear. This important fact can be cited as evidence for the functional significance of fixation microsaccades, or, for that matter, of *any* eye movement whose size is sufficient to place the target image on fresh retina. Once, however, one looks critically at the literature on the effect of high and low velocity eye movements on visual acuity, the importance of fixation microsaccades in detail vision is not compelling (see RIGGS, 1965, for a discussion of the role of eye movements in visual acuity). Also, our

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[2] FIORENTINI and ERCOLES (1966) had previously reported that one of their subjects "seemed to be able to avoid the so-called involuntary flicks when required to keep her eye as steady as possible" and "maintained the assigned fixation direction with reasonable accuracy".

subjects were not troubled by target-fading on "hold" trials even when there were no saccades, whatsoever, during periods as long as 10 sec. Low velocity drifts (about 6 min arc/sec) seemed to be sufficient to provide fresh retina when they "held" their eyes in place. Additional evidence against the functional significance of microsaccades in the prevention of target-fading was provided by CORNSWEET (1956) who showed that saccadic initiation was not correlated with the disappearance of stabilized targets.

In summary, saccades are not made in response to target disappearance and when they are not made, targets do not tend to disappear. Since it is not clear that fixation microsaccades are beneficial to vision and since they are not essential for the control of image position, we were encouraged to consider alternative functional explanations for the prevalence of these small high velocity movements in the "fixation" pattern of our subjects.

One possibility is that microsaccades, like large "voluntary" saccades, are *scanning* eye movements. In the case of the large movements this assertion is not controversial. Large saccades serve to bring successively attended features of the visual array to the central fovea where vision is best. Fixation microsaccades may also be part of a visual search pattern. In this view, microsaccades are small high velocity movements made when a subject searches for very fine detail in a fixation target. This assertion presupposes that a large number of the microsaccades observed during "fixation" are not "corrective" in the sense that they return the retinal image of the target object to some "optimal" fixation position (estimated from the long term mean fixation position). But, rather, that many "fixation" microsaccades serve to place various regions within or near the fixation target at the "optimal" locus where details can be most readily attended. Some support for this "scanning" hypothesis can be found in prior research on the role of eye movements during maintained fixation. CORNSWEET (1956), for example, noted that although fixation saccades on the average moved the target towards the mean fixation position the standard deviation of directed magnitudes of saccades was "very large" and that saccades, on the average, overshot the mean fixation position by more than 1 min arc. Such "fixation errors", confirmed in other experiments (NACHMIAS, 1961), are large particularly when you consider that the median size of fixation saccades is only about 4·5 min arc. Also, BOYCE (1967) found that only 30 per cent of his *S*'s saccades compensated for previous drifts and concluded "that although there is some [saccadic] compensation of preceding drift, this compensation is very inaccurate. The direction and magnitude of preceding drift do have some influence on the direction and magnitude of the saccade but cannot be regarded as the sole or even the main determinants of these quantities".

In short, it seems that "fixation" microsaccades serve, over the long run, to keep the target image near the "center of best vision", but, we feel that it is reasonable to suggest that many of these small high velocity fixation movements, if they are not simply very inaccurate, serve some purpose other than the control of image position.

The present experiment is a first step in evaluating this possibility. If all high velocity movements, large and small, are considered to serve the same purpose—visual search—their frequency of occurrence should be the same because they would be controlled by a common high velocity scanning system. Experimentally, we would expect the same probability distributions of time intervals between fixation microsaccades and of time intervals between large saccades in a stereotyped visual search task such as reading. If, however, different systems control the small fixation and large reading saccades, the intervals between saccades of such markedly different sizes might well be quite different. Similarly, if the systems are different, a large number of microsaccades might occur during reading pauses since such pauses are analagous to brief periods of maintained "fixation" of successive single letter targets in a text.

There is an extensive literature on eye movement patterns during reading. In most instances corneal reflection or, occasionally, electro-oculographic techniques have been used to measure eye movements. These methods are not sufficiently sensitive to reveal the presence of saccades smaller than 10 min arc in extent. The available literature could not, therefore, be used to determine whether microsaccades occur during reading pauses or to compare the probability distributions of very small saccades that occur during fixation with the intervals between the large saccades that rapidly move the visual axis to new positions in a line of text.

METHODS

A contact lens-optical lever was used to record horizontal eye movements during fixation of a single letter target and during normal reading. Recordings were made on 35 mm infrared film moving at 1 cm/sec in a modified Grass Model C4H Camera. The recording technique was similar to that introduced by RATLIFF and RIGGS (1950). Our apparatus and alignment procedures are described elsewhere (STEINMAN, 1965). Records were measured with a Richardson Camera Co. Model V-F 550 M projection film reader which permitted measurement of differences in eye position of about 20 sec arc and differences in time of about 2 msec.

Two experienced emmetropic subjects participated in the experiment (*AS*, a graduate student at the University of Maryland, and *RS*, the second author). The stimulus materials were cut out of *Science*. A capital letter "T", whose horizontal and vertical members subtended 15·0 min arc, was presented on a $4{\cdot}2 \times 5{\cdot}9$ deg arc white field for fixation trials of 20 sec duration. On alternate trials, *S*s were given 20 sec to read a 10 line paragraph they had never seen before. The text subtended $3{\cdot}1 \times 4{\cdot}9$ deg arc. It was viewed on a $4{\cdot}2 \times 5{\cdot}9$ deg arc white field. Each letter or space subtended 7·7 min arc on the horizontal dimension. The fixation target and texts (0·68 m from the right eye) were viewed through a beam splitter. Fixation and reading trials were alternated by illuminating one or the other field for 20 sec. The luminance of both fields was 1 mL. Luminance was measured with an S.E.I. Photometer calibrated with a Spectra Regulated Brightness Source. This luminance level was sufficient for good legibility in the otherwise darkened environment.

Subjects were instructed to "fixate" the letter target just as they "fixated" points or discs of light in prior eye movement experiments and to "read" the paragraphs for comprehension. They expected to be tested on their mastery of the texts at the end of the experiment. We did not actually perform these tests but both *S*s "read" with this expectation.

RESULTS

"Normal" reading eye movements were observed for both subjects. The records were similar with respect to the number of fixations/line, the number of regressions, and the duration of reading pauses to descriptions of normal reading which may be found in standard secondary sources (see YARBUS, 1967 or WOODWORTH and SCHLOSBERG, 1956).

1. *Microsaccades during reading pauses*

In the first experiment records were made while subject *RS* read 20 paragraphs and maintained fixation of the "T" 20 times. Subject *AS* read 30 paragraphs and maintained fixation 29 times. In our first analysis, we counted the number of microsaccades that occurred during pauses in normal reading. Our criterion for making the micro vs. large saccade distinction was 11·6 min arc. We selected this value on the basis of a compilation by DITCHBURN and FOLEY-FISHER (1967) of the characteristics of high velocity fixation eye movements from about 30 subjects in 14 sets of experiments that employed the contact lens optical lever technique. In their compilation the median fixation microsaccade was 4·5 min arc and the interquartile range was 3·0 min arc. Our criterion value for microsaccades during reading pauses was much larger than the size of high velocity movements that would usually be observed during "fixation" of a single target. Our value, then, would tend to overestimate the number of microsaccades during reading pauses.

The most striking feature of the records was the low frequency of microsaccades observed during the reading pauses. *RS* made only 18 microsaccades during the 1063 times he paused while reading 20 paragraphs. *AS* made only 82 microsaccades during 1712 pauses while reading 30 paragraphs.

If the large reading and very small fixation saccades were independently produced, a much larger number of microsaccades would be expected during reading pauses. For example, *RS* spent 400 sec reading 20 paragraphs. If each saccade is estimated to take 50 msec, his reading pauses occupied approximately 337 sec (*RS* made 1064 reading saccades and 200 retraces from the end of one line to the beginning of the next). His mean intersaccadic interval during fixation was 0·371 sec. Thus, 908 microsaccades would be expected to occur in the 337 sec he paused while reading 20 paragraphs. Only 18 were observed. Similarly, the expectation for *AS*, based on his mean fixation intersaccadic interval of 0·473 sec, would be 1055 microsaccades during the 499 sec he paused while reading 30 paragraphs. Only 82 microsaccades were found in his records.

2. *Distribution of intersaccadic intervals*

For our initial analysis intersaccadic intervals were measured to the nearest 50 msec and the modal values of the following 3 distributions were determined: (1) time intervals between microsaccades during fixation of the letter "T", (2) time intervals between large reading saccades (the duration of reading pauses) and (3) the intervals between the start of reading pauses (the end of large reading saccades) and the onset of microsaccades that occurred before the next large reading movements. The modal values for all three distributions were within measurement error of each other (200–300 msec for *RS* and 150–250 msec for *AS*).

Probability distributions of intersaccadic intervals were calculated from a random sample of reading and fixation trials in which time was measured to 2 msec. The probability distribution for each subject is shown in Figs. 1 and 2 and summarized in Table 1.

The distributions of time intervals between fixation microsaccades and between large reading saccades (reading pause durations) overlap considerably for each subject. The difference between the means of the log transformed data was examined statistically. For subject *RS* the difference between the mean log intersaccadic interval and mean log reading pause duration was not statistically significant ($t=0{\cdot}240$, $df=470$, $p>0{\cdot}8$). A similar test for subject *AS* was significant ($t=7{\cdot}37$, $df=408$, $p<0{\cdot}001$). As can be seen in Fig. 2, this significant difference can be attributed to an appreciable number of long periods (>600 msec) during which *AS* did not make a microsaccade while fixating the letter "T". *RS* also showed a few very long intervals between fixation microsaccades (see Fig. 1). For subject *AS* the interquartile range of intersaccadic intervals during fixation was almost twice as

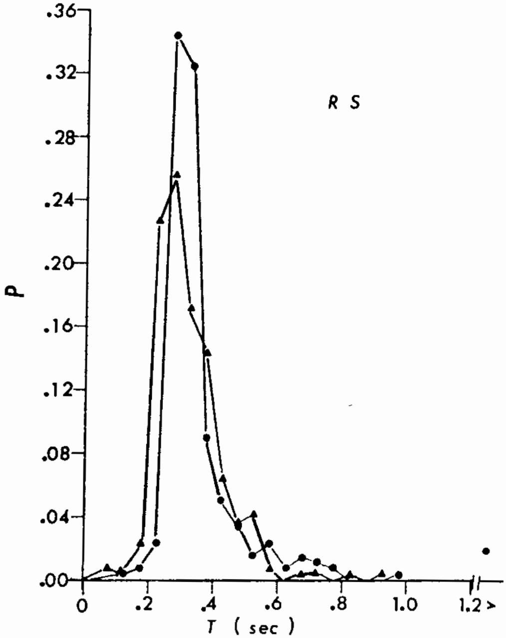

FIG. 1. Proportions of intersaccadic intervals of different durations for 5 randomly selected trials under each condition for subject *RS*. The distribution marked by filled circles is of time intervals between microsaccades during fixation of the letter "T"; the distribution marked by filled triangles is of reading pause durations.

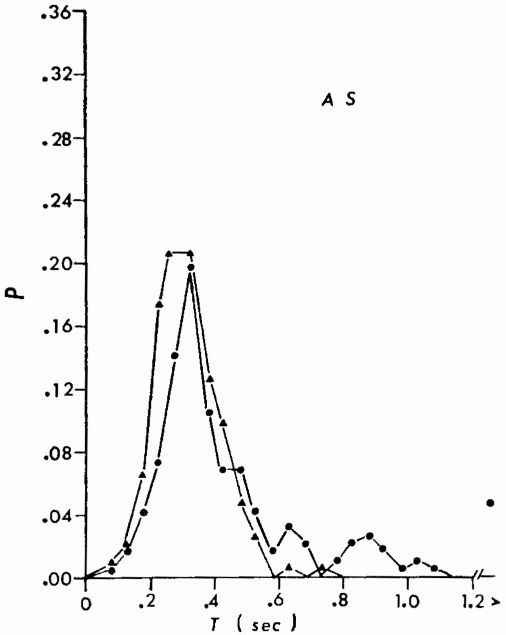

FIG. 2. Proportions of intersaccadic intervals of different durations for 5 randomly selected trials under each condition for subject *AS*. The distribution marked by filled circles is of time intervals between microsaccades during fixation of the letter "T"; the distribution marked by filled triangles is of reading pause durations.

TABLE 1. MEDIAN INTERSACCADIC INTERVALS FOR A RANDOM SAMPLE OF 5 20-sec FIXATION AND 5 20-sec READING TRIALS

	Median (msec)	Interquartile range (msec)	*N*
Subject *RS*			
READ	285	120	213
FIX	315	100	259
MS	275	85	18
RPMS	535	145	18
Subject *AS*			
READ	305	140	216
FIX	355	270	194
MS	295	100	82
RPMS	520	175	82

READ refers to the duration of reading pauses; FIX refers to the intervals between microsaccades during fixation trials; MS refers to the intervals bounded by the end of a large reading saccade (beginning of a reading pause) and the onset of a microsaccade that occurred in the reading pause, and RPMS refers to the duration of reading pauses that contained microsaccades.

large as the interquartile range of reading pause durations (see Table 1). His greater variability during maintained fixation was brought about by occasional long periods during which there were no microsaccades. If these relatively rare events are ignored, reading and fixation show very similar distributions. The modal intersaccadic intervals and reading pause durations, for example, were very similar for both subjects (see Figs. 1 and 2).

TABLE 2. MEAN SACCADE SIZE FOR A RANDOM SAMPLE OF 5 20-sec FIXATION AND 5 20-sec READING TRIALS

	READ		
Subject *RS*	Mean (min arc)	SD (min arc)	*N*
Absolute	48·8	16·2	213
Left	24·8	11·1	9
Right	49·8	15·5	204
	FIX		
	Mean (min arc)	SD (min arc)	*N*
Absolute	5·6	4·8	259
Left	5·2	2·9	137
Right	6·1	6·3	122
	READ		
Subject *AS*	Mean (min arc)	SD (min arc)	*N*
Absolute	51·4	27·5	216
Left	20·0	9·6	50
Right	60·8	23·9	166
	FIX		
	Mean (min arc)	SD (min arc)	*N*
Absolute	11·1	14·4	194
Left	9·5	13·1	104
Right	13·0	15·5	90

READ refers to the size of reading saccades (microsaccades and large saccades which brought the eye from the end of one line to the beginning of the next are not included) and FIX refers to the size of microsaccades during fixation of the letter "T". Eye movements towards the right and left are listed separately. These movements are combined (without regard to direction) under the heading *Absolute*.

3. *Reading pauses containing microsaccades*

The median duration of all reading pauses that contained microsaccades was almost twice as long as the median duration of reading pauses without microsaccades (see Table 1). The difference between the mean log transformed intervals defined by the start of a reading pause and the mean onset of the relatively few microsaccades that did occur in reading pauses was not statistically different from the mean log transformed reading pause durations of reading pauses that did not contain microsaccades (for *RS*, $t=0{\cdot}787$, $df=229$, $p>0{\cdot}4$; for *AS*, $t=0{\cdot}151$, $df=296$, $p>0{\cdot}8$). On those few occasions when microsaccades were made during reading pauses, they were made at about the same time that a large reading saccade would be expected. The probability of a saccade occurring during reading was independent of the size of the saccade that was made.

4. *Longer reading pauses*

Perhaps the low microsaccade frequency observed during reading pauses was due to the relatively short duration of most reading pauses. An attempt was made, in a second experiment, to produce a greater number of long reading pauses by presenting *RS* with 4 paragraphs which 7 judges had unanimously categorized as "hard" to read and 4 paragraphs unanimously categorized as "easy" to read. It was hoped that difficult material might increase the amount of time the subject stayed at a given position in the text.

The median intersaccadic interval for "hard" material was 290 msec (IQR=120 msec) and 270 msec (IQR=115 msec) for "easy" material. There were very few long reading pauses. A *t*-test of the means of the log transformed "hard" and "easy" reading pause duration was not significant ($t=1{\cdot}09$, $df=327$, $p>0{\cdot}1$). The attempt to lengthen reading pause duration by increasing the difficulty of the material was unsuccessful. The level of difficulty of the reading material did affect the size of the mean reading saccade and the number of pauses made in each line of text. *RS* made slightly larger saccades while reading the "easy" material (Mean size=48·2 min arc, SD=14·7 min arc) and smaller saccades while reading the "hard" material (Mean size=42·8 min arc, SD=12·1 min arc). The difference between these mean saccade sizes was statistically significant ($t=3{\cdot}61$, $df=327$, $p<0{\cdot}001$) as was the difference between the mean number of fixations/line of text. *RS*'s mean fixations/line was 6·22 (SD=1·04, $N=32$) while reading the "hard" material and 4·89 fixations/line (SD=0·75, $N=38$) while reading the "easy" material ($t=6{\cdot}05$, $p<0{\cdot}001$). There were also more regressions when the "hard" text was read. *RS* went backwards 9 times while reading 40 lines of difficult material and only 5 times when he read an equal amount of "easy" material.

5. *Saccade size*

Saccade size measurements were made on the random sample of trials described in Section 2 in order to determine the relationship between the spatial and temporal characteristics of reading and fixation saccades. Figures 3 and 4 show distributions of saccade sizes during fixation of the "T" and during reading of the texts.

Note that the two subjects read quite differently; *AS* made more regressions and his forward movements were more variable in size than *RS*. Such individual differences are common in reports of reading eye movements. Also, *AS* made very large microsaccades (Mean size=11·1 min arc) suggesting that he frequently looked from one side to the other side of the "T" while fixating (the bars of the "T" subtended 15 min arc). In many prior

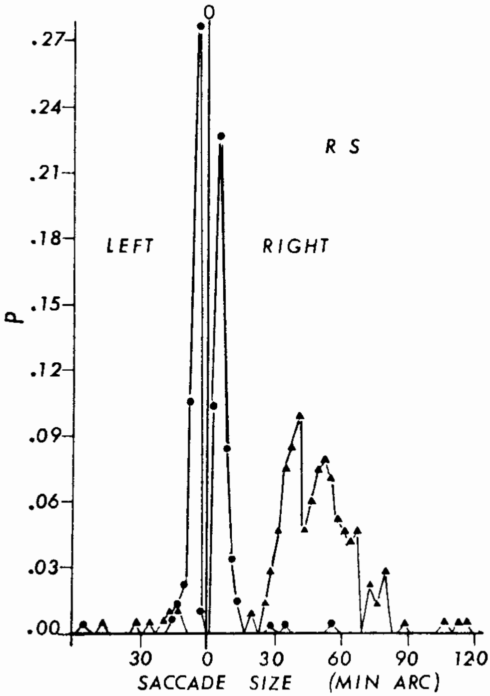

FIG. 3. Proportions of saccades of different sizes and directions for 5 randomly selected trials under each condition for subject *RS*. The distribution marked by filled circles is of directed microsaccade sizes during fixation of the letter "T"; the distribution marked by filled triangles is of saccade sizes during reading. Points to the left of zero represent eye movements from right to left (for reading, these are regressions in the text); points to the right of zero represent eye movements from left to right (for reading, these are forward movements in the text). Retraces from the end of one line to the beginning of the next have been removed from the reading distribution.

experiments, when this *S* fixated a very small point of light, his average saccade was typically half the size of the saccades he made while fixating the "T" in the present experiment.

Each *S* performed quite differently with respect to the direction and size of his saccades in both reading and fixation conditions. The temporal characteristics of these movements do not show similar differences (see Figs. 1 and 2). The size and direction of saccades did not seem to influence, or to be influenced by, the temporal distribution of these high velocity movements. Whether you go forwards or backwards in a text while reading, or whether you make very small or relatively large microsaccades during fixation was not, in any obvious way, related to when one of these movements was likely to occur.

SPECULATION

The temporal distribution characteristics of high velocity eye movements in two quite different tasks, fixating a letter and reading a text, gave no indication of temporal independence of movements that differed quite markedly in size and direction. This finding suggests that the initiation of all saccades, large and small, is controlled by a single system. ZUBER, STARK and COOK (1965) have already presented convincing evidence that a single physiological system controls the velocity-amplitude characteristics of all high velocity movements, small as well as large. Our finding that the maximum average saccade rate is

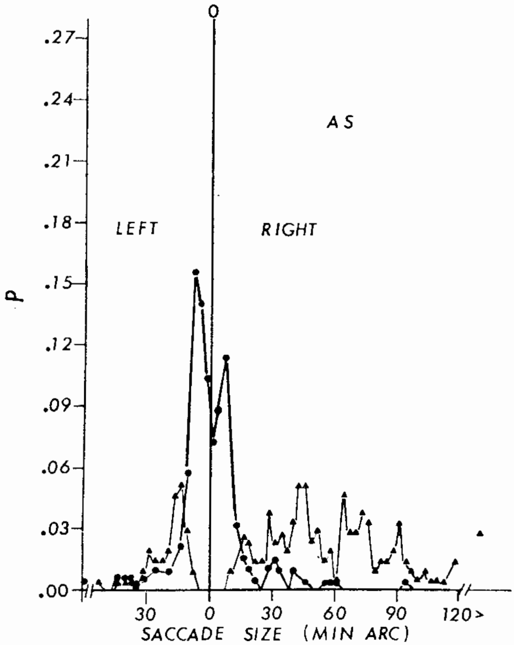

FIG. 4. Proportions of saccades of different sizes and directions for 5 randomly selected trials under each condition for subject *AS*. The distribution marked by filled circles is of directed microsaccade sizes during fixation of the letter "T"; the distribution marked by filled triangles is of saccade sizes during reading. Points to the left of zero represent eye movements from right to left (for reading, these are regressions in the text); points to the right of zero represent eye movements from left to right (for reading, these are forward movements in the text). Retraces from the end of one line to the beginning of the next have been removed from the reading distribution.

independent of the amplitude and direction of the high velocity movements may simply be further evidence that all saccades share a common output system whatever their "purpose".

We would like to propose that many "fixation" microsaccades serve the same purpose as large "voluntary" saccades, *viz* they are used to make very small shifts in the line of regard so that an attended feature of the visual array falls at a preferred locus within the center of best vision. We think that microsaccades occur whenever a subject is asked to maintain "fixation" because this instruction encourages him to look for fine detail in a very circumscribed portion of his visual field. The search goes on and tiny high velocity movements will be made even when there is no actual detail in the fixation target. In this view saccades, large and small, are emitted behaviors made when a subject searches his visual array. Many of the microsaccades that occur during "fixation" may not, then, be position correction movements elicited by "fixation errors" but, rather, peripheral indicators of small changes in attention within a very circumscribed portion of the visual field. These miniature high velocity movements are found in the "fixation" pattern because they have little or no effect on the amount of information that can be gleaned from a single detail.

This view implies that the occurrence of microsaccades during "fixation" may be a relatively late development in the control of the visual search pattern. The ability to resolve small visual details as well as the ability to execute, accurately, very small high velocity eye movements would be necessary before the adult "fixation" pattern would be possible.

If this is correct, it becomes interesting to ask whether microsaccades can be seen in the oculomotor behavior of very young infants whose visual acuity is poor and whose oculomotor skills are probably primitive?

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REFERENCES

BEELER, G. W., JR. (1967). Visual threshold changes resulting from spontaneous saccadic eye movements˙ *Vision Res.* **7**, 769–775.

BOYCE, P. R. (1967). Monocular fixation in human eye movement. *Proc. R. Soc., B.* **167**, 293–315.

CORNSWEET, T. N. (1956). Determination of the stimuli for involuntary drifts and saccadic eye movements. *J. opt. Soc. Am.* **46**, 987–993.

DITCHBURN, R. W. (1955). Eye-movements in relation to retinal action. *Optica Acta* **1**, 171–176.

DITCHBURN, R. W. and FOLEY-FISHER, J. A. (1967). Assembled data in eye movements. *Optica Acta* **14**, 113–118.

FIORENTINI, A. and ERCOLES, A. M. (1966). Involuntary eye movements during attempted monocular fixation. *Atti Fond. Giorgio Ronchi* **21**, 199–217.

KRAUSKOPF, J., GRAF, V. and GAARDER, K. (1966). Lack of inhibition during involuntary saccades. *Am. J. Psychol.* **79**, 73–81.

LATOUR, P. L. (1962). Visual thresholds during eye movements. *Vision Res.* **2**, 261–262.

NACHMIAS, J. (1959). Two-dimensional motion of the retinal image during monocular fixation. *J. opt. Soc. Am.* **49**, 901–908.

NACHMIAS, J. (1961). Determiners of drift of the eye during monocular fixation. *J. opt. Soc. Am.* **51**, 761–766.

RATLIFF, F. and RIGGS, L. A. (1950). Involuntary motions of the eye during monocular fixation. *J. exp. Psychol.* **40**, 678–701.

RIGGS, L. A. (1965). Visual acuity. In *Vision and Visual Perception* (edited by CLARENCE H. GRAHAM). pp. 343–344, John Wiley, New York.

STEINMAN, R. M. (1965). Effect of target size, luminance and color on monocular fixation. *J. opt. Soc. Am.* **55**, 1158–1165.

STEINMAN, R. M., CUNITZ, R. J., TIMBERLAKE, G. T. and HERMAN, M. (1967). Voluntary control of microsaccades during maintained monocular fixation. *Science, N.Y.* **155**, 1577–1579.

VOLKMANN, F. C. (1962). Vision during voluntary saccadic eye movements. *J. opt. Soc. Am.* **52**, 571–578.

VOLKMANN, F. C., SCHICK, A. M. L. and RIGGS, L. A. (1968). Time course of visual inhibition during voluntary saccades. *J. opt. Soc. Am.* **58**, 562–569.

WOODWORTH, R. and SCHLOSBERG, H. (1956). *Experimental Psychology*, pp. 504–510, Henry Holt, New York.

YARBUS, A. L. (1967). *Eye Movements and Vision* **1**, pp. 196–200, Plenum Press, New York.

ZUBER, B. L., STARK, L. and COOK, G. (1965). Microsaccades and the velocity-amplitude relationship for saccadic eye movements. *Science, N.Y.* **150**, 1459–1460.

Abstract—A contact lens-optical lever technique was used to record horizontal eye movements of two subjects while they read paragraphs of technical material or fixated a letter "T." Large reading saccades and small fixation microsaccades displayed very similar distributions of intersaccadic intervals. Very few microsaccades occurred during pauses in normal reading. In those rare instances when they did occur, they occurred in the middle of reading pauses whose durations were twice as long as those usually observed. These results imply that both microsaccades and large reading saccades are scanning eye movements controlled by a single high velocity eye movement system.

Résumé—On enregistre par la technique du levier optique à verre de contact les mouvements horizontaux des yeux de deux sujets pendant qu'ils lisent des paragraphes d'un texte technique ou qu'ils fixent la lettre "T". Les grandes saccades de lecture et les petites microsaccades de fixation présentent des distributions très semblables d'intervalles entre saccades. Il se produit très peu de microsaccades pendant les pauses de lecture normale. Dans les rares cas où il y en a eu, eiles se produisent au milieu des pauses de lecture dont la durée est double de celles qu'on observe d'habitude. Ces résultats impliquent que les microsaccades et les grandes saccades de lecture sont des mouvements oculaires de balayage contrôlés tous deux par un unique système rapide de mouvement des yeux.

Zusammenfassung—Mit Hilfe von Kontaktschalen wurden durch eine optische Hebelmethode die horizontalen Augenbewegungen zweier Versuchspersonen beim Lesen von technischen Texten und beim Fixieren des Buchstabens "T", aufgenommen. Die großen Lesesakkaden und die kleinen Mikrosakkaden beim Fixieren zeigten sehr ähnliche Verteilungen der Intervalle zwischen den Sakkaden. In den Pausen beim normalen Lesen traten nur sehr wenige Mikrosakkaden auf. In diesen seltenen Situationen erschienen sie in der Mitte der Lesepausen, deren Dauer doppelt so groß war, wie die der gewöhnlichen beobachteten. Aus diesen Ergebnissen kann gefolgert werden, daß sowohl Mikrosakkaden als auch große Lesesakkaden Suchbewegungen des Auges darstellen, die durch ein einziges Hochgeschwindigkeits-Augenbewegungssystem kontrolliert werden.

Резюме — Для записи горизонтальных движений глаза у двух испытуемых, в то время когда они читали параграфы технической инструкции или фиксировали букву «Т», была применена техника с использованием оптических контактных линз. Большие саккадические движения, сопровождающие чтение, и малые микросаккадические движения наблюдаемые при фиксации, обнаруживали очень сходное распределение интервалов между саккадами. Очень немного микросаккад появлялось во время пауз при нормальном чтении. В те редкие моменты, когда эти движения появлялись, они обнаруживались в середине пауз в чтении, длительность которых была в два раза больше, чем наблюдалось обычно. Эти результаты заставляют думать, что как микросаккады, так и большие саккадические движения во время чтения являются сканирующими движениями глаза, контролируемыми единой высокомобильной системой движений глаза.