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FIXATION OF TARGETS NEAR THE ABSOLUTE FOVEAL THRESHOLD

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A SUBJECT, asked to fixate a dim "white" light that is not visible when he looks directly at it, will rotate his eye, causing the faint image to fall on his peripheral retina where the target can be seen. Many important features of this phenomenon have been known for a long time. SIMON (1904) used after-image and blind spot mapping techniques to examine changes in fixation position that occurred during the course of dark-adaptation. He found that the preferred fixation position shifted from the central fovea to some peripheral region whose locus depended on the stage of adaptation and the intensity of the fixation target.

Simon also reported that faint targets, visible only when they fell in the periphery, disappeared and reappeared from time to time. He believed, and as you will see, rightly so, that eye movements were responsible for these fluctuations in visibility. He suggested, but could not show objectively with his method, that eye movements periodically brought the faint image to fall onto insensitive portions of the retina, such as the optic disk or the central fovea.

In the experiments to be described, a contact lens optical lever technique was used to examine eye movements of two experienced subjects presented with targets that were too faint to be seen when they fell in their dark-adapted central foveae.

METHOD

1. *Apparatus*

The apparatus has been described in detail elsewhere (STEINMAN, 1965) and only those features necessary for interpreting representative recordings are presented in this paper.

A small wedge-shaped portion of infra-red light was focused on a plane mirror attached by means of a stalk to a tightly-fitted scleral contact lens worn on the right eye. One edge of the wedge of light was vertical and the contact lens mirror was oriented so as to be normal to a line parallel to the line of regard. The wedge of light, after reflection from the contact lens mirror, was focused on a horizontal slit located in front of 35-mm infra-red film moving vertically at 22 in./min. This arrangement permits two-dimensional recording of eye position uncontaminated by translations of the head or torsions of the eyeball.

When the subject made a horizontal eye movement, the recorded trace displaced laterally on the film; when he looked up or down, narrower or wider portions of the wedge of light fell on the slit. For any portion of a recorded trace, then, the position of the left edge is proportional to the horizontal position of the eye, and the width of the trace is proportional to its vertical position. This method of simultaneous two-dimensional eye movement recording was first employed by NACHMIAS (1959).

Subjects saw a round 5·4 min arc dia. disk of "tungsten white" light produced by an aperture placed in front of an opal diffuser transilluminated by collimated light from a *GE* 1183 bulb operated at 5·0 A. Neutral density filters, mounted on a solenoid, were inserted in the stimulus path to alter target luminance. Neutral density filters were calibrated with a Macbeth Quanta-Log Densitometer and absolute luminance calibration was done with a S.E.I. Photometer calibrated with a Spectra Regulated Brightness Source.

2. *Procedure and measures*

The contact lens technique imposed a number of limitations on our study of the disappearance-reappearance phenomenon reported by Simon. We needed a moderately *bright* target that yielded fixation patterns characteristic of normal central foveal fixation but at the same time did not light adapt the fixating eye appreciably or disappear during prolonged fixation. Also, target luminances chosen to examine the fixation pattern associated with disappearances could not yield eye movements too large (> 3 deg arc) to be recorded on film, only 35 mm wide, with the relatively long optical lever employed. Each *S* served in a number of preliminary recording sessions in order to find target luminances that met these restrictions.

Subjects, RS, the first author and AS, a graduate student at the University of Maryland, were instructed to maintain fixation of the bright and two lower luminance targets. When a faint target disappeared *S*s indicated its disappearance by operating an infra-red strobe flash that marked the recording and then made a saccade (a high velocity eye movement) that would bring the target to a more sensitive region. Once the target was visible, *S*s were instructed to maintain fixation until such time as the target disappeared again.

In the experiments each trial with one of the low luminance targets was 45 sec long. Each low luminance trial was preceded and followed by a 10-second trial with the *bright* target. Trials with each of the low luminance targets were alternated.

The position of the preferred central foveal fixation locus was estimated from the mean of a random sample of paired horizontal and vertical positions measured on trials with the *bright* target. A position measure was obtained within each second of the 10-second periods. When mean positions for both preceding and following *bright* trials did not differ appreciably, measures were combined and the grand mean used to estimate the central foveal locus to which the movement pattern on the intervening trial with a faint target could be compared. Occasionally, pre- and post-trial means did differ appreciably and the intervening low luminance trial was discarded since it was felt that contact lens slippage had occurred.

Low luminance targets disappear and reappear. Three position measures were made in order to describe the disappearance cycle: namely, disappearance position, eye position at the moment of target disappearance; saccade-onset position, eye position at the onset of the first saccade following target disappearance; and saccade-offset position, the position of the eye at the end of the target-finding saccade.

Reaction times were measured for each of our subjects in a separate experiment in order to estimate the disappearance position. For this determination the bright target was obscured for 0·5 sec by a high-speed silent shutter 200 times at randomly selected temporal intervals. Subjects responded to the objective disappearance of the bright target by pressing the response key they used to mark subjective target disappearances during recordings with low luminance targets. In the reaction time determination *S*s were instructed to make a target-finding saccade after they responded to each target disappearance. This procedure closely simulated events that occurred when faint targets disappeared during recording sessions. The mean reaction times to objective target disappearance were 413 msec and 356 msec for subjects RS and AS, respectively.

Daily recording sessions were 40 min long; they included an initial period of 15 min in dim illumination while the subject inserted his contact lens; followed by a 5-min period in darkness while the recording system was aligned. During alignment and thereafter, only light from the fixation target was visible.

RESULTS

1. *Disappearance cycle*

Figure 1 shows the mean disappearance, saccade-onset and offset positions for each subject viewing dim and very dim targets.

This figure may be viewed as a projection of the subject's visual field. UP refers to up in the *S*'s visual field, RIGHT to his right, and so forth. Position measures were normalized and the intersection of the axes represents the mean bright fixation locus.

Consider subject RS, fixating his dim target (solid line). The mean disappearance position (triangle) was less than 10 min arc away from the bright locus (intersection). After the target disappeared, his eye drifted for a short period toward the saccade onset position (circle). His target-finding saccade vector was up and to the right: At the offset of the target-finding saccade (the square), he begins to move back to his disappearance position. The cycles under dim and very dim conditions are very similar, except that the very dim target disappeared more than 40 min arc from the bright locus.

Both subjects represented here, and a third subject who participated in a limited number of sessions, always made their target-finding saccades in the same direction. The particular direction for each subject, however, was idiosyncratic. RS always went up and to the right, AS up and to the left, and the third subject to the left. Following this target-finding saccade their eyes moved towards the mean bright position where the target disappeared again and the cycle repeated itself.

The disappearance, saccade-onset and offset positions as well as the bright fixation locus were relatively stable. Table 1 gives the bivariate contour ellipse areas ($p=68$ per cent) of each of the mean positions shown in Fig. 1. (See Steinman, 1965 for a description and test of the assumptions underlying this measure of bivariate variability.) The standard deviation on an average meridian is also included to facilitate comparison with research where eye movements have been recorded on only a single meridian.

2. *Eye movement patterns*

What did the eye do during the period the dim and very dim targets were visible, and how did the eye movement pattern with faint targets differ from that observed when continually suprathreshold targets were fixated? Figures 2 and 3 show representative performance for each subject under his three luminance conditions. Trials were shortened in order to make these demonstration figures.

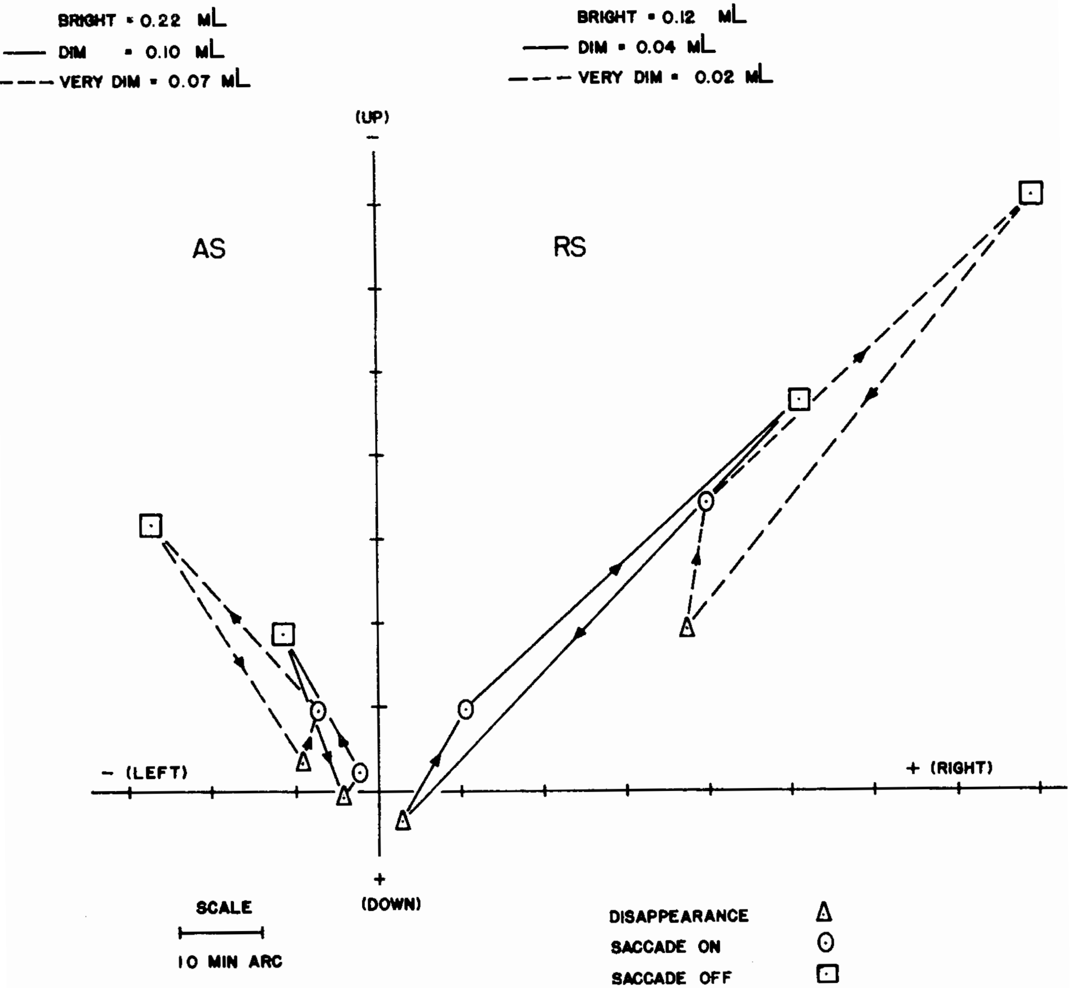

FIG. 1. Disappearance cycles for subjects AS and RS fixating dim (solid lines) and very dim (dashed lines) targets. Mean disappearance position is indicated by triangles, mean saccade-onset position by circles and mean saccade-offset position by squares. This figure can be viewed as a projection of the subject's visual field: up is above him, left to his left and so forth. The intersection of the axes represents the mean bright fixation locus. Target luminances for each subject are given in the quadrant containing his cycles.

Consider first the recording on the left in Fig. 2. A 5-second bright trial starts at the top of the strip; the arrow points to a line indicating when the dim target was substituted. The 3 dark horizontal lines show when RS reported the disappearance of the dim target. There was a large target-finding saccade up and to the right shortly after the disappearance was reported. (The trace narrows showing that the eye went up, and the left edge shifted to the right, showing it also went to the right.) Notice that RS then made a smooth movement, or drift, downwards towards the mean bright position. This drift movement contributed the major portion of the return to the next disappearance position. The cycle, then, repeated itself. Also note that the disappearance position (413 msec above the disappearance line) was relatively stable from disappearance to disappearance.

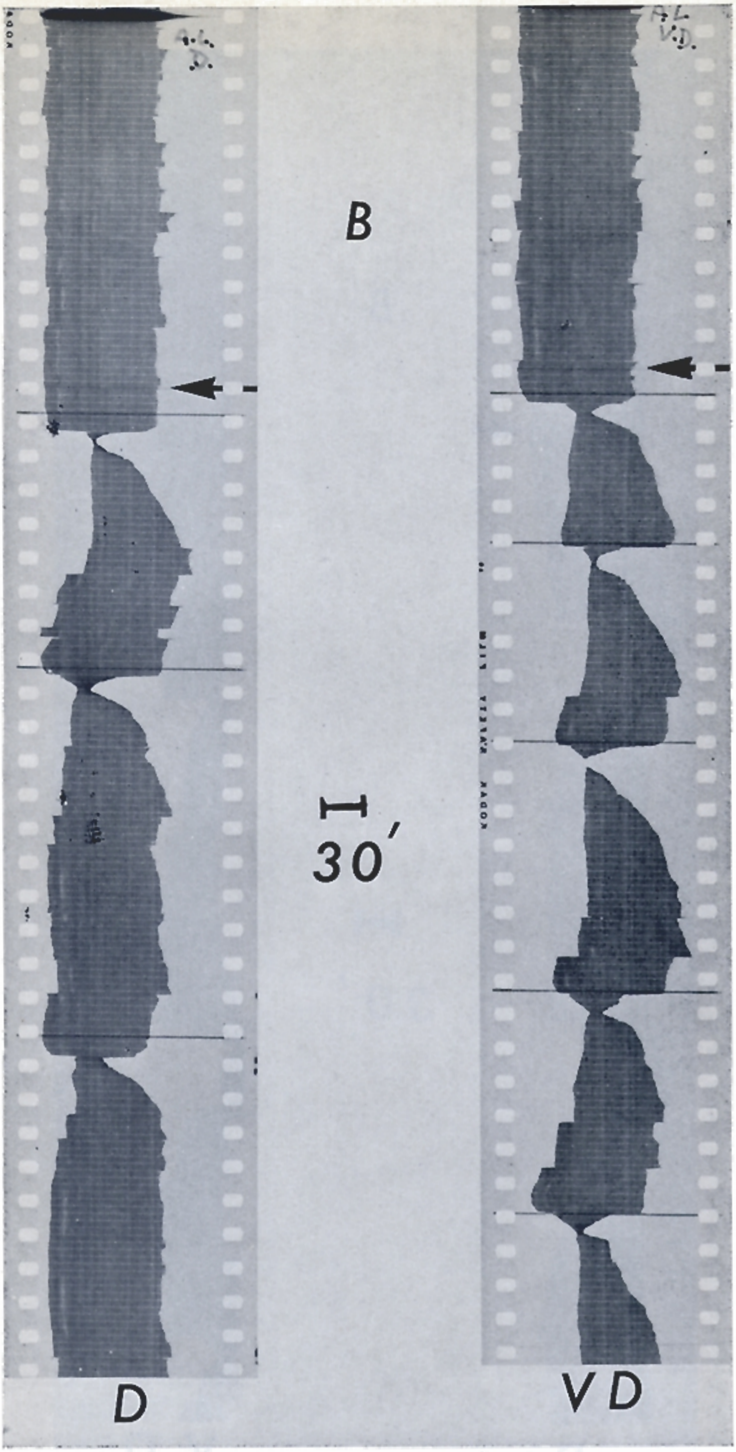

FIG. 2. Representative eye movement recordings of subject RS fixating bright (B), dim (D) and very dim (VD) targets. The arrow shows when target luminance was reduced from bright to dim (left record) or very dim (right record). The horizontal dark lines indicate subjective disappearance of the fixation target. The position of the left edge of the recording is proportional to the position of the eye on the horizontal meridian and the width of the trace is proportional to eye position on the vertical meridian. A 0·1 sec time base was produced by interrupting the recording (repetitive faint white lines).

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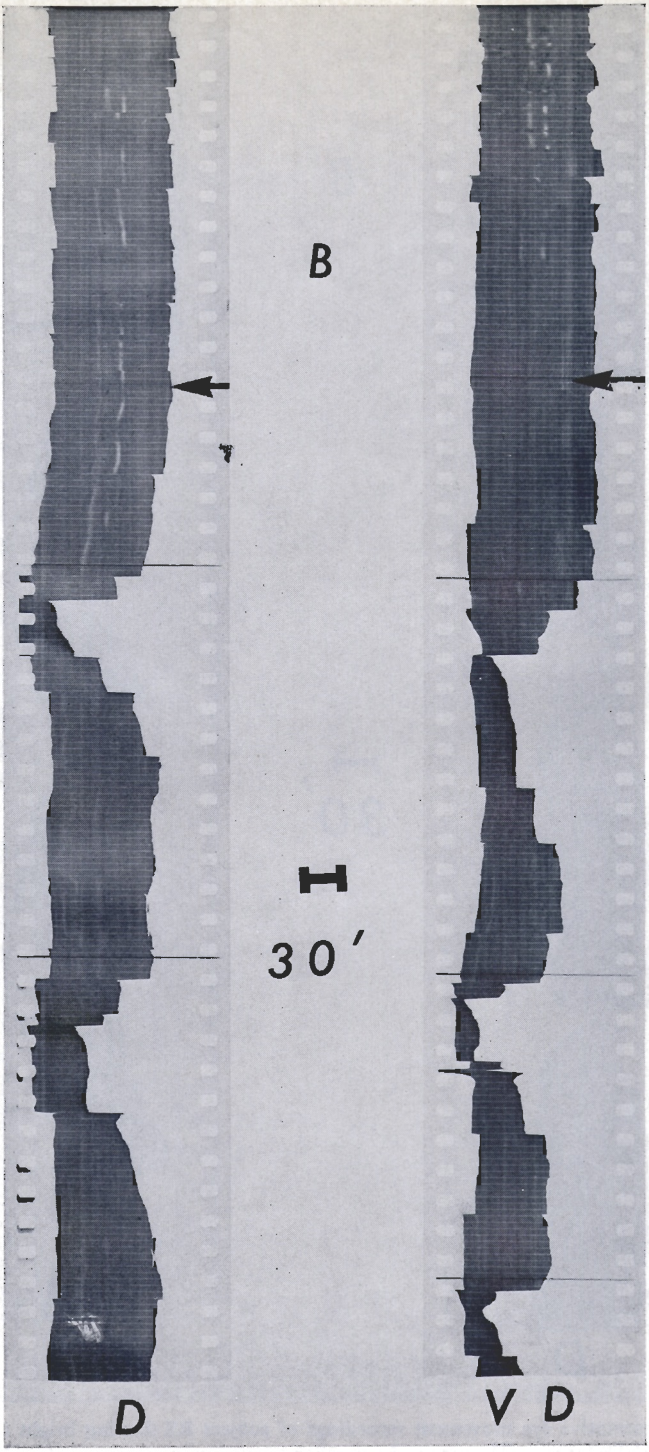

FIG. 3. Representative eye movement recordings of subject AS fixating targets whose luminance was above and below foveal threshold. See Fig. 2 for an explanation of the symbols and other features of these recordings.

TABLE 1. BIVARIATE CONTOUR ELLIPSE AREAS (AREA) AND STANDARD DEVIATIONS (SD) ASSOCIATED WITH THE MEAN BRIGHT FIXATION LOCUS, MEAN DISAPPEARANCE POSITION (DIS), SACCADE-ONSET (ON) AND OFFSET (OFF) POSITIONS WITH DIM AND VERY DIM TARGETS

bright	(14 trials)					Subject RS
Area	(min arc)^2	89·7				
SD	(min arc)	3·6				
dim	(36 cycles)		dis	on	off	
Area	(min arc)^2		115·7	130·8	618·6	
SD	(min arc)		4·1	4·3	9·5	
very dim	(63 cycles)					
Area	(min arc)^2		258·3	359·5	1321·0	
SD	(min arc)		6·1	7·2	13·8	
bright	(22 trials)					Subject AS
Area	(min arc)^2	131·8				
SD	(min arc)	4·4				
dim	(33 cycles)		dis	on	off	
Area	(min arc)^2		455·5	358·5	347·1	
SD	(min arc)		8·1	7·2	7·1	
very dim	(55 cycles)					
Area	(min arc)^2		457·4	441·4	537·9	
SD	(min arc)		8·1	8·0	8·8	

The trace on the right shows typical fixation of the very dim target. There are two important differences that can be seen. First, the disappearance position is not as close to the bright locus. The major difference between dim and very dim disappearance positions can be seen in the extent of the return on the horizontal meridian. (This was evident in Fig. 1 that showed the average cycle for this subject.) Second, cycles were shorter. For RS, the dim target disappeared, on the average, every 7·5 sec; the very dim target every 4·3 sec. The recordings of our second subject, AS, shown in Fig. 3 are very similar except for the direction of his target-finding saccade and his tendency to make a few relatively small saccades rather than a single large one in order to place the target in a more sensitive region where it would be visible. AS reported a disappearance every 14·1 sec with his dim target and every 7·4 sec with his very dim target. The cycle differences for both *S*s were on the order of 2:1 in the several hundred seconds of film sampled.

We examined in detail the eye movements that returned the target to the disappearance position for our more experienced subject, RS. In order to obtain a representative sample of fixation during the period faint targets were visible (the period beginning with the offset of the large target-finding saccade and continuing until the next reported disappearance) we first measured the time and distance between target-finding saccade-offset and disappearance position for all 99 (36 dim and 63 very dim) of RS's disappearance cycles. The velocity (min arc/sec) was calculated for this return portion of each disappearance cycle. The median return-velocity cycle for each low luminance condition and four cycles just above and below the median were chosen for exhaustive measurement. During each of these 18 representative returns, a count was made of the number of saccades and inter-saccadic drifts that moved the eye towards and away from the disappearance position. Movements away would serve to keep the target in a peripheral region where it would remain visible. Movements towards would contribute to its disappearance.

With the dim target 54 per cent of the saccades moved the eye towards the disappearance position: saccades were almost as likely to move the target towards the periphery as to return it to the disappearance position. With the very dim target the tendency of saccades to go towards the disappearance position increased (62 per cent towards). The picture was quite different for inter-saccadic drifts: 76 per cent of the drifts with the dim and 83 per cent with the very dim target went towards the disappearance position. Drifts were performing the major role in the return of the target image to a region where it would disappear. With both low and high velocity movements, however, the tendency for a movement to contribute to target disappearance increased when target luminance was reduced. The relative contribution of drift movements in the return of the faint targets as well as the effect of target luminance become apparent when the size of the average saccade and inter-saccadic drift vectors towards and away from the mean disappearance position are examined. This analysis is summarized in Table 2.

TABLE 2. MEAN INTER-SACCADIC DRIFT AND SACCADE VECTORS (MEASURED FROM TARGET-FINDING SACCADE-OFFSET) OF SUBJECT RS TOWARDS AND AWAY FROM HIS MEAN DISAPPEARANCE POSITION WHILE FIXATING DIM AND VERY DIM TARGETS. STANDARD DEVIATIONS ARE GIVEN IN PARENTHESES

	Drifts (min arc)		Saccades (min arc)	
	Towards	Away	Towards	Away
dim	64 (9·3)	42 (9·9)	39 (4·4)	34 (5·9)
very dim	80 (7·4)	10 (4·4)	36 (6·0)	23 (7·5)

The inter-saccadic drifts towards the disappearance position were not only relatively much more frequent but, on the average, carried the eye much farther than the average saccade in either direction. Note, however, that as luminance was reduced the size of the mean drift vector towards the disappearance position increased and the mean saccade and drift away from the disappearance position became appreciably smaller. *The higher disappearance-cycle rate observed with the very dim target results, then, from changes in the size and frequency of both high and low velocity movements.*

3. *Target-finding saccade direction*

In our first experiment both subjects reported that they made a "voluntary" saccade to bring the dim and very dim targets back into view after they had disappeared. A second experiment was performed to evaluate this subjective report. Subjects were instructed to make saccades in directions specified by the experimenter. They were told to look UP, DOWN, RIGHT or LEFT when the dim target disappeared. Blocks of 10 trials were run under each instruction. At least 2 directions were recorded in each daily session. Figure 4 shows representative performance of subject RS under such directional instructions. The performance of AS did not differ in any important characteristics.

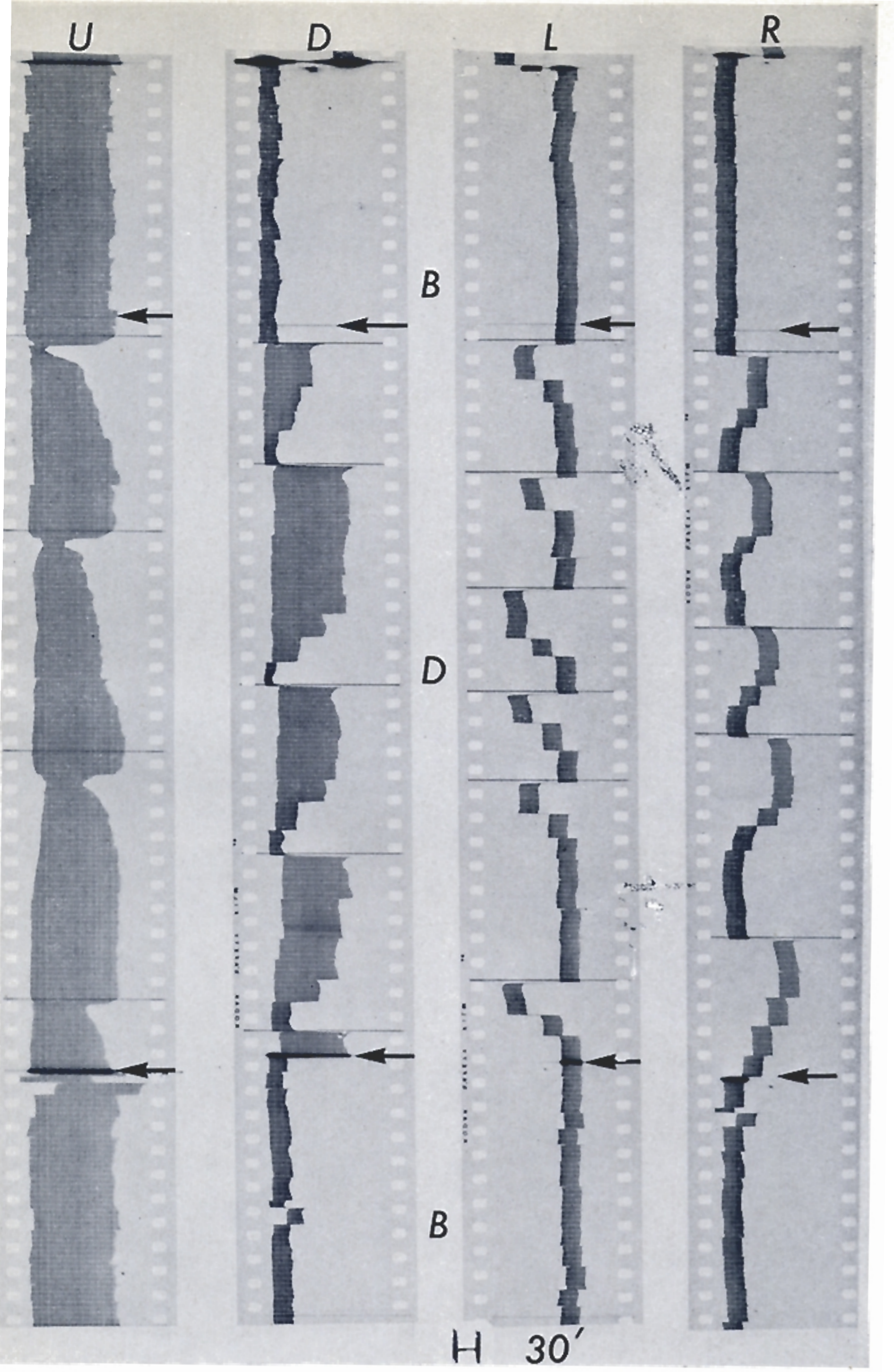

FIG. 4. Representative eye movement recordings for subject RS fixating bright (B) and dim (D) targets after instructions to make target-finding saccades up (U), down (D), left (L) or right (R). Target disappearances are indicated by horizontal dark lines and changes in target luminance are indicated by arrows. In the two recordings on the right only movements on the horizontal meridian were recorded. The two recordings on the left are two-dimensional; the left edge shows eye position on the horizontal meridian and the width of the trace shows position on the vertical meridian. A 0·1 sec time base was produced by interrupting the recording trace (repetitive faint white lines).

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Again, the arrows indicate changes of target luminance and the horizontal lines, disappearances. A portion of the next bright condition can be seen at the bottom of each film strip.

The left-hand strip is a sample of performance under instructions to look up when the target disappeared. The subject followed the instruction as shown by the abrupt narrowing of the trace accompanied by only a negligible shift of its left edge. The return towards the bright locus was made primarily by drifts. In the second strip from the left, the subject was instructed to look down when the target disappeared. There is a very prominent difference in the kind of return movements made when the subject looked down compared with his performance when he was asked to look up. The return after looking down was primarily saccadic. A sample of fixation under instructions to make left and right target-finding movements can be seen in the two right-hand strips. The subject went in the appropriate direction to find the target. Note that saccades were more important than inter-saccadic drifts in the return of the eye to its disappearance position on the horizontal meridian.

We again made a detailed analysis of the direction of saccades and drifts for 9 representative disappearance cycles under each instruction. Sampling was accomplished in the same manner employed in the first experiment. When RS looked up, only 33 per cent of his saccades, whereas 82 per cent of drifts, returned his eye. When he looked down, however, only 62 per cent of his drifts and 81 per cent of his saccades returned his eye. The relative importance of the two kinds of movements in the return of the target was reversed. On the horizontal meridian saccades accounted for most of the return from both directions: 75 per cent when he looked right and 81 per cent when he looked left. When he looked right only 50 per cent of his drifts returned the target whereas somewhat more (63 per cent) of his drifts went towards the disappearance position when he looked left. The mean drift and saccade vectors following target-finding saccades in each direction are summarized in Table 3. The sizes as well as relative frequencies of drift and saccadic return movements depend upon the direction the subject looked to find the target.

TABLE 3. MEAN INTER-SACCADIC DRIFT AND SACCADE VECTORS OF SUBJECT RS TOWARDS AND AWAY FROM HIS MEAN DISAPPEARANCE POSITION FOLLOWING A VOLUNTARY TARGET-FINDING SACCADE IN ONE OF FOUR DIRECTIONS. STANDARD DEVIATIONS ARE GIVEN IN PARENTHESES

	Drifts (min arc)		Saccades (min arc)	
	Towards	Away	Towards	Away
Up	93 (8·0)	17 (6·8)	12 (4·1)	30 (5·3)
Down	32 (4·9)	30 (6·8)	82 (3·7)	5 (2·6)
Left	27 (4·2)	5 (1·3)	73 (7·5)	26 (7·0)
Right	21 (3·5)	14 (4·3)	74 (5·2)	22 (4·9)

DISCUSSION

SIMON (1904), employing subjective techniques, accurately described the gross changes that occur when subjects fixate targets too dim to be visible when they fall in the central fovea. Under such conditions eye movements return faint targets to the central region where they disappear. We found that both saccades and inter-saccadic drifts contribute to the return of the target to the insensitive central region: The relative contribution of each kind of movement depends, moreover, on the direction the subject chooses for his voluntary target-finding saccade. The relative roles of drifts and saccades in the return towards the preferred central locus would seem, then, to depend either on the signal characteristics of the particular portion of the retina stimulated by the faint target; or, perhaps, on the motor-control system that responds with either high or low velocity return movements depending on the orientation of the eye in the orbit following voluntary target-finding saccades that bring the faint image to fall above, below, to the right or to the left of the preferred central locus.

STEINMAN (1965) has shown that the preferred central fixation locus is both small ($<$ 10 min arc) and invariant for a given subject. The present experiments suggest that there are direction signalling elements arranged about the central region whose activity increases as target luminance is reduced. Stimulation of these scotopic directional elements, which become active when target luminance is subthreshold for the centermost portion of the fovea, leads to eye movements, both drifts and saccades, that guide the faint target image back towards the preferred central locus even when subjects know that the target will disappear once it falls in that region; and after they have been instructed to try to keep the faint target in view.

OYSTER and BARLOW (1967) have recently reported that the directional organization of ganglion cell receptive fields in the rabbit retina is arranged "to correspond to the directions of apparent object displacement produced by contractions of the four rectus muscles." These authors suggest that similar arrangements (complicated by a torsional movement component) may be found in man and other animals and serve to guide fixation eye movements. We feel that our experiments support this suggestion in the sense that under appropriate and very restricted conditions, a primitive and perhaps relatively peripheral eye movement signalling system will, reflexly, bring targets to the preferred central fixation locus; that portion of the human retina that normally permits the best view of the target object. Under our conditions, of course, no such result ensues inasmuch as the region of best detail vision is relatively ineffective as a detector of feeble white lights.

We have subsequently observed that subjects can look away from a bright target and then maintain eye position reasonably well when the bright target falls on a portion of the retina that, when stimulated by a much more feeble light, led to the dramatic high and low velocity return movements described in this paper. A fixation error is not reduced by reflexive eye movements if subjects are suitably instructed and the fixation target is bright. We have also noted that eye movements do not seem to be related to the periodic disappearances of low luminance long wave length targets. We asked one of our subjects, RS, to reproduce the conditions of our first experiment with a red target (Kodak Wratten 70); i.e. red and white bright targets were matched for brightness and the luminance of dim and very dim red targets was set to yield approximately the same number of disappearances during 45 sec trials as had been observed with the faint white-light targets. The recorded disappearance positions of the faint red targets were scattered over a large region within the fovea and near periphery: The movement pattern following target-finding saccades did not show a marked tendency to bring the faint red targets back towards the small portion of the central fovea preferred when the bright red target was fixated. A reduction in the luminance of the red targets to a level that led to periodic disappearances resulted, primarily, in marked increases in variability of eye position.

We are left with the following puzzle: What is there about highly visible white or very faint red targets that allows the subject to cancel the fixed-directional-signals that have been found to dictate events when the fixation target is white and its luminance is near foveal threshold?

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Abstract—A contact lens technique was used to record 2-dimensional eye movement patterns While subjects fixated small "white" light targets just above and two levels below foveal threshold. The subthreshold targets disappeared periodically. Eye movements, primarily drifts, were responsible for these disappearances. They repeatedly moved subthreshold targets near to the insensitive preferred central fixation locus. Disappearances were followed by a target-finding saccade that placed the target in a more sensitive retinal region. Each subject's saccades were consistent but idiosyncratic in direction.

In a second experiment subjects were instructed to make target-finding saccades in four specified directions. They did so and subsequent movements brought the target back to the central disappearance position. The importance of drifts and saccades in the return varied with the direction of the voluntary target-finding saccade.

These experiments imply a reflexive guidance system that comes into play when the fixation target is feeble. This system is maladaptive: it guides faint targets to a retinal region where they can not be seen.

Résumé—Avec un verre de contact, on enregistre les mouvements à 2 dimensions des yeux pendant que les sujets fixent une petite cible de lumière "blanche" juste au-dessus et deux niveaux en dessous du seuil fovéal. Les cibles infraliminales disparaissent périodiquement. Ces disparitions sont dues aux mouvements des yeux, surtout aux dérives. Ces mouvements déplacent d'une façon répétée les cibles infraliminales près du point de fixation centrale préféré et insensible. La disparition est suivie d'une saccade à la recherche de la cible, qui amène celle-ci dans une région rétinienne plus sensible. Les saccades des divers sujets sont analogues, mais de direction variable.

Dans une seconde expérience, on demande aux sujets de faire leurs saccades de recherche de cible dans quatre directions spécifiées. Après qu'ils l'aient fait, des mouvements amènent à nouveau la cible dans la position centrale de disparition. L'importance des dérives et saccades de retour varie avec le direction de la saccade volontaire de recherche.

Ces expériences impliquent un système réflexe de guide qui entre en jeu quand la cible de fixation est peu éclairée. Ce système est mal adapté, en ce sens qu'il guide les cibles faibles vers une région rétinienne où elles ne peuvent pas être vues.

Zusammenfassung—Mittels Kontaktlinsen wurde eine 2-dimensionale Aufzeichnung der Augenbewegungen vorgenommen, wobei die Beobachter kleine "weiße" Lichter gerade oberhalb und zwei Stufen unterhalb der fovealen Schwelle fixierten. Die unterschwelligen Lichter verschwanden periodisch. Augenbewegungen, hauptsächlich Driftbewegungen, waren für dies Verschwinden verantwortlich. Sie bewegten unterschwellige Lichter mehrfach zu dem bevorzugten, unempfindlichen, zentralen Fixationsort hin. Das Verschwinden wurde von einer zielfindenden Sakkade gefolgt, die das Objekt in ein empfindlicheres Gebiet der Netzhaut verlagerte. Die Sakkaden der einzelnen Beobachter waren konsistent, wiesen aber unterschiedliche Richtungen auf.

In einem zweiten Experiment wurden die Versuchspersonen angehalten, die zielfindenden Sakkaden in vier spezielle Richtungen zu verlegen. Die dementsprechenden Augenbewegungen ließen das Ziel wieder in die zentrale Lage des Verschwindens wandern. Der Einfluß von Driftbewegungen und Sakkaden bei der Rückkehr änderte sich mit der Richtung der gewollten Suchsakkade.

Diese Experimente lassen ein reflexives Steuerungssystem folgern, das bei schwachen Fixierobjekten ins Spiel kommt. Das System hat schlechte Adaptationseigenschaften: Es führt schwache Signale in ein Netzhautgebiet, wo sie nicht mehr wahrgenommen werden können.

Резюме — Для записи формы движения глаз в двух направлениях во время фиксации маленького светящегося «белого» об'екта, яркость которого была слегка выше фовеального порога или же на два уровня ниже фовеального порога, была использована техника с применением контактной линзы. Подпороговые об'екты периодически исчезали. Эти исчезновения об'яснялись движениями глаз, в первую очередь, дрейфом. Они повторно смещали подпороговые об'екты ближе к нечувствительному, но предпочитаемому пункту центральной фиксации. После того как об'екты исчезали, возникали ищущие об'ект саккадические движения, при помощи которых об'ект вновь перемещался в более чувствительную область сетчатки. Каждое саккадическое движение испытуемого было определенным, но идиосинкратическим в направлении.

В следующем эксперименте испытуемые были инструктированы делать поисковые саккадические движения в четырех заданных направлениях. Эти движения они производили, но последующими движениями возвращали об'ект вновь в центральную позицию, где они исчезали. Значение дрейфа и саккадических движений при этом возвращении изменялось в зависимости от направления произвольных поисковых движений саккадического характера.

Эти эксперименты заставляют предполагать, что имеется рефлекторная ведущая система, котрая вступает в действие в тех случаях, когда фиксируемый об'ект плохо видим. Эта система отличается плохой адаптивностью: она перемещает слабо видимый об'ект в ту область сетчатки, где он не может быть видим вообще.