Visual Acuity When Eyes Are Pursuing Moving Targets

Abstract. Acuity for a stationary test object decreased when the eye followed a moving fixation target. This effect became larger with increased target speed, with decreased illumination, and with longer exposure of the acuity object. The acuity object's orientation also influenced the results.

A person maximizes the resolution of a moving object by following it with his eyes (*1*). The effectiveness of this process has been studied by measuring visual acuity with a moving test object (*2*). Visual tracking has a side effect, however, for the clarity gained by fixating a moving object is accompanied by blurring of the stationary environment. The present experiment (*3*) was intended to determine the effects of pursuit eye movement upon acuity for a motionless test object.

Ocular pursuit was elicited by a moving target which the subject was instructed to fixate. This target was a small white rectangle that moved horizontally across a large black screen. Target speed was varied from 0° to 120° of visual angle per second. An acuity object in the middle of the screen was briefly illuminated when the target passed directly beneath it. The center of the test object was 54 min above the target. The brightness and duration of the illuminating flash was varied.

The acuity object was a pattern of three parallel white stripes on a black background. Minimum resolvable size of the pattern was determined by the method of limits. An increase in threshold stripe width indicated a decrease in visual acuity.

The relationship between target speed and acuity was found to be influenced by the orientation of the stripes (horizontal or vertical) and by the brightness and duration of the flash that illuminated them. Figure 1 shows minimum stripe width in minutes plotted against target speed in degrees of visual angle per second. Exposure duration was 99 msec. When the acuity object was brightly illuminated, target speed had little effect. When the light was dimmer, however, ocular pursuit raised thresholds. Acuity was reduced more for vertical stripes than for horizontal ones. Also, the rise in threshold produced by a given increment in target speed became less at the higher speeds.

With the luminance of the stripes equal to 60 mlam, minimum resolvable stripe width did not increase as target speed increased. In fact, threshold width was somewhat below its initial value when the target moved at 60° per second. When the target was at rest, minimum width was 1.53 min for vertical stripes and 1.75 min for horizontal ones. At this luminance the flash looked glaringly bright against the dark background and the stripes seemed to spread. Eye movement made the light appear less bright. The slight improvement in acuity produced by ocular motion was about equal to the improvement produced by dimming the light to eliminate glare. Vertical stripes were as visible as horizontal ones at all speeds.

At 0.28 mlam pursuit movement raised threshold. When the fixation target was stationary, horizontal and vertical thresholds were both 1.61 min —about what they were at 60 mlam. But target motion raised vertical threshold to almost 5 min and horizontal threshold to about 3.5 min. The rise in threshold was even greater with the luminance decreased to 0.071 mlam, as was the disparity induced between vertical and horizontal thresholds. Thus the uppermost pair of curves in Fig. 1 begins at about 2.5 min, and the horizontal threshold rises above 5 min while the vertical exceeds 7.5 min at 120° per second. Each of the four highest curves is steeper at the lower speeds. More than half their overall rise occurs in the first 30° of the 120° range of target speeds.

Ocular pursuit had little effect on acuity when the test object was illuminated by a very brief stroboscopic flash. A 99-msec flash of 7.9 μlam yielded thresholds of about 5 min for both horizontal and vertical stripes under steady fixation. The same light energy concentrated into a 1-μsec strobe flash gave approximately the same thresholds, for within certain limits a constant product of luminance and duration results in a constant acuity level (*4*).

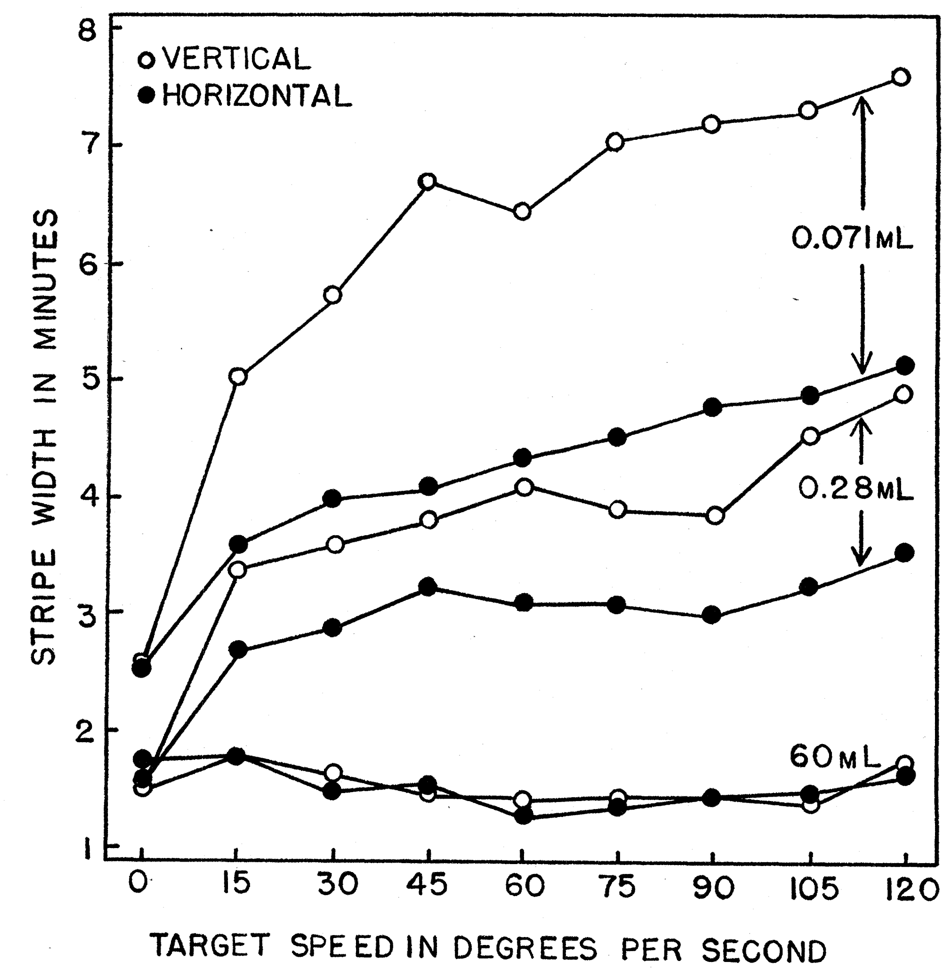

Fig. 1. Minimum resolvable stripe width in minutes of visual angle as a function of target speed in degrees of visual angle per second. Thresholds for horizontal and vertical stripes were obtained at three luminance levels. Each point is the average of eight determinations on one subject.

This relation between energy and acuity held with steady fixation, but it did not hold with a moving fixation target. Thresholds obtained with the 99 msec flash were greatly increased during visual tracking, and vertical thresholds became much higher than horizontal ones. In contrast, when the 1-μsec flash was used there was a maximum increase of less than 1 min with no separation between horizontal and vertical thresholds.

Tracking the target naturally causes motion of the acuity object's image on the retina. Since there is a lag in the visual response to the changing pattern of retinal illumination, the acuity object looks blurred. Horizontal movement makes the horizontal stripes appear longer and dimmer. Resolution of vertical stripes is affected more than that of horizontal ones because light from the vertical stripes is spread, in effect, over the dark spaces between them, thereby reducing contrast as well as brightness.

The smaller effect of ocular pursuit at higher luminances may be related to the fact that the acuity loss caused by a given decrement in brightness is smaller at high luminances than at lower ones (*5*). Over a certain range of high brightness, visual acuity is not altered by varying luminance. Faster discrimination of the moving image may also reduce the effect of eye movement at higher brightnesses. The perception of flicker presents a similar case of improved temporal resolution accompanying increased luminance (*6*).

The stroboscopic flash minimizes the effect of eye movement by virtually stopping motion of the retinal image. During the 1-μsec exposure the acuity object's image moves hardly any distance at all on the retina. Hence threshold was constant under varied target speed.

The reason that equal increments in target speed have less effect at higher speeds is probably that they do not produce corresponding increments in speed of eye movement. The eye can make smooth following movements at velocities up to about 30° per second, but at higher target speeds sustained pursuit motion becomes increasingly slower than target speed (*7*).

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Mating Competitiveness of Chemosterilized and Normal Male House Flies

Abstract. Male house flies sterilized by feeding on a diet containing 1 percent of apholate (2,2,4,4,6,6-hexa(1-aziridinyl)-2,4,6-triphospha-1,3,5-triazine) were as successful as normal males in competition for mates. The percentage of sterile eggs laid by females in cages containing normal and chemosterilized males was as high as, or higher than, would be expected from the ratio of sterile males present.

Insect control by means of sterilization has received much attention in recent years, and the release of sterilized males has been used in screw-worm eradication (*1*). Sterility in insects has been achieved primarily through irradiation, but recently chemicals producing this same effect have been found and possibilities of using them have been discussed (*2, 3*). Laboratory and initial field studies (*4*) have indicated the possibility of using chemosterilants to control house flies [*Musca domestica* (L.)], but much remains to be learned about the effects of these compounds on the behavior and physiology of the insects. One important aspect to be considered is the sexual competitiveness of chemosterilized males. According to Bushland (*5*) gamma irradiation does not affect the mating of sterilized screw-worms, but Davis *et al.* (*6*) found that radiosterilized male mosquitoes are not as competitive as normal males.

To determine the effect of chemosterilants on the mating behavior of house flies, experiments were conducted with male flies sterilized with apholate (2,2,4,4,6,6-hexa(1-aziridinyl)-2,4,6-triphospha-1,3,5-triazine). The male flies were isolated from the females and, for the first 3 days after emergence, they were given food (6 parts of sugar, 6 parts of powdered milk, and 1 part of powdered egg) which contained 1 percent of apholate; for the next 2 days they were given untreated food. On the fifth day the sterilized males, and/or normal 5-day-old males that had also been isolated from females but had been given only untreated food, were placed in cubic mating cages 4 feet square. To give both types of males an equal opportunity for initial mating, all males in each cage were given 30 minutes to become oriented before the 5-day-old virgin females, which had been

Table 1. Fertility of normal female house flies caged with normal and/or chemosterilized males at various ratios.

Ratio*	Number of females	Number of egg masses	Eggs per mass	Number of pupae	Percentage of egg masses with > 20% sterility	Percent sterility†
			Series 1			
0 : 1 : 1	80	61	82		15	12
1 : 1 : 1	40	50	85		62	66
1 : 1 : 2	30	18	93		100	69
2 : 1 : 1	53	29	73		93	92
3 : 1 : 1	35	14	126		100	98
5 : 1 : 1	30	18	92		100	100
10 : 1 : 1	30	19	141		100	100
1 : 0 : 1	20	26	67		100	100
			Series 2			
0 : 1 : 1	20			265		0
5 : 1 : 1	20			11		96
10 : 1 : 1	20			0		100
			Series 3			
0 : 1 : 1	20			2141		0
1 : 1 : 1	20			1168		46
1 : 1 : 1	20			665		69
2 : 1 : 1	20			610		72
3 : 1 : 1	20			275		87
1 : 0 : 1	20			0		100

* Chemosterilized males : normal males : normal females. † Based on all eggs in series 1 and on the number of pupae produced by flies in control cage containing only normal males in series 2 and 3.