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ABSTRACT

This study investigated whether the acuity threshold for distant targets is elevated for infants ranging in age from 24 to 63 days. Using square wave gratings and a modified staircase procedure, acuity thresholds for each of 331 infants were determined for one or more of the distances 30 cm, 60 cm, 90 cm and 150 cm. Acuity threshold was defined as the finest grating toward which the infant directed a significant proportion of first fixations. Results indicate that these thresholds were centered around a modal grating-stripe width of 30 minutes of visual angle, regardless of the infant's age. The predominant threshold of 20 - 30 minutes of an arc was found for the 150 cm distance, and no general improvement in acuity threshold was found over the age range tested. These results are in agreement with other infant acuity studies, showing that 1- to 2-month-old infants are sensitive to gratings of 2 cycles per degree or coarser. This value was relatively constant across large distances, suggesting that the 1- to 2-month-old infant's lens does not accommodate as a function of target distance. This finding is compatible with the evidence to date that the low visual acuity of the infant does not vary with the distance of the pattern being viewed. (It is suggested that the young infant is sensitive only to low spatial frequencies, so that there is not effective stimulus for accommodation.) (GO)

Infant accommodation and acuity threshold as a function of viewing distance.

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I'd like to start by reading to you from two well known and oft used textbooks of child development. First: "The neonate's eyes have a fixed focus at about 7½ inches [19 cm], which may mean that more distant objects are seen as blurred." (1) And second: "It appears that for the first month the infant does not make any adjustment to objects at varying distances from his eyes (called accommodation). He seems to have a fixed focus at about 8 inches from his face. The poor accommodation for the first 8 weeks would make the perception of detailed form at a distance difficult." (2)

These statements are based on the findings of two studies, one by Haynes, White, and Held (3), and a replication by White and Zolot (4). Both employed the technique of dynamic retinoscopy to assess the refractive state, i.e., the focus, of the lens as infants fixated targets at varying distances. The results indicated that during the first month or two refraction of the lens did not vary appropriately with the distance of the target being fixated. Each infant's lens was fixed in focus for some distance--called the focal plane--within 32.5 cm from his eyes. The particular distance of this focal plane varied from infant to infant, with a median distance of 19 cm.

These retinoscopic data have some interesting implications for acuity threshold, psychophysically determined as a function of distance. If there is a fixed focal plane at about 19 cm., then, at least according to the geometric optics of the adult eye, a target distance of 150 cm would be about 5 diopters out of focus. For the adult, a refractive error of this magnitude would markedly elevate the acuity threshold. Only a limited number of studies (5) have examined the acuity threshold of very young infants for a stationary target. Typically, the infant made a spontaneous visual choice between a square wave grating--a striped panel--and an unpatterned panel matched to the grating in size and luminance. Across all studies it has been generally found that the acuity threshold of the infant two months of age or younger is somewhere between 15 and 40 minutes of arc or, 2.0 and

.75 cycles per degree. No study has reported sensitivity to gratings finer than 2.0 cycles per degree. For a comparison, adults with good vision are sensitive to gratings of at least 30 cycles per degree (6).

However, most investigators using square wave gratings have determined acuity threshold using targets 35 cm or less from the infant's eyes. Fantz, Ordy, and Udelf (7) were the only ones who varied target distance, and in their study no effect of target distance on acuity threshold was found across the range employed, 13 to 50 cm from the eyes.

We investigated whether in fact the acuity threshold for distant targets is elevated for young infants, as the retinoscopic data suggest it may be.

Thirty three infants, ranging in age from 24 to 63 days, provided useful data; nine of them did so on more than one visit. The mean age of our subjects was 37.7 days. Infants were placed in an infant seat centered in front of a large Polacoat rear projection screen. On each trial a black and white square wave grating was rear projected on one side of the screen, along with a gray patternless field of the same size on the other side. The two fields adjoined at midline. The gratings presented had stripes of projected size of 10, 20, 30, 40, 50, or 75 minutes of visual angle at each test distance and were of high contrast. Gratings and gray fields were of moderate brightness and their overall projected size was $24^{\circ} \times 24^{\circ}$ of visual angle. To ensure that the line of sight of each infant was at midline before the introduction of each grating and control field, a vertical hatched bar was projected at midline prior to each trial. When the infant was judged by an observer to be fixating the bar, it was removed and the test fields introduced for 3 seconds. Two observers stationed on either side of the infant independently scored whether the infant's first eye movement following the introduction of the two fields was to the left or to the right, if he made one at all. Agreement between scorers was 73 percent.

A modified staircase procedure was used to determine acuity thresholds for each infant at one or more of the following distances--30 cm, 60 cm, 90 cm, or 150 cm. Side of presentation of the grating and gray field was randomly varied across consecutive trials at each stripe width, and normally at least 20 trials at each stripe width were presented. Acuity threshold was defined as the finest grating towards which the infant directed a significant proportion of first fixations ($p < .05$ according to a one-tailed, exact binomial probability test).

Table 1 summarizes the acuity thresholds determined at the various distances for all acceptable Ss. Note first that the thresholds are distributed in a similar fashion at each of the four distances. The thresholds in each case are centered around a mode of 30 minutes. This, incidentally was true regardless of age. Second, the predominant threshold we found for the 150 cm distance, 20-30 min, is similar to the value reported in the literature for one to two month olds looking at stationary targets close to the eyes. Third we observed no general improvement in acuity threshold over the age range we tested. This finding too is consistent with the literature--other researchers noted improvements with age only after 2 or even 3 months. Finally Table 2, lists our within subject data. Of the infants for whom both a near, i.e., 90 cm or closer, and a far, i.e., 150 cm, threshold were determined, 5 infants had identical near and far thresholds, 4 had higher near thresholds than far thresholds, and 2 had lower near thresholds than far thresholds. In only two cases did an infant's near and far thresholds differ by more than 10 minutes. The across distance differences are of the same magnitude as the differences between thresholds for the same distance determined on different days.

Our results, then, agree with other infant acuity studies, indicating that the one to two month old infant is sensitive only to gratings of 2.0 cycles per degree or coarser. In addition, our results suggest that this value is relatively constant across a large distance. This finding would seem to conflict with the findings of Haynes, White, and Held, and White and Zolot. How can fixed focus of the lens be reconciled with no effect of target distance on acuity threshold?

An initial possibility is that the retinoscopic data are inaccurate. One could argue that the infants were not fixating the targets in the retinoscopy studies and that one month olds are very difficult and unreliable clinical subjects. We do not wish to entertain this possibility. Haynes, White, and Held report good agreement among repeated measurements on the same infant, and they were able to detect consistent differences among infants of different ages. They were also able to detect consistent differences between sleeping and alert infants. The lenses of the infants when asleep were relaxed, with some 5 diopters less refractive power than when the same infants were awake and alert. This latter finding, incidently, demonstrates that if the infant's focus is fixed, it is not because the lens is rigid.

As an alternative, let's assume that the one to two month old does have a fixed focal plane. Also suppose that his acuity is limited to 2 cycles per degree or coarser by something other than the optics of the eye. Perhaps the immaturity of the retina or the central nervous system is responsible. As you may know, a square wave grating is made up of infinitely many sine waves, the lowest frequency sine wave specifying the fundamental frequency of the square wave (see Figure 1). What we are supposing is that the infant is insensitive to the higher spatial frequencies of a square wave grating, even when the grating is viewed at his fixed focal plane. At best what he sees is a 2 cycle per degree sine wave grating. He never sees sharp edges or resolves fine details.

Some work with adult subjects now becomes relevant. Green and Campbell (8) induced various amounts of refractive error or blur by placing lenses in front of their subjects' eyes. They found that the introduction of considerable refractive blur had a negligible effect on the sensitivity of adults to sine waves of low spatial frequencies, but effected a marked and increasing lowering of sensitivity to sine waves of higher spatial frequencies (see Figure 2).

What this suggests is that perhaps the one to two month old infant's lens does not accommodate as a function of target distance precisely because the infant is sensitive only to low spatial frequencies. That is, if the effective stimulus for accommodation is provided primarily by high spatial frequency information, or even simply by noticeable blurs, then for the young infant there is no effective stimulus for accommodation. He is not sensitive to high spatial frequencies and the low ones to which he is sensitive do not look different through refractive errors of considerable magnitude. Perhaps the lens of the young infant could exhibit variable accommodation if the visual system at or beyond the retina were more sensitive to higher spatial frequencies or if an optical situation in which even low spatial frequencies were unavailable unless the infant accommodated could be arranged. But whether or not the one to two month old CAN accommodate, findings that he does not are compatible with the evidence to date that the low visual acuity of the infant does not vary with the distance of the pattern being viewed.

References and Notes

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   Acuity thresholds for moving or flashing targets, e.g., Atkinson, J., Braddick, O., & Braddick, F. Nature, 1974, 247, 403; Dayton, G. O., Jones, M. H., Aiu, P., Rawson, R. A., Steele, B., & Rose, M. Arch. Ophthal., 1964, 71, 865; Gorman, J. J., Cogan, D. G., & Gellis, S. S. Sight-Saving Rev., 1959, 29, 80, will not be considered here since such thresholds do not appear to be comparable to those for stationary targets during early infancy.

6. Green, D. G. & Campbell. J. Opt. Soc. Amer., 1965, 55, 1154.

7. Fantz, et al. Ibid.

8. Green & Campbell. Ibid.

TABLE 1 DISTRIBUTION OF THRESHOLDS OBTAINED AT EACH TARGET DISTANCE

		STRIPE WIDTH						
		10	20	30	40	50	75	MINUTES OF ARC
		3.0	1.5	1.0	.75	.625	.4	CYCLES PER DEGREE
VIEWING DISTANCE (CM)	30	1	2	7	6	0	1	
	60	0	2	1	0	1	0	
	90	0	1	1	0	0	0	
	150	0	12	13	3	2	0	

TABLE 2 WITHIN SUBJECT DATA: THRESHOLDS ACROSS DISTANCE AND REPEATED THRESHOLD DETERMINATIONS

DISTANCE (CM)

SUBJECT	30 SESSION A	30 B	30 C	60 A	60 B	90 A	90 B	150 A	150 B	150 C
A.N.						30′		30′		
M.L.						30′		30′		
J.S.				50′				20′		
D.W.				30′	20′			20′	30′	20′
J.R.								40′	30′	
M.B.	20′	30′						20′	20′	
J.F.	40′							50′		
A.H.	30′							30′		
A.L.	20′	30′								
S.C.	10′							20′		
D.S.	30′							20′		
C.A.	40′	30′	30′					20′		
P.W.	75′							40′		

Figure 1

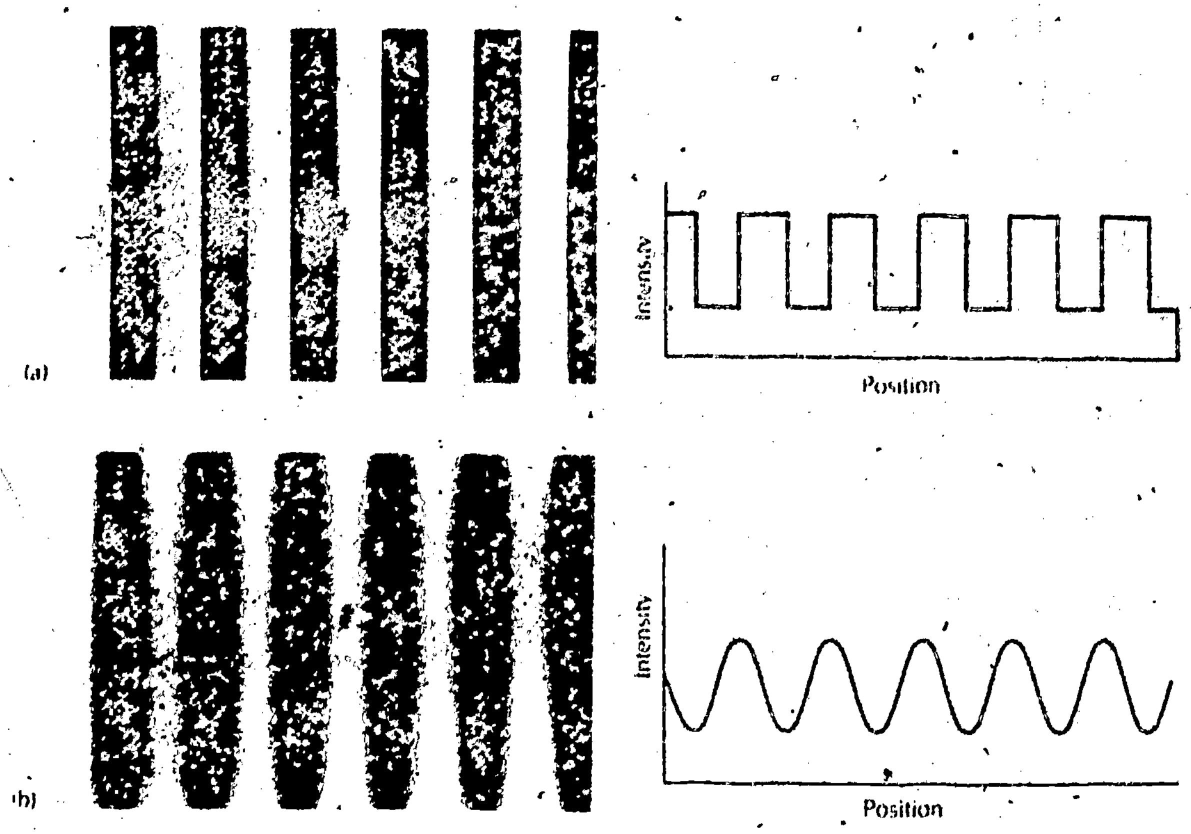

Figure 1. Sine and square wave gratings of the same fundamental frequency.

Figure 2

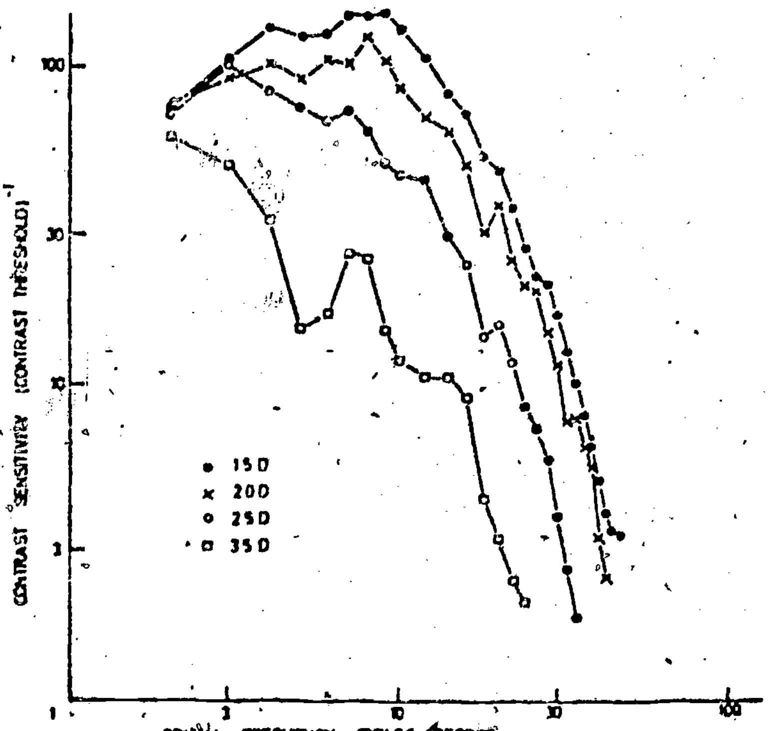

FIG. 2. Effect of focus on the contrast sensitivity measured for increasing positive lens power. A 2-mm-diam pupil was used. The eye was in focus for the viewing distance when corrected with +1.5 D lens (closed circles). Each point is the average of three measurements (observer D.G.G.).

Figure 2. From Green & Campbell, 1965.