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The temporal course of the relationship between retinal disparity and the equidistance tendency in the determination of perceived depth*

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Changes in perceived depth as a function of exposure duration were compared for two stimulus conditions. In one, a depth interval between two points of light was produced by the retinal disparity cue, and in the other condition, otherwise identical to the first, the light points were connected by a thin luminous line. The principle finding was that the perceived depth interval between the light points increased as a function of exposure durations greater than 1 sec, while no change in the perceived depth interval between the end points of the line occurred. The results were interpreted in terms of a greater equidistance tendency (ET) operating for the line than for the point condition. It was concluded that both the ET and the retinal disparity cue increase in strength as a function of exposure duration.

It has been repeatedly found that, except for very short distances, depth intervals are underestimated. This is true whether many cues to perceived depth are present (Gilinsky, 1951; Gogel, Wist, & Harker, 1963; Wist, 1972) or few cues are present (Gogel, 1960; Foley, 1967). One possible way of interpreting this fact, in addition to considering the role of perceived egocentric distance (Gogel, 1972), is to consider the possibility that the equidistance tendency (ET) opposes cues to perceived depth, and that the discrepancy between perceived depth and veridical perception is the result of the opposition of ET to whatever depth cues exist in the stimulus situation as well as to underestimation of egocentric distance.

Gogel (1965) has defined ET as the tendency for objects or parts of objects to appear visually at the same distance in the absence of effective depth cues to the contrary. Gogel (1956) found that ET varies with the lateral separation of stimuli. It has been shown to be operative in a variety of stimulus situations (Gogel, 1965). Most appropriate to the present experiment, however, are those studies in which the retinal disparity cue was involved. Gogel, Brune, and Inaba (1954) found that the ET would modify a stereoscopic depth judgment. When an ET existed between the binocular comparison stimulus and a monocular stimulus appearing either nearer or farther than the binocular standard stimulus, a constant error in the adjustment of the comparison stimulus to perceptual equidistance with the standard stimulus resulted.

Evidence for the modification of stereoscopic depth by the ET has also been found in a quite different situation. Harker (1962) investigated the role of cyclotorsional eye movements on the reduction in the perception of tilt in depth of a luminous grid whose edges were not visible. He found that the amount of reduction of perceived tilt in depth during the viewing period was much greater than could be accounted for in terms of induced cyclotorsional eye movements. This excess was attributed to ET, since no other depth cues were present in the display to produce such an effect. Gibson (1950) and Bergman and Gibson (1959) have obtained results comparable to Harker's, using a display consisting of a textured surface slanted in depth with both monocular and binocular viewing conditions. The perceived slant in depth of the surface whose edges were not visible decreased with viewing time.

The latter studies suggest that the ET grows over time in opposition to the cues of retinal disparity and texture gradient which indicate nonequidistance of the elements of the display. Lodge and Wist (1968) studied the temporal course of the ET specifically. They examined the effect on the location in depth of a monocular disk centered in a display consisting of two binocular rectangles, one to the left and far, the other to the right and nearer. They found that when both rectangles were present simultaneously, creating opposing ETs between the disk and each rectangle, about 4 min of viewing was necessary before the disk assumed a final position in depth midway between the rectangles. When no conflicting ETs existed, only

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about 2 min were required for the disk to assume its final position. Thus, the temporal course of the ET depends upon the nature of the cues for depth localization.

The Harker (1962), Gibson (1950), and Bergman and Gibson (1959) studies support the conclusion that the ET can reduce the amount of perceived depth resulting from the retinal disparity cue as a function of viewing time. These studies suggest, furthermore, that if it were possible to completely remove the ET, perception of depth based on the retinal disparity cue would be veridical, assuming, of course, the veridical perception of egocentric distance. This analysis also implies that if it were possible to increase the strength of the ET opposing the retinal disparity cue without at the same time introducing additional depth cues, the slope of the function relating perceived depth and exposure duration would be reduced. This reduction would be proportional to the strength of the added ET. The present study was concerned with this latter implication. First, a stimulus situation was created in which retinal disparity was the only cue to depth and in which the ET was minimal. This situation consisted of two points of light with a large lateral separation, at two different distances in the dark. To increase the ET between these light points without at the same time adding additional depth cues, they were simply connected with a thin, horizontal, luminous line. Since the line was narrow, its appearance, slanted away in depth, offered no perspective cue to depth. Furthermore, since its surface was textureless, no retinal disparity cues existed between successive points along its length. Accommodation and convergence differences between the end points were ruled out by presenting the stimuli 3 m from the eyes. The line, therefore, tended to appear oriented in the frontoparallel plane with respect to S. The retinal disparity between the end points of the line was identical to that between the two points of light. Thus, this cue can be considered to be unaffected by the addition of the line. In this manner, it was possible to create two conditions, one containing a minimum ET, the two-point condition, and another containing a maximum ET, the line condition. Retinal disparity was identical for the two situations, but they differed in the strength of the ET. The amount of perceived depth as a function of both retinal disparity and exposure duration was determined for both stimulus situations. A comparison of the resulting functions allowed a determination of the relative strength of ET in the two situations over time and thus an evaluation of the possible role of the ET in the underestimation of depth from the retinal disparity cue.

METHOD

Subjects

Twenty-four psychology students with a stereoacuity of at least 19 sec of arc and a visual acuity of at least 20/22, as measured with a Bausch and Lomb orthorator, served as Ss for the main experiment. Eight additional students, with a stereoacuity of at least 32 sec of arc and a visual acuity of 20/25, were used in a preliminary experiment.

Apparatus

The experiment was conducted in a light-tight visual alley 8.9 m in length and 2.4 m in width. The S was seated in an observation cubicle at one end of the alley. The interior of the cubicle was covered with white cloth and illuminated by a cool-white fluorescent lamp at the center of the cubicle ceiling. The S viewed the stimulus display through two apertures, 2 cm in diam and 7 cm apart. In order to eliminate motion parallax, the S was discouraged from moving his head through the use of a head- and chinrest. A remote-controlled guillotine shutter prevented the S from looking down the visual alley between trials.

The stimulus was constructed from a 1 m x 5 cm strip of electroluminescent material obtained from the Polymetric Corporation. This strip was mounted on an aluminum bar masked with opaque Plexiglas so that only a 3 mm x 1 m strip of the electroluminescent material was exposed. This exposed portion served as the stimulus line and was mounted horizontally 3 m away at the same height as the viewing apertures in the S's median plane. This was done in such a manner that the line could be rotated at various angles to the S's frontoparallel plane. The pivot point was at the right end of the line so that, at all orientations, the right end remained at a constant distance from the S while the left end could be positioned at various greater distances from the S. The line illumination was held constant at 1 fL, and there were no discriminable variations in luminance or texture along its surface.

On the basis of pilot data, retinal disparities of 5, 10, and 15 min of arc were chosen. For the maximal ET condition appropriate maskers were constructed from black construction board to maintain the exposed frontal extent of the stimulus line at 5 deg for all three depth disparities. Thus, the orientation of the line could be set so that the right (front) and left (rear) end points of the line appeared at a disparity of 5, 10, or 15 min of arc while the lateral separation of the end points was held constant at 5 deg.

For the minimal ET condition, maskers were constructed so that only two points of light of equal apparent size and luminance were visible along the surface of the line at any of the three disparity orientations. The points of light for each of these orientations were positioned so that they corresponded to the end points of the line at that retinal disparity. Thus, two points of light could be presnted at a disparity of 5, 10, or 15 min of arc while the lateral separation of these points was maintained at 5 deg. Views of the stimulus arrangements can be found in Fig. 1.

The stimulus exposure duration was controlled by a Hunter interval timer. The durations used were .10, .25, 1.0, 5.0, and 15.0 sec. Since the 10-msec rise time of the electroluminescent material was only 1/10th of the shortest exposure duration, the luminance of the stimulus can be considered to be essentially constant during each exposure.

A fixation point, approximately 35 min of arc above the center of the stimulus array, was presented prior to stimulus onset and extinguished simultaneously with stimulus onset. This fixation point was of approximately the same luminance as the stimulus line.

All Ss made their depth estimates on a hand kinesthetic device. This device consisted of two vertical rods, 1 cm in diam and 10 cm long, which were grasped by Ss. The right rod was stationary, while the left was attached to a sliding meter stick which extended through the observation cubicle wall to a reference pointer. At this position, E could read off remotely the separation of the two vertical rods to the nearest millimeter by means of a closed-circuit television system.

The left (movable) rod was connected to a cable-and-pulley system, which enabled the E to vary its starting position. White material was used to cover the S's lower arms and the rods so that he could not see the device while the lights in the cubicle were on during the light adaptation periods between trials.

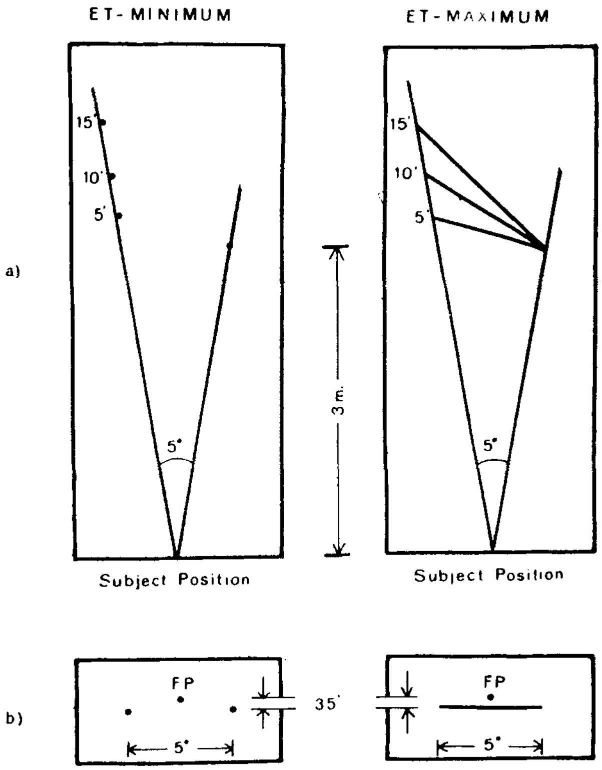

Fig. 1. Schematic views of the stimulus conditions (not to scale). (a) Overhead view of arrangement in depth of the light points (ET minimum) and line (ET maximum). (b) Frontal views. Fixation point (FP) extinguished upon presentation of the points or line.

Procedure

Independent groups of 12 Ss each were used for the maximal ET and minimal ET conditions. The procedure was identical for both conditions.

After being tested for stereo and visual acuity, S was taken into the observation cubicle and was read the instructions. He was told that his task would be to judge the magnitude of the depth inteval between the end points of a line tilted in depth (or between two points of light, in the minimal ET condition), that the stimulus would be visible for varying lengths of time, and that he should refrain from making his judgment until the stimulus had disappeared. S was then instructed on the use of the hand kinesthetic device. It was stressed that, after each response, the rods should be separated by a distance equal to the size of the depth interval he had just seen, regardless of the starting position for that trial. He was instructed to fixate on the fixation point before each trial and to say "ready" when he was sure he could see the fixation point clearly, first with each eye independently and then binocularly fused as a single image. S was then told that he would have a short rest period after every fifth trial during which he should " look at the white material lining the cubicle." These rest periods lasted approximately 2 min and served the dual purpose of giving the E an opportunity to adjust the apparatus to the appropriate orientation for the next block of five trials, and of maintaining the light adaptation of the S at a relatively constant level across trial blocks.

The S was given two sets of practice trials. During the first, the S observed the stimulus at various disparities for 6.0 sec and judged whether a depth interval was or was not present. During the second set, the S was required to use the hand kinesthetic device to estimate the magnitude of the depth intervals he saw. If any S was found to have particular difficulties during either set of practice trials, he was given additional practice on that set.

After completion of the practice trials, the S was given a rest period, and then the experimental trials were begun. The same retinal disparity was used throughout each block of trials. Within each block, the S was presented each of the five exposure durations: 0.10, 0.25, 1, 5, and 15 sec. The order of durations for each block was determined according to a pseudorandom method in which six duration orders were constructed such that the occurrence of a given duration in the same serial position on successive trials was minimized. These duration orders were then assigned to each S's trial blocks in a rotating order, such that S 1 was given Order 1 first, S 2 was given Order 2 first, etc.

Each S received six trial blocks, two blocks for each of the three disparities. The order of presentation of the disparities was counterbalanced so that each was seen by the same number of Ss first and each was seen by the same number of Ss last. Thus, each S saw each disparity-duration combination twice over the course of the experimental session. On one of these trials, S was required to respond in the ascending direction (rods together) and, on the other, in the descending direction (rods wide apart). The order of ascending and descending trials was alternated across disparity-duration combinations for each S; the direction of the first trial was alternated across Ss. At the beginning of each ascending trial, E set the rods at the "zero" position, approximately 6 cm apart. At the beginning of each descending trial, the handles were set at a separation of approximately 75 cm.

After completing all experimental trials, S was required to make depth estimates with the hand kinesthetic device under full-cue conditions. At this time, the guillotine shutter was raised and the alley was fully illuminated. S was asked to make six estimates at each of the three retinal disparities. For the first three, S made his estimates in the ascending direction. The same were then presented a second time while the S made his estimates in the descending direction. For all of these presentations the E pointed to both ends of the line or to the two points simultaneously in order to maximize available cues for depth. The entire session took approximately 1 h, after which the S was debriefed.

RESULTS

Each S made a total of 30 depth judgments, 2 for each of the five durations at each of the three retinal disparities. From these data, the mean depth judgment for each disparity/exposure-duration combination was calculated for each S.

The task used in the present study was a "scalar" judgment. As defined by Gogel (1968, p. 126), a scalar judgment is one which "refers to some unit not simultaneously present in the modality in which the judgment is being made." A major problem with the use of scalar judgments is that they cannot be considered to be equal to scalar perceptions. In order to compare the scalar perceptions of two Ss or groups of Ss, their obtained response scores must be converted to perceptual scores. In the present study, this conversion was accomplished through the use of the depth judgments obtained under full-cue (FC) conditions. The mean depth judgment for each retinal disparity under FC was calculated for each S. Using the method of least squares, a linear function representing the relationship between these FC judgments and the actual physical depth intervals was derived for each S. Since the FC situation contained many cues for the veridical perception of depth, it was assumed that Ss perceived nearly identical depth intervals which were proportional to the actual physical depth intervals. It follows that variation in FC response scores can be considered to be largely due

Table 1
Summary of Analysis of Variance of Corrected d′ Data

Source	SS	df	MS	f	p
Stimulus Condition (Stim)	1952.4	1	1952.4	.85	n.s.
Disparity (Disp)	13562.3	2	6781.2	12.57	< .001
Duration (Dur)	5645.9	4	1411.5	9.98	< .001
Stim by Disp	1091.1	2	545.5	1.01	n.s.
Stim by Dur	1483.9	4	371.0	2.62	< .05
Disp by Dur	1306.2	8	163.3	2.25	< .05
Stim by Disp by Dur	1427.4	8	178.4	2.46	< .025
Error Stim	48153.4	21	2293.0		
Error Disp	22651.8	42	539.3		
Error Dur	11883.4	84	141.5		
Error Disp by Dur	12197.0	168	72.6		

to differences in response bias between Ss. Since it was assumed that perceived depth is proportional to actual depth, the ratio of the function representing veridical perception and that representing a given S's FC function can be considered to be proportional to the ratio of a given S's response score obtained under reduced-cue conditions and his perceptual score. Thus, the amount by which an S's FC function deviated from veridicality can be considered to

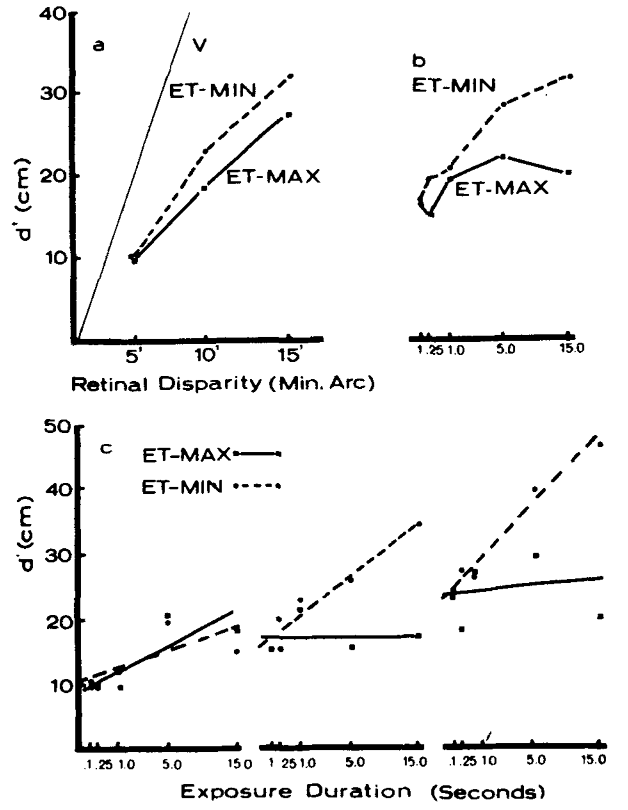

Fig. 2. Mean perceived depth (d′) as a function of retinal disparity. Veridical perception (V). Means calculated over exposure durations. (b) Mean perceived depth (d′) as a function of exposure duration; data for all retinal disparities combined. (c) Mean perceived depth (d′) as a function of exposure duration. (Disparities: left panel, 5 min; middle, 10 min; right panel, 15 min of arc.)

represent the amount of response bias. Therefore, a correction factor was calculated for each S by finding the multiplier and additive constant necessary to match the slope and Y intercept of his FC function to that representing veridical perception (i.e., slope = 1, Y intercept = 0.[1] The correction factor for a given S was then applied by first multiplying each of his mean response scores by the multiplier constant and then adding the additive constant to the resulting product. The mean perceived depth interval for each exposure duration at each retinal disparity was calculated from the corrected data and was used for the graphs and the statistical analysis.

An analysis of variance (three-factor mixed design: repeated measures on two factors) was run on the corrected data of the two groups. A summary of this analysis is presented in Table 1. It can be seen that no significant effects were found for stimulus (ET-MAX vs ET-MIN) or the Stimulus by Disparity interaction, while significant effects were found for disparity, duration, and the Stimulus by Duration, Disparity by Duration, and Stimulus by Disparity by Duration interactions.

Figure 2a shows the mean perceived depth (d′) of the two stimulus conditions as a function of retinal disparity. The data for all exposure durations were used in the calculation of these means.

It has been found, in many instances, that changing perceptions of unchanging stimuli "progress linearly with the square root of the observing time [Taylor, 1966, p. 113]." Since a similar effect was obvious in the present study, a square root time scale was used in all figures in which exposure duration was the independent variable. In Fig. 2b, mean d′ for the two stimulus conditions (ET-MIN and ET-MAX) is plotted as a function of exposure duration. As exposure duration increased, the difference in d′ for the two stimulus conditions also increases. This increased difference between the two conditions with increased durations illustrates the significant Stimulus by Duration interaction found in the analysis of variance (see Table 1). Post hoc Scheffé tests showed that there was no significant increase in perceived depth across exposure durations for ET-MAX, while significant increases were found for

ET-MIN between the .10- and 5.0-sec exposure durations and between the .10- and 15.0-sec exposure durations ($p < .05$ and $p < .001$, respectively).

Figure 2c is a breakdown of the data given in Fig. 2b as a function of retinal disparity. It represents the triple-order interaction between stimulus conditions, exposure duration, and retinal disparity. It can be seen that there is little difference between ET-MIN and ET-MAX conditions at the 5 min of arc disparity (left section), and that these functions are increasingly divergent with increased disparity (middle section, 10 min of arc; right section, 15 min of arc). When the slopes of the functions are compared, it can be seen that the ET-MIN functions have greater slope, indicating a greater rate of increase in d′ with increased exposure durations than for the ET-MAX functions. Finally, it should be noted that there is little difference between stimulus conditions at the .10-sec exposure for any of the retinal disparities. Post hoc Scheffé tests showed the following: (1) The d′ estimates for the 5 min of arc disparity, summed across durations, plus the d′ estimates for the .10-sec duration, summed across disparities, for the maximal ET condition were compared with the same data from the minimal ET condition. No significant difference was found. (2) The d′ estimates for the 15 min of arc disparity, summed across durations, plus the d′ estimates for the 15.0-sec duration, summed across disparities, for the maximal ET condition were compared with the same data from the minimal ET condition. This comparison was found to be highly significant ($p < .001$). Since no significant difference between stimulus conditions was found at the 5 min of arc disparity or the .10-sec duration and a highly significant difference was found at the 15 min of arc disparity and the 15.0-sec duration, it can be said that under the minimal ET condition significantly more depth was perceived with increased duration and disparity than was under the maximal ET condition.

In order to permit a more detailed comparison of the amount of d′ under the two stimulus conditions at each of the exposure durations, separate figures presenting perceived depth as a function of retinal disparity for each exposure duration were constructed (Figs. 3a-3e). For each of these figures, a linear function was fitted to the data points for each stimulus condition by the method of least squares. In addition, each figure includes a function representing veridical (V) perception and a function representing the mean perceived depth for all Ss under full-cue (FC) conditions (again fitted by the method of least squares). The number adjacent to each function indicates its slope. It can be seen that under FC conditions Ss underestimated depth and that depth was underestimated to an even greater extent under the ET-MIN and ET-MAX conditions. It should be noted that, with one exception (Fig. 3c), the slopes for the minimal ET functions are greater than those for the maximal ET functions. This is especially evident at the 5.0- and 15.0-sec durations (Figs. 3d and 3e). Although it is true that differences in slope appear evident at the .10-, .25-, and 1.0-sec durations, no significant differences in d′ were found at these exposure durations.

DISCUSSION

The results of Fig. 2b show that, consistent with the rationale given in the introduction, the additional ET contributed by the connection of the two points of light with the thin luminous line in the ET-MAX condition resulted in smaller changes in d′ as a function of exposure duration than were obtained for the ET-MIN condition. In fact, the added ET was so great that no increase in d′ over exposure duration resulted for this condition.

Furthermore, the statistical analysis revealed that the amount of d′ produced by the retinal disparity cue in the two stimulus situations did not differ significantly until the 5-sec exposure duration. Thus, up through the exposure duration of 1 sec, d′ can be considered to be identical for the two conditions. Why was it the case that 5 sec of exposure duration were required in order to reveal the difference between the ET-MIN and ET-MAX conditions? An answer to this

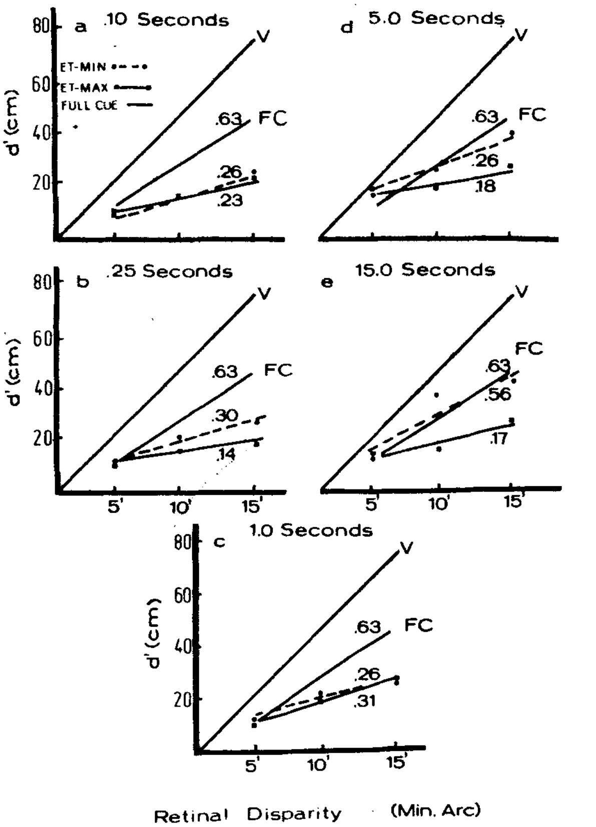

Fig. 3. Mean perceived depth (d′), in centimeters, as a function of retinal disparity for each exposure duration. Number adjacent to each line represents slope. Veridical perception, V; full-cue condition, FC.

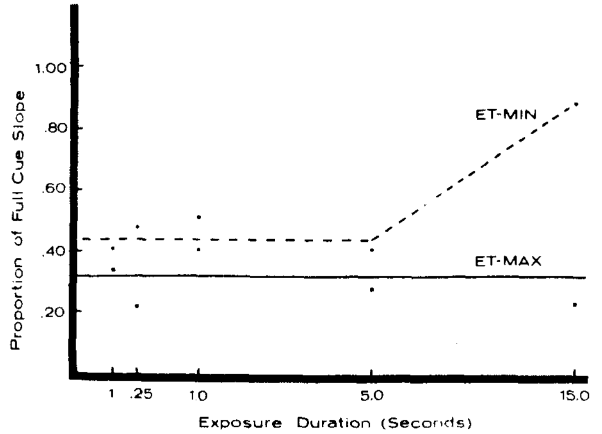

Fig. 4. Proportions of full-cue slope as a function of exposure duration. See text for explanation

question involves an assessment of the relative strengths of both ET and the retinal disparity cue over exposure time in both situations.

First, it can be argued that the retinal disparity cue was weak for exposure durations of 1 sec or less. The lateral separation between the points and the ends of the line was large (5 deg), and Ogle (1962) has shown that stereoacuity falls off rapidly at 5 to 7 deg of lateral separation. Furthermore, the weakness of the retinal disparity cue may have been due in part to the fact that some time is required for the visual system to process the depth information available from a given retinal disparity. Ogle and Weil (1958) found that stereoacuity increased with exposure duration up to 1 sec. In the present experiment, d′, rather than stereoacuity, was measured, and it is quite possible that even more time is required for depth magnitude information than for the simpler detection of the presence or absence of a depth interval as is required in the stereoacuity task. Thus, it seems reasonable to suppose that the retinal disparity cue was initially weak for both the ET-MIN and ET-MAX conditions.

Second, it can be argued that the ET was also initially weak for both conditions. This assertion can be supported by noting that only at the longer exposure durations of 5 and 15 sec was it able to produce a difference in d′ between the two conditions (see Fig. 2b). Thus, it must have been weaker at the shorter exposure durations. If the ET had been stronger at shorter exposure durations or equally strong for all exposure durations, then a difference in d′ between ET-MIN and ET-MAX would have been obtained for shorter durations. The d′ for ET-MAX would have been significantly smaller than that for ET-MIN because of the depressing effect on d′ of the greater ET in the former condition. It was found, however, that d′ did not differ between the two conditions.

Additional, and perhaps more convincing, support for the argument that both the retinal disparity cue and the ET were weak for exposure durations of 1 sec or less is provided in Fig. 4. This figure is based on the calculated slopes of the ET-MAX and ET-MIN functions relating d′ and retinal disparity at each of the exposure durations indicated in Figs. 3a-3e. These slopes are expressed in Fig. 4 as proportions of the full-cue slope of .63. Thus a proportion of 1.0 would mean that the ET-MIN or ET-MAX slope at a given exposure duration was identical to that obtained under the full-cue condition.[2] Fig. 4 shows that, for the ET-MAX condition, a mean proportion of full-cue slope of about .3 was maintained over all exposure durations. For the ET-MIN condition, this proportion was about .4 through the 5-sec exposure duration. At the 15-sec exposure duration, it increased to about .9, which is quite close to being equal to the slope obtained under the full-cue condition. Thus, it can be seen that the explanation offered above for the discrepancy in d′ between the ET-MIN and ET-MAX functions in Fig. 2b applies equally well in the case of Fig. 4. At the shorter exposure durations for both conditions, the retinal disparity cue is producing only about 30% or 40% of the d′ produced under the optimal full-cue condition. Only after 15 sec of exposure for the ET-MIN condition has it attained sufficient strength to approximate the amount of d′ produced under the full-cue condition. The counter interpretation, that d′ is low initially due to a stronger ET, is countermanded by the finding that the ET-MAX function, which contains an even stronger ET, is not significantly lower than the ET-MIN function at these shorter durations. Yet, if ET were responsible for "holding down" d′ in the ET-MIN condition, d′ should be held down even further in the ET-MAX condition. Thus, the data of both Figs. 2b and 4 support the conclusion that the lack of a difference between the ET-MIN and ET-MAX conditions in d′ for the shorter exposure durations was the result of both a weak retinal disparity cue and a weak ET at these durations.

The failure of the ET-MAX function to rise at longer exposure durations, as did the ET-MIN function, can be most simply accounted for in terms of the stronger ET produced by the line which was able to "neutralize" the increasing strength of the retinal disparity cue (as revealed in the ET-MIN function) and thus hold d′ constant over the entire range of exposure durations. In order for this to have been possible, the strength of ET for the ET-MAX condition must have been growing over time at a rate equal to or greater than that of the retinal disparity cue.

It should be noted that while the ET-MIN function shown in Fig. 2b appears to increase with exposure duration over the entire range of exposure, no significant difference was found between the 5- and 15-sec exposures. Furthermore, in a preliminary experiment, no significant difference in d′ was found for this condition between exposure durations of 10 and 25 sec. Thus, it is likely that this function is asymptotic at 5 sec. Still, an increase in d′ based on the retinal disparity cue over a 5-sec period has not, to the authors' knowledge, been previously reported. Emphasis has been on changes in stereoacuity as a function of exposure duration (e.g., Ogle & Weil, 1958). Howard and Templeton (1964), however, have reported decreased d′ after continuous "adaptation" to a retinal disparity. This effect, though, required several minutes of exposure rather than several seconds as in the present study. Other studies in which reductions in d′ due to the retinal disparity cue over time have been reported (Bergman & Gibson, 1959; Gibson, 1950; Harker, 1962) also required exposures of a minute or more and did not involve measurement of d′ during the first few seconds of observation. Thus there is no conflict between the present study and the earlier ones.

Our interpretation of the obtained results implies that if the initial strength of the retinal disparity cue were increased, then the maximum d′ for the ET-MIN condition would be obtained in less than 5 sec. Such an increase could be effected by decreasing the lateral separation between the two points of light from 5 to, say, 2 deg. Ogle (1962) has shown that retinal disparity is a much more effective depth cue with smaller lateral separations. Whether a reduction in lateral separation would result in a change in the slope of the function in Fig. 2b or simply an upward displacement of the Y intercept cannot be predicted from the present data. A further study, in which lateral separation is systematically varied, is planned. If it is found that the slope of the function relating d′ and exposure duration is unchanged by variations in lateral separation, then it can be concluded that the rate of increase over time in the effectiveness of the retinal disparity cue is independent of its initial strength.

In conclusion, it is appropriate to return to the problem of the underestimation of depth from the retinal disparity cue discussed in the introduction. Can it be concluded that the ET is responsible for a portion of this underestimation? For the longer exposure durations in the present study, the ET was responsible for a portion of the underestimation of depth.[3] Also, for the shortest exposure durations, it was found that the strength of the retinal disparity cue itself was low and thus contributed to depth underestimation. However, even with unlimited viewing time, when the strength of both the retinal disparity cue and the ET is maximal, considerable underestimation of depth still occurs. In the full-cue situation in which viewing time was not restricted, the slope of the function relating d′ and retinal disparity was .63 instead of 1.0. This finding is comparable to those of other studies using full cues in a visual alley (Gogel, Wist, & Harker, 1963; Wist, 1972). Can this discrepancy of .37 in slope be attributed to a residual ET which cannot be eliminated? While it is possible that a portion of this remaining discrepancy may be attributed to the ET, it is more likely that the largest portion is due to the underestimation of egocentric distance resulting from the specific distance tendency and residual oculomotor cues (Gogel, 1972). The nearest point in the visual field in the present study was at 3 m, but its median perceived egocentric distance was only 1.3 m.

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NOTES

1. The data of one S in the MAX-ET condition were not included in the statistical analysis. His FC function had a slope of only .2, which deviated significantly from the slopes of the other Ss in this group ($z = 3.01$, $p < .001$).

2. One apparent discrepancy between this figure and the statistical analysis should be noted. While a significant difference in d' was found between the 5- and .10-sec exposure durations, thus implying a nonzero slope between these points, this fact is not reflected in Fig. 4. This is because the d' data used in the analysis of variance involved averaging the d' values across disparities, thus washing out slope differences, but was influenced by the Y intercepts of the functions in Figs. 3a-3e. This is apparent in Fig. 3d if one examines the 5-sec exposure data for ET-MIN and compares this to the corresponding function for the 1-sec exposure in Fig. 3c. It can be seen that, while both functions have an identical slope of .26, the function for the 5-sec exposure is displaced vertically, indicating a greater mean d'.

3. It cannot be argued that the *differences* in perceived depth obtained for the ET-MAX and ET-MIN conditions were due to a difference in the perceived distance (D') of the stimuli. Estimates of the latter were obtained at the end of the experiment in feet and inches and converted to centimeters. No significant difference in perceived egocentric distance was found for these two conditions (ET-MAX—mean = 214.6, median = 121.9, SD = 93.8; ET-MIN—mean = 174.9, median = 137.1, SD = 105.7).

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