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SUMMARY

Observers typically overestimate the angular size of distant objects. Significantly, overestimations are greater in outdoor settings than in aircraft visual-scene simulators. In this experiment, the effect of field of view and monocular and binocular viewing conditions on angular size estimation in an outdoor field was examined. Subjects adjusted the size of a variable triangle to match the angular size of a standard triangle set at three greater distances. Goggles were used to vary the field of view (FOV) from 11.5° to 90° for both monocular and binocular viewing. In addition, an unrestricted monocular and binocular viewing condition was used. It was concluded that neither restricted fields of view similar to those present in visual simulators nor the restriction of monocular viewing causes a significant loss in depth perception in outdoor settings. Thus, neither factor should significantly affect the depth realism of visual simulators.

INTRODUCTION

One objective of aircraft simulation technology is to develop visually realistic simulators. Such development requires the ability to measure simulator realism. Traditional methods of such measurement include obtaining subjective opinions of visual fidelity from pilots and assessing pilots' flight performance in simulators. These methods can, however, only discriminate between "good" and "bad" simulators and cannot identify those specific visual cues missing in the simulators that are essential for maximum realism. In contrast to the usual approach, Palmer and Petitt (ref. 1) used a psychophysical method that could assess the importance of specific cues in producing realism in simulators.

They used a perceptual task in which pilots made judgments about the relative angular sizes of triangles placed at different distances along a simulated runway. The task was first used in a study by Gilinsky (ref. 2).

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She showed that in outdoor settings angular size is overestimated and that this overestimation increases with distance between the two stimuli.

It has been demonstrated that by reducing visual cues to depth, angular size can be more accurately estimated (refs. 3-5). Accordingly, the more realistic a simulator is, the more the subjects should overestimate angular sizes as they would in an outdoor setting.

Using the angular size estimation task, Palmer and Petitt (ref. 1) found that collimated simulated scenes provided estimates that were closer to outdoor perceptions than those obtained from an uncollimated display. (In the collimated display, the subject viewed the CRT through two large plastic lenses; these produced a virtual image of the CRT display 10 m from the subject's eyes.) Similarly, Petitt found that collimated cathode-ray-tube (CRT) scenes of outdoor settings provided estimates that were closer to outdoor perception than uncollimated scenes (ref. 3).

Results from these studies provide good support for the utility of angular size judgments as a measure of simulator realism. However, this deduction requires some reservation because of the lack of control of the field of view (FOV) across conditions. When subjects viewed a CRT, FOV was limited to about 40°, whereas when judgments were made in the direct viewing condition, the FOV was unrestricted. It is possible that the FOV influenced judgments of angular size. Mitchell (ref. 6) used collimated rear-projection slide system to investigate the effect of FOV on angular size judgments. Using four FOV's that ranged between 10° and 40°, she found no significant effect of FOV alone or in interaction with stimulus distance. In addition, Mitchell found that subjects overestimated angular size increasingly with distance as was the case in outdoor studies, but that the magnitude of overestimation was considerably less than when judgments were made with real-world cues. Results under all FOV conditions were similar to those obtained by Petitt in the collimated CRT viewing condition. This suggests that the low overestimation values obtained by Petitt in his CRT viewing conditions did not result from the restricted FOV present in these conditions. Nevertheless, the effect of restricted FOV's greater than 40° on overestimation of angular size in real-world situations remains to be examined.

The primary objective of this study was to examine the effect of reduced FOV on the ability of test subjects to perform the angular-size estimation task in an outdoor setting. In addition, since visual displays present visual information with no stereoscopic depth cues, a second objective was to examine whether monocular viewing results in significant loss of depth cues.

METHOD

Subjects

Thirteen males having corrected visual acuity of 20/25 or better and normal phorias, color vision, and depth perception (as determined by an

Orthorater) were used as subjects. All subjects were paid for their participation.

Test Triangles and Test Site

All judgments were made on a flat field of short dried grass at Ames Research Center. Test objects consisted of two triangles. The test site and the triangles are shown in figures 1 and 2. The "standard triangle" (fig. 1) was fixed in size (130 cm altitude by 130 cm base) but was set at three different positions on the field: 80.0, 112.5, and 168.8 m from the subject, subtending visual angles of 0.93°, 0.66°, and 0.44°. The variable triangle (fig. 2) was made of a white, plastic-slat window shade cut into the shape of an isosceles triangle with a base of 180 cm and an altitude of 180 cm. The apex of the variable triangle shade was attached to the arm of a spring-loaded collapsible wooden apparatus. An angle of 90° was subtended by the lines of sight to the standard triangle and the variable triangle, thus making simultaneous foveal viewing of both triangles impossible.

The length of steel cable, attached to the apparatus, could be adjusted by turning a crank (fig. 3). Winding or unwinding the cable caused the arm of the apparatus shown in figure 4 to move up or down; this, in turn, raised or lowered the tip of the variable triangle, making it possible to control the altitude of the triangle. The apparatus (similar to that used by Gilinsky) allowed for a straight up and down motion of the tip of the arm so that the triangle did not slant as its size was varied. The base of the triangle was attached to a shade roller, which rolled up the triangle when the tip was lowered. The roller's spring tension was adjusted high to keep the triangular shade taut, thus minimizing movement by the wind. Because the shade roller was 15.2 cm (6 in.) below the surface and because the rest of the apparatus remained behind the triangle, all but the triangle remained concealed from the subject's view.

The crank was mounted on a wooden horse. From the triangle apparatus, the steel cable stretched 50 m to the horse, ran under and past the horse and, via a pulley, ran back to the front of the horse and up to the crank. A measuring tape was located behind the horse. The position of an indicator mark on the cable over the measuring tape indicated the amount of cable wound in and thus provided the experimenter with a measure of the height of the variable triangle.

In order that the position of the indicator mark be a direct measure of the height of the triangle, the experimenter set the triangle at a known height and then set the indicator mark on the cable so that it pointed to the corresponding value on the measuring tape beneath the cable. Checks were made periodically during the experiment to ensure that the position of the indicator consistently measured the height of the triangle. (Fine adjustments of the indicator mark position never exceeded 1.5 cm.) For convenience, marks were placed on the triangle at known distances from the apex. With the aid of binoculars, the experimenter could easily use the marks to quickly set the triangle at a known height and then check the position of the indicator mark. The marks were too small to be seen by the subject.

Figure 1.— Standard triangle at a distance of 80.0 m.

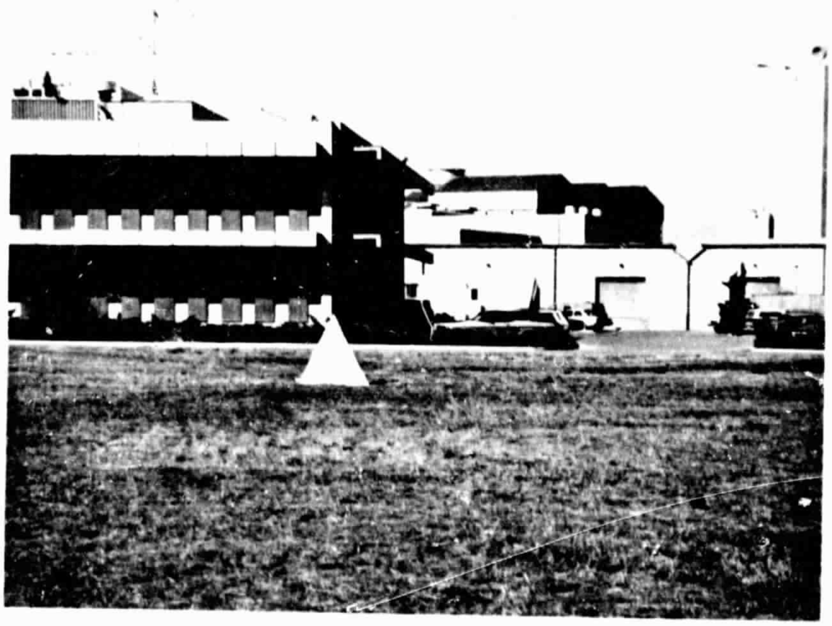

Figure 2.— Variable triangle at a distance of 50 m.

Figure 3.— A person in position to make an angular size judgment. His hand rests on the crank used to adjust the height of the variable triangle. He is wearing the 22.5° FOV goggles.

Figure 4.— Variable triangle apparatus.

The experiment was conducted from 7:30 to 11:30 each morning. The path of the Sun approximately bisected the lines of sight of the standard and variable triangles so that the difference in illumination during the experiment was minimized. Luminance was measured using a calibrated photographic light meter about 1 m from the triangle (so that nothing other than the triangle was measured). The luminance of the standard triangle varied from about 3,200 candles/m^2 at 7:30 a.m. to 6,300 candles/m^2 at 11:30 a.m. Luminance of the variable triangle ranged from about 6,300 candles/m^2 at 7:30 a.m. to 3,200 candles/m^2 at 11:30 a.m.

Field-of-View Goggles

The FOV was restricted by plastic safety goggles. A 5-cm-diam hole was cut in each side of the goggles (fig. 3). A tube, cut to the length necessary to provide a given FOV, was inserted in each hole and secured with screws. The tubes were made of thin white plastic. Translucent tubes were used in order to avoid any dark adaptation and contrast effects that might affect size judgments.

A rectangular piece of cardboard with two 5-cm holes was slipped over the free ends of the tubes to support them and to maintain the circular shape of the FOV. It also kept the ends of the tubes the correct distance apart to allow convergence of both eyes and thus provide single binocular vision.

The length of each pair of tubes was determined to allow for FOV's of 90°, 45°, 22.5°, and 11.25°. Monocular viewing was established by simply using a cotton ball to plug the tube in front of the nondominant eye. Unrestricted monocular viewing was established by the subject holding a sheet of white plastic to his nondominant eye.

Procedure

Each subject performed a total of 60 trials using the method of adjustment. There were 10 experimental viewing conditions consisting of 5 FOV's which were tested both monocularly and binocularly. Within each of the 10 viewing conditions, the standard triangle was presented at 3 different distances, yielding a total of 30 experimental conditions. Each of the 30 conditions was conducted as a pair of consecutive trials, thus there was a total of 60 trials. One trial of a pair began with the variable triangle set at its minimum height (15 cm) with the subject adjusting to make it larger. The other trial of the pair began with the variable triangle set at its maximum height (180 cm) with the subject adjusting to make it smaller. Whether the first trial of a pair began with the maximum or minimum height setting was randomly determined. The order in which the 30 pairs of trials was presented was also randomized. Two subjects were tested each day, taking turns making the judgments for each trial.

Before running the experiment, subjects were given a demonstration that illustrated the difference between actual and angular size. Subjects were shown that, by bringing a small paper triangle closer than a larger one, one could equate their angular sizes although their actual sizes remained different. After demonstrating their understanding of angular size, subjects were driven to the test site. Upon approaching the test site, subjects were instructed to look down to prevent viewing the field from any vantage point other than that specified by the experimenter. In addition, once seated at their designated position, subjects were asked to look at the field only when told to do so.

Before conducting the angular size judgment experiment, all subjects performed a brief series of distance estimation tasks. Half the subjects were randomly chosen to perform the tasks while viewing through 11.25° binocular goggles. Head position was fixed by a headrest mounted on a table. The other half of the subjects had an unrestricted view of the target. All subjects performed one relative distance judgment and five absolute distance judgments.

Relative distance judgments involved the subject viewing two triangles positioned about 5° apart. One triangle was placed at 50.0 m and the other at 168.8 m. Subjects were asked how many units the far triangle was away from them if the near triangle was one unit away. In performing absolute distance judgments, subjects were asked to estimate the distance of a triangle on the field in any unit and to any degree of precision they desired. The triangle was placed at 30, 50, 80, 112.5, and 168.8 m.

To prepare for the angular size judgment experiment, one subject was seated at the crank facing the triangles on the field and was instructed to look down. The other subject was seated facing away from the triangle. An assistant sat concealed behind the standard triangle. Appropriate FOV goggles were given to the subject and the trial began by the subject responding whether the variable triangle had to be made larger or smaller to match the angular size of the standard triangle. The experimenter then turned the crank in the appropriate direction until the subject said "stop." The experimenter did the initial cranking to avoid the possibility that subjects could have used the number of cranks as a cue to the variable triangle's height. Other sources of cueing between the experimenter and the subject were controlled by the experimenter being out of the subject's FOV at all times. After the initial rough adjustment, the subject used the crank to make fine adjustments until he was satisfied with the angular size match. The experimenter noted the position of the marked cable over the meter stick behind the crank (which indicated the actual height of the variable triangle) at the completion of the repetition.

After this first trial, the subject was instructed to look down while the experimenter set the variable triangle at its maximum or minimum height, depending on how he began the first trial. The subject repeated the task, after which another actual height reading was taken. The two subjects exchanged places and the second subject made the judgments. The assistant repositioned the standard triangle for the next trial. This continued until completion of the last trial. Calibration checks of the measuring setup were performed about every eight trials. After the experiment, each subject's vision was tested with an Orthorater. The Orthorater tested a number of visual parameters, the most important of which was distance acuity.

RESULTS

For each subject, two angular size judgments were obtained for each of the 30 experimental conditions. During the experimental run, the actual height of the variable triangle was recorded after being adjusted by the subject. The mean of the two trials was determined for each subject for each condition.

The ratio of perceived to actual angular size was computed for each condition by the formula:

$$\text{Perceived size/actual size} = (HV/DV)/(HS/DS)$$

where HV is the average height of the variable triangle, DV is the distance of the variable triangle (50 m), HS is the height of the height of the standard triangle (1.3 m), and DS is the distance of the standard triangle. The ratio of the perceived to actual angular size is shown in figure 5 and table 1, averaged over subjects. The appendix lists the data for each subject averaged over monocular and binocular conditions and repetitions. An analysis

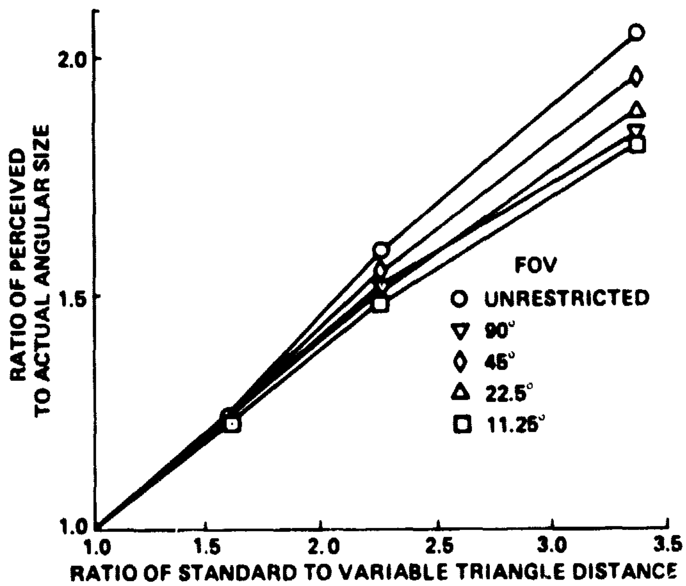

Figure 5.— Effect of FOV on angular size estimation in outdoor viewing conditions for various ratios of standard to variable triangle distance. The data from this study are averaged over the 13 subjects and the monocular-binocular viewing condition.

TABLE 1.— RATIOS OF PERCEIVED TO ACTUAL ANGULAR SIZE FOR VIEWING CONDITIONS AND STANDARD TRIANGLE DISTANCES AVERAGED OVER SUBJECTS

Viewing condition	D = 80 m		D = 112.5 m		D = 168.8 m	
	M	SD	M	SD	M	SD
Unrestricted FOV:binocular	1.25	0.24	1.60	0.41	2.04	0.86
90° FOV/binocular	1.20	.15	1.53	.27	1.77	.52
45° FOV/binocular	1.24	.24	1.53	.44	1.99	.78
22.5° FOV/binocular	1.24	.23	1.47	.34	1.85	.80
11.25° FOV/binocular	1.22	.21	1.48	.37	1.84	.75
Unrestricted FOV:monocular	1.25	0.26	1.58	0.46	2.06	0.88
90° FOV/monocular	1.27	.23	1.50	.26	1.89	.66
45° FOV/monocular	1.25	.22	1.55	.41	1.92	.73
22.5° FOV/monocular	1.26	.27	1.52	.36	1.91	.90
11.25° FOV/monocular	1.24	.22	1.47	.38	1.78	.80

of variance (ANOVA) was performed on these data using a 2 × 3 × 5 factorial design with repeated measures on subjects. Independent variables were FOV (five levels), distance of standard triangle (three levels), monocular-binocular viewing conditions (two levels), and subjects. Results of the analysis are shown in table 2. The ANOVA showed a significant effect for distance on perceived to actual angular size ratios ($F(2,24) = 18.5$, $p < 0.001$). As shown in figure 5, the ratios increased as target distance increased, indicating an increase in overestimation with distance. ANOVA revealed no effect of FOV nor any interaction between variables.

Because of the large variability between subjects, a small effect might not have been detected by the ANOVA. A sign test was therefore performed on the data. The ratio of perceived to actual angular size was averaged over distance and monocular-binocular viewing conditions for each subject. A linear regression was performed with FOV as the independent variable and the ratio of perceived to actual angular size as the dependent variable. Equations for each of the 13 subjects all had very small positive slopes, indicating an extremely small but statistically reliable (sign test $p < 0.001$) effect of FOV on angular size judgments (table 3). A similar test performed on the monocular-binocular conditions showed no effect of monocular viewing.

Before the main experiment, half of the subjects performed relative and absolute distance judgments while viewing through a fixed 11.25° FOV; the other half performed the task with an unrestricted view. The results presented in figure 6 show that there were large individual differences but that the viewing condition did not affect their accuracy. On the average, both groups slightly underestimated the true distance. The subjects were more consistent in making relative distance judgments, but the judgments again showed no statistically reliable effects of viewing condition (see fig. 7).

TABLE 2.— A SUMMARY OF THE ANALYSIS OF VARIANCE FOR A 2 × 3 × 5 FACTORIAL DESIGN WITH REPEATED MEASURES ON SUBJECTS

Source	SS	Df	MS	F
F	0.79	4	0.20	1.69
F × S	5.63	48	.12	
E	.02	1	.02	1.17
E × S	.18	12	.015	
F × E	.09	4	.02	1.38
F × E × S	.08	48	.02	
D	28.55	2	14.27	18.54[a]
D × S	18.48	24	.77	
F × D	.46	8	.06	1.78
F × D × S	3.15	96	.03	
E × D	.01	2	.004	.30
E × D × S	.29	24	.01	
F × E × D	.13	8	.016	.84
F × E × D × S	1.85	96	.019	

Note: Independent variables were field of view (F), monocular and binocular viewing (E), and standard triangle distance (D). The dependent variable was the ratio of perceived to actual angular size.

[a] $p < 0.001$.

TABLE 3.— THE RATIO OF PERCEIVED TO ACTUAL ANGULAR SIZE AND THE SLOPE (m) AND INTERCEPT (b) OF THE BEST STRAIGHT-LINE FIT FOUND BY LINEAR REGRESSION.

Subject	Field of view					FOV = m(ratio) + b		
	180°	90°	45°	22.5°	11.25°	m	b	Corr.
1	2.04	1.92	1.89	1.84	1.85	1.16×10^{-3}	1.83	0.99
2	1.23	1.28	1.23	1.20	1.19	2.5×10^{-4}	1.21	.50
3	1.19	1.28	1.15	1.12	1.13	5.1×10^{-4}	1.13	.54
4	1.36	1.40	1.35	1.36	1.28	3.0×10^{-4}	1.33	.48
5	1.81	1.71	1.63	1.70	1.44	1.5×10^{-3}	1.55	.77
6	---	---	---	---	---	---	---	---
7	1.38	1.34	1.30	1.29	1.32	4.7×10^{-4}	1.29	.91
8	1.11	1.13	1.09	1.03	1.04	4.6×10^{-4}	1.05	.73
9	1.21	1.26	1.21	1.12	1.1[illegible]	5.2×10^{-4}	1.15	.61
10	1.81	1.82	1.77	1.70	1.66	8.0×10^{-4}	1.70	.79
11	1.58	1.54	1.67	1.59	1.48	1.2×10^{-4}	1.56	.12
12	1.47	1.35	1.52	1.29	1.27	8.8×10^{-4}	1.32	.55
13	2.40	2.24	2.29	2.28	2.28	6.4×10^{-4}	2.25	.74
14	2.74	2.52	2.55	2.59	2.21	2.0×10^{-3}	2.38	.72

Note: The data were averaged over the monocular-binocular viewing condition and distance for each subject. The data from subject No. 6 were lost due to equipment malfunction.

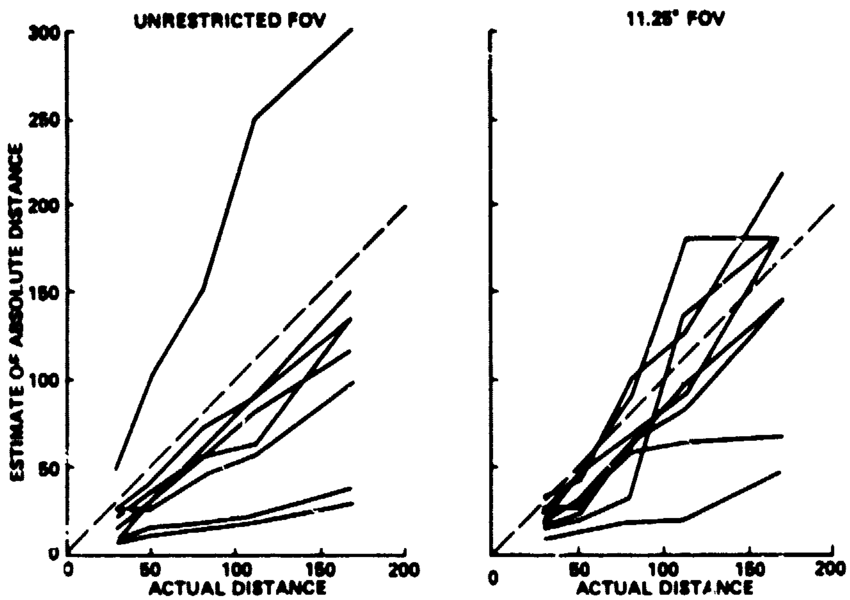

Figure 6.— Absolute distance judgments with both unrestricted and restricted FOVs for 16 subjects. The data from three additional subjects run only on this pre-experimental test are also included.

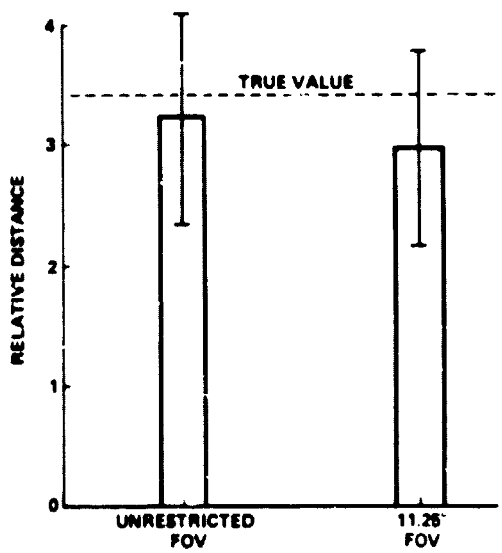

Figure 7.— Relative distance judgments with both unrestricted and restricted FOV. Error bars indicate ±1 standard deviation.

DISCUSSION

Overestimation of angular size was found to increase with distance. This effect was similar in magnitude to the outdoor viewing conditions tested by Gilinsky and Petitt (refs. 2, 3). In addition, no effect due to monocular viewing was observed; moreover, there was only a very small but statistically significant effect due to FOV.

The cause of angular size overestimation is probably linked to subjects' perceptions of depth. Gilinsky suggested that angular size judgments were biased by the observer's tendency to perceive actual size independent of viewing distance, that is, size constancy. This concept is also central to Kaufman and Rock's explanation of the Moon illusion termed the "apparent distance hypothesis" (ref. 4). They suggested that the terrain in front of the horizon Moon gives it a large apparent distance which, in turn, causes subjects to overestimate the Moon's apparent size. If perceived distance causes overestimation of angular size, it follows that removing depth cues should result in better angular size judgments. If, in turn, restricting FOV and monocular viewing effectively eliminates depth cues, then better angular size judgments should be observed under these conditions.

Holway and Boring (ref. 5) showed that significantly better angular size matches were obtained under conditions of monocular viewing and reduced FOV. With regard to monocular viewing, it should be emphasized, however, that the stimulus used in Boring's experiment was presented as close as 3 m (10 ft) to the subject. At this viewing distance, binocular stereopsis is much more significant and monocular viewing imposes a greater loss to the perception of depth than if the stimulus was viewed from a distance of 50 m or more, as in the present study. The lack of a monocular effect on angular size judgments obtained in the present study suggests that binocular depth cues are not essential to the fidelity of visual simulators since distances represented by the displays are rarely less than 50 m.

With respect to FOV, Boring used a 30- by 1- by 1-m (100 × 3 × 3 ft) tunnel as a reduction tube. It is very likely that this small (1.7°) FOV was more effective in eliminating depth cues than larger FOV's used in the present experiment and in Mitchell's study. Interestingly, in the preliminary test before the experiment, subjects who made absolute and relative distance judgments while looking through a fixed 11.25° FOV were approximately as accurate as those whose view of the scene was unrestricted. A fixed FOV with a headrest was used in the distance judgments because head movements would have allowed at least some head and eye movement and would have provided a very strong monocular movement parallax depth cue; a better perception of depth might thus have resulted. It should be noted that subjects were not restricted by headrests during the angular size experiment; as in prior experiments they were allowed to look back and forth between the variable and standard triangles as often as they wished. The finding that judgments made with a restricted, fixed FOV were similar to those made with an unrestricted FOV strongly suggests there was little or no effect of FOV.

There may be reason to suspect that the effect of FOV detected by the sign test was actually an experimental artifact. In each trial, subjects viewed both the standard and variable triangles through FOV goggles. At its closest distance the standard triangle displaced about 10% of the smallest FOV. Subjects may have noted the amount of FOV filled by the standard triangle and then adjusted the variable triangle so that it filled the same amount of FOV. The larger the FOV the more difficult it would be to use the FOV as an angular size measuring device. This would have resulted in better angular size matches at small FOV, which in turn would have yielded a false effect. To check this possibility, two additional subjects were tested, using three fixed fields of view; these subjects were positioned in front of only the standard triangle. Three binocular fields of view, 180°, 45°, and 11.25°, and three target distances, 80, 112.5, and 168.8 m, were used for the standard triangle. A sign test similar to that used in the main experiment was performed on the resulting data. A linear regression was performed with FOV as the independent variable and the ratio of perceived to actual angular size as the dependent variable. Table 4 shows that both subjects in this followup experiment had slight negative slopes. All subjects in the main experiment had positive slopes of similar magnitude (table 3). The difference in slopes is consistent with the hypothesis that the affect of FOV found by the significance test was a result of the subject's limited ability to use FOV goggles to measure angular size.

TABLE 4.— ANGULAR SIZE ESTIMATES OVER DISTANCES AS A FUNCTION OF FIELD OF VIEW FOR TWO SUBJECTS IN THE FIRST FOLLOWUP EXPERIMENT. LINEAR REGRESSION SIMILAR TO THOSE IN TABLE 3 ARE PRESENTED.

	FOV			FOV = m(ratio) + b		
Subject	180°	45°	11.25°	m	b	Correlation
A	1.81	1.93	1.80	-2.1×10^{-4}	1.85	-0.26
B	1.94	1.93	1.99	-5.3×10^{-1}	1.95	-.53

It is probable that very small FOV would have yielded stronger effects, as Boring has demonstrated; however, such effects would not be relevant to the fidelity of visual displays since displays commonly have at least a 40° FOV. Thus, we can conclude that a restricted FOV of a magnitude similar to those tested in the present experiment does not impose a significant loss of simulator depth realism.

It is interesting to speculate on the large range of angular estimation values between subjects. Past experience may influence angular size perception. Petitt examined this possibility by comparing judgments of pilots with those of nonpilots. No significant difference was observed. Nevertheless, during the last run of the present experiment, one subject was tested for his ability to be trained to make good angular size estimations. The subject repeated 12 experimental trials (6 different conditions). During the first trial he was asked to hold a stick at arm's length while viewing the standard triangle and to mark the angular size with a pencil. He then used the mark on the stick in adjusting the variable triangle to match the actual angular size of the standard. The remaining trials were conducted without use of this reference. Results shown in table 5 indicate decreased angular size overestimation. The subject reported that, although the judgments performed before training seemed correct, they now seemed too large and that the new judgment now looked correct. Note, however, that even with training this subject was still overestimating the angular size of the distant standard triangles.

TABLE 5.– COMPARISON OF TRIALS CONDUCTED BEFORE TRAINING IN ANGULAR SIZE ESTIMATION WITH TRIALS CONDUCTED AFTER TRAINING FOR SUBJECT No. 13.

Condition	Ratio of average perceived to actual angular size	
	Before training	After training
1. D = 80 m FOV = 45° Binocular	This trial used for training.	
2. D = 112.5 m FOV = 90° Binocular	2.43	1.45
3. D = 168.8 m FOV = unrestricted Binocular	3.90	1.89
4. D = 80 m FOV = 22.5° Monocular	1.94	1.38
5. D = 112.5 m FOV = 45° Binocular	2.63	1.38
6. D = 168.8 m FOV = 222.5° Binocular	3.74	1.74

CONCLUSIONS

The current study investigated the effect on angular size estimates of FOV and monocular viewing. Viewing targets were placed at three different distances in an open field. Thirteen male subjects were tested at five FOV's; the FOV's were presented both monocularly and binocularly. Results were consistent with previous experiments in that overestimation of angular size increased with target distance and that the magnitude of overestimation was similar to that obtained in other outdoor settings. No effect of monocular viewing or FOV was detected by ANOVA, although a sign test detected a minute but statistically significant effect of FOV. A followup study showed that there is reason to suspect that this small effect may be due to subjects using the angular size of FOV goggles to help estimate the angular size of the standard triangle. Nevertheless, the effect, if indeed present, was too small to be of practical importance. From this it was concluded that FOV plays a minor role in judgments of angular size and depth perception in a static outdoor scene.

A preliminary test demonstrated that the smallest field of view used did not significantly degrade judgments of relative or absolute distance; a followup study showed that training may reduce angular size overestimation.

APPENDIX

RATIOS OF PERCEIVED TO ACTUAL ANGULAR SIZE AVERAGED OVER MONOCULAR AND BINOCULAR CONDITIONS AND REPETITIONS FOR EACH SUBJECT. DATA FROM SUBJECT NO. 6 WAS LOST DUE TO EQUIPMENT MALFUNCTION.

Subject	Standard triangle distance, m			Standard triangle distance, m		
	80	112.5	168.8	80	112.5	168.8
	FOV = 180°			FOV = 90°		
1	1.37	2.00	2.76	1.46	1.77	2.52
2	1.03	1.29	1.37	1.11	1.30	1.45
3	1.04	1.17	1.36	1.04	1.42	1.39
4	1.12	1.42	1.56	1.07	1.58	1.55
5	1.35	1.61	2.47	1.33	1.80	2.01
6	---	---	---	---	---	---
7	1.17	1.35	1.63	1.15	1.37	1.50
8	1.03	1.11	1.18	1.08	1.23	1.09
9	1.03	1.20	1.39	1.08	1.09	1.60
10	1.34	1.74	2.45	1.33	1.92	2.22
11	1.21	1.53	2.00	1.26	1.52	1.83
12	1.26	1.57	1.65	1.16	1.34	1.55
13	1.64	2.19	3.35	1.57	1.86	3.30
14	1.80	2.55	3.87	1.74	2.47	3.34
	FOV = 45°			FOV = 22.5°		
1	1.22	1.85	2.61	1.29	1.64	2.60
2	1.07	1.22	1.39	1.06	1.29	1.23
3	.98	1.15	1.32	1.01	1.14	1.20
4	1.37	1.12	1.40	1.15	1.35	1.54
5	1.32	1.61	1.96	1.29	1.70	2.11
6	---	---	---	---	---	---
7	1.08	1.34	1.49	1.10	1.35	1.40
8	1.04	1.10	1.13	.92	1.06	1.07
9	1.07	1.20	1.35	1.06	1.16	1.13
10	1.28	1.78	2.26	1.33	1.85	1.93
11	1.32	1.49	2.19	1.33	1.57	1.86
12	1.24	1.21	1.50	1.25	1.25	1.36
13	1.69	2.13	3.35	1.62	1.97	3.34
14	1.74	2.52	3.41	1.83	2.17	3.75
	FOV 11.25°					
1	1.28	1.77	2.50			
2	1.04	1.26	1.26			
3	.99	1.17	1.22			
4	1.15	1.37	1.32			
5	1.18	1.45	1.68			
6	---	---	---			
7	1.18	1.33	1.48			
8	.98	1.07	1.07			
9	1.09	1.12	1.23			
10	1.33	1.71	1.93			
11	1.22	1.40	1.82			
12	1.21	1.22	1.37			
13	1.60	2.05	3.19			
14	1.72	2.30	3.43			

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