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WADC TECHNICAL REPORT 54-23

VISUAL FIELD RESTRICTION AND APPARENT SIZE OF DISTANT OBJECTS

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JANUARY 1954

WRIGHT AIR DEVELOPMENT CENTER

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FOREWORD

This report was prepared at the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, under Research and Development Order No. 696-67, "Requirements, Visual, Aircraft."

The study which this report summarizes was initiated at the request of Lt. Colonel Elwin Marg, Project Engineer on the above Research and Development project. The experiment described in the report was carried out by personnel of the Psychology Branch, Aero Medical Laboratory. Numerous discussions with members of the Vision Section, Physiology Branch, resulted in significant contributions to the design of the study and to the interpretation of the results.

ABSTRACT

It is well established that the apparent size of distant objects is reduced when they are viewed through a telescope of unit power having a restricted field of view. Previous studies have not given a fully satisfactory explanation of this phenomenon. The present study was an attempt to isolate the factor of visual field restriction, without optical magnification, and to determine what effect, if any, this kind of restriction in the visual field has upon the apparent size of distant objects.

Four observers made judgments comparing the apparent size of a variable-sized white square, set at a distance of 500 feet and viewed monocularly through an aperture, with the apparent size of a standard 20 inch square, viewed binocularly at a distance of 30 feet. Aperture sizes from 5 to 60 degrees were used to restrict the visual field. The psychophysical Method of Constant Stimuli was used as a sensitive measure of the effects of aperture size on the apparent size of the distant objects.

The results indicate that no consistent decrease in apparent size results from visual field restriction *per se*. It was found that a slight (2 percent) but consistent increase in apparent size occurred with all apertures used, but this effect was not found to be correlated with aperture size. It is hypothesized that slight overestimation of distance by the observers under the conditions of the study may have resulted in the apparent size increases found. It is suggested that factors inherent in optical systems may account for the large decreases in apparent size found when telescopes or periscopes are used.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Jack Bollerud

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

TABLE OF CONTENTS

Introduction

It is well established that when observations are made through an optical system having a restricted field of view the apparent size of objects in the visual field is often distorted. If the optical system is a unit power telescope, objects often appear smaller when seen through the telescope than when seen with the unaided eye. Recent studies on the design of optical viewing devices have mentioned this phenomenon, and they have reported observations indicating that distances may often be overestimated when objects are viewed through reduced-field periscopes (3, 9).

The phenomenon of reduced apparent size of objects, when they are seen through a unit power system, has been a matter of concern to optical designers. Attempts have been made in many cases to correct for the phenomenon, in the design of periscopes and sighting telescopes, by introducing magnification. The precise amount of magnification used appears to vary with different systems, and it seems in each case to have been determined empirically. Most magnifications used are of the order of 1.12X to 1.5X, and this range of values suggests that reduction in apparent size may be as much as 30 percent (3, p. 49; 7). But just why this large amount of reduction in apparent size should occur is not at all clear. The amount of reduction appears to vary with the situation, with different telescopes, and with many other factors (3, p. 50).

Several hypotheses have been advanced to account for this phenomenon. The most common of these attributes most of the reduction in apparent size to the "framing effect" resulting from restriction of the field of view by the telescope field stop (3, p. 49), or to the "psychological effect of looking through a narrow tube" (7). One report concludes, on the basis of an extensive survey of the literature on this and other problems, that "there is insufficient information on the phenomenon to even isolate the factors involved, let alone evaluate their individual significance" (3, p. 50). Some evidence from two studies has shown that reduction in apparent size may occur when objects are viewed through a small pinhole aperture (6, 8). But neither of these studies advances an acceptable explanation for the phenomenon, even for the precisely controlled conditions of the experiments. These studies were performed using near objects under reduced-cue conditions, and the question concerning the phenomenon remains to be explored in the case of distant objects, seen under more natural conditions, with larger apertures such as those normally used in telescopes and periscopes.

It was the purpose of the study reported here to investigate the effect of reduced visual field size upon the apparent size of distant objects, when the factors inherent in optical systems are eliminated from the situation.

Procedure

The experimental situation is illustrated in Figure 1. The observer sat comfortably behind the drum with the eyepiece at a comfortable position. He viewed the variable card monocularly through the drum apertures, and he

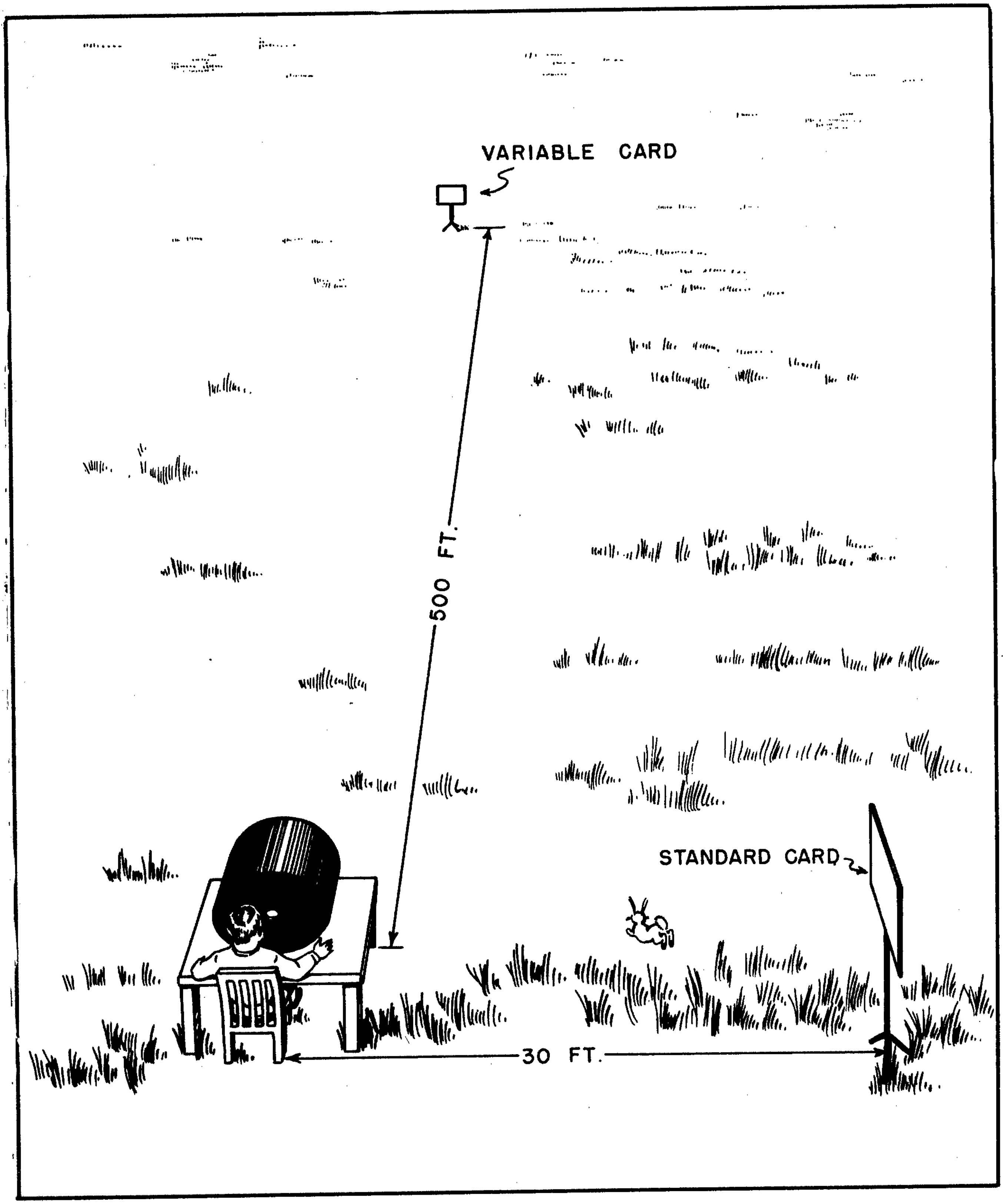

Figure 1: Sketch of the experimental situation

viewed the standard card binocularly without using the drum. He indicated by a system of hand signals whether the variable appeared larger, smaller, or equal in size to the standard. Observers were instructed to vary the order of viewing the variable and the standard card so that each was viewed first approximately equally often. The drum was large enough so that the observer could not see the variable card while he was viewing the standard, nor could he see the changing of the variable cards between trials. The positions of the cards and the drum were arranged so the sunlight fell on the face of the standard and variable throughout the observation period. This was accomplished by conducting all experimental sessions between the hours of 8 A.M. and 11 A.M. The test site was a large open field at Wright-Patterson Air Force Base. The background contained a fence and a road at a distance of approximately 1000 feet from the observer.

The viewing apparatus consisted of a drum, 18 inches long and 28 inches in diameter, constructed of poster board mounted on the inside of a plywood frame. In one end of the drum a hole 2 inches in diameter served as the exit pupil. A foam rubber eyepiece from an aircraft gunsight was fixed over the hole to provide a comfortable headrest and also to provide a fixed eye position while the observers made their monocular judgments.

Circular apertures, of such a size as to restrict the visual field to 5, 10, 20, 40, and 60 degrees, were constructed of poster board. These aperture boards could be fitted interchangeably to the front of the drum. The entire interior of the drum and the inside surfaces of the aperture boards were coated with black rayon flock to eliminate reflected stray light within the drum. The exterior of the drum was painted flat black. The appearance of the visual field, when viewed through the drum, was similar to that of a telescope field, except for the lack of an optical system.

The objects whose apparent size was to be judged by the observers consisted of white poster card squares. The standard card was a 20 inch square, and the variable cards ranged in size from a 10 inch to a 30 inch square, in one-inch intervals. The boards were displayed on modified music stands, at a height of 4 feet from the ground. The variable was at a distance of 500 feet, the standard was at a distance of 30 feet and at right angles to the line of sight from the observer to the variable.

The observers in the study were four persons, three military and one civilian, employed at the Psychology Branch, Aero Medical Laboratory. All had 20/20 visual acuity, either corrected or uncorrected. Their ages were between 23 and 27 years. All had training in psychology and theory of visual perception, but were not experienced as observers in psychophysical studies of this kind. One observer (WRJ) had a slight astigmatism (+.50 diopters cylinder correction), along different axes in the two eyes.

Each observer made observations over a period of 5 days. Each day a single aperture was used and all monocular observations were made through that aperture. The day-by-day order of aperture size was counterbalanced across the group of observers. The first and third observers made their observations in ascending order of aperture size and the second and fourth observers made their observations in descending order.

To afford a comparison of the monocular observations, a series of binocular observations was made using the same procedure as that used with the monocular observations, except that the drum was not used. The binocular observations were made over the 5-day period of observations, one fifth of them being made each day either before or following the complete set of monocular judgments on that day, in counterbalanced order. Thus the binocular judgments provided both an indication of the mean apparent size over the entire period of observations and also a measure of the day-to-day variation in apparent size.

Whenever possible, judgments were obtained on 5 successive days. All judgments were made on clear sunny days, and the longest interval between experimental sessions was three days. Total time required for each day's observations was 1-1/2 hours. Five-minute rest periods were taken after every 40 to 60 observations, depending on the total length of the series of variable-object sizes.

Instructions to the observers were as follows: "This is an experiment to determine how apparent size of distant objects is affected by various conditions. For each day's experimental session, you will observe a number of white squares in the distance (sample object pointed out). Cards of different sizes will be placed on the stand, one at a time. Each time a new card is placed on the stand, you are to look through the drum at the distant card, using your right eye, and at the near card over there (point) using both eyes. Compare the apparent size of the two cards and indicate whether the distant card appears larger, smaller, or equal in size to the near card. Look first at the distant card and then at the near card for one half of the observations. For the other half, reverse this sequence. Remember: be certain that you indicate the <u>apparent</u> physical size of the object; do not indicate what you infer the <u>actual</u> size to be. We want to know whether the distant card <u>looks</u> physically smaller, or larger, or equal in size to the near card, <u>not</u> what size you may infer it to be."

The experiment required two experimenters. One experimenter was located near and behind or to the side of the variable board, the second experimenter was about 10 feet to the side of the variable board. The first experimenter changed the boards on the stand while the second recorded the observer's judgments and indicated which board was to be presented next in the sequence. The position of the first experimenter was varied unsystematically from trial to trial to avoid the possibility of providing the observer with a consistent reference in his judgments of size. Observers were questioned following the experiment, and all agreed that this method was effective in minimizing the stability of the reference size of the experimenter.

For each day's observations, the entire set of cards was presented once in random order to establish the approximate range of sizes to be used that day. Cards which were of such size that all cards above and below them in size were judged larger and smaller, respectively, were deemed to be close to the 100 percent and zero percent points with respect to judgments of 'larger' and 'smaller'. These were removed from the series to be presented that day. A table of random sequences (2) was employed to determine the order of presentation of the cards within each series. On each day, observers made 25 monocular and 5 binocular comparison judgments of each size of the variable-sized card. The total number of observations varied from day to day and from observer to observer. The number of observations depended upon the total range of sizes required to give a complete range of response frequencies from zero to 100 percent.

The data were compiled and calculations were made in accordance with the Method of Constant Stimuli (5, ch. VI). For each observer a graph was constructed showing the percent of judgments, larger, smaller, or equal, of the variable with respect to the standard, for each aperture size and for the combined binocular judgments. In addition, a graph was constructed showing the mean percent of these judgments for the combined group of observers for each aperture size and for the combined binocular judgments. From these data upper and lower Limens[1], h values[2], and PSE's[3] were computed, for each observer and for the group, for each aperture size and for the binocular judgments. These constants were computed, using the data for the judgments larger and smaller, according to Urban's Constant Process (5, pp. 176-178).

Results

The major results of the experiment are shown in Table I, which contains the upper and lower Limens, h values, and PSE's for each observer and for the combined group, for the monocular judgments at each aperture size and for the binocular judgments. The PSE's shown in the Table are Urban's Xi (5, p. 189), computed from the data of the judgments larger and smaller. An examination of Table I shows that there was a fair amount of agreement among the observers with respect to the PSE for apparent size, for the binocular judgments as well as for the monocular judgments with the apertures. One observer (WRJ) deviated considerably from the other three, having a binocular PSE of 16.25 inches. The other three observers' PSE's range between 21.18 inches and 21.98 inches. Examination of the PSE's for the monocular judgments shows very little, if any, effect of aperture size upon apparent size. The largest range of PSE's is from 20.41 to 22.96 inches, for observer WFS, and if anything indicates a decrease in apparent size with increasing aperture.

1. The upper and lower Limen is the median of the normal ogive of best fit to the data for the judgments larger, or smaller, respectively, or the point at which the probability of a judgment larger or smaller equals 50 percent.

2. h is the slope of the normal curve of best fit.

3. PSE is the point of subjective equality, and is computed by the formula:

$$PSE = \frac{Luhu + Llhl}{hu + hl}$$

Table I

Points of Subjective Equality (PSE), Upper and Lower Limens (Lu and Ll) and Slope of Psychophysical function (h), for each Observer and for the Group, for each aperture size and for binocular judgments. (PSE's and L's are in inches).

Observer	Constants	Binocular Judgments	Aperture Size (Monocular judgments) 15°	10°	20°	40°	60°
WFS	Lu	22.73	21.90	22.58	23.80	23.89	24.51
	hu	0.54	0.57	0.63	0.78	0.48	0.46
	Ll	19.85	19.44	20.06	20.54	21.06	21.76
	hl	-0.49	-0.88	-0.63	-0.97	-0.58	-0.59
	PSE	21.36	20.41	21.32	21.99	22.34	22.96
GHC	Lu	23.63	24.34	21.48	22.66	22.75	25.04
	hu	0.38	0.39	0.52	0.36	0.46	0.31
	Ll	18.97	19.88	18.04	18.54	19.21	20.22
	hl	-0.42	-0.40	-0.49	-0.52	-0.74	-0.52
	PSE	21.18	22.08	19.80	20.23	20.57	22.02
WRJ	Lu	17.90	17.70	17.88	15.50	16.31	17.11
	hu	0.28	0.73	0.67	0.66	0.51	0.55
	Ll	15.14	16.10	15.45	12.80	13.87	13.84
	hl	-0.14	-0.83	-0.47	-0.11	-0.75	-0.77
	PSE	16.26	16.85	16.88	15.11	14.86	15.20
RS	Lu	23.73	20.97	22.82	20.87	23.42	22.15
	hu	0.51	0.37	0.39	0.38	0.44	0.37
	Ll	20.47	19.50	19.12	18.49	19.31	18.45
	hl	-0.59	-0.43	-0.39	-0.45	-0.35	-0.36
	PSE	21.98	20.19	20.97	19.58	21.60	20.33
GRP	Lu	21.93	21.23	21.23	21.05	20.73	22.22
	hu	0.22	0.24	0.29	0.13	0.18	0.20
	Ll	18.61	18.50	18.30	17.76	18.39	18.39
	hl	-0.27	-0.37	-0.33	-0.21	-0.21	-0.21
	PSE	20.10	19.57	19.67	19.02	19.47	20.26

The Limens for all observers are quite small, the largest being at 25.04 inches and occurring for observer GHC with the 60 degree aperture. In general, the deviations of the Limen from the PSE are also quite small, indicating that the observers were able to discriminate small changes in the size of the variable. The largest deviation of the Limen from the PSE occurs for observer GHC at the 60 degree aperture, a value of 3.02 inches.

The result of major importance in the experiment, the effect of aperture size, is shown in Figure 2, which contains a graph of the PSE (in inches) and the upper and lower Limen as a function of aperture size for the combined group of observers. An examination of the graph of Figure 2 reveals little effect of aperture size upon apparent size of the variable object. The largest PSE, which would indicate the greatest reduction in apparent size, is 20.26 inches, and occurs for an aperture size of 60 degrees. The remainder of the graph appears to illustrate that the apparent size of the variable was <u>increased</u> rather than decreased, by the use of the aperture.

In Figure 3 the data are shown re-plotted in terms of the difference between the PSE for the monocular judgments and the PSE for the binocular judgments, averaged over the group of observers (data from Table I). The PSE for each aperture is again consistently below the PSE for the binocular judgments. A simple sign test of significance shows that the probability of such a result is $(1/2)^5$, or 0.03, if these consistently low PSE's were a result of chance factors. We might observe that this result indicates a general increase in apparent size as a result of any restriction of the field of view. However, Smith (10) has shown that such apparent increases in size occur under many other conditions where judgments are made of distant objects, including those where no field size restrictions are imposed, and the present data are merely consistent with these findings.

Discussion

The data of the present study do not offer strong support for the hypothesis that restriction in the size of the visual field results in a decrease in the apparent size of objects in the field. The conditions of the study and the method of measurement were designed to be sensitive enough to measure any real effect on apparent size which may have existed as a result of a decrease in visual field size. The data, contrary to whatever hypothesis may be constructed to predict a decrease in apparent size, revealed no consistent effects which could be correlated with changes in visual field size, under the conditions of the study. There was found a slight increase in apparent size (about 2 percent) of the objects used, for all apertures studied. This result is, however, probably not due to an effect of aperture size, since the data are consistent with other results obtained under similar conditions without visual field restrictions. Smith (10) showed that the apparent size of small blocks increased consistently as a function of distance, over a range from 16 to 320 feet. Gibson (4), using photographs containing only monocular visual cues, found that apparent size increases with distance over a range from 80 to 675 feet. Chalmers (1) and Weber and

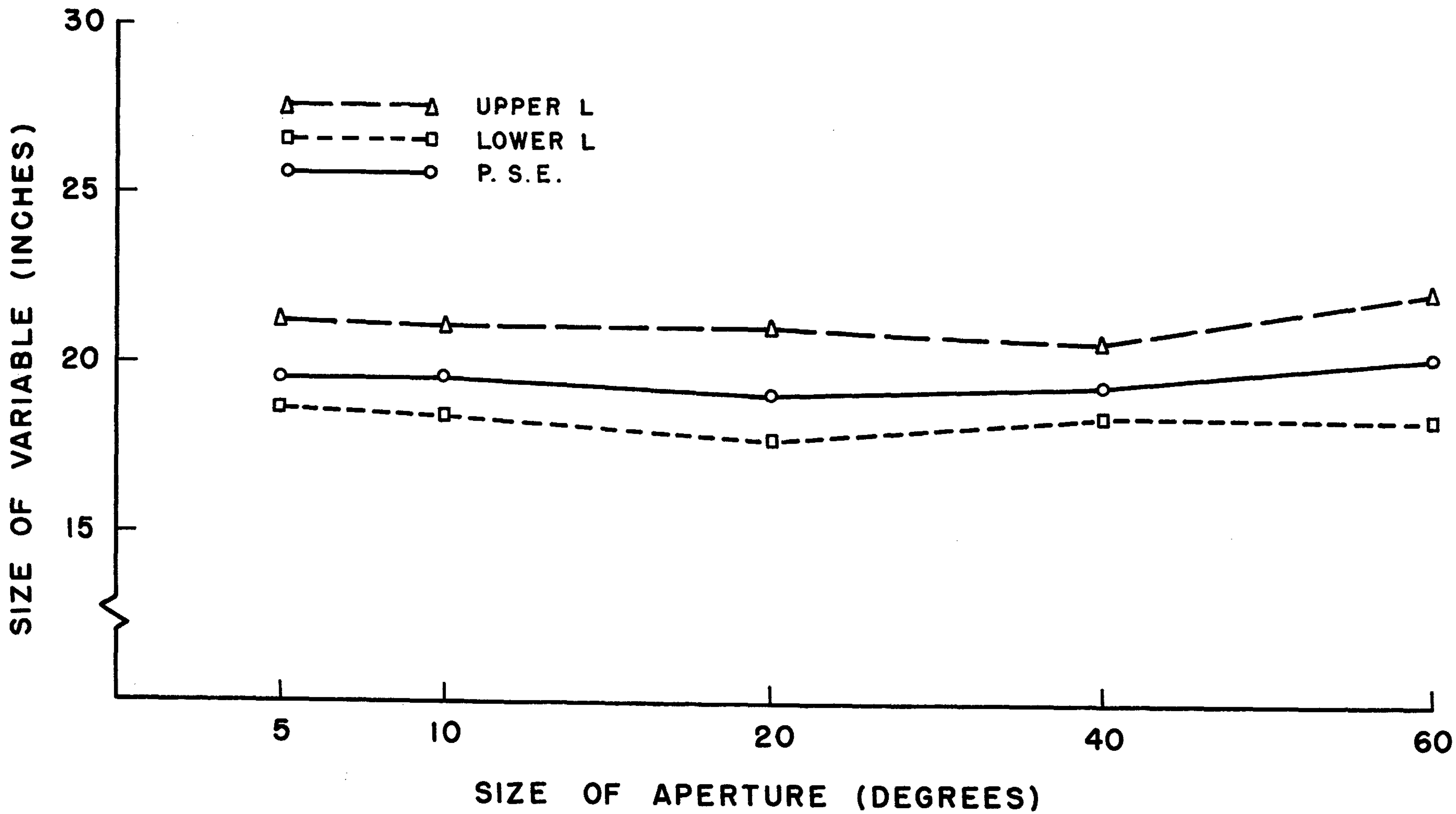

Figure 2: Upper and lower Limen (L) and Point of Subjective Equality (PSE) as a function of size of aperture. Standard card size is 20 inches.

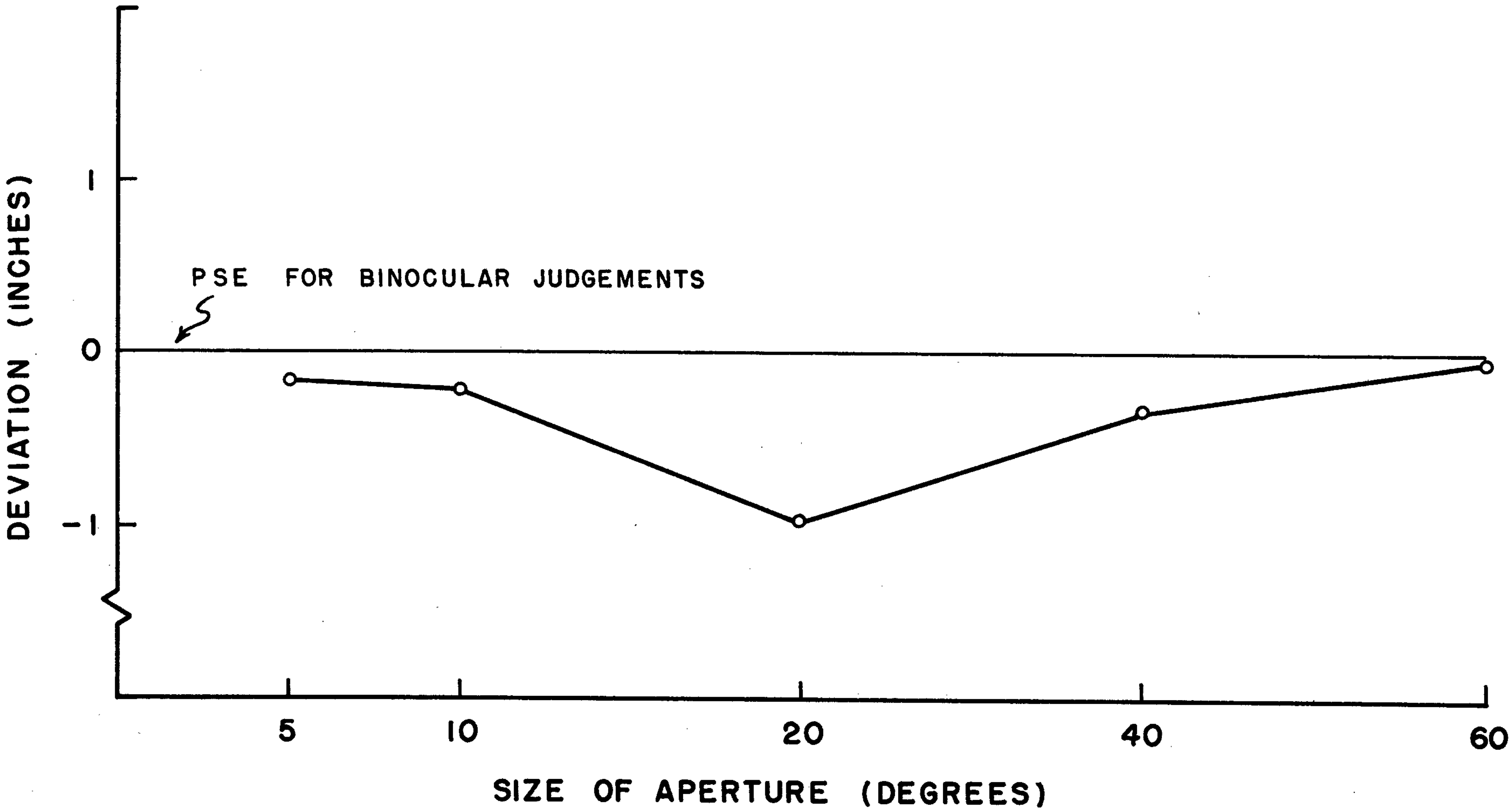

Figure 3: Deviation of Mean PSE for Monocular observations from Mean PSE for binocular observations at each aperture size.

Bicknell (11) found similar effects using real objects viewed both binocularly and monocularly.

One interpretation of these results (of increased apparent size) is that distances may be overestimated when objects are viewed at great distances, and this overestimation may be exaggerated when a restriction is placed on the size of the visual field. If this occurs, then the judged size would be greater than it would be if distance were judged accurately or if it were underestimated. The present data appear to substantiate this view, but it should be noted that the effect is small, and it was not found to be a consistent function of aperture size in the data of Figure 3. The increases in apparent size found in this experiment may best be said to be similar to those found in other studies involving judgments of the size of objects at great distances.

In light of the above results, there still remains the question of reduced apparent size of objects viewed through unit power telescopes or periscopes. Since the data of the present study do not show a significant effect due to aperture size, it appears desirable to mention one possible reason for the phenomenon as it is encountered in optical viewing devices. One possible factor, which may affect the apparent size of objects, is magnification of the images of the objects by the optical system. It is commonly known among optical engineers that a unit power optical system is not unit power for objects at all distances. The power of a telescope is defined only for an object at infinity, and in most systems the power (usually defined as the ratio of the angles of object and image) increases with decreasing distances. Thus, objects viewed at great distances would be magnified less than near objects (with which the distant object may be compared), and the total effect could produce an illusory decrease in apparent size of the distant object. The illusion thus created would be due to the fact that the distant object, although its image is unmagnified, is being compared with near objects whose images are magnified more and more with decreasing distance. Since the distant object is the one being most closely attended to, it would be reasonable to assume that an observer would perceive the distant object as smaller, rather than to perceive the near objects as larger. Obviously, this hypothesis should be treated only as a tentative suggestion concerning one possible factor which may operate to influence apparent size of objects viewed through telescopes. However, it does offer a possible avenue of approach to the solution of a very difficult and puzzling problem.

Summary and Conclusions

An attempt was made to isolate the effects of size of visual field upon the apparent size of distant objects viewed monocularly through an aperture. Four observers made judgments of the apparent size of a variable white square, set at a distance of 500 feet and viewed both binocularly and monocularly, compared to a standard 20 inch square, set at a distance of 30 feet and viewed binocularly. Aperture sizes of 5, 10, 20, 40, and 60 degrees were used for the monocular judgments. The Method of Constant Stimuli was employed as a sensitive measure of the effects of aperture size upon apparent size of the variable object. The results

indicated a small (2 percent) but consistent increase in apparent size of the distant object under all monocular viewing conditions of the experiment, regardless of the aperture size used. The results are interpreted to indicate that restriction in visual field size does not result in decreased apparent size of a distant object. It is hypothesized that overestimation of distance by the observers under the conditions of the study may have resulted in the small apparent size increases found, but this effect was not shown to be a consistent function of visual field size. It is suggested that differential magnification as a function of distance may be a factor influencing apparent size of objects viewed through optical systems.

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