THE PERCEPTION OF A FORM IN A DARK FIELD AS INDICATED BY THE OBSERVER'S DRAWINGS

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S Howard Bartley
Major professor

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THE PERCEPTION OF A FORM IN A DARK FIELD AS INDICATED BY THE OBSERVER'S DRAWINGS

By

Thomas Morgan Nelson

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I. INTRODUCTION

An answer to the question "How do we see things as we do?" must be given by any system, psychological or otherwise, purporting to provide a comprehensive account of human behavior. Despite this, experimental answers to ancient but basic questions concerning phenomena apparently central to this quest are lacking. Generalized statements that treat the perception of objects without taking recourse to arbitrary use of artificial devises are largely absent, even though in recent years psychology has witnessed at least one noteworthy although partial advance in this direction (6).

Interest in the relationship between a percept and its correlating environmental object seems to have predated psychology itself by centuries.* A similar interest accompanying an increased comprehension of visual mechanisms gained throughout the nineteenth century provoked a number of extra physiological explanations concerning the "hows" of certain sorts of experimentally observed phenomena. The phenomenon referred to came to be known as the "constancies".

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*A historian (4) notes that the 18th century scientist and philosopher Bouguer evinced curiosity regarding aspects of the relationship and that an age before Euchid himself had established a distinction between apparent size and visual angle.

In this century, despite formidable technological progress and the manifold possibilities consequently opened for neurological analysis, these phenomenon have so far eluded explanations from this quarter. This is not to say however that certain correlations between experience and neurophysiology, neurophysiology and the illumination patterns of the retina would not be of direct relevance to a more complete undertaking than the present. Studies of the neurophysiological conditions associated with edges and gradients are presumably propaedeutic to any discussion of shape. These are considerations however, which have been treated extensively elsewhere (3) and which are beyond the scope of this paper.

From the outset constancy enjoyed an ill-defined existence that apparently has improved little during the past decades. During the past score years various writers have questioned its value because a certain theoretical orientation seems to be implicitly associated with the word. Nevertheless the quarters in which the word constancy regularly occurs have increased and are varied to the extent that its catholicity of use now approaches that of "perception". To some observers this march of affairs perhaps imparts a flavor of homogeneity of method or material, stands for a unity

of knowledge within psychology, produces the feeling that "now we are getting somewhere," etc., while for others it seems only to add a regretable and avoidable confusion. One investigator, Sheehan (14), attempted to discover whether a high or low constancy will be maintained throughout a variety of perceptual judgements by single subjects. The universally low intercorrelations which were obtained lead her to "question any use of the term constancy which implies the existence of a unit trait...." The danger inherent in abstracting a name for a group of phenomena that seem off hand to resemble each other is well recognized. So while the task crucial to this paper of course lies in a direction that largely precludes an attempt to make this semantic muddle intelligible, if indeed this be possible,* nevertheless a certain ordering is demanded if one is to do otherwise than contribute to the prevalent potpourri.

Within the area of visual perception constancy has a two-fold meaning. The first might be called the obvious meaning and the second the current meaning. The first does not particularly concern us here for the second is

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*While the present paper must forebear inquiry of any completeness into the problem, others have discussed possible meanings that might be given to constancy of the sort that concerns us. (10)

encountered most often nowadays. However since both meanings are employed, and in at least one case even in the same article (15), it might be well to say a few words concerning each.

First, constancy is used to indicate the perceptual recognition or identification of an object as being a such and such. This, although it is the obvious usage, implies an either-or occurrence and for this reason, unless one chooses to state some further relationship (such as degree of perceptual certitude, probability of the perceptual occurrence), is of lesser interest scientifically than the second.

Currently it is used in a relative sense. It is used to specify one out of all the possible relationships that can be obtained between the physically measurable so called primary or secondary properties of the actual "in space" concrete entity and its physiological and/or psychological correlates. Thus in this latter case one always uses or implies a referent. Using such a referent one can apply the propositions "toward", or "from" and speak in terms of derivative nouns such as "regression", "progression", "transformation", "substitution", etc. It is also possible to scale some property of the perception and, using this, state the degree to which this property approaches that of the referent. All this would not of course be possible using the first definition.

Although the properties alluded to just previously are apparently infinite in number, color, size, distance, shape, weight, motion, and lightness of surface are those which have been commonly studied. Relative constancy of these properties can be investigated using many methods. Any manipulation of retinal organization or intensities could possibly affect the perceptual outcome. Primary depth cues such as retinal disparity, accommodation and convergence may also play a role. In the studies to be mentioned gross enough manipulations of primary and collateral cues have been made to alter the consequent perception measurably.

Systematic investigation of relative object constancy may perhaps be said to have begun with an extensive series of experiments reported by Thouless (17), (18), (19) in 1931 and 32. The earliest of these experiments demonstrated that the perceived shape of objects* viewed obliquely under many experimental conditions lay between the concrete in-space object shape and its retinal correlate.

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*This is also known as behavioral shape, matching response, phenomenal shape.

Thouless speaks of this as "regression to the real object" (Rg).* This concept and those of the "real" object, "stimulus" object, and "phenomenal" object enjoy widespread usage by shape constancy experimenters and will be used by this writer. By the term "real" object (R)** is meant the physical character of an in-space object. The "real" shape of an object is independent of any context. The retinal correlate is styled the "stimulus" shape (S)*** and the experiential result the "phenomenal"

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*Thouless suggested "phenomenal regression to the real object" because it seemed to be an apt description of the process and because it seemed devoid of the implications of "all or none" that constancy has. Although it doubtless has been an improvement, as far as concerns clarity, still it seems to carry the implication that the target rather than the subject is the organizing force.

**This is also referred to as the distant object, distant stimulus, distant shape, real stimulus, real shape, objective shape, objective stimulus, objective object, test-object, target.

Bartley (2) employs the last term when he refers to what is looked at. Target seems to be a preferable term to use in all instances that we shall be dealing with, because, as he points out, it does not specify what is being looked at but only indicates that differentiation exists within the visual field. Hence it does not tend to render the concrete correlate of the perception the organizing force as other of these terms seem prone to do.

During the first section the present author will not generally attempt to maintain a strict terminology although the term target will be used exclusively in the latter part.

***Also called proximal shape, proximal stimulus, proximal object, stimulus object, projected shape, projected stimulus, and projected object by different authors.

shape (P). The three shapes are most often expressed operationally for circles and ellipses by the minor-major axis ratios. The operations defining a phenomenal shape are frequently performed on figures matchéd or drawn by the subjects.*

The data entered in Table 1 perhaps are representative of the results that are obtained when no attempt is made to control physiological or collateral cues.

Thouless found it desirable to have a numerical measure to express the degree to which the so-called regression takes place. The index arrived at he called the "Law of Phenomenal Regression". The law can be expressed in its simplest form as P-S/R-S.** It will be at once observed that this formula is designed to yield coefficients between 0 and 1.0. Expressing the results given above by means

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*Hastorf (8) has added the fourth member, the "assumed size". This addition was made on the basis of an experiment in which he found that a suggestion as to the identity of the real object influenced the perceived distance of a rectangular object.

E. Brunswik's (5) "Psychology of Objective Relations" recognizes a similar relationship. He emphasizes that perception is greatly influenced by the implicit "hypotheses" the organism entertains concerning the real object.

**Thouless included the formula (log P-log S)/(log R-log S) and advised its use since it precluded anomalies of measurement that arose when the simpler form P-S/R-S was employed in brightness and size regressions. The formula included in the text proper however is just as satisfactory for purposes of stating shape regressions.

of this law yields a Rg of .57 for circle A, a Rg of .46 for circle B, and a Rg. of .44 for circle C. It is a potentially very useful measure, for by means of this formula it is possible to compare the extent to which phenomenal regression occurs for different shapes in identical surrounds as well as the "cue value" of the various surrounds themselves.*

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*A criticism similar to that made in a previous footnote concerning Rg can be extended to the indexes of Rg, i.e. (P-S/R-S and log P-log S/log R-log S). The implicit assumption inherent in this formulation renders the target the organizing force rather than the organism. This leads to serious difficulties of several kinds.

A priori there seems to be no reason why the perceptual shape of a circle tipped at an angle 45 degrees to the line of regard should lie between 1.0 and .707 (minor axis/major axis values for the real object and stimulus object respectively). If, to cite one possibility, P occurs as less than the value for S, the result is a negative value about which it is difficult to say anything meaningful using the concept regression. This would actually occur if we would attempt to express size relationships of S, P, and R existent in the Koster-phenomenon. The opposite is possible a-priori also and indeed has occurred in color and shape experiments. Considering the latter case, Koffka remarks (12, pp. 227) "This seems at first not to impair the values of the measures, the constancy would simply assume values greater than 100 in Brunswick's formula and greater than 1 in the log-arithmetic measure. ----And yet it comes as something of a shock to find values which are greater than complete constancy. The main point however is this: These measures were so useful because, by referring each result to a well-defined range, they yielded comparable figures for very diverse constellations, each having its own range defined in the same way. But the fact of more than complete constancy destroys this advantage. The range itself becomes a function of the constellation----."

TABLE 1

DATA FROM THOULESS' EXPERIMENT

Mean of drawings for circle at A (54.5 cm. from observer) by subject S.

Reproduced ratio	Stimulus ratio	Real ratio
.78	.56	1.00

Mean of drawings for circle at B (109 cm. from observer) by subject S.

Reproduced ratio	Stimulus ratio	Real ratio
.58	.36	1.00

Mean of drawings for circle at C (163.5 cm. from observer) by subject S.

Reproduced ratio	Stimulus ratio	Real ratio
.47	.255	1.00

Using his index Thouless experimentally related shape Rg to several factors and found that: 1) Rg diminishes to zero with a circular figure inclined at both 90 degrees and 0 degrees to the line of vision in uncontrolled situations. The largest indexes were obtained at a 10 degree inclination, 2) Rg is correlated with target size, shape, and distance,* 3) Rg decreases as cues acting to indicate the real object are controlled, 4) Rg can be eliminated in certain well-controlled situations, 5) Rg does not seem to increase if the subject has knowledge of the objects being presented, 6) Rg tends toward the real figure and not necessarily toward assuming a "best shape", 7) Rg does not occur with after images.

Eissler (12) computed Brunswik ratios** for shape perceptions gotten under a number of different conditions in which various depth cues were reduced. The ratios obtained under these reduced conditions*** show the

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*No data given.

**This ratio is identical to the simpler ratio of Thouless except that the initials are selected according to a different terminology.

***The reduced conditions were: 1) moving head from side to side while viewing the object, 2) fixating a point between the standard and comparison object which put both in poor focus, 3) monocular vision, 4) monocular vision and poor focus, 5) monocular vision through tinted glasses, 6) viewing the object through half opened eyes.

reduction of constancy from "normal" to be approximately equal under all conditions. This led Eissler to conclude that the different cues can be substituted for one another without this affecting the perceptual outcome importantly.

Color perception and perception of illumination, perceived size and distance have been experimentally related. However the usual phenomenal shape responses have not been supplemented by phenomenal responses orientation although this has been generally recognized as desirable. Koffka (12) stated his expectations in this regard most strongly, holding that the two aspects of the percept will be coupled together in a way that makes the relationship an "invariant" (pp. 229). That is, when one aspect of the percept, orientation or shape, changes the other must change also. Relating this to constancy theory he declares, "The amount by which the figure appears turned from the normal decreases as the 'constancy of shape' decreases" (pp. 233). An attempt by Stavorianos (16) to test a hypothesis that shape depends upon explicit perception of orientation met with only indifferent success. From Koffka's statement that "the amount by which the figure appears turned from the normal decreases as the 'constancy of shape' decreases" (pp. 233) she derived the operationally testable statement

that "when the tilt of an object is correctly perceived, the apparent shape of the object should correspond most closely to the real (objective) shape" (pp. 6). The test made however does not seem to have been a fair one. A number of possibly vitiating factors may have conditioned the outcome. Besides those related to the apparatus and methodology employed, no account seems to have been taken of what Bartley has called "geometrical equivalence". These three factors will be considered in a later section.

Stavrianos tested the hypothesis in three major experiments using rectangles and ellipses as targets. The experimental set-up and analysis of data lead her to conclude that: 1) shape judgements of tilted figures were accurate and showed little variation as a function of presented angle or different conditions, 2) tilt judgement values varied and fluctuated greatly as a function of presented angle and different experimental conditions, 3) correlations of paired shape and tilt judgements revealed no constant relation to that of the real object, 4) accuracy of tilt judgement decreased as a result of cue reduction (via reduction tube and/or monocular vision). This was not accompanied by a decrease in accuracy of shape judgement and there was no uniform decrease in constancy. It was noted however, that an

approximate relationship between apparent shape and judged inclination occurred for some observers under the conditions in which depth cues were at least abundance. Also when the possibilities of response were reduced, an approximate relationship held.

The not too completely reported work of several other experimenters also has yielded results that are not in accord with the expectations of Koffka. Eissler's and Klimpfinger's experiments, discussed in several places (11), (12), generally are imputed to demonstrate a lack of relationship between shape perception and phenomenal orientation of simple plane form. They report instances in which a target perceived as non-frontal parallel-plane oriented showed almost no constancy and more frequent instances in which non-frontal parallel-plane targets were seen normally positioned and exhibiting constancy. Koffka disputed these findings and pointed out that the effect might be due to the serial character of presentation or that the orientation differed in some third aspect.

In the well known book The Perception of the Visual World (6) Gibson asserts that shapes manifesting constancy are not disembodied geometrical contours but rather are shapes existing in phenomenal three dimensional space. For the above author, however, depth perception fundamentally is not mediated by the traditional primary and secondary signs. He hypotheses "the possibility that there is literally no such thing as perception of space without the perception of a continuous background surface" (pp. 7). Accepting this as true it follows that the problem of shape constancy or shape at a depth can then be largely reduced to the determinants of surface perception. Gibson suggests that the determination is retinal, namely, due to the occurrence of unidirectional compression of the texture gradient and foreshortening of the contour in the retinal correlate when a surface is non-normally oriented (pp. 172-173). Traditional cues are supposed generally effective only as they interact with these that are more primitive. If however, surface texture and foreshortening become ambiguous or are non-existent, and if retinal disparity and motion are controlled, he predicts that the form will phenomenally assume the frontal parallel plane position (pp. 174). It would also be expected from what he has said, that the correlating phenomenal shape would show zero constancy, that is, the phenomenal shape should be a "copy" of the proximal stimulus shape.

It is possible that the experiment of Miller (13) and certain of Thouless' were conditioned to an extent by these then unrecognized factors. On the other hand,

experiments in which Thouless had his subjects view the targets monocularly, texture gradients and foreshortening did not seem to have had a demonstrable effect. Stavrianos' test of the shape-orientation hypothesis may have been complicated by the same factors.

In the previously reviewed experiments, changes in object identity were effected chiefly by means of manipulation of orientation and/or manipulation of primary and secondary cues. Another variable, little studied until of late, which can alter the identity of certain properties is that of optical magnification. These changes arise because of the way in which the magnifying instrument itself behaves and because of the way in which the observer organizes the stimulus materials awarded it.

Use of an optical instrument, such as binoculars, changes the two dimensional retinal representation of a focused object. These instruments enlarge the retinal image but the characteristics of the image resulting are different in some respects than they would be if the magnification was accomplished by bringing the object closer. This can perhaps best be understood through study of the several illustrations in Figure 1. The target represented in Figure 1 is a solid object viewed under three conditions, 1) at distance A, 2) at distance

1/2 A, and 3) at distance A with two power optical magnification. For the sake of simplicity only a half of the solids are represented. Comparing condition 1 with 2, it can be seen that with physical movement of the target, the retinal image has been made twice as large and that the visual angles formed by light refracted from the corners o, a, b, and converging at nodal point N have increased disproportionately. Thus corresponding points o1, a1, b1, of the retinal image bear a different relationship to one another than they did at distance A. In short, assymetry has increased.* This does not occur with optical magnification, rather all the visual angles as well as the size are increased proportionately. That is, size is doubled when two-power binoculars are used and the distributions about the fovea is left unchanged. Assymetry is not altered. Condition 3, Figure 1 demonstrates this. The question now arises, however, as to just how the organism will utilize this unique set of circumstances.

An all-inclusive answer to this question cannot be given beforehand despite the fact that a lawful relationship exists between the object and its retinal representation.

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*Assymetry is present when the fovea is not in the center of the image. It is always present to some extent when a non-spherical solid object is seen as three dimensional, or when a two dimensional object is perceived as not lying in the frontal parallel plane.

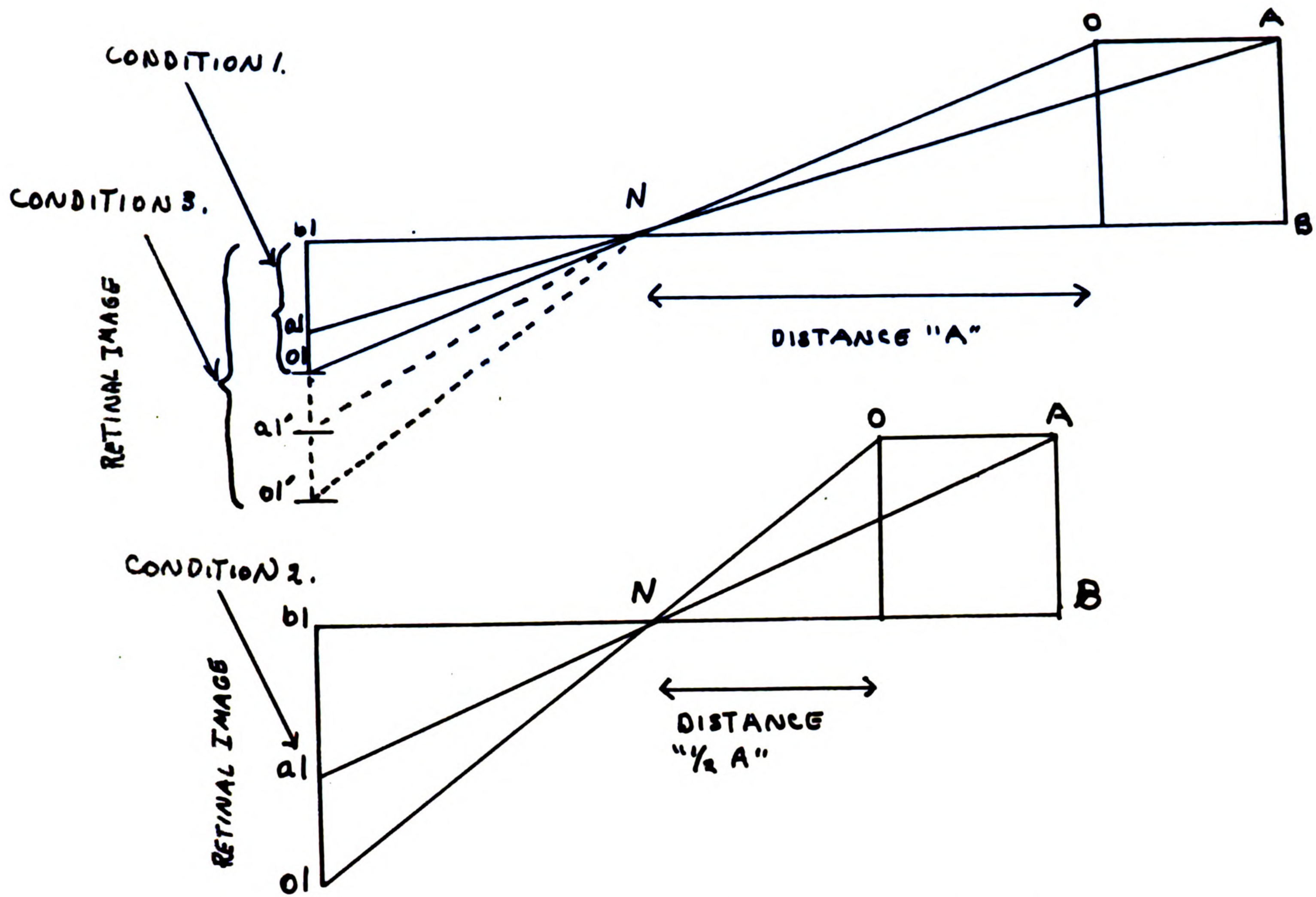

Figure 1 THE EFFECTS OF OPTICAL MAGNIFICATION ON THE PECEPTION OF A SOLID

However in most circumstances in which optical magnification is employed the object observed appears to maintain a constant size. It is perceived as being nearer rather than larger. When as a result of 2 power binocular magnification, for example, the target is seen as being twice as near rather than as twice as large, certain departures from normal "twice as near" appearance must be expected. This is because, as we have already observed, the internal components of this double sized image are dissimilar from those resulting when the target is actually moved nearer by one half the distance. Uninvolved objects such as cubes usually seem to be foreshortened because the distance from all points is perceived as having been proportionally decreased.*

A study in some respects similar to the shape constancy experiments of Thouless previously discussed was performed by Miller (13). He concerned himself only incidentally with phenomenal regression however and seems to have principally directed himself toward determining just

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*More complex objects such as buildings exhibit what is known as "chinese perspective". In this case alterations in apparent shape differ according to the various surfaces of the object and the end result is "peculiar", although presumably precisely determined. This topic has been given extensive treatment elsewhere (1), (2).

what experimental effects can occur when a simple two-dimensional real object placed in a relatively cueless environmental field is viewed with the two-power binocular and with the naked eye. His subjects observed the targets through reduction screens at close range and were asked to draw the shape they saw. The targets themselves were black circles and ellipses drawn on white cardboard and presented at various angles of inclination to the observer. Target shape was operationally defined as the ratio of minor to major axis. It was expected that the phenomenal ratio would indicate the way in which the optically altered distributions on the retina are utilized when visual field conditions are less than "compelling". The outcome illustrated in Table 2 is typical. As one can readily see the phenomenal shapes show the same characteristics as those of Thouless. Namely, they generally occupy a position somewhere between the real object and phenomenal object although the values are somewhat smaller on the average. The degree of relative object constancy under both conditions was expressed in terms of Thouless' simpler index of regression. Table 3 contains the Rg's corresponding to the Table 2 shapes.

TABLE 2

"REAL" RATION, "STIMULUS" RATIO AND "PHENOMENAL" MEAN RATIOS OBTAINED WITH AND WITHOUT GLASSES FOR A CIRCLE AT FOUR INCLINATIONS TO THE LINE OF REGARD

	at 90°	at 67.5°	at 45°	at 22.5°
"Real" ratio	1.00	1.00	1.00	1.00
"Phenomenal" unaided ratio	1.02	.99	.85	.71
"Phenomenal" aided ratio	.99	.96	.69	.62
"Stimulus" ratio	1.00	.92	.71	.38

TABLE 3

INDICES OF PHENOMENAL REGRESSION COMPUTED ON DATA OBTAINED WITH AND WITHOUT GLASSES FOR A CIRCLE AT FOUR INCLINATIONS TO THE LINE OF REGARD

	at 90°	at 67.5°	at 45°	at 22.5°
Unaided	.02	.83	.49	.54
Aided	-.01	.50	-.17	.39

Miller's major finding however had to do with optical magnification rather than constancy. That is, the tables show that there is a lesser amount of Rg with instrumental observation than without. This outcome prompted several conclusions; namely that: 1) two dimensional objects occupying three dimensions in space in reference to the observer can undergo changes similar to three dimensional objects, when they are viewed through binoculars, 2) the operation of a different set of retinal cues, brought about through binocular magnification, can lead to a two dimensional object being seen approximately twice as near rather than twice as large even in a restricted visual field, 3) retinal image assymmetry for some properties under certain circumstances in interaction with other cues, can assume a determining role as regards magnitude of relative object constancy.

The full considerations which dictated the foregoing interpretation must forebear discussion here. However, it should be recognized that in his interpretation of the data, Miller has been oriented primarily toward gaining an understanding of the effects that instrumental magnification has on shape when conditions of encounter are specified. This need not have been the case.

In an attempt to provide a more comprehensive set of principles to account for all perceptual behavior, Bartley has discussed the broader implications of Miller's results. In a short monograph (1) he suggests that it is possible to account for perceptual performance with three broad generalizations. The generalizations, based on experimental evidence, are the principles of "geometric equivalence", "constancy", and "internal consistency". While his treatment of constancy parallels that of this paper closely enough to make further discussion redundant, it is necessary, before proceeding further, to afford formal recognition to the first and last because of their relevance for all later sections.

"Geometrical equivalence" is simply a formal recognition of the fact that any given visual angle or set of angles can be subtended by an infinite number of shapes and an infinite number of orientations.

The principle of "internal consistency" points up the fact that while all factors, that is the total retinal patterning, are taken into account certain factors always have greater prepotence than others. Bartley speaks of the process as being analogous to reasoning, wherein certain facts serve as the premises on which the organism bases a conclusion. In Miller's experiment, for example, the fact that increased retinal asymmetry did not follow increased retinal size seemed to serve as a leading factor or premise for the organism. Internal consistency rejects the idea that a simple isomarphism can exist between the retinal components and the perception. This principle insists that the functional significance of differential light intensities impinging on the retina rests upon more central considerations. This principle, and that of constancy, are at the bottom of descriptions of the two general ways by which the organism confronts geometrical equivalence in its environment.

II. GENERAL STATEMENT OF THE PROBLEM

In the introduction, the varying perceptual behavior, displayed by the human organism with reference to similar stimulus shapes, was described. The foregoing introduction indicated the subtility of the problem of ascertaining the factors that determine the apparent shape of objects. Variations in apparent shape were correlated with many coordinate extra-shape retinal existencies, binocular factors, and response conditions. The experimental evidences concerning the role of the correlates treated are impressive, but nevertheless, a great number of questions still remain to be answered. The studies indicated that there is still much to be done to reduce the matter to systematic understanding. The present study aims at making a step in this direction.

The present study is one in which the targets consist in forms in an undifferentiated field, where obviously there are no visual-field influences. The sole influences outside the targets themselves are those of experimental design, and the characteristics of the observers themselves. Accordingly the present work is an experimental attempt to study the perceptual behavior of the organism in rather unique circumstances. The circumstances are unique in that while the retinal patternings responded to can be definitely determined, they are not of the sort that seem a-priori to allow for only a single phenomenal outcome. It is hoped that this approach will demonstrate the relation of certain stimulus and response variables under more extreme conditions than others have hitherto been able to realize. For these reasons, it will not be possible to state a fixed hypothesis regarding any specific phenomenal outcome.

The chief problems of interest are three in number. Briefly they concern: (1) the relative shape constancy obtained with circular and elliptical outline targets in an impoverished situation, (2) the effect of instrumental magnification as regards perception of shape when cue conditions of observation are at a minimum, and (3) the relation of shape to judged inclination.*

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*In addition, while the experiments were not designed to test the role of general variables of the perceptual task, a statement of the matter is to be given. These incidental findings will be found in the Appendixes 1, 2, and 3. Also included in the Appendixes (4 and 5) are two short studies related to the main problems quite directly.

III. EXPERIMENTAL APPARATUS AND SUBJECTS

Subjects

Fourteen subjects, divided equally as regards sex were used in this experiment for "Group A". For "Group B" ten different subjects, mostly female, were used. All subjects were in their twenties. All had, at minimum, sixteen years of education and possessed or were corrected to, normal vision. As far as could be determined, all observers were unaware of the nature of the experimental variables and naive as to the method of their manipulation.

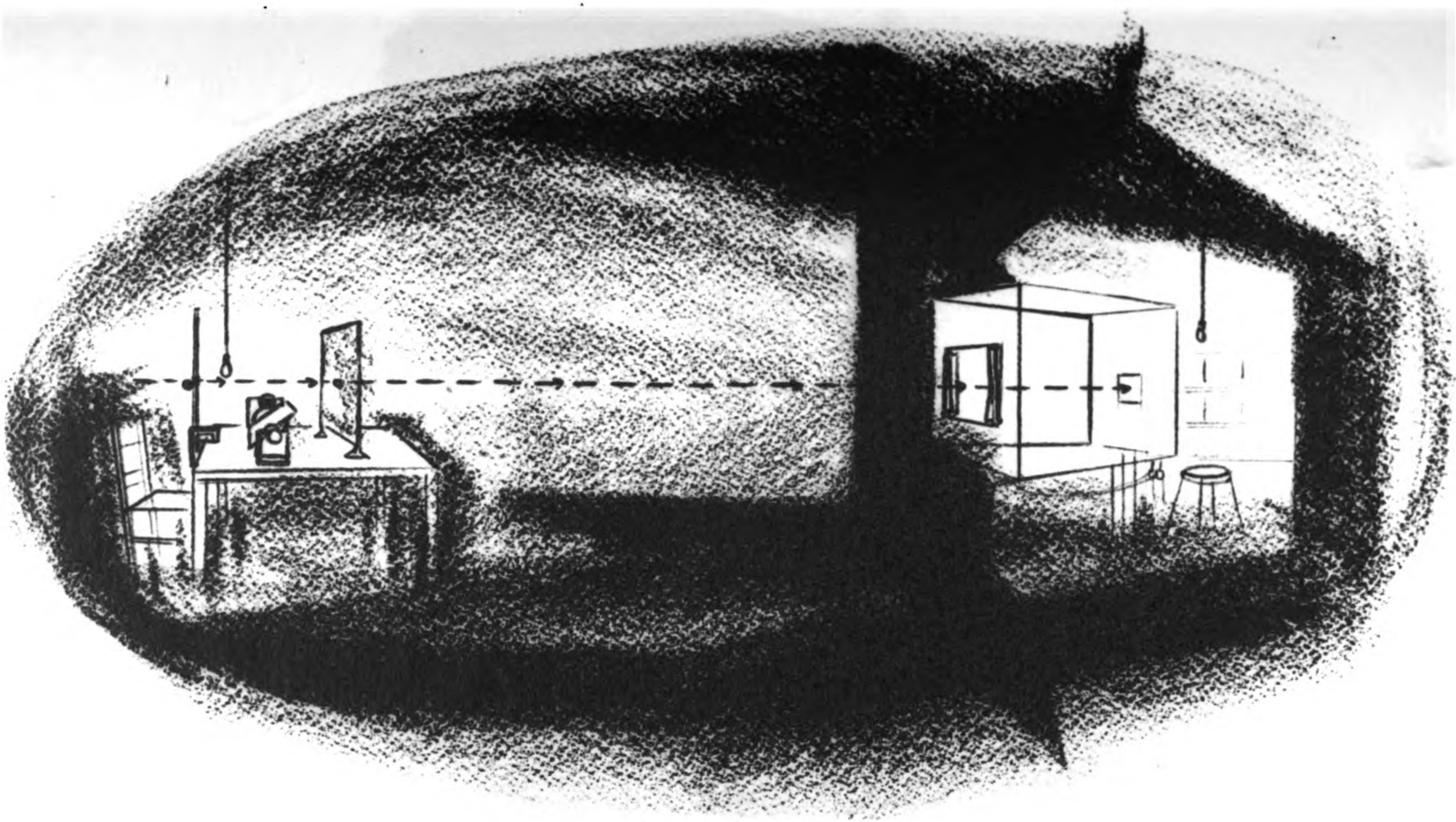
Apparatus

All experiments were performed in the same two adjoining light proof rooms (see Fig. 2). An aperture 14 x 28 inches was cut into the wall between the two rooms and located at eye-level to the subjects who were seated at a table thirteen feet six inches from this aperture. Attached to the center wall and immediately around the aperture was a large plywood box, referred to as the stage, and which measured 46 inches long, 30 inches wide, and 35 inches high, and contained an opening 7 inches square into which the targets were placed for presentation (see Fig. 5). Thus the distance from target to observer became 17 feet 4 inches. Located above the front aperture

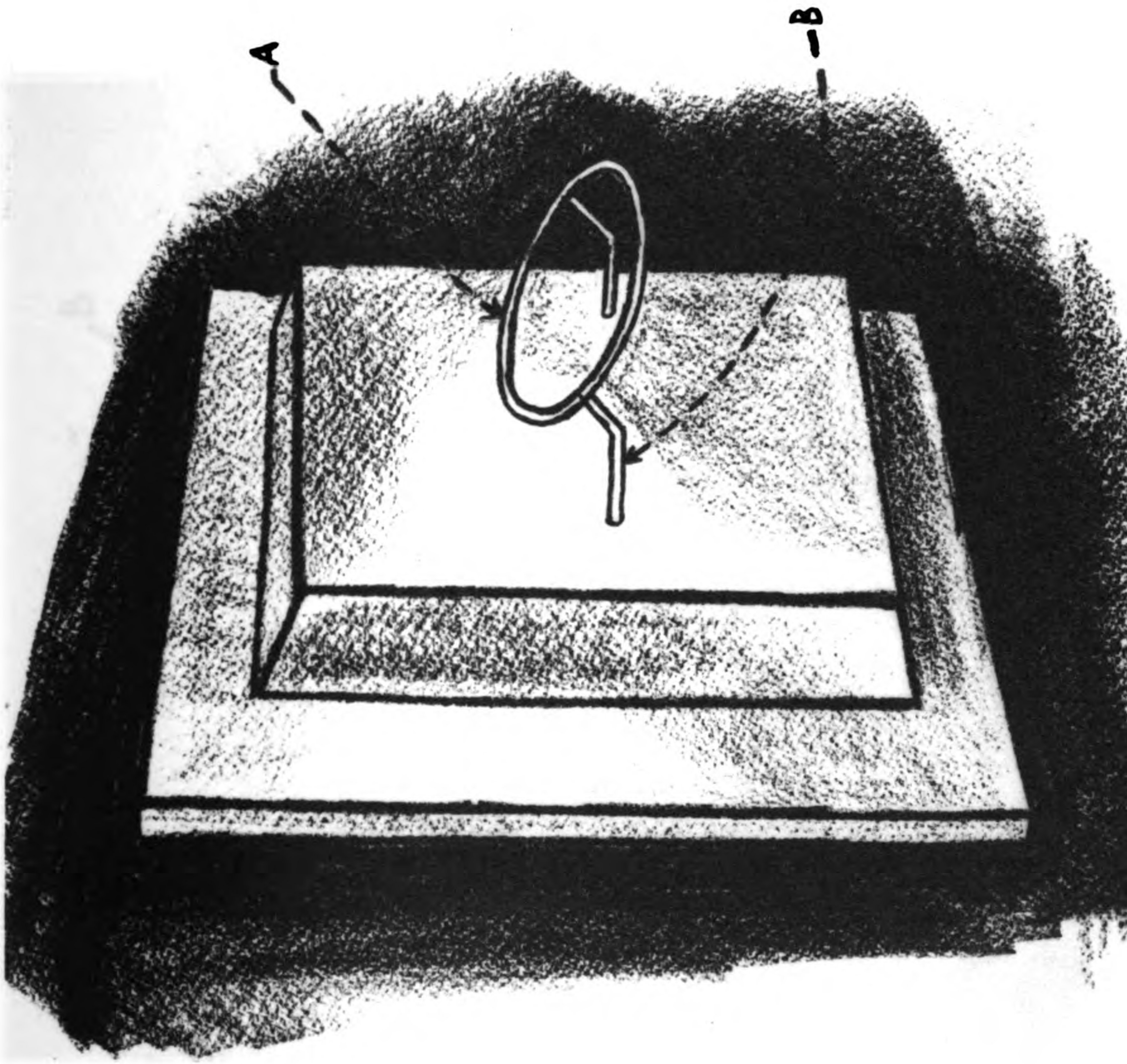
and inside the stage was the light source, a General Electric CH-4 ultraviolet lamp and its accessory parts, which included its screw base socket, transformer and special filter which eliminated the fractional percentage of white light emitted by the source. The lamp was of spotlight construction and was beamed directly on the target area. All surfaces except those of the target proper (see Fig. 3-A) were painted flat black to absorb not only the fractional amounts of white light which might still have been present in the emission from the source but also to absorb the traces of white light reflection caused by any foreign matter present in commercial fluorescent paint used to coat the targets themselves. Between presentations, all target changing activity was hidden from the observer by means of a pair of monks cloth curtains suspended from a traverse rod. The traverse rod was operated from the rear of the stage by the experimenter. The curtains provided complete occlusion of the stage interior during target changing.

There were 12 targets fabricated from 12 gauge wire. The targets are described in terms of the size of their minor-major axis ratios and angles at which they were mounted. Thus three different sized targets were used: a) 5 x 3.2 (a major axis of five inches and a minor axis of 3.2 inches), b) 5 x 4, and c) 5 x 5. Four each size targets were constructed and one each of the four mounted at a different angle than that of the others. The angles of presentation were approximately 90° (upright), 67.50 (22.50 away from the subject), 45° and 22.5°. These twelve figures were mounted on 7 inch squares, constructed to afford a light-tight fit when placed in the opening at the rear of the stage for presentation (see Fig. 3 and Fig. 5-B). Although many of the targets were mounted at a tilt the use of the fine gauge wire assured that the difference in perceived size between the nearest and farthest segments was never sufficiently great to have cue value for distance.

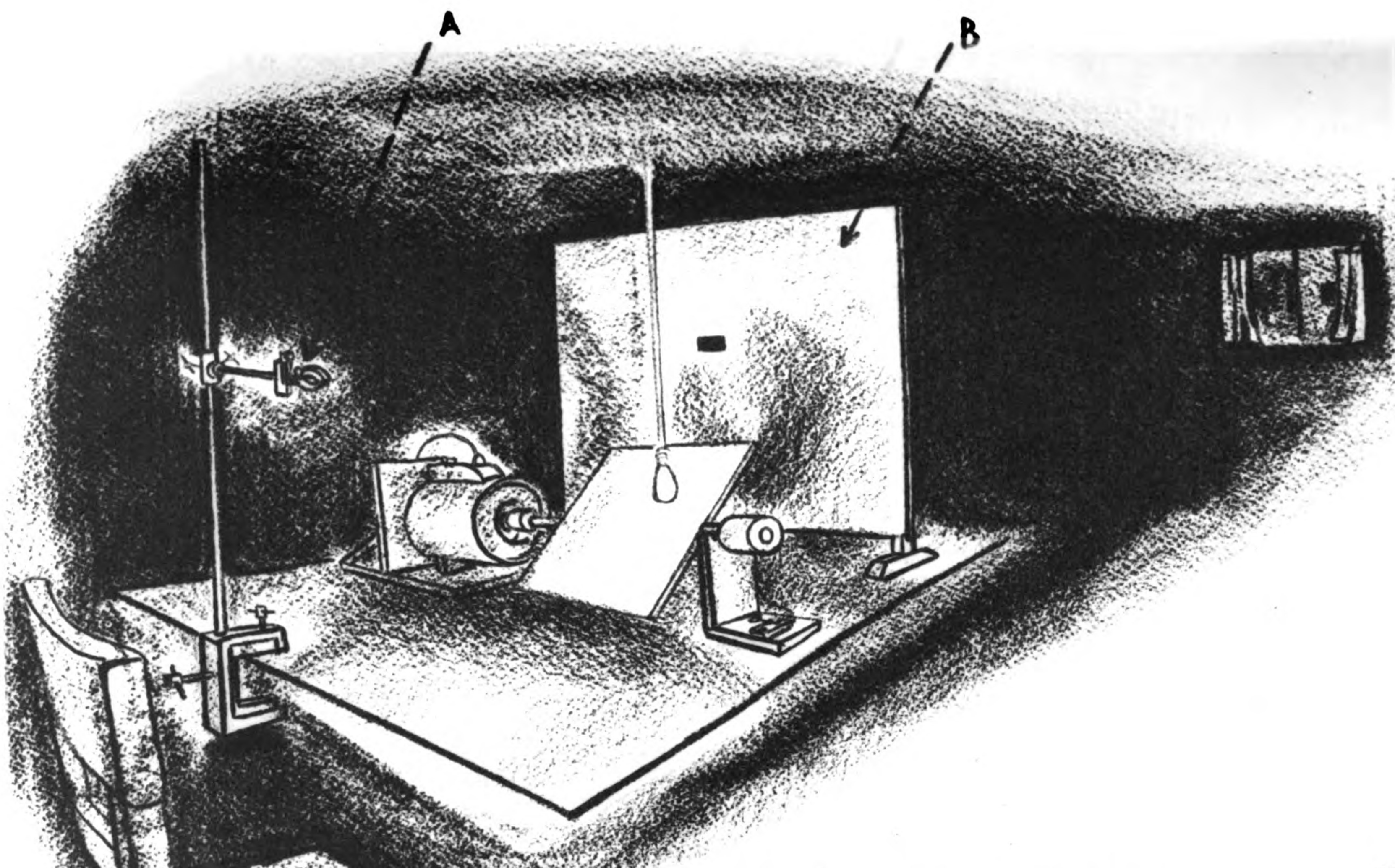
A reduction screen with an aperture 2-1/4 inches high and 3-1/4 inches wide was placed 30 inches from the subject to restrict the field of vision (see Fig. 4-B). The aperture in the reduction screen was movable to compensate for variations in sitting height of the subjects. The relationship of the various apparatuses to one another can be seen in Fig. 4. In this Figure, apparatus A held the glasses and was removed when the condition was that of unaided vision.



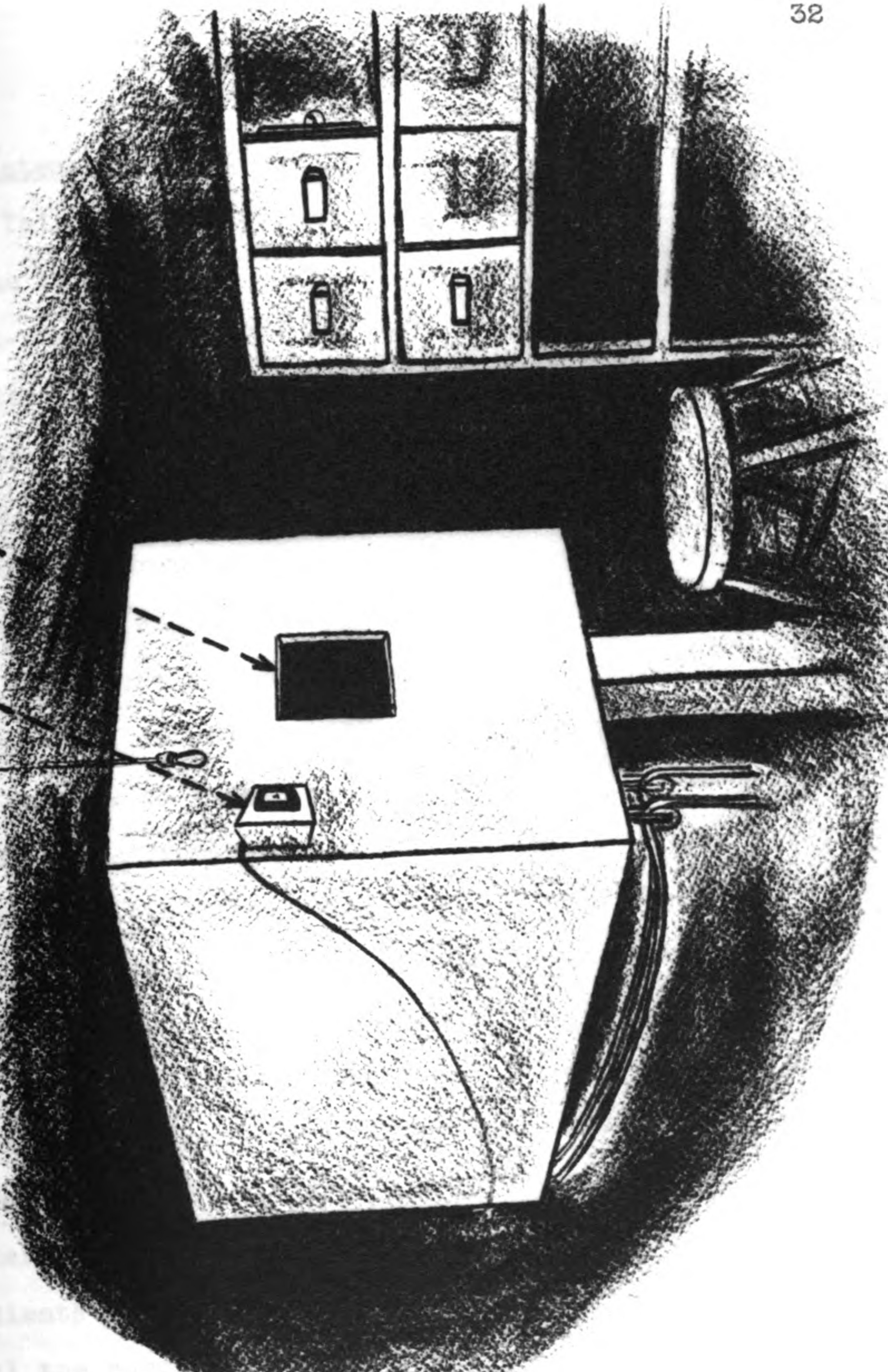
CUT-AWAY VIEW OF EXPERIMENTAL ROOMS



TYPICAL TARGET USED



VIEW FROM OBSERVER'S POSITION



STAGE AND EXPERIMENTER'S ROOM

IV. PROBLEM 1.

A. Statement of Problem

This problem concerns the measurements of shape, for the circular and elliptical targets described, when visual-field influences are totally lacking. It is known from the results of previous experimentation that the experienced shape varies as a function of collateral retinal stimulation. Usually a decrease in relative constancy accompanies the elimination of collateral cues. In Thouless' experiments for example as the traditional depth cues were reduced, the index of Rg approached zero. Nevertheless despite existence of this continuum, reduction of a regression index to zero has been difficult to accomplish. Thouless, Eissler, and Miller show no values of zero for binocular observation or monocular observations in an unrestricted field. In explaining this, one is, of course, tempted to conjecture that these greater than zero indexes occurred because all relevant stimuli collateral to the retinal image itself had not been successfully controlled. This argument appears to be rendered all the more likely when one recalls that texture gradients were not conceived of as being salient features until the advent of Gibson's book and could have been complicating factors in all cases where target surfaces

were involved. Compelling as the above alternative may sound however there are two other possibilities that cannot be ruled out summarily.

Certain shape targets observed in very impoverished circumstances might yield phenomenal shapes showing an index other than zero. For example, under our experimental conditions the targets are structurally simple outline shapes tipped from the line of regard and viewed in complete darkness at distances too great for binocular disparity to be operative. The observer is responding to a simple retinal organization and for several reasons regression or progression seem a-priori as possible in this situation for some of the targets as does an index of zero.

Eissler's results for example indicated that no single condition of those he considered was an absolute necessity for depth perception. All members were found to a large extent replaceable by others. The function of one cue does not seem to be independent of the presence of other cues. If the extent of the relative constancy expressed is, as it seems, a function of the prepotent cues that serve as "premises", or as the "frame of reference" for the others, a dearth of "common" premises might lead the organism to center the perception on conditions previously given little weight, or to center the perception on cues discriminant over only a small part of the entire range of possible responses. For example, to state a possible case, tipped targets are always foreshortened. In regard to ellipses and circles this is known as the "flattening effect". Flattening probably has steadily less cue value as the target approaches the line of regard. Hence an ellipse vertical to the line of regard might show a differing extent of constancy than a circle at 65 degrees. This might occur because of a foreshortening cue even though the operational stimulus shapes were identical. Here we could speak of foreshortening as a discriminant or differentiating determinate. Conversely however, when the targets lie close to the line of regard identical stimulus shapes might produce identical phenomenal shapes even though the real targets were an ellipse, a circle and an elongated ellipse (ellipse hinged on its minor axis). This is because differences in foreshortening would be too slight to be usable by the organism. Foreshortening would not be a discriminant in this part of the range and, if used as a premise, might result in progression, regression or zero constancy depending upon the real target used as the referent.

Other factors such as Koffka describes as "external" and "internal forces" produced by the retinal configuration might be operative. Neuro-physiological factors relatively independent of the proximal stimulation might also play a role under such circumstances. Other agents not having to do directly with the retinal stimulation such as "assumed shape" might prove impossible to preclude in this setting. Accordingly, even though any comprehensive attempt to determine the nature of any "new" premise possibly operating is beyond the scope of this paper, no assumption concerning the exact indexes to be expected can be entertained.

B. Procedure and Directions to the Subject

During this part of the experiment the binocular mount and the variac with tilt board coaxial with it were removed from the Table (see Figure 4). The experiment then proceeded in the following manner. The subjects were asked to seat themselves at the end of the table supplied with paper and pencils. After the subject had seated himself, normal illumination was removed and replaced by illumination afforded by a red bulb of 25 watts. The subject was partially dark adapted in this environment for three minutes, during which time he was given the instructions and allowed to operate the buzzer system which informed the experimenter in the other room of the completion of a response to one target and readiness for the next.

The following directions were given, "Draw what you see as accurately as you can. Take all the time you care to. Size is unimportant, but what is desired is that the internal relationships, that is, the relation of the major to the minor axis, the proportions, be in as close accord with those of the target as you can make them." After this the experimenter indicated to the subject that the experiment was about to begin. Then placing in position the first of the twelve targets of the series (the order of appearance of which had been determined by reference to tables of random order), the experimenter drew open the curtains, exposing the target. When the subject had satisfied himself as to the adequacy of his response, he pressed the buzzer to indicate completion of the task. The experimenter then closed the curtains and replaced the target with the next. This cycle was repeated through the series of twelve targets. The complete series was repeated ten times without pause under these conditions. After the complete set of responses were made, the drawings were transposed into shape indexes and the means for all trials per target were derived. Standard deviations were then computed and an analysis of variance applied to the compiled data of "Group A".

C. Results

The data for this experiment are presented in Table 4. It may be observed that the means of the phenomenal shape responses are both larger and smaller than those of the respective stimulus shapes. Twice as many of the means are less than the stimulus shape ratio as are greater than the same ratio. Also the average deviation is somewhat larger in the less than stimulus ratio direction. The range of responses varies from a greater than of .09 to a less than of .12. There is a general tendency for phenomenal ratios greater than those of the stimulus ratio to occur at the ends of the distribution of shapes while those values occurring in the middle ranges are uniformly smaller than their respective stimulus ratios. This is depicted graphically in Figure 1 in which the mean phenomenal ratios are plotted against the stimulus ratios. A simple isomorphism would demand that all points fall on the diagonal line. The Figure 6 shows the plot of points to roughly conform to the contour of a positive accelerated curve. The pattern of changes varies consistently as a function of the magnitude of minor major axis ratio. Table 4, column 5 contains the standard deviations for each mean of the phenomenal responses of Group A reported in the table. The variability does not appear to be closely dependent upon either angle of presentation or on the real shape presented. Because of the very small size of these standard deviations some of the differences between phenomenal and stimulus shape values would doubtlessly be found to be significant statistically.

TABLE 4

TABLE COMPARING REAL SHAPE, STIMULUS SHAPE, AND MEAN PHENOMENAL SHAPE FOR "GROUP A" AND "GROUP B". STANDARD DEVIATIONS FOR "GROUP A" ARE INCLUDED.*

	Real	Stim.	Phenomenal		S. D.
			Group A	Group B	Group A
	(1.00	1.00	1.01	.97	.08
90°	(.80	.78	.68	.68	.07
	(.68	.68	.56	.58	.07
	(1.00	.95	.95	.92	.08
67.5°	(.80	.76	.67	.68	.07
	(.68	.59	.53	.57	.06
	(1.00	.70	.60	.63	.08
45°	(.80	.63	.51	.54	.06
	(.68	.38	.43	.47	.06
	(1.00	.31	.28	.29	.05
22.5°	(.80	.28	.30	.32	.07
	(.68	.24	.28	.31	.06

*Each combined mean for "Group A" represents 140 unaided condition responses. Each combined mean for "Group B" represents 100 unaided responses. Total number of unaided responses for "Group A" is 1680. Total number of unaided responses for "Group B" is 1200.

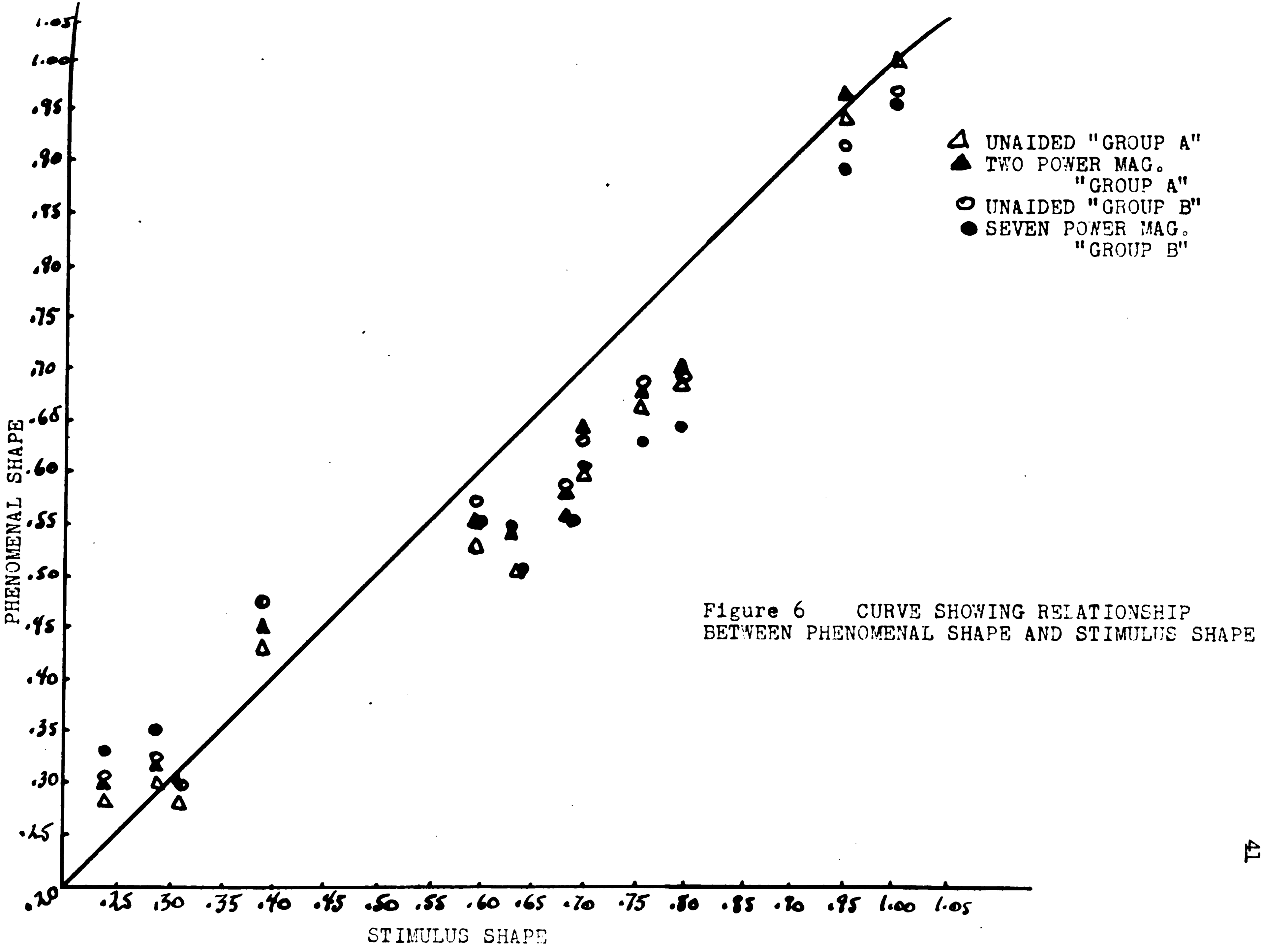


Figure 6 CURVE SHOWING RELATIONSHIP BETWEEN PHENOMENAL SHAPE AND STIMULUS SHAPE

V. PROBLEM 2

A. Statement of the Problem

The second question concerns the effect of low power optical magnification on phenomenal shape under conditions in which the target is viewed in an undifferentiated field. It was noted in a previous section that two power binoculars double all visual angles and hence exactly double the retinal image size. This increase is effected however without changing the relative distribution of the image about the fovea. Asymmetry is not altered. The size of the retinal image can also be doubled in another way. That is by halving the original observation distance. However when the increase is brought about by moving the target closer, an alteration in the distribution of the images about the foveas does occur and asymmetry increases. If these conditions of retinal asymmetry are the only variants and are supraliminally different then we may expect, as Koffka (12, p. 230) points out, not entirely equal perceptual effects. The direction of the change is predictable under ordinary conditions because certain objective and subjective factors are known.

Under ordinary conditions when glasses are used to view simple two dimensional target shapes maintenance of size seems to be more basic than maintenance of the invarient of distance.*

That is, with two power magnification the target is seen as being of a fairly constant size but almost twice as near rather than as being at a fairly constant distance with approximately twice as large a size. Because of this and our knowledge of the geometry of optical magnification, several givens or premises are available from which the direction of change, that is the approximate shape and orientation to be expected under ordinary conditions can be predicted.

As an example, in Figure 7, retinal distance a b and the associated visual angles a N b and A N B are objective facts under the illustrated conditions. Now suppose that a two power magnifying instrument is interposed between the retina and the two dimensional target at the nodal point. Under this latter condition the doubled visual angle and the doubled retinal distance designated x y are now the objective facts. Putting these objective factors together with those of size and distance determines target X Y. This is because the relative constancy of size, if expressed in terms of Rg, would approach 1.0 while that

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*The invarient relationship has been demonstrated experimentally. See Hermans (9).

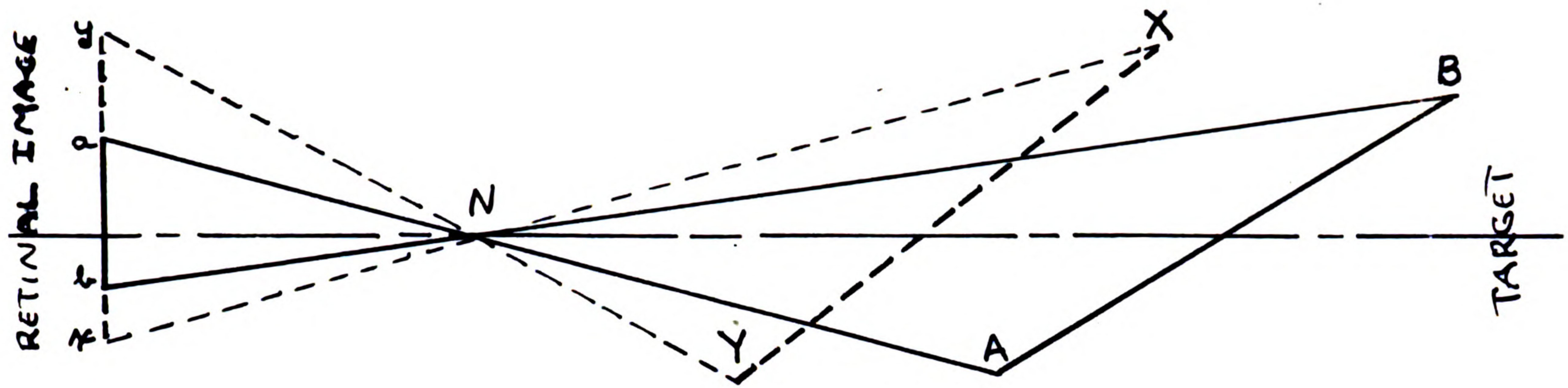

Figure 7 THE EFFECTS OF OPTICAL MAGNIFICATION ON A TILTED PLANE FIGURE

of distance would approach O. Distances N A and N B would be perceived as approximately halved. Drawing a line through points T and S, which are halves of this distance, and extending it to the visual angle determined by the optical instrument should approximate the phenomenal outcome. The line X Y suggests that the phenomenal result should be a perception with approximately the shape and orientation qualities of X Y.

Miller's experiment generally bears this out as far as shape is concerned. He obtained, on the whole, smaller indexes of Rg for drawings of tilted circles and ellipses with conditions of optical magnification than with conditions of unaided observation.

Reduction of retinal stimulation collateral to the stimulus shape to a point below threshold value does not make possible prediction of the shape indexes to be obtained. This is because, although the objective facts, i. e. retinal patternings, are just as determinable here in ordinary conditions of perception, there is no way to know prior to examining the data how the organism will structure the subjective factors of size and distance. A-priori all three shape responses are possible. Namely, the shape indexes can be larger, the same, or smaller than those got under the unaided condition of observation.

Considering these facts several things may perhaps be said.

If the obtained indexes are larger or the same as those of the unaided condition then the results will not be in accord with those obtained in experiments in which less severely reduced fields were used. From equal or larger indexes one would surmise that retinal asymmetry is not functioning as a premise and/or that size has varied, with distance showing a greater relative constancy. If smaller indexes should occur with instrumental magnification the differences would be in agreement with those obtained in less reduced situations by other experimenters. Given this the case, one would perhaps suppose that retinal asymmetry was functioning as a premise and that with optical magnification distance and not size had been altered.

A comparison of the absolute positions of the shape responses on the range of possible responses should suggest the factors on which the responses are founded. However the possibilities in this connection are so manifold that any attempt to delve into all logically possible relationships prior to treatment of the data would be wasteful of the reader's time.

B. Procedure and Directions to the Subject

During this part of the experiment two and seven power binoculars and the binocular mount were used. The variac with tilt board coaxial to it were removed from the table (see Figure 4).

The experiment consisted of the same task performed under the same conditions as those previously described, except for the introduction of instrumental magnification into the situation. The subjects were divided into two groups as regards the aided situation, twelve using two power (2X) opera glasses (Group A), and nine using seven power (7X) military glasses (Group B). In both the aided and unaided situations, techniques of presentation by experimenter and representation by the subject were the same.

After the complete set of responses were made, all drawings were transposed into shape indexes and the means for the all trials per target, were derived. Standard deviations were then computed and an analysis of variance applied to the compiled data of "Group A".

C. Results

The mean phenomenal ratios for "Group A", unaided and two power optical magnification, and "Group B", unaided and seven power binocular magnification are entered in Tables 5 and 6 respectively. Noting first the data in Table 5, we can observe that the subjects tended to draw slightly larger shapes where the targets were viewed through two power binoculars. Although these larger ratios were obtained for eleven of the twelve computed means, an analysis of variance shows the difference to be insignificant ($F = .0088$). Turning to Table 6 one can observe in the case of "Group B" data a trend in an opposite direction from that of the data of "Group A". It may be noted here that only in two of the twelve cases are the phenomenal ratios larger than the stimulus ratios in instances where the targets were viewed through seven power binoculars. This difference was not tested for significance because it is of smaller magnitude than that found to be insignificant for "Group A". These relationships may be seen more clearly in Figure 7. In this figure the phenomenal ratios for both groups, under both conditions, are plotted against the stimulus ratio. All of the four plotted distributions roughly correspond to the contour of a positively accelerated curve. It will be noted that consistent within all of the experimental conditions is the occurrence of phenomenal shape values which were greater than the stimulus shape values at the ends of the distributions of the shapes, and less than stimulus shape values in the middle ranges. The pattern of change suggests that the shape indexes of the responses vary absolutely as a function of the minor-major axis ratios. That is, the contour and position of the curve does not seem to be significantly influenced by optical magnification or differences in optical magnification in our situation. The standard deviations are contained in Table 5, columns 4 and 6. They show only small differences in variability of observation under unaided, and two power binocular aided condition. When these small differences are found, they are generally in favor of the unaided condition.

TABLE 5

TABLE COMPARING PHENOMENAL SHAPE AND STANDARD DEVIATIONS UNDER CONDITIONS OF UNAIDED VISION AND TWO POWER OPTICAL MAGNIFICATION*

	Real	Stim.	Phenomenal Unaided	S. D.	Phenomenal 2 Pr. Mag.	S.D.
90^{0}	(1.00	1.00	1.01	.08	1.00	.05
	(.80	.78	.68	.07	.70	.06
	(.68	.68	.56	.07	.58	.06
67.5^{0}	(1.00	.95	.95	.08	.97	.07
	(.80	.76	.67	.07	.68	.08
	(.68	.59	.53	.06	.56	.06
45^{0}	(1.00	.70	.60	.08	.64	.06
	(.80	.63	.51	.06	.54	.06
	(.68	.38	.43	.06	.45	.07
22.5^{0}	(1.00	.31	.28	.05	.30	.05
	(.80	.28	.30	.07	.32	.06
	(.68	.24	.28	.06	.30	.05

*Each combined mean represents 140 responses. Total number of responses per condition is 1680.

TABLE 6

TABLE COMPARING PHENOMENAL SHAPE UNDER CONDITIONS OF UNAIDED VISION AND SEVEN POWER OPTICAL MAGNIFICATION *

	Real	Stim.	Phenomenal	
			Unaided	7 Pr. Mag.
90°	(1.00	1.00	.97	.96
	(.80	.78	.68	.64
	(.68	.68	.58	.56
67.5°	(1.00	.95	.92	.89
	(.80	.76	.68	.63
	(.68	.59	.57	.55
45°	(1.00	.70	.63	.61
	(.80	.63	.54	.51
	(.68	.38	.47	.47
22.5°	(1.00	.31	.29	.29
	(.80	.28	.32	.35
	(.68	.24	.31	.33

*Each combined mean represents 100 responses. Total number of responses per condition is 1200.

VI. PROBLEM 3

A. Statement of the Problem

This part of the paper concerns the relation of perceived shape to judged orientation of the target. Although Stavrianos was unable to show a consistent relation, the problem is of significance. The determination is felt to be of importance because inherent in the work of most experimenters in the area of shape constancy is an implicit assumption that these abstractions are related in some orderly, if not necessarily direct, fashion.

As previously indicated, the present writer suspects that Stavrianos' failure to confirm the shape-orientation hypothesis may have been conditioned to some extent by the method of experimentation employed. Accordingly the present experiment will employ apparatus and methodology entirely different than those of Stavrianos. Besides these there is a difference in the orientation of the present experimenter from that of Stavrianos. These factors will lead to a difference in the organization of the data.

Firstly, as regards apparatus, the test will be made using outline target shapes as standards instead of surface target shapes. It is felt that a combination of lighting effects and the use of surface targets for both standard and comparison targets could have produced material dissimilarities in texture gradients in Stavrianos experiment. Secondly, the standard target and tilt comparison target will be at different distances and be of different shapes to assure that an abstraction rather than a gross matching is being made. Thirdly, shape will be expressed via drawing. In Stavrianos' experiment shape was shown by the adjusting of a light patch lying on a milk glass screen until it appeared to be of the same proportions as the standard. The drawing method would seem to better assure that an abstraction and not a match is being made. This is particularly true because with Stavrianos' setup any representation with less than the greatest expressable minor axis would be bound to be foreshortened, with the foreshortening increasing as the minor axis was decreased.

Methodologically it is felt advisable to deal with the abstractions independent of one another. This is done to preclude interaction of the very things tested. Stavrianos subjects were required to make successive determinations, first of tilt and then of shape. However it is recognized that in her case interaction may not have been an important factor because she reports using observers who were all skilled in making the type of judgement necessary for the experiment.

Stavrianos attempted to demonstrate the invariance by relating phenomenal tilt and phenomenal shape to those of the real object. The assumption was made that if the tilt was perceived correctly, that is, if it was in accordance with that of the standard target, the shape should correspond most closely to the shape of the real object. She supposed that an experimenter with knowledge of the stimulus shape and knowledge of the perceived inclination should be able to predict phenomenal shape. Although in her experiment phenomenal tilt does seem to agree fairly with real target tilt, it appears to be needless to confound the test of invariance by positing a vertical aspect to perception, particularly under the conditions of her experiment. To the present writer it would seem to be preferable to simply treat the phenomenal responses independently of the objective measurements. By doing this a test might be effected without making the assumption of a simple isomorphism between the two.

In the present experiment, phenomenal tilt responses will be plotted against phenomenal shape responses. If the operational phenomenal shape responses are demonstrated to be identical under our conditions to the operational stimulus shape, then phenomenal tilt, if it is an invariant, will show a similar relation. That is it will be a straight line function just as shape. An invariant relation will be represented by a straight line function in any direction.

B. Procedure

The shape indexes already reported for "Group A" were compared to tilt judgements made to the same targets by the same subjects.* The tilt responses were made after all shape data had been collected.

C. Results

The corresponding phenomenal shape and phenomenal tilt values are presented in Tables 7 and 8. Table 7 contains the phenomenal values for "Group A", unaided condition, and Table 8 the phenomenal values for "Group A" observations, when vision was aided by two power binoculars. From these tables it can be seen that the judged inclination of the targets observed increases as the phenomenal shape values decrease. Comparing Tables 7 and 8 it can be seen that the values for phenomenal tilt are in all cases larger than those of the unaided condition. Figure 8 illustrates, graphically, the functional relationship obtained between phenomenal tilt and phenomenal shape for all "Group A" conditions. Phenomenal tilt has been plotted against phenomenal shape in this Figure. The data appears to fall

*Regarding the data for the tilt experiment see Haan (7).

in a fairly straight line along the dotted function representing the objective relationship between tilt and shape, that is, the relationship of real tilt to stimulus shape. It is thus apparent from the location of the points that the relationship between these phenomenal abstractions is very similar in position and direction to that of the objective abstractions. It is further obvious that if a line were drawn to depict the phenomenal relationships for "Group A" data, under the aided and unaided conditions, that the aided function would occupy the higher position on the graph. This is because while the phenomenal shape indexes did not differ significantly between the aided and unaided conditions, as the previous section showed, the inter-condition phenomenal tilts do differ significantly. This outcome was not entirely unexpected.

TABLE 7

TABLE SHOWING CORRESPONDING PHENOMENAL SHAPE AND PHENOMENAL TILT VALUES FOR "GROUP A", UNAIDED CONDITION*

Real Shape	Approximate Real Tilt	Stimulus Shape	Phenomenal Shape	Phenomenal Tilt
1.00	90°	1.00	1.01	85.5
1.00	67.5°	.95	.95	85.5
1.00	45°	.70	.60	50.5
1.00	22.5°	.31	.28	25.5
.80	90°	.78	.68	58.0
.80	67.5°	.76	.67	56.0
.80	45°	.63	.51	44.0
.80	22.5°	.28	.30	29.0
.60	90°	.68	.56	46.0
.60	67.5°	.59	.53	44.0
.60	45°	.38	.43	36.0
.60	22.5°	.24	.28	25.0

*Each combined mean represents 140 responses. Total number of responses per condition is 1680.

TABLE 8

TABLE SHOWING CORRESPONDING PHENOMENAL SHAPE AND PHENOMENAL TILT VALUES FOR "GROUP A", AIDED (2X BINOCULARS) CONDITION *

Real Shape	Approximate Real Tilt	Stimulus Shape	Phenomenal Shape	Phenomenal Tilt
1.00	90°	1.00	1.00	85.5
1.00	67.5°	.95	.97	58.0
1.00	45°	.70	.64	63.0
1.00	22.5°	.31	.30	27.0
.80	90°	.78	.70	77.5
.80	67.5°	.76	.68	58.0
.80	45°	.63	.54	48.0
.80	22.5°	.28	.32	31.0
.60	90°	.68	.58	63.0
.60	67.5°	.59	.56	39.0
.60	45°	.38	.45	46.0
.60	22.5°	.24	.30	25.0

*Each combined mean represents 140 responses. Total number of responses per condition is 1680.

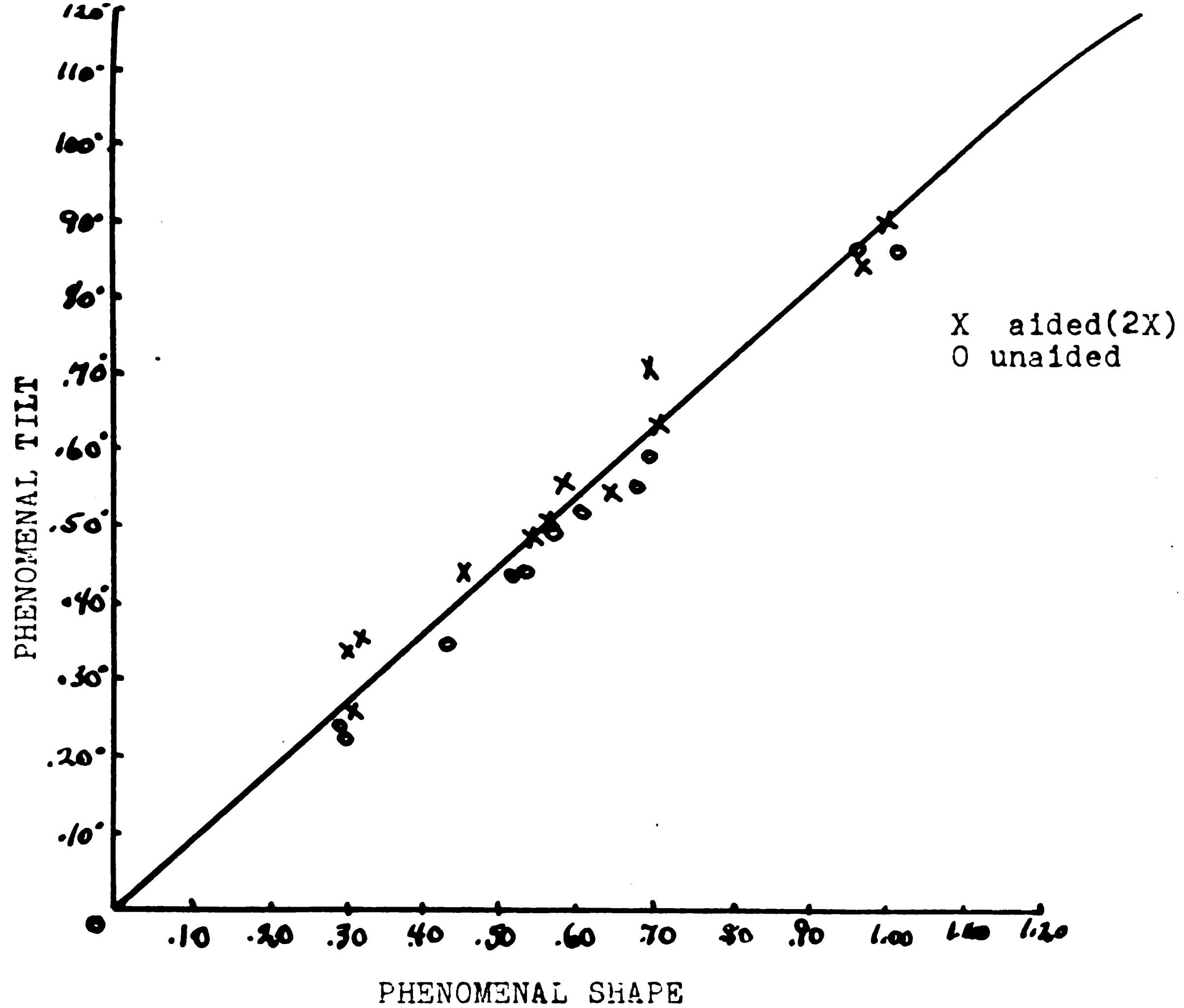

Figure 8 CURVE SHOWING RELATIONSHIP BETWEEN PHENOMENAL SHAPE AND PHENOMENAL TILT

VII. DISCUSSION

The phenomenal shape responses resulting when the circular and elliptical outline targets were viewed in the described circumstances, are, in certain respects, consistent with those of previous investigators. The present experiment has again demonstrated that perceptual shape responses are determined in large measure by the presence or absence of retinal factors collateral to the image itself. It has been shown that when these collateral factors are completely eliminated the shape perceptions, as indicated by the observer's drawings, show a decrease in the minor-major axis ratios over those obtained under other conditions. Tables 1, 2, and 4 illustrate this by making possible comparison of the outcomes of two previous phenomenal shape experiments with that of the present.

However, in an important respect, the shape indexes reported in the preceding section (Table 4) are at variance with expectations one might entertain on the basis of the prior publications. In this regard we may state that, in many cases, the phenomenal shape values are less than those of the respective stimulus shape. That is, the data in Table 4 clearly shows that all mean phenomenal shape values do not fall within the range tacitly assumed by the equations of the types developed by Thouless and

Brunswik. There is not a simple copy of the peripheral stimulus shape even when collateral retinal stimulation is at bottom. Relative object constancy-like responses tend to occur toward the ends of the distribution, while the combined means of the middle ranges fall significantly outside the assumed range of responses. Thus, if the results are accepted, and if one is to use the objective or real shape as the referent, then it is manifest from the data that it will be necessary to speak of "progression from the real object," as well as, "regression toward the real object." The expression, "progression from the real object," or its equivalent however, while perhaps satisfying enough as a descriptive devise, certainly would seem to pose special problems for a "Psychology of Objective Relation," and the "Law of Phenomenal Regression." Neither previous knowledge of a real character nor present perceptual indicants of a real character seem to be able to account for the results. Responses suggestive of those labeled "relative object constancy" do occur in the absence of collateral cues. The dependence of Rg on the presence of the usual perceptual indicants over the whole range of possible responses has not been demonstrated. It is perhaps also worthy of recognition that, under identical environmental conditions, drawings representing both regression and progression were obtained to stimulus shapes on different parts of the continuum.

The data shown in Table 4 and the contour of the correlated graph in Figure 6 might be considered attributable to several possible factors. Gibson has suggested, for example, that foreshortening of an outline, when it is inclined to the observer, can determine constancy. However, the outcome of this experiment fails to substantiate this tenet. Two facts suggest that this determination is unlikely. One, the largest phenomenal indexes, relative to the stimulus shape used, occur at the ends of this distribution. This occurs although one would expect a general decrease in constancy or an increase in progression as the targets approached the frontal plane, if foreshortening were functionally effective. Two, given similar stimulus shape ratios, similar "regression" or "progression" can result irrespective of the extent of foreshortening involved. In fact, a glance at Table 4 shows that, with those targets of greatest inclination, the smallest indexes of regression are shown by the real circle rather than by the real ellipses. This, too, is contrary to the foreshortening hypothesis.

Discarding foreshortening, one might suspect that the results are a function of the method of representing the experience. Thouless, for example, abandoned the method of drawing in favor of a matching response, since with drawings he discovered that slightly less than stimulus shape reproductions were consistently made. Nevertheless, several facts lead us to doubt that the method of representation can account for the outcome. Firstly, the underestimations, Thouless reports, are too small to account for the progression. Secondly, the data of an unreported study, done under the supervision of the author, demonstrated that the operational perception shape did not change in terms of the surface on which it is projected.*

Thirdly, because phenomenal shape and phenomenal tilt have been demonstrated to act as invariants, we know that the reported shape perceptions probably did not occur as artifacts of the method of expression.

The data indicate that all targets were treated as though lying on the frontal plane regardless of the amount of foreshortening present. Analysis of verbal reports by the subjects supports this possibility. On a descriptive

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*Three of the targets were drawn twelve times apiece on surfaces at different orientations to the observer. The differences in the combined means of several subjects for reproductions of single targets made on a surface upright to the observer, at 45° to the observer and 0° to the observer showed no critical ratios of above .073. More complete data are contained in Appendix 4.

level, the results are in keeping with Koffka's hypothesis concerning perception of non-normal orientation. He maintains that shape constancy is a result of a stimulus shape being organized into a field of stress. That is, he predicts that as collateral retinal cues are eliminated, the perceptual response will indicate an approach in the direction of frontal plane orientation.* Gibson's similar hypothesis, that perception of space is not possible independent of continuous background surface, also receives confirmation.

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*Koffka conceives of space as being anistropic in the main directions and as being dynamically balanced within itself only in the frontal parallel plane. He holds that special forces are required to turn the figure into a non-normal orientated plane and that these in turn are opposed by field forces which direct the figure toward the normal orientation. Because of this, any stimulus pattern of a figure that is non-frontal parallel plane oriented leads to an organization in a field of stress, which in turn leads to a different perception that can occur in a stress free field. In addition to the field forces, so-called "external forces" and "internal forces" produced by the retinal pattern itself are said to be operative. Hence, within this framework, any perception is seen as being the resultant final equilibrium between all participating forces. The relation is not, however, one of the simple proportionality but rather the proportionality is determined by total field conditions. Because of this we find degrees of relative constancy.

Koffka's theoretical position is largely founded upon deductions which have in turn arisen from broad principles abstracted from simple perceptual demonstrations. Often his tenets are devoid of experimental support.

Successful experimental predictions of shape, however, have previously been made by several workers who used an approach dictated by a similar theoretical scheme. These have been reviewed by Bartley (3).

Turning to the results obtained when optical magnification was used, we can see by comparison of the results of Table 5 to those of Miller in Table 2 that the effect of optical magnification differed in the two situations. There were not the significant differences between aided and unaided vision that Miller reports. "Regression" and "progression" were not altered in our case. Evidently when collateral retinal conditions are sufficiently improverished, the same functional set of perceptual circumstances will operate in both instances. The statistical indexes in Table 2 of the Appendix confirm this fact. The pertinent F score suggests that the disparate retinal cues provided by optical magnification and/or the size of the retinal image per se were not important variables. The question as to whether these results indicate that the targets were seen as nearer or as larger with optical magnification, can probably not be answered conclusively. The differences in the sizes of the reproductions, from condition to condition, hint that size rather than distance is the chief variant. However, the fact that assymetry was not sufficient in isolation or with foreshortening to produce the experience of or shape correlate of an object in three dimensional space*makes test of this, with the shape indexes reported, difficult.

It is apparent from the graphed function, Figure 8, that a relationship of invariance holds between phenomenal shape and phenomenal tilt over the entire range considered as well as under conditions of aided and unaided vision. The fact that the phenomenal shape values decrease, as the judged inclination increases, hints that the observers treated the targets approximately as though they were all circles at various inclinations to the observer. Perceptual veridicality, the assumption believed to have confounded Stavrianos test, occurred only accidentally. In light of Hastorf's work it might seem possible, on the basis of these results, to infer than an assumed shape; i.e., a circle, at various inclinations, played the decisive role in determining the internal consistency of these responses. This inference is believed to be untenable, however, because of several considerations. For example, the subjects' statements, concerning what they were "really looking at,"

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*In another unreported study, done under the supervision of this author, outline targets were viewed by several subjects at a very close distance under binocular and monocular conditions. The targets, circles and ellipses, were four in number and mounted at four inclinations. The data showed no significant differences in the combined phenomenal shape indexes under these two conditions. Assymetry evidently did not act as an important determinant in isolation. For more complete data see Appendix 5.

fail to confirm the existence of such an object. Only one-half of the subjects judged the targets to be circles at various inclinations while, despite the urging of the experimenter, the remainder ranged from "no idea" to "all different from one another." This strongly suggests that the perceptual responses were of the nature of "givens." It is also important to note, in this regard, that knowledge of the real conditions evidently did not influence the responses of the subjects. The test of invariance was successful even though, in the first instance, (drawing task) the subjects were given no reason to and did not assume that the targets were other than frontal-plane oriented targets, while in the second they were necessarily told that some of the targets were inclined to the observer. In addition, the less than stimulus shape ratios found for the phenomenal shape indexes "progression" was obviously counterbalanced by "regression" in the tilt responses and, conversely, the shape "regression" by tilt "progression." Again, this occurred even though the responses were rendered in qualitatively differing conditions. Koffka's hypothesis, that the two abstractions are coupled together in an invariant relationship, seems to be confirmed in this instance.

Finally the present experiment has again demonstrated the fundamental contribution that the organism makes to the internal consistency of perception. The retinal patterning is frequently dealt with as though it determines the occurrence of one shape out of almost an infinity of possible perceptions. Internal consistency is treated as though it can be accounted for as being a direct result of the stimulus patterns existing on the retina. It appears to this author as likely that any explanation of these results, on the basis of proximal or distal stimulus conditions, will prove difficult.

Further correlations to and manipulations of these reported functions might well be considered as inviting problems for further experimentation. New shapes and surface targets might be embedded in the experientially undifferentiated visual-field.

VIII. SUMMARY

The purposes of this experiment were three-fold. They concerned: (1) the measurement of phenomenal shape for circular and elliptical outline targets embedded in an undifferentiated visual-field, (2) the effect of optical magnification on perceived shape for the same targets under the same visual-field conditions, (3) the relation of phenomenal shape to judged inclination.

Twenty-four observers were used in this experiment. Fourteen served in "Group A" and the remaining ten in "Group B." All presumably were experimentally naive.

The apparatus was such that all visual-field influences collateral to the stimulus shape itself was absent.

The targets were twelve in number and all "outline shapes." Physically, four were circles with 5 inch diameters, four were ellipses with a 4 x 5 inch measurement, and four were ellipses with a 3.2 x 5 inch measurement. One each of the three target types described above were mounted at approximately 22.5° to the observer, one each at 45°, one each at 67.5°, and one each at 90° (upright).

The observers were told to draw what they saw, particularly, to reproduce the internal relationships as accurately as possible.

One hundred-twenty drawing responses were recorded with unaided vision for both "Group A" and "Group B." An additional one hundred-twenty drawing responses were recorded for "Group A" using two power binoculars and another one hundred-twenty responses for "Group B" using seven power binoculars. This made a grand total of two hundred-forty responses for each observer.

The ratios of the reproductions were measured and grand means computed. Standard deviations for all "Group A" data were found and an analysis of variance run on the data.

The major findings are six in number and are entered below:

(1) The elimination of retinal conditions collateral to the stimulus shape reduced the minor-major axis ratios in the direction expected on the basis of previous experimentation.

(2) The reductions were both greater and smaller than one would expect on the basis of proximal stimulation alone. The perceptions showed both "regression" to and "progression" from the real object.

(3) The data indicated that foreshortening of the outlines, through tipping, did not play a role in determining the "regression" or "progression" obtained.

(4) Simple targets seen in an undifferentiated field appeared to assume the frontal-parallel position.

(5) Optical magnification did not alter perceived shape significantly.

(6) Phenomenal tilt and phenomenal shape enjoy an invariant relationship.

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APPENDIX 1

A statement has yet to be made concerning the rate of certain of the "grosser" variables in perpetual performance. An inquiry of this sort might serve to suggest possible co-ordinate areas of research for further experimentation just as it has provided statistical indexes useful for discussing problems more particular to this paper. To achieve this eight variables were analyzed out and the contribution each makes to the total experimental variance calculated. Designation of the variables is as follows: "sex", "binocular magnification", "targets", "degrees", "figure", "figure X degrees", "trials" and "subjects". The classification "sex" needs no explanation. The variable "binocular magnification" separates unaided responses from those of vision aided by two power optical magnification. "Targets" includes the contribution made to variance by the twelve separate targets. The variable "degrees" indicates the extent to which the tipping of the targets from the vertical influenced the subjects performance. "Figure" refers to the three real shapes used, i.e. the 3.2 x 5, the 4 x 5, and the 5 x 5 targets. "Degrees X figure" is an "interaction index" and measures the effect of the two previous variables in combination. By use of this latter index, it was hoped that one could determine whether, if given the three groups of real shapes and four groups of angles of inclination, certain combinations would result in significantly more variance than others. "Trials" indicates how consistently the same target was reproduced from trial to trial by the same subjects. "Subjects" recognizes the importance of individual determination.

An analysis of variance was undertaken on all of the data for "Group A" relating to the shape drawing task. The mathematical values are entered in Table 1.

As can be seen from this table, "binocular magnification" shows an F of .0088 indicating that binocular magnification did not influence the index of shape we used significantly as compared to unaided vision. The variables, "Targets", "Degrees", and "Figure", show "F's" of significant magnitudes. "Figure X Degree" is not significant, indicating that trend lines are similar for any degree through the different figures or any figure through the different degrees. This suggests that while these two abstractions are significant as regards the shape indexes, that they may not in isolation account for the perceived shapes. There were significant differences between "Trials" and "Subjects". "Sex" has an insignificant F.

TABLE 1. APPENDIX

ANALYSIS OF VARIANCE VALUES FOR PHENOMENAL SHAPE INDEXES OBTAINED FROM ALL SUBJECTS OF "GROUP A" *

	Variables	Contribution	5%	1%	Level
1.	Aided (2 power mag) vs. Unaided	.0088	3.84	6.64	
2.	Targets	4.7468	1.76	2.24	1%
	a) Degrees	3.9073	2.60	3.78	1%
	b) Figure	17.0499	2.99	4.60	1%
	c) Figure and Degree	1.0656	2.09	2.80	
3.	Trials	141.2316	1.17	1.25	1%
4.	Subjects	280.6840	1.79	2.24	1%
5.	Sex	.0339	3.84	6.64	
6.	Sittings				

* N = 3360

APPENDIX 2

For similar reasons, an analysis of variance was undertaken on all of the data for "Group A", relating to the perception of tilt task. The contribution of the same eight variables were analyzed out. The mathematical values are entered in Table 2.

The "F" scores of this Table show, as before, that there were significant differences between "Target", "Degree", and "Figure". However in this analysis, the interaction term, "Degree X Figure", was found to be significant beyond the 1% level of confidence. This is taken to indicate lack of consistent trend lines for any degree through the different figures or any figure through the different degrees.*

A "significant F" was also obtained with the variable "binocular magnification".**

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*Inspection of the combined means show that, in this case, phenomenal tilt, correlation with the "Targets", tipped at a real 22.50, appeared to violate the trend occurring at the other degrees.

**However this outcome was probably conditioned by a single subject who registered her responses during the aided condition in a different quadrant than any of the other responses obtained. A translation of these responses to the appropriate quadrant suggests no difference as regards this variable.

A highly significant difference between the two sexes is shown.*

*This, but to a lesser extent, might also be a function of the one subjects responses.

TABLE 2. APPENDIX

ANALYSIS OF VARIANCE VALUES FOR PHENOMENAL TILT INDEXES OBTAINED FROM ALL SUBJECTS OF "GROUP A" COMBINED*

	Variables	Contribution	1%	Level
1.	Aided (2 power mag)	554.75	6.64	1%
2.	Targets	940.89	2.24	1%
	a) Degree	1916.40	3.78	1%
	b) Figure	1316.34	4.60	1%
	c) Figure and Degree	327.98	2.80	1%
3.	Trials	4.34	2.41	1%
4.	Subjects	876.96	2.32	1%
5.	Sex	2285.01	6.64	1%
6.	Sittings	1.04	6.64	

* N = 2800

APPENDIX 3

"Time to response" records were taken for four subjects when the task was representing tilt. For reasons similar to those of Appendix 1 and 2, an analysis of variance was undertaken on the data. The breakdown of the variables is identical to those of the previous appendixes. The mathematical values are entered in Table 3.

It will be noted from the Table that all the variables are significant at the 1% level with the exception of "Degree" and the interaction term "Degree X Figure". The latter is significant at the 5% level and the former is insignificant.*

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*The large difference between aided and unaided was doubtlessly produced in large part by conditions related more closely to the apparatus than optical magnification per se.

TABLE 3. APPENDIX

ANALYSIS OF VARIANCE VALUES OF "TIME TO RESPONSE" MEASURES WHEN CONDITION WAS THAT OF REPRESENTING TILT OF TARGET. DATA FROM FOUR SUBJECTS OF "GROUP A"*

	Variables	Contribution	5%	1%	Level
1.	Aided (2 power mag) vs. Unaided	116.60	3.86	6.70	1%
2.	Targets	2.57	1.81	2.29	1%
	a) Degree	.26	2.62	3.83	
	b) Figure	6.72	3.02	4.66	1%
	c) Figure and Degree	2.34	2.12	2.85	5%
3.	Trials	22.47	1.96	2.55	1%
4.	Subjects	199.61	2.62	3.83	1%
5.	Sex	353.24	3.86	6.70	1%

* N = 960

APPENDIX 4

1. Problem

The problem is to determine whether the perceptual shape responses (drawings) are in any way a function of the inclination of the surface on which they are expressed.

2. Procedure

The experiment was carried out under circumstances identical to those of Problem 1 of the main experiment, excepting for the orientations of the drawing surface and the number of targets used.

As regards the former, the surface was, at various randomized times, flat to the subject (0° inclination), inclinated at 45° to the subject, and vertical to the subject (90° inclination). As regards the latter only three targets were used. The targets were, a 4 x 5 ellipse, tilted at approximately 67.5° to the observer, a 4 x 5 ellipse, tilted at 45°, and a 4 x 5 ellipse tilted at 22.5°.

Two naive subjects were used. These subjects made nine responses to each of the three targets when the drawing surface was at each orientation. This made a grand total of eighty-one responses per subject.

3. Results and Interpretation

Table 4 shows the critical ratios, student t's, resulting from comparison of the combined means for each target. The table shows that differences resulting from the expression of the perceptions, projected on the various surfaces, are uniformly insignificant. Hence, the perception does not seem to be a function of the surface on which it is expressed and some validity is lent to the drawing method as it has been used in measuring phenomenal shape.

TABLE 4. APPENDIX

COMBINED MEANS AND CRITICAL RATIOS RESULTING BETWEEN DRAWING SURFACES ORIENTED AT 90°, 45°, AND 0° TO THE OBSERVER WHEN PHENOMENAL SHAPES OF THREE TARGETS ARE EXPRESSED BY DRAWING

	4 x 5 Target at 67.5° Inclination			4 x 5 Target at 45° Inclination			4 x 5 Target at 22.5° Inclination		
	D.S.* 0°	D.S.* 45°	D.S.* 90°	D.S.* 0°	D.S.* 45°	D.S.* 90°	D.S.* 0°	D.S.* 45°	D.S.* 90°
Combined means	0.80	0.76	0.75	0.65	0.65	0.59	0.33	0.37	0.34
Critical ratios**									

*Drawing Surface

**The largest difference showed a critical ratio of only 0.073. Because of this small sized ratio, no further statistical checks were made.

APPENDIX 5

1. Problem

The problem is to determine whether retinal disparity alone will serve to mediate depth perception.

2. Procedure

The experiment was carried out under circumstances identical to those of Problem 1 of the main experiment, excepting for distance, method of observation, and the use of a chin rest.

As regards the first change, the distance of observation was reduced to five feet, so as to make retinal disparity pronounced. As regards the second change, in order to control for size, the targets were viewed both binocularly and monocularly at this distance.

Four targets were used. The targets were a circle with a 5 inch major axis, presented at approximately 90^{o} to the observer (upright), a 4 x 5 ellipse at 67.5^{o}, a 4 x 5 ellipse at 45^{o}, and a 4 x 5 ellipse at 22.5^{o}.

Two naive subjects were used. The subjects drew each figure four times under both the monocular and the binocular conditions. Target presentation was randomized.

3. Results and Interpretations

Table 5 shows the critical ratios, student t's, resulting from comparison of the combined means for each target. The differences resulting from perception, monocularly and binocularly, are insignificant for each target. Retinal disparity, alone, was not sufficient to mediate depth perception.

TABLE 5. APPENDIX

COMBINED MEANS AND CRITICAL RATIOS RESULTING BETWEEN BINOCULAR AND MONOCULAR CONDITIONS OF OBSERVATION WHEN VARIOUS SHAPES ARE VIEWED AT CLOSE DISTANCES.

	5 x 5 circle at 90°		4 x 5 ellipse at 67.5°		4 x 5 ellipse at 45°		4 x 5 ellipse at 22.5°	
	monoc.	binoc.	monoc.	binoc.	monoc.	binoc.	monoc.	binoc.
Combined means	1.05	0.94	0.60	0.65	0.44	0.42	0.26	0.25
Critical ratios	0.11		0.05		0.02		0.01	