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Visual discrimination as a function of stimulus size, shape, and edge-gradient

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VISUAL DISCRIMINATION AS A FUNCTION OF STIMULUS SIZE, SHAPE AND EDGE-GRADIENT

by

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CHAPTER I

INTRODUCTION

The fundamental task for Psychology is to define what constitutes the stimulus for behavior (80,35,32). This involves specifying the conditions which leaves the response invariant. In visual perception the most successful approach to this problem has been made by psychophysics which attempts to relate physically measurable attributes of stimuli to changes in response.

Visual discrimination involves essentially two different kinds of responses to the same stimulus condition. The first is the least complex discrimination: the response is a statement concerning the presence or absence of a change in stimulus conditions. The second response concerns identification of the class properties of the stimulus and is a more complex event, in that the past experience of the observer must be utilized to enable him to assign the stimulus to an appropriate category. Up to the recent past it was customary to investigate single isolated attributes of the stimulus, on the assumption that these yielded sensations which were definitive for perception. Now the relationship between sensation and perception does not appear as well defined. The investigation of descriptive stimulus categories such as brightness, position, extent, color, contrast, etc., must be related to such problems as form discrimination, for example, and ultimately to the perception of meaning and symbols, which makes possible the prediction and control of behavior in complex environments.

The concept of the stimulus as a signal to be detected and identified, provides a framework to examine previous experimental and theoretical considerations against, and also for the organization of future experimental work.

CHAPTER II

REVIEW OF THE LITERATURE

Visual responses are discriminations of luminous intensity changes in the visual world. These sensory discriminations are basic for detecting the presence of objects and also for their identification. In the following, the theoretical and experimental literature for detection and for recognition will be separately discussed.

Factors Affecting Visual Signal Detection

When intensity of the signal is held constant, three main stimulus parameters affect the detection of that signal. These are: (a) area of the stimulus, (b) temporal exposure, and (c) definition of the edge (contour) which delineates the stimulus from the remainder of the visual world.

(a) Areal Summation: Aubert (3) was one of the first experimenters to relate area of the stimulus to changes in the response to luminous intensity. Ricco (4) proposed that the areal effect was a simple linear summation over the extent of the fovea, and Piper (4) expressed the same relationship as holding over 10° of arc in the periohery of the retina. The relationship,

$$A \times I = C,$$

was advanced to describe this summation effect. Now, it is felt that this holds well over only the first 10' of visual angle for the fovea, and even this region appears in doubt.

Wald (84) proposed that the response corresponds to the stimulation of a constant number of elements and advanced,

$$A^k \times I = C,$$

where k is an emperical constant based on the size of the retinal field, as a better fit, than,

$$A \times I = C.$$

However, Otero et al (69) recently advanced,

$$K \times S^{\frac{1}{2}} = C,$$

where K is a constant depending on the background illumination, and S is the slope of a line drawn through the threshold points which result as area changes, as descriptive of areal threshold change over the first 20' of arc for the fovea.

Graham, Brown and Mote (36) presented a theory to account for the excitatory effect of areal summation which takes account of the Styles-Crawford effect (the distortion of light passing through a pupil). They found that no simple function such as Wald's fit their data and that they had to have a separate set of emperical constants for the fovea as well as for the periphery.

Kristopherson (60) has expanded Graham's et al theory to account for area-shape effects and has demonstrated that changes in detection threshold follow as predicted, except when very long targets or targets forming right angle crosses were used. This is in agreement with Langstroth et al (63) who found no detectable difference in the probability of detection for square, rectangular, triangular and circular targets of equal area.

Crozier (16) has demonstrated that summation is not twice as great for two eyes but takes an intermediate level. He states:

> For simultaneous excitation of the two eyes (when of very near equivalent excitation) ΔI_p is less than for stimulation of each eye alone, at all levels of I, A, and λ. These facts are consistent with the view that the properties of Δ I are quantitatively determined by events central to the retina. p. 139.

Perinne (70), however, argued against summation, for he found by doubling the brightness of a flash in one eye the frequency of seeing was raised from an average of 38 to 86 percent, whereas, the binocular frequency for the initial brightness was only 56 percent. He concluded that the possible amount of partial summation, which cannot be ruled out due to errors of measurement, must be small in degree.

The size of the retinal element has been considered as the limiting anatomical parameter by the theorists who consider retinal geometry as an explanation of brightness discrimination. They believe a cone or a row of cones must be excited, when compared to a neighboring cone or row of cones, to produce a sensation; but Wald claims the discrimination of a point or line against a background depends only upon its brightness and that there is no theoretical or emperical limit to the size of the object, provided it is bright enough. Hecht and Mintz (46) have shown that fine wires can be discriminated even when they subtend only 0.5", which is 1/60 th of a cone diameter approximately. This effect has been demonstrated for vernier adjustments as well.

(b) Temporal Summation: Parallel with the area studies has been the investigation of the effect of the temporal span of the stimulus. The Bunsen-Roscoe law states that small areas and brief flashes are receprocally related. The relationship,

$$I \times T = C,$$

holds only for short durations (approximately 50 msec.) though. This point is termed critical duration, beyond which the threshold response depends on I alone. Hartline (43) recording from a single retinal cell of Limulus (horseshoe crab) demonstrated that below a certain critical duration the intensity, (I x t) necessary to produce a constant frequency of impulses is constant. Beyond this critical duration, intensity alone was effective.

Graham and Kemp (37) investigated $\Delta I/I$ with exposures from 2-500 msec. duration. $\Delta I/I$ values of constant intensity were highest for the shortest duration up to the limits of critical exposure time. At durations longer than CD, $\Delta I/I$ remained constant. They state the Bunsen-Roscoe law holds for the effect due to ΔI, as indicated by $\Delta I \times t$ remaining constant for any value of the relationship between intensity, I.

Graham and Margaria (38) investigated the periphery of the retina to determine the absolute threshold of the area-time relationship, with test fields from 2-180' of arc, and found an approximately reciprocal relationship between intensity and time of exposure. This held precisely for values below 0.1 sec. Moreover, the data approached a form which has been described for Limulus (43). It was also demonstrated with Limulus that intensity, not time was the more important parameter, for when very brief flashes were presented at high intensity levels, the output from the cell maintained a constant high amplitude of discharge for nearly 60 sec.

Holway and Hurvich (51) investigated differential sensitivity and the size of the retinal image for several levels of illumination. They found that $I/\Delta I$ varied directly with the size of the retinal image and inversely with illumination. They proposed that differential sensitivity varies directly with the total excitation potentially available for the discrimination of a just noticeable difference in brightness.

Hecht (45) attempted to determine the absolute limit of the intensity discrimination and believed that a response would be elicited if only 5-14 quanta of light were present in close proximity. He maintained that the absolute limit is determined by the corpuscular nature of radiant energy. Furthermore, this effect should hold for differential thresholds also. To explain this phenomena, he proposed a theory of a photochemical process which produced a stable state at the retina, involving primarily three things: (1.) a sensitive substance which absorbs light and is changed by it into one or more active products, (2.) necessity of maintaining a supply of (1.) (by his primary light and dark reactions) and (3.) the active products of the primary light reaction must do something which results in an impulse from the receptor cell. Under continuous illumination the photoreceptor system reaches a stationary state, in which the opposing rates become equal.

However, in attempting to use this theory, the additional facts from the on/off mechanism must be considered. The evidence seems to point to some kind of edge discrimination mechanism as the activator of the post retinal neural transmission system.

(c) Edge Effects: Weymouth et all (89) proposed that as the eye scans a line or similar object, a bell-shaped gradient of excitation will be established on the retina. A threshold gradient changed the "local sign" (cf Hering) and a sensation was reported. Adler and Fleigelman (1) carefully recorded eye movements photographically and found that the eye is constantly in motion, sweeping a band varying from 2-30 secs of arc, 10-100 times per sec. The movements are characterized as a rapid fluctuation over the short range, with slow drifts over the wider range. They proposed that these movements could be the limiting factor in visual acuity.

Marshall and Talbot (55) used this concept of physiological nystagmus to construct a theory which shifted the explanation of brightness discrimination from a static condition of retinal geometry and photochemistry to dynamic neural mechanisms across the total visual mechanism. Their main argument is that neural impulse frequencies are temporally dispersed, and that brightness discrimination is largely a cortical event. As a result of nystagmic scanning,

> The neural "image" plays continuously over the projection area at every synaptic level, building gradients and peaks of activation at every edge and line. This is inherent in a partially shifted reciprocal

> overlap and refines the mosiac in proportion to the steeper gradients and peaks produced, as sand forms sharper peaks than bricks. The slopes and amplitudes, however, are further modified by dynamic mechanisms; first the relation of this image-flutter to the neural recovery cycle, and second the relation of the intensity distribution to the recovery cycle. For near an edge the light intensity falls off and with it the impulse frequency pattern transmitted. Both factors cause neural amplification for impulses within the facilitation period, and neural subnormality for longer periods. For both reasons, propagated activity at an edge is peaked at the bright side and depressed at the dim side, while gradient is enhanced. p. 139.

Byram (11,12) has attempted to resolve the difficulty which retinal motion imposes on the areal summation problem. He cites the Marshall and Talbot concept of cortical grain, as being much finer than the grain of the retina, to which they attribute certain accomplishments of the visual system, such as the perception of the vernier offset, to the fineness of this grain and the operation of certain neural mechanisms. He states:

> This would mean that the cortical image and the test object would have in common certain energy differentials which would be lacking in the retinal and photochemical images. In view of the physical concept of entropy, it is hard to see how the energy in the cortical image could be in a more highly organized state, with respect to the test object, than the energy in the retinal image. p. 737.

Byram feels this can be resolved if we assume that visual resolving power is determined by the energy rate discrimination instead of retinal illumination discrimination. This makes it possible to explain most of the data of visual acuity except areal threshold phenomena. The effect of area on the absolute and differential thresholds cannot be explained if visual stimulation is nonfluctuating, unless neural interaction is invoked. However, the effect can be explained if the number of light quanta actually utilized by the receptors fluctuate about a mean value.

Riggs, Ratliff et al (72,73,74) attemoted to determine the role of physiological nystagmus to visual acuity. Their measurements were quite similar to those of Adler and Fleigelman. In addition, large slow waves and slow drifts of fixation were observed. They found fixation limited to about one second. They also found that acuity measurements did not correspond consistently to the nystagmic movement. Then a second experiment, designed to counterbalance eyemovements, was performed. It was demonstrated that for long exposures, a fine line appears bright and clear but soon fades and disappears. Heavy lines seldom disappeared and when nystagmic movement is doubled, the fine lines seldom dissappear. It was concluded that vision is impaired when retinal motion is impeded, and that the rate of dissappearance of a target is related to its angular width. In addition, for exposures of short duration (0.10 sec.) visual discrimination is poorer under conditions of normal or exaggerated movement than when the eye motions are counterbalanced. Nystagmic movement below 10 msec. extends over only 5" of arc which appears to negate the concept of eye motion as full explanation for brightness discrimination across an edge.

Jones and Higgins (52) have used the Marshall and Talbot theory to account for the perception of physical rate of change across edges in photographic systems. They believed that the high correlation they obtained between the subjective response of sharpness of image detail and the physical measure of this rate of change, to be due to enhanced acuity as a result of nystagmic scanning. Yet they state that:

> The dynamic concept does not force discarding of static notion of receptor size: as elements of the retinal image will determine the time rate of change of the illumination incident on the receptors which, as much evidence indicates, is an important determinant of the magnitude of the retinal response evoked by a stimulus. p. 227.

Lamar et al (62) investigated edge effects and present data that support an edge discrimination concept rather than an areal concept per se. They held area constant for small rectangles and found that the brightness threshold decreased as a function of increase in perimeter. They introduced a concept of "useful area", a small ribbon of area around the border of a target, to account for this phenomena. The threshold is defined as follows,

$$\Delta I/I = C\ P^{k}/UA$$

For small targets, length or width of less than 2', a change in either dimension makes no change in the total flux required for detection. Beyond this, to about 100 square minutes, the change in threshold appears to follow the change in useful area. They conclude that,

> ...the concept of useful flux indicates that the critical sensory events in brightness discrimination takes place in the narrow ribbon around the

> image of the target which is comprised by the retinal brightness gradient produced by diffraction (1-2' in width). Since foveal cones are about 0.5' in diameter, the gradient width covers about 3-4 cones. It is to the behavior of those cones that we must look for an understanding of brightness discrimination. p. 543.

Nachman (68) recently tested this useful area concept and found that it predicted his data, where area was held constant and the useful area varied, and also where two targets were presented, up to a limit at 100 square minutes where the threshold remained constant for further increase in useful area.

Brown and Niven (10) investigated the relation of foveal intensity threshold and length of an illuminated slit, by varying the length of two slits, 0.65 and 0.13' of arc in width (the latter is narrower than a cone diameter). They found the threshold decreased as the slit length increased. Decrease in width beyond a critical width increases the threshold uniformly, irrespective of length of slit. Fry (27), also investigated the relationship of the length of a border to its visibility. By varying the length-width ratio, he demonstrated that the length of the longest side of a rectangle is more important than the total area. He concluded that the width of a narrow bar affects the threshold only in relation to the blurredness of the optical image on the retina. He also investigated the effect of border configuration on brightness contrast visibility, (28). Varying the angle between segments of a sawtooth pattern, decreased threshold as the angle between segments increased. LeGrand (64) placed dark bands of varying widths between two test fields of different brightnesses and found that error of photometric measurement increased as the width of the band increased.

Middleton (66) introduced a diffraction blur optically between a bipartite field differing slightly in brightness, and found that the threshold stayed at 0.02 until the blur reached 5' of arc, then more light had to be added to the brighter side for the subject to report the two fields as different.

Kruithof and Zijl (61) presented a 3.1° circular test object against two different background brightness levels. They introduced six blur increments from 0 to 36' of arc and found that:

> It appeared that when the daytime organs of sight are used, contrast sensitivity is not reduced by a blurred contour until the width of the area of confusion has grown to an angle of about 7', where it rapidly declines to about 2/3 of its original value at an arc of confusion having a width of 12' after which it remained constant. p. 339.

It is apparent from the examination of the literature that the role of contour attenuation and shape of stimulus on visual signal detection is not well defined and is in need of further experimental elaboration.

Factors Affecting Visual Signal Recognition

Theoretical Background: Identification of the visual signal involves assigning to the signal a descriptive category which relates to the shape or form of the stimulus.

Since Herring and Helmholtz, psychologists concerned with form perception, have tended to maintain themselves in two separate theoretical camps: The role of the past-experience versus the role of the innate properties of the stimulated organism as prime determinative of form perception. The former group was identified with associationistic theory, the latter with Gestalt psychology. Needless to say, the distinction is still current in contemporary studies of form perception.

The precursor to Gestalt psychology occurred when von Ehrenfels raised the problem that the summated effect of the individual elements comprising the perception was not the same as the combination before the breakdown. He cited the classical example of how the notes of a melody can be transposed and you will still recognize the melody. The idea of form-quality goes back to 1885 to Mach's The Analysis of Sensations. His contention was that sensations constitute the basis of all science, both physical and psychophysical. Sensations had both space and time-form. Spatial patterns, like figures and temporal patterns such as melodies, were considered as sensations which are independent of any particular quality such as color or pitch. This conception von Ehrenfels developed into the concept of form-qualities or Gestaltqualitaten which had properties independent of basic sensations. The Graz school then took up the problem, considering form an element, but one that is not a sensation. This element was constructed from simpler elements by intellectual synthesis. This view differed from Wundtian elementalism where elements were not recognized as produced by mental acts. Gestalt psychology agreed with a continuity view like James, but was holistic. Several principles were advanced, to account for organization of behavior. Wertheimer, introduced the first, called the Law of Pragnanz: psychological organization will always be as good as the prevailing conditions permit. The simplist condition is defined as a completely homogeneous stimulus distribution. However, Koffka (56) said we should regard behavior, not as composed of responses, but as governed by a field of interacting forces organized into definite, though changing patterns. The dynamic field is a molar affair in the same sense as behavior is molar. This field is organized by the laws of proximity, similarity, continuity and closed figure. Organismic factors which interact with the field are familiarity and set. Finally, the laws of Pragnanz and good figure are the result of combination of field and organismic factors. The figure depends upon the ground on which it appears--the ground serves as a framework in which the figure is suspended. However, a contour bounding a figure acts inward toward the center of the figure, not outward on the ground, because this is the more stable organization.

These field processes are "isomorphic" with the corresponding brain processes. That is, the two sets of processes stand in a one-to-one relationship with each other.

More recently, Culbertson (17) has advanced a mathematical model for optic nerve conduction to explain form discrimination. The task of the model is to handle the reduction from the number of sensory elements to the number of nerve fibers in the optic tract to provide a means for different "patterns" to be conveyed to the central nervous system. Such behavioral problems as size constancy are overlooked, and it appears that this model is of limited value for predicting the data of form discrimination.

Gibson (34) considers form discrimination from the standpoint of the problem of knowledge. He points out that form has many meanings; that shape, figure structure, pattern, order, arrangement, configuration, plan, outline, and contours are similar terms without distinct meanings. A definition of what is pereived is necessary before the problem of how men and lower organisms perceive form can be solved. Previous experiments were criticized on the ground that they used lines to represent forms, when they are abstract concepts of forms. He proposed that there are three general meanings of the term form (dealing only with those associated with or derived from physical objects): (1) the substantial shape of an object in three dimensions, (2) the projection of the object on a flat surface, and (3) the abstract geometrical form composed of imaginary lines, planes, or families of them.

Outline-form stands for something to the observer. To demonstrate this, Gibson presented ten subjects with simole outlines on cards, and reports that:

> At no time did any observer describe anything like black deposits or marks or traces on a white surface. All the terms and phrases used fell into three other classes: lines and angles, geometrical figures, and solid objects with physical surfaces.

He concludes that the primary task of the psychologist is, "to isolate the invarient properties in visual stimulation which are in psychophysical correspondence with constant phenomenal objects."

Experimental Studies on the Role of Form: The effects of simple geometric forms have been studied in the periphery of the retina by Kleitman and Blier (54), Collier (15), Munn and Geil (67) and Whitmer (90). In general, the triangle was the easiest form to discriminate, with the circle performing next to the end of the series. The vertical quadrant gave fewer correct responses than the others.

Helson and Fehrer (47) examined the central retina to determine if form affects the threshold for recognition. They used ascending series of the method of limits as method, in an attempt to prevent knowledge of the stimulus from biasing the results. The rectangle had the greatest efficiency, with the circle in fourth position. They conclude that their data did not support the Gestalt concept of good form, but that... "form perception is the result of mechanisms at a higher level of integration than those responsible for the perception of formless light." They also did not find support for the assertion that form, as such, is present at the lowest levels of perception, or that every perception must be of the figure-ground type.

Wilcox (91) next did an experiment, whose purpose was to show that threshold stimuli have a definite perceptual form, which is circular regardless of the actual shape used as stimuli. He exposed a square, rectangle, triangle, L-shaped figure, semicircle, and an irregular figure with increasing illumination until the figures were just noticeable, and concluded from his data that threshold stimuli have a definite perceptual form, and this is circular regardless of the objective shape of the stimuli.

Sleight (78) investigated the relative discriminability of several geometric forms using sorting time as the index of performance. The sorting time for the first figure, swastika, was ten times faster than for the last, the star. Also a high positive correlation was found between the sorting rank and the Ss ordering of the selection of items according to their " attention-getting" value. Casperson (13) used a similar technique and found the square best for his study.

Hanes (41) used a paired comparison technique, where the variable was increased to match a standard brightness level, and found that the triangle needed less light to match the circle and the square. Cheatham (14) used latency of response as a function of illumination as an index of perceptibility of form. He advanced the hypothesis that figures with angular convolutions would be easier and thus quicker to see, as a function of the number of angles. His results did not support this and it was rejected. The square had the lowest threshold in his study.

Recently, several experiments have been done by Hochberg et al (49), Bitterman et al (7) and Krauskopf et al (59) in an attempt to demonstrate that the visual threshold for form follows the Gestalt concept of "simplicity". In the first experiment (49) a circle, square and cross of equal area were projected on a screen in a dark room. The intensity was increased until the figure was identified. They found that the intensity threshold for the three figures followed the Gestalt principle of simplicity and compactness, which is defined in terms of minimum perimeter to area ratio for "best" figure. The threshold of the circle was significantly lower than that of the square and cross. In another experiment (50),"figural goodness" is defined in terms of the least amount of information needed to specify a given organization, as compared to other alternatives. This minimal amount will define the lowest threshold. Using Kopfermann cubes as stimuli, they maintain that the resulting responses are not inconsistent with the working hypothesis that the probability of a given perceptual response to a stimuli is an inverse function of the amount of information required to define that pattern.

Bitterman et al (7) have proposed a diffusion model derived Kohler and Wallach (58) theory of figural after-effects, to account for the perception of form. The retinal pattern is translated into a field of excitation at the cortical level. The neural fibers are assumed to free chemical substances at their termination points, the rate of this secretion being proportional to the frequency of impulses from these fibers. These are held to establish the cortical figural currents which determine perception. Since the cortical field is supposed to be isomorphic with the geographical field, a circle is held to generate a circular field of activity in the cortex, where the diffusion rate is equal in all directions from the contour representation. They hypothesized that different figures would have different diffusion rates depending upon their complexity (operationally defined in terms of increasing perimeter to area ratio). To test this hypothesis, they presented a circle, square, diamond, L-shaped figure, cross, T and H-shaped figures to 24 Ss. They used only one trial per figure in this study to eliminate previous experience with the stimuli. The illumination was increased until the S could identify the figure. Their results followed the simplicity concept, in that the circle was perceived first and the response ranking for all figures correlated at 0.78 with the physical ranking. However, these results should only be considered as pilot data and not definitive for the general problem of recognition.

Krauskopf et al (59) performed a further experiment in an attempt eliminate the sampling problem in the previous experiment. The stimuli were the same as in the first study, except that the arm length of the cross and L were manipulated as well. Temporal as well as brightness thresholds for recognition were determined. They found that the thresholds followed the increase in perimeter to area ratio as before, except for the cross and the L. To explain the increase in threshold for those figures they introduced a concept of critical detail. This states that each arm must have a certain dimension before the response would be similar to those of the other figures. They maintained that their concept of diffusion would still predict the effect of critical detail for local diffusion would obscure these parts at a faster rate They conclude that the problem of knowledge of form may mask real differences in form thresholds. In one of the early experiments, Fehrer (23) studied the learning of visually perceived forms to determine whether the forms easiest to learn are the simple, closed, symmetrical ones, and whether perception consists of the gradual differentiation of an originally simple impression. She concluded from this study that figures are learned in accordance with configuration theory, such that the simplist forms; circles, triangles, rectangles, symmetrical figures and figures composed of few parts are the easiest to learn.

In a related study, Braly (8) exposed simple forms with a tachistoscope, which were followed by a series in which some new figures as well as test figures were presented. The Ss reproduced the figures by drawing. The impression figure affected the reports on subsequent test series by increasing the number of times the impression figure was used in place of the test figure, and also increased the number of times the test figures were seen correctly. In this study the square was most readily seen, the triangle next, and then the pentagon.

Djang (20) studied masked forms by giving prior experience on figures and then embedding them in a complex figure. She found that E group saw the embedded figures 20 times more often than the C group. The figures differed among themselves in frequency of recall. A search attitude did not appear to be a decisive factor.

Vinacke (81) studied the discrimination of color and form at illuminations below conscious awareness with yellow, green and red circles and triangles. The Ss were instructed to give a positive response and rate this as to certainty. The results indicate that guessed judgments below threshold are no more accurate than chance would allow. Of the eight conditions, only color, when presented as a single variable, appeared to increase accuracy beyond chance. The remaining combinations yielded results within chance limits. However, Kin et al (53) found that when an illuminated circle, square, and triangle were projected on a screen and the screen illumination raised until the target was no longer visible, that the Ss would guess the form correctly beyond chance. The triangle was called correctly most often, whether presented alone or with the two other figures. The response frequency during control trials followed chance expectancy and the Ss reported no indication of success, for they believed that they were no more accurate than chance.

Freeman (26) studied the integral operation in the perception of objects with familiar forms presented in four positions. He found three levels of development: (1) the level of preperceptive, (2) level of perceptive particularity, and (3) level of perceptive familiarity. He suggested that part or the figure becomes "focal", while total figure serves as background.

Gibson (32) investigated the reproduction of forms, using seven curved and seven straight figures, which were exposed for 1.5 sec. and then again later for 2 sec. He observed that the stimuli were changed to familiar objects. The effects for one figure interacted with the effects for another. Gaps tended to become closed and curved lines were reproduced as straight more often than the reverse.

Recognition as a Function of Edge Discrimination: Rubin (92) made the classical investigations on the effect of the contour on the perception of a figure. He concluded that, (1) the figure possesses a contour which the ground lacks, (2) the figure portion has the character of an object or thing, and (3) the ground appears to be continuous, extending somehow behind the figure. Wever (85) amplified Rubin's position as follows: After the contrast ratio reaches a certain value, a region of separation becomes apparent, extending over an area. It is grey in quality (for black and white), marking off one field from another, In the early stages of the perception, this separation is not abrupt, for fuzzy contours appear and then definite boundaries. Shape occurs before contour is completely formed -- a gradual transition is sufficient to outline the shape of the figure.

Werner (86) found that the contour of one figure could inhibit the perception of another. A small annulus was presented and then followed immediately afterwards by a disk, whose inner border was the same as the inner border of the annulus, in rapid succession and found that the disk would not be seen. Reversing the sequence, caused only the disk to be seen. When the disk was succeeded by a half ring instead of the full ring, the part of the disk which fits into the half ring will be absorbed. On the other hand, the semi-disk which has not fitted into the ring will appear increasingly dark from the inside out towards its enframed edge. In another study (87), where the disk was presented strobostereoscopically to one eye and the ring to the other, the disk still disappeared. If the order is reversed so that the ring appears first, the disk does not disappear. The disappearance of the disk,when succeeded by the ring, can be observed whether both figures are seen binocularly, or if one figure is presented to the right eye and the other to the left eye. From this phenomena, he concluded that higher neural centers are involved, for the observer could enhance or reduce the effect intentionally.

Seward (77) investigated the effect of practice on perception of indistinct forms exposed through a ground glass window for 1.5 sec. The stimuli were numbers and letters. He found that the number of letters correctly reported after the practice session increased with further practice. Variability of response per trial session increased, but the variability of responses to a given stimulus decreased. Gerathewohl and Haber (30) performed a similar experiment with aircraft insignia. They presented twelve patterns behind a ground glass screen simulating haze conditions. The objects were moved toward the Ss until they were recognized. They found, "that such factors as originality, symbol strength, and esthetic value, as well as form, influence recognizability." In another study, Gerathewohl and Rubinstein (31) investigated circles, ellipses, squares, rectancles, triangles, and a trapezoid on a simulated PPI scope on the assumption that stimuli below the recognition threshold appear round. They found that the triangle, trapezoid and circle had a higher frequency than chance, while the square, rectangle and ellipse fall below.

Harrison and Phoenix (42) studied the effect of size and degree of imperfection on the recognition of triangles and semi-circles. They found, for sizes between 25-159' of arc, that the number of correct responses increased as the object-size ratio increased.

As far as it is known there is no published literature on the effect of manipulating the edge-gradient systematically on visual signal identification.

CHAPTER III

STATEMENT OF THE PROBLEM

Detection of the Visual Signal: The literature indicates that while areal changes will be followed by systematic changes in brightness discrimination (within limits), the effect of shape on this function needs further elaboration.

For small sizes, the response appears to be related to the amount of perimeter present, but becomes indeoenden of this as size increases, just as the response becomes independent of area.

There is also scattered evidence to the effect that as the edge-gradient is altered, the response to this change will also be altered.

An additional problem that requires further study is the familiar versus non-familiar characteristics of the stimulus and its effect on detection.

Recognition of the Visual Stimulus: No single geometric figure has been demonstrated as "best" in terms of lowest threshold. In addition, considerations from Gestalt psychology do not prove adequate to predict form recognition consistently.

The contour of the figure has been proposed as the "information" or "cue" carrier, but no adequate manipulation of this gradient has been carried out.

The effect of form familiarity again is not well defined. There has been no experimental demonstration that even simple forms behave the same across the limits of an homogeneous region such as the fovea.

<u>Detection Versus Recognition</u>: The relationship between probability of seeing and probability of recognition also needs experimental elaboration. There has been no adequate attempt to determine just how much brightness has to be added to a detected stimulus in order to recognize it with any efficiency.

<u>Statement of the problem</u>: The purpose of this investigation was: (1) To determine the effects of measurable stimulus parameters of object size, shape, and edge-gradient change on detection and recognition within one experimental set-up; and (2) To determine whether recognition efficiency can be predicted from detection thresholds.

CHAPTER IV

THE EXPERIMENTAL PROCEDURE

A. Subjects: Two young adults, one male and one female served throughout the experiment. Both Ss had 20/20 acuity (Snellen) and no discernable astigmatism (Thomas astigmat test). The Ss were paid for their services at the rate of one dollar per hour.

B. Apparatus: A tachistoscope, modified to a transluminance system, as indicated schematically in figure 1., was used. The background (B) and stimulus (Δ B) "white" light sources were in parallel circuit, preventing any change in Δ B/B ratio with line voltage shift. The background (B) field was presented at a constant 3 millilamberts throughout the experiment. Photo cell measurements indicated that this (B) field was homogeneous across its extent, within $\pm$ 1 percent. The field illumination dropped slightly at the edge, but this region was beyond the view of the S. Color temperature change from the 15W tungsten lamps was below the perceptive level. The stimulus illumination, Δ B, was manipulated by inserting neutral density filters in the light path. Pupillary accomodation was controlled by having the Ss view the stimuli through a 2 mm aperture (dominant eye). Ambient illumination in the experimental room was excluded by enclosing the Ss head and shoulders within a frame covered by a photographer's hood.

C. Stimuli: Five simple geometric figures and one irregular figure varying in their perimeter to area ratio were used.

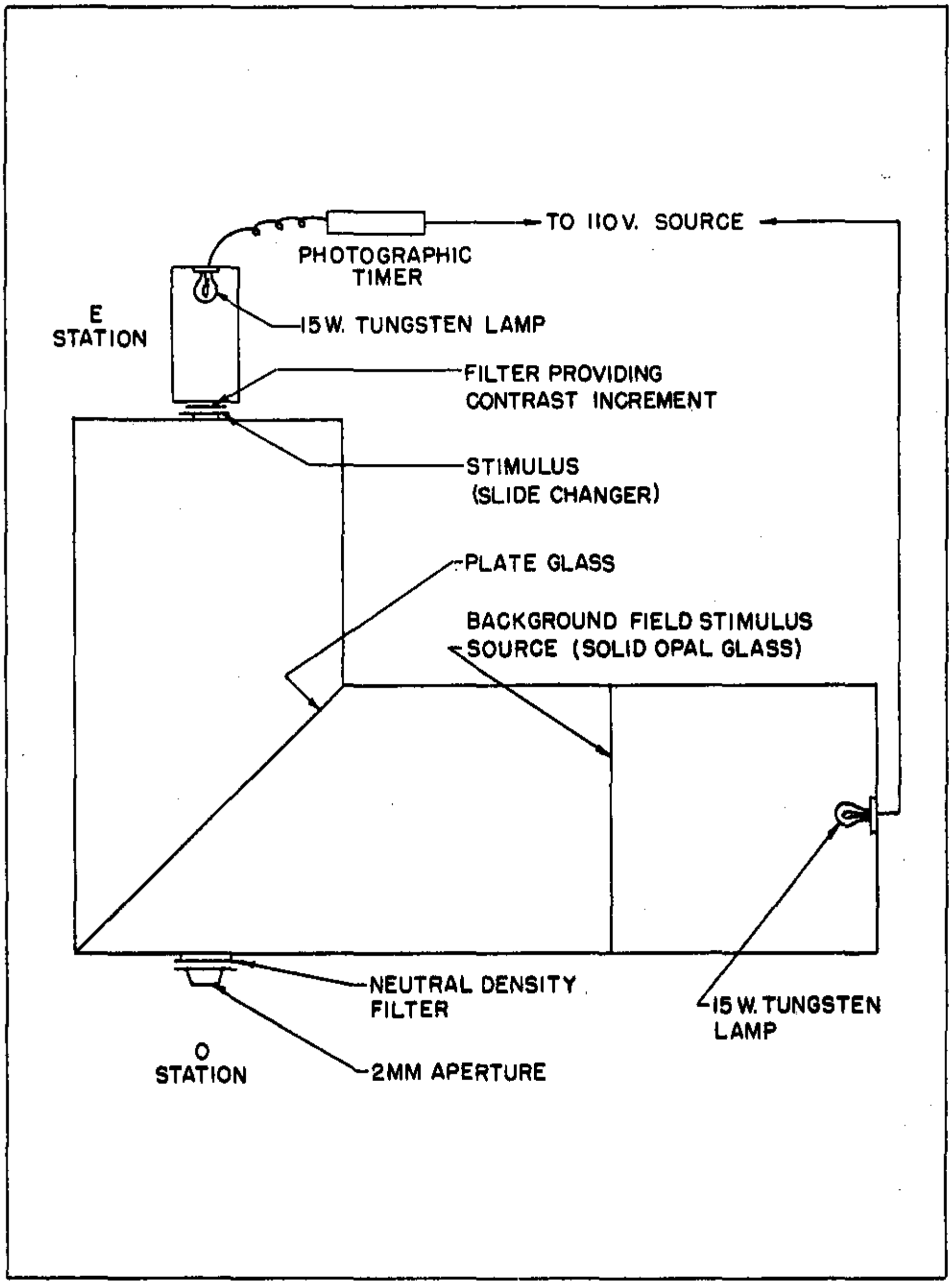

Figure 1. Schematic Diagram of the Apparatus.

These figures in order of increasing perimeter were: circle, irregular figure, square, triangle, cross and star. Holding area constant, the stimuli were constructed by cutting the figures from black photographic paper. These cut-outs were then placed on a bright luminous screen and individually photographed on Super XX film, from a distance of 171 feet. Exposure for each negative was six minutes. The photographic negatives were developed to a gamma of approximately one. Different edge-gradients were obtained by placing various small apertures in front of the camera lens. This introduced a diffraction gradient across the edge of the figures ranging from a very sharp edge to a blur obscuring most of the contour of the figure. The maximum sharp gradient approached a slope of infinity, while the minimum was sigmoid-shaped and approached a slope of unity. The three stimulus size ranges were constructed by enlarging and printing on contrast plates. The enlargement process altered the gradient slightly between each size range by decreasing the slope by a small increment so that the change between each size range was relative rather than absolute. The essential features of the stimuli are characterized in figure 2, however, to achieve this figure several intervening photographic processes occurred which altered the appearance of the original stimuli somewhat. The angular subtense of the figures are indicated in Table I.

The slope of the gradients and extent (95%) of region of change are indicated in Table II.

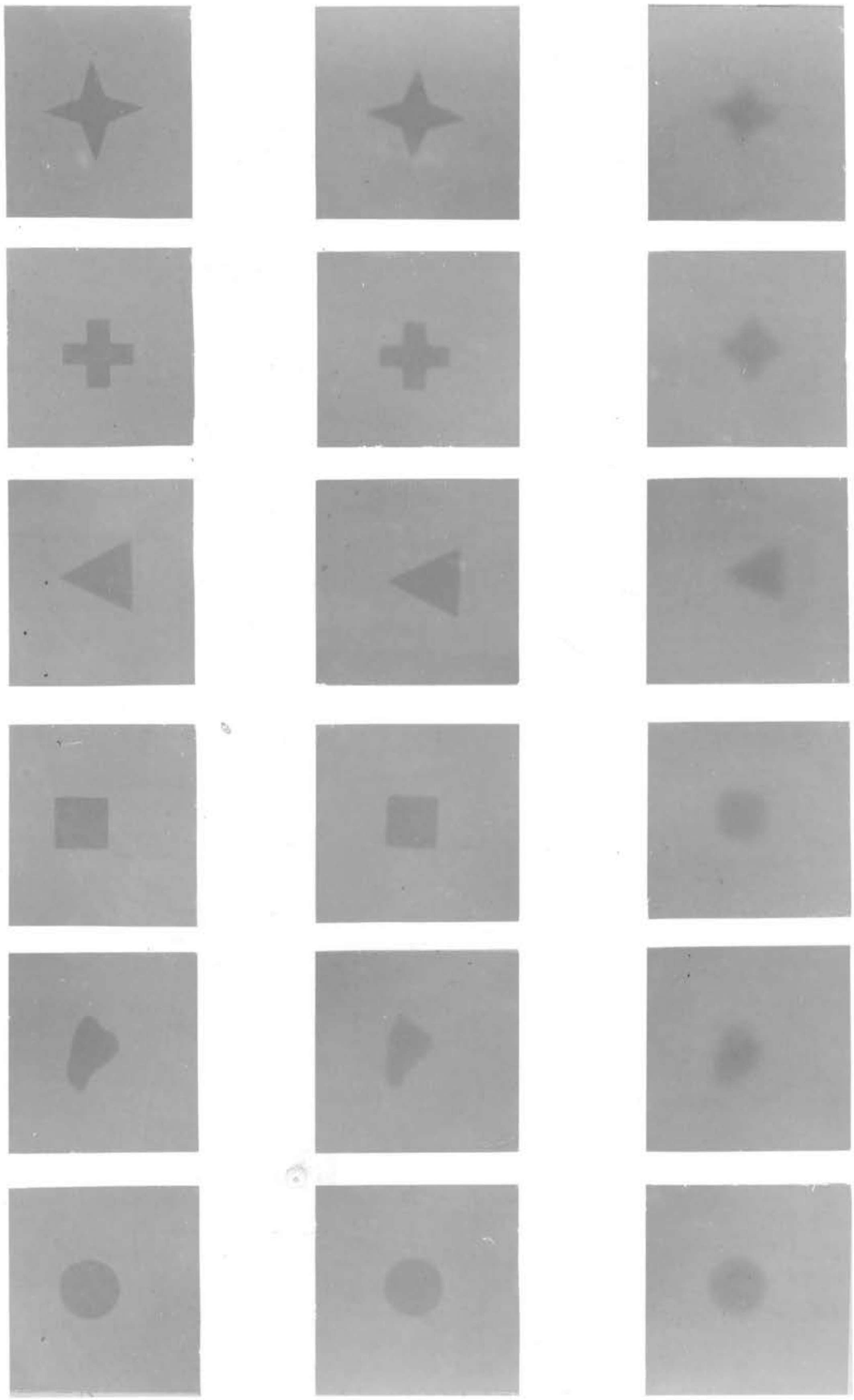

Figure 2. Stimulus figures (not to scale).

TABLE I

Angular Subtense of the Stimuli in Minutes of Arc

Size	Circle	Irreg. Fig.	Square	Triangle	Cross	Star
I	10.0	15.3	9.0	13.2	12.0	17.1
II	54.0	68.0	47.3	72.0	62.0	90.0
III	102.0	146.0	91.0	127.0	117.0	169.0

TABLE II

The Rate of Change and Width of the Edge Gradients in Minutes of Arc

Size		Edge I	Edge II	Edge III
I	Slope	62.00	32.60	11.00
	Width	0.56'	0.93'	3.40'
II	Slope	20.90	6.20	1.40
	Width	2.24'	5.08'	17.90'
III	Slope	9.60	3.80	0.98
	Width	3.08'	6.73'	20.16'

D. <u>Instructions to the Ss</u>: The S was brought into the experimental room and given the following instructions.

> In this experiment we are concerned with the problem of how people discriminate different forms visually. Please sit down in this chair and look through this eyepiece (E adjusted chin and forehead rest until S was comfortable). You are to fixate on an imaginary center between the four dots. I will present several figures to you, which will appear inside the dots. I will give you a ready signal and then present the figure immediately. Your task is to tell me what you see. For example, on some of the trials you will see nothing, on others, only a dim patch of light and you may not be able to recognize the figure, and on others, the figure will be easy to identify. I will give you several trials and then we will take a rest. If you become tired, please say so and you can have a rest. I need your interest and cooperation to obtain reliable data. Remember, your first response is to tell me if you see anything or not, and then to identify the figure. Please do not try to guess the figure, but just tell me what it looks like to you. Are there any questions?

E. <u>Method</u>: The experimental design was a modified method of single stimuli, in that the combinations of shape, size and edge-gradient were set up in five lists of 54 items each. These lists were arranged by drawing from the table of random numbers without replacement. The contrast condition for each trial was added by drawing the five increments on chits until all five values were assigned to the lists. This randomization process was done to minimize the problem of sequential dependency which has recently become a theoretical and experimental concern (66,76,82). The Ss were presented seven lists to acquaint them with the experimental task. The Ss were than run in daily 1½ - 2 hr. sessions, with breaks at the end of each list, until 25 replications for each stimulus condition were obtained (total responses recorded per S: 6750). The S began each experimental session with normal daylight adaptation. The targets were exposed for two seconds immediately after the ready signal, and then the response recorded and a new trial made ready. Three to four lists were presented during regular morning sessions and during occasional afternoon sessions.

CHAPTER V

RESULTS AND DISCUSSION

Reliability of the Method: The data were analyzed first to establish reliability of the method. This was established in two ways. In the first case, the detection and recognition responses for the first half of the experiment for each S were correlated with those of the second half, using the Pearson product moment technique. The detection and recognition scores for the Ss were also correlated. These correlations are indicated below in Table III. It can be seen that the method employed in this study yielded reliable data.

TABLE III

Product Moment Coefficients for Reliability of Responding

		Detection	Recognition
Within S	RM	0.894	0.900
	EF	0.973	0.937
Between Ss	RM X EF	0.840	0.934

An additional check on reliability of responding was introduced by using a blank for the smallest contrast increment for Size III. Only one S responded incorrectly, and with only one response for a total of 900 control trials.

The results of these correlations indicate that the Ss were attending primarily to the stimulus conditions, and not to the sequences of trials involved. This appears especially so when one considers that only one incorrect response was given for the entire number of control trials. Had guessing been permitted, the reliability of this method would probably have been reduced.

The Determination of the Detection and Recognition Functions

The detection functions were obtained by determining the percent frequency of detection responses for the five contrast increments and then, using the probit technique (24) fitting a straight line to these points. These data were also plotted on log probability paper and no appreciable change in threshold was found. The 50 percent detection threshold values are indicated in figures 3 and 4 and are plotted over size and increasing perimeter to area ratio.

The recognition functions were established in the same manner as for detection, and the 50 percent thresholds are indicated in figures 5 and 6. These data, for both detection and recognition, were not corrected for guessing.

Effect of the Experimental Variables on Detection

Size: Due to the slight shift in edge-gradient with each size increase, the effect of size could not be analyzed by analysis of variance. However, the effect of size can be deduced from figures 3 and 4. It can be seen that the threshold decreases rapidly at first, and then begins to level off. This finding is consistent with previous areal studies, except that the functions previously reported became asymptotic at 60' of arc for

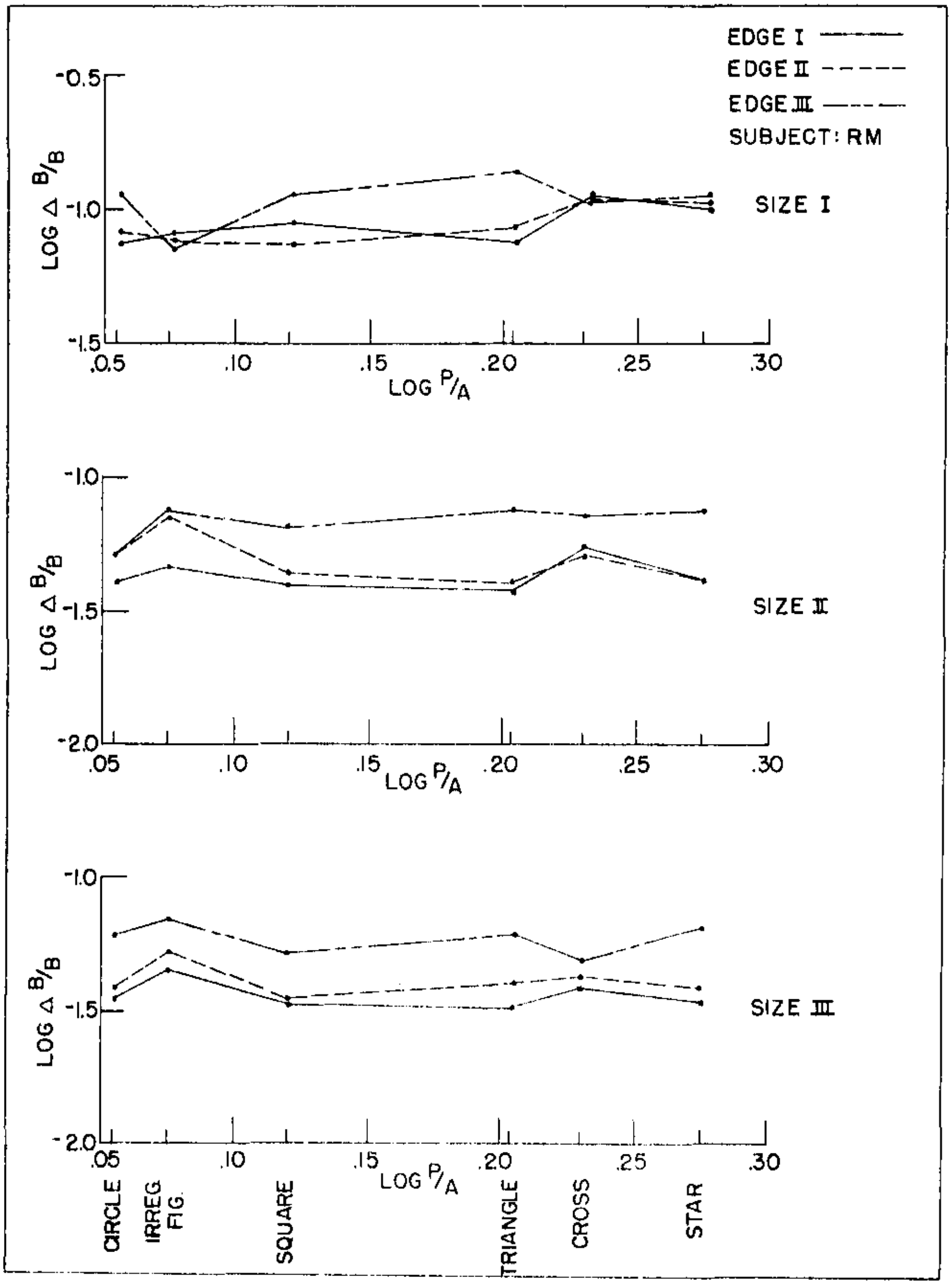

Figure 3. Fifty Percent Detection Thresholds.
Subject: RM.

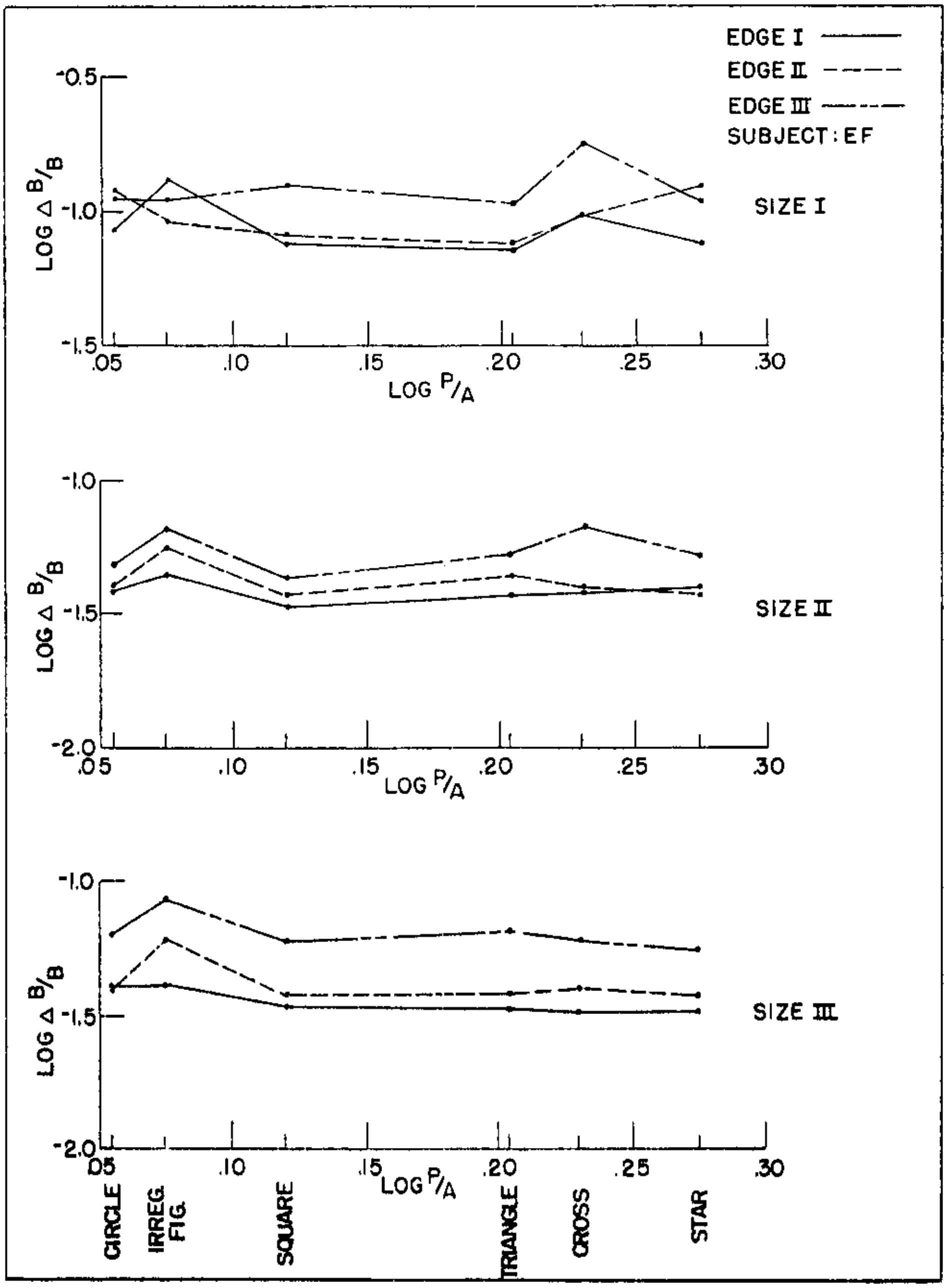

Figure 4. Fifty Percent Detection Thresholds.
Subject: EF.

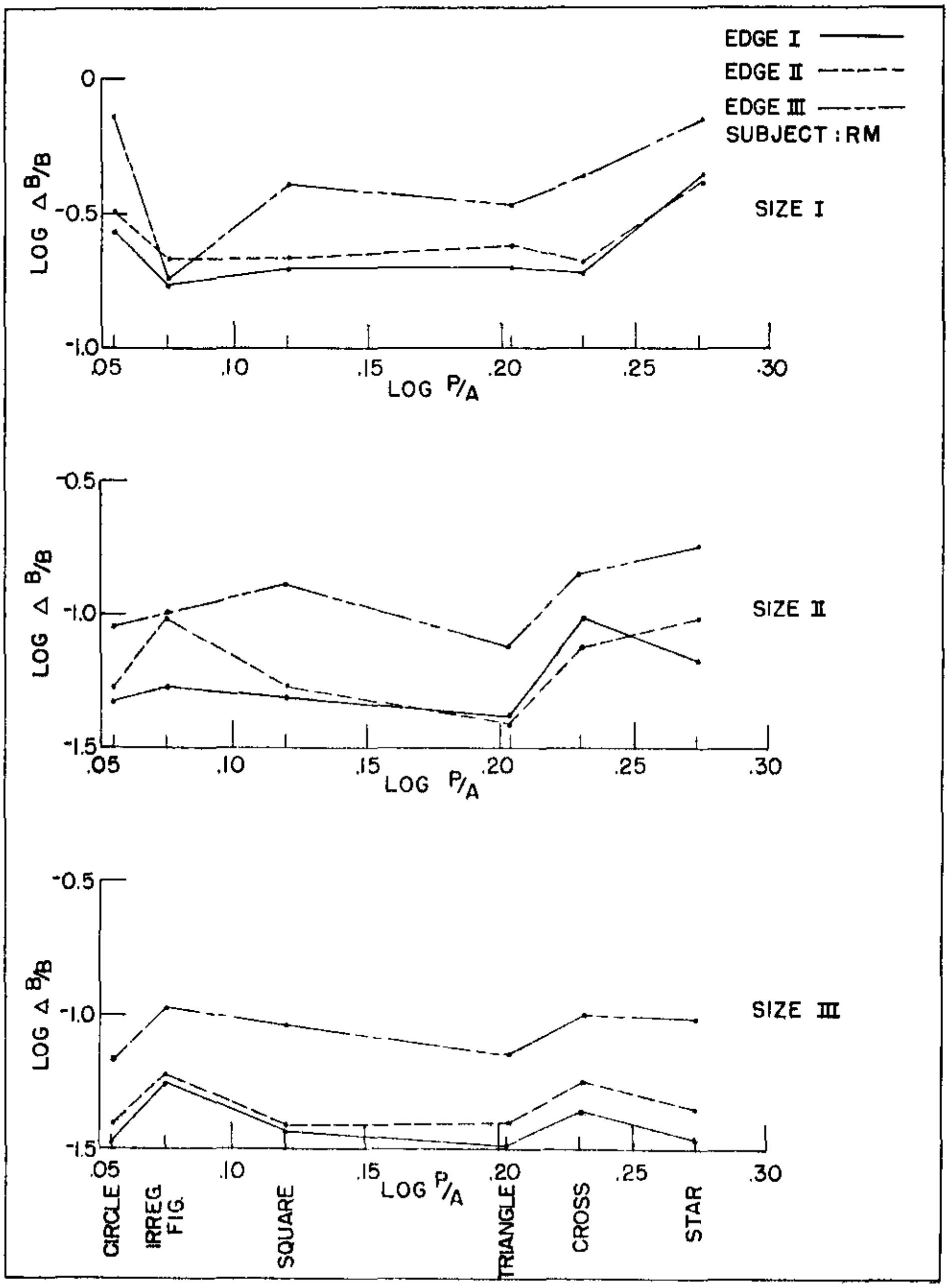

Figure 5. Fifty Percent Correct Recognition Thresholds. Subject: RM.

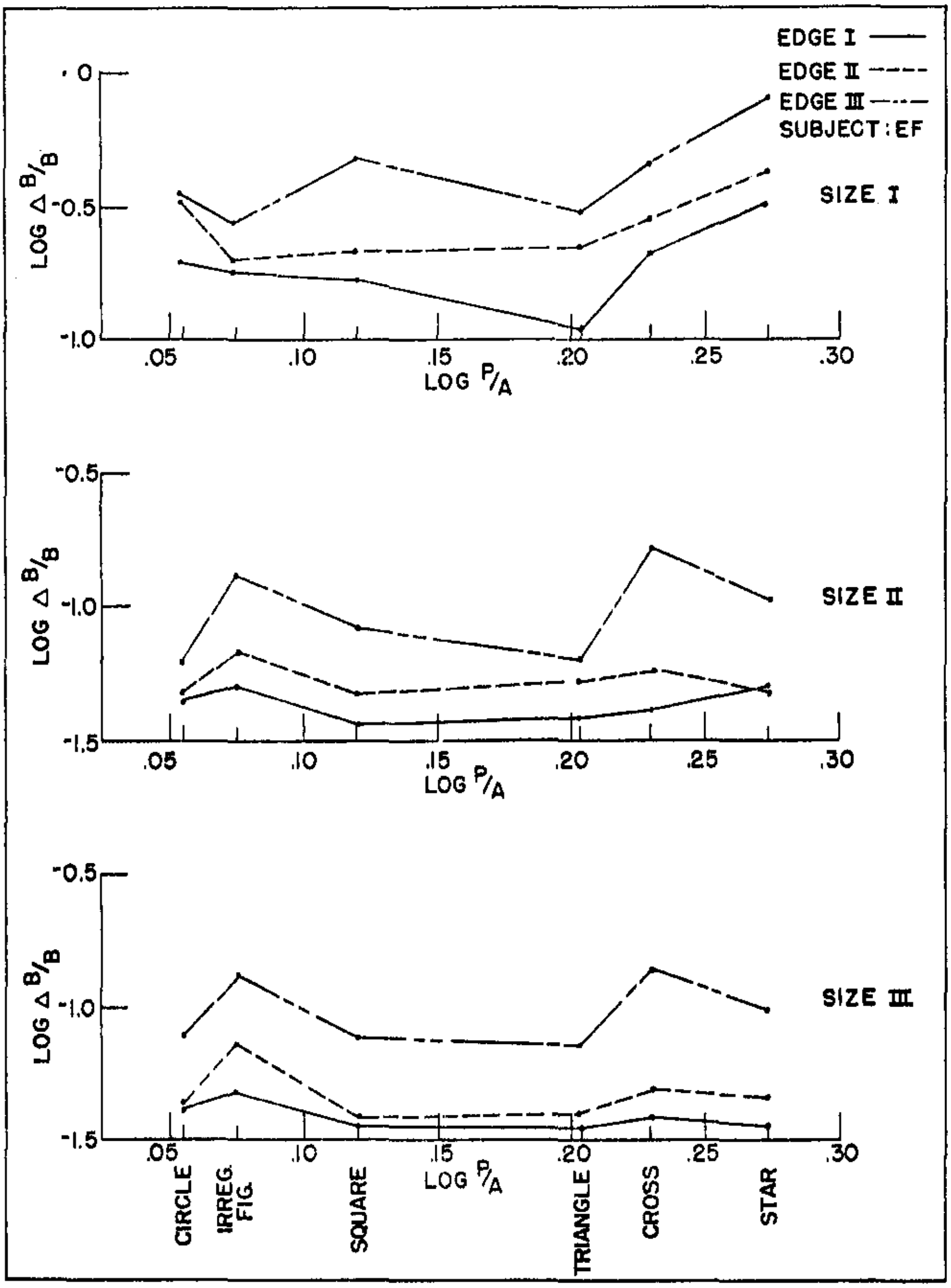

Figure 6. Fifty Percent Correct Recognition Thresholds. Subject: EF.

binocular viewing. The slight decrease in threshold beyond 60' in this study is no doubt due to the monocular viewing through an aperture - a condition known to reduce the incident illumination level on the retina.

Shape: Since analysis of thresholds by a variance technique may obscure any effect of the slope of the functions, these data were analyzed both for threshold effect and for the rate of change effect by analysis across the contrast increments. Bartlett's test for homogeneity of the variance was carried out first on the 50 percent threshold data and the resultant X^2's were not significant. The thresholds were than analyzed by analysis of variance and the results are indicated in Tables IV-A through VI-B.

The frequency of response over contrast increments were then analyzed by analysis of variance to determine whether the slope effects was essentially the same as for the results of the threshold analysis. Again the X^2's from Bartlett's test on the frequency scores were not significant. However, an angular transformation was performed to reduce further the possibility that the variance was a result of chance effects. The results of the variance analysis for the responses to contrast increments are summarized in Tables VII-A through IX-B.

Analysis of variance on the detection thresholds indicates no appreciable effect for shape, except in the largest size for one S. However, when the results of the analyses of variance on the scores across contrast increments are examined

TABLE IV-A

ANALYSIS OF VARIANCE FOR LOG DETECTION THRESHOLD DATA

SIZE I. SUBJECT: RM

Source	SS	df	MS	F
Figure	.060	5	.0120	2.10
Edge	.027	2	.0135	2.36
Remainder	.057	10	.0057	
Total	.144	17		

TABLE IV-B

ANALYSIS OF VARIANCE FOR LOG DETECTION THRESHOLD DATA

SIZE I. SUBJECT: EF

Source	SS	df	MS	F
Figure	.047	5	.0094	1.03
Edge	.054	2	.0270	29.67***
Remainder	.091	10	.0091	
Total	.192	17		

***Significant at the .001 level of confidence.

TABLE V-A

ANALYSIS OF VARIANCE FOR LOG DETECTION THRESHOLD DATA

SIZE II. SUBJECT: RM

Source	SS	df	MS	F
Figure	.042	5	.0084	2.04
Edge	.120	2	.0600	14.63**
Remainder	.041	10	.0041	
Total	.203	17		

**Significant at the .01 level of confidence.

TABLE V-B

ANALYSIS OF VARIANCE FOR LOG DETECTION THRESHOLD DATA

SIZE II. SUBJECT: EF

Source	SS	df	MS	F
Figure	.045	5	.009	4.00*
Edge	.074	2	.037	205.55***
Remainder	.018	10	.0018	
Total	.137	17		

*Significant at the .05 level of confidence.
***Significant at the .001 level of confidence.

TABLE VI-A

ANALYSIS OF VARIANCE FOR LOG DETECTION THRESHOLD DATA

SIZE III. SUBJECT: RM

Source	SS	df	MS	F
Figure	.035	5	.0070	4.11*
Edge	.147	2	.0735	43.23***
Remainder	.017	10	.0017	
Total	.199	17		

*Significant at the .05 level of confidence.
***Significant at the .001 level of confidence.

TABLE VI-B

ANALYSIS OF VARIANCE FOR LOG DETECTION THRESHOLD DATA

SIZE III. SUBJECT: EF

Source	SS	df	MS	F
Figure	.051	5	.010	33.33***
Edge	.216	2	.108	360.00***
Remainder	.003	10	.0003	
Total	.270	17		

***Significant at the .001 level of confidence.

TABLE VII-A

ANALYSIS OF VARIANCE OF FREQUENCY OF DETECTION RESPONSES

SIZE I. SUBJECT: RM

Source	SS	df	MS	F
Edge	900.54	2	450.27	3.84*
Figure	1178.77	5	235.71	
Contrast	46178.66	2	23089.33	111.70***
Interaction E X F	2868.52	10	286.85	
E X C	481.77	4	120.44	
F X C	203.54	10	20.35	
E X F X C	2343.61	20	117.18	
Total	52076.10	53		

*Significant at the .05 level of confidence.
***Significant at the .001 level of confidence.

TABLE VII-B

ANALYSIS OF VARIANCE OF FREQUENCY OF DETECTION RESPONSES

SIZE I. SUBJECT: EF

Source	SS	df	MS	F
Edge	1012.19	2	506.09	4.37*
Figure	522.85	5	104.57	
Contrast	46646.12	2	23323.06	201.20***
Interaction				
E X F	1708.87	10	170.88	
E X C	1972.18	4	493.04	4.25*
F X C	457.82	10	45.78	
E X F X C	2318.00	20	115.90	
Total	54638.03	53		

*Significant at the .05 level of confidence.
***Significant at the .001 level of confidence.

TABLE VIII-A

ANALYSIS OF VARIANCE OF FREQUENCY OF DETECTION RESPONSES

SIZE II. SUBJECT: RM

Source	SS	df	MS	F
Edge	6073.94	2	3036.97	288.68***
Figure	1773.40	5	354.60	33.70***
Contrast	55966.93	3	18655.64	1773.34***
Interaction E X F	2107.55	10	210.75	20.03***
E X C	1656.76	6	276.12	26.24***
F X C	1463.18	15	97.54	9.18***
E X F X C	315.61	30	10.52	
Total	69357.37	53		

***Significant at the .001 level of confidence.

TABLE VIII-B

ANALYSIS OF VARIANCE OF FREQUENCY OF DETECTION RESPONSES

SIZE II. SUBJECT: EF

Source	SS	df	MS	F
Edge	4514.51	2	2257.26	24.95***
Figure	2109.44	5	421.88	4.99***
Contrast	39558.74	3	13186.24	152.54***
Interaction				
E X F	545.57	10	54.55	
E X C	9478.62	6	1596.43	18.46***
F X C	1901.02	15	126.72	
E X F X C	2593.49	30	86.44	
Total	60801.39	53		

***Significant at the .001 level of confidence.

TABLE IX-A

ANALYSIS OF VARIANCE OF FREQUENCY OF DETECTION RESPONSES

SIZE III. SUBJECT: RM

Source	SS	df	MS	F
Edge	10054.94	2	5027.47	177.64***
Figure	2015.14	5	403.02	11.87***
Contrast	45590.58	3	15196.86	447.88***
Interaction				
E X F	928.65	10	92.86	2.73*
E X C	5058.61	6	843.10	24.84***
F X C	742.70	15	49.51	
E X F X C	1017.92	30	33.93	
Total	65408.54	53		

***Significant at the .001 level of confidence.
*Significant at the .05 level of confidence.

TABLE XIX-B

ANALYSIS OF VARIANCE OF FREQUENCY OF DETECTION RESPONSES

SIZE III. SUBJECT: EF

Source	SS	df	MS	F
Edge	12353.75	2	6176.87	229.30***
Figure	2263.02	5	452.60	16.81***
Contrast	41372.91	3	13790.97	512.29***
Interaction				
E X F	618.45	10	61.84	2.22*
E X C	2975.69	6	495.94	18.42***
F X C	867.38	15	57.82	2.11*
E X F X C	807.88	30	26.92	
Total	61259.08	53		

***Significant at the .001 level of confidence.
*Significant at the .05 level of confidence.

(Tables VII-A through IX-B), one can see that while shape is not significant for the small size, it is for the two larger sizes. The Cross and the Irregular figure appear to be contributing the greater part of the shape variance. Kristopherson's (60) data also showed an increase in threshold for the Cross. The comparative increase in threshold for the Irregular figure may be a result of the unfamiliarity of this figure. Furthermore, the high threshold for this figure may be due to the lack of subliminal cues, (due to corners, angles, etc.) as King et al (53) found their figures were seen correctly when presented at threshold level, even though the Ss believed that they were not doing better than chance performance.

Edge-gradient: That edge is an important factor in detection can be seen from the results of the analyses of variance for thresholds and for contrast scores. The variance due to the edge-gradient change is significant, except for one S in Size I. It will be recalled that at this size level, the amount of change which can be manipulated is very small.

The effect of change in the edge-gradient is not uniform for all figures. This can be seen from the fact that most of the interactions are highly significant for the two larger sizes (Tables VIII-A through IX-B). Thus, any attempt to predict edge-gradient effects must take this interaction into consideration.

The increase in threshold across the edge cannot be adequately explained by the slight reduction in area due to the blurring of the edge. For one thing, the threshold for size becomes asymptotic at approximately 60'. Furthermore, the increase in threshold is much greater than would be predicted from such slight decreases in area.

The statement by Bartley (4) that, "Whatever depresses or destroys the border formation, obliterates the appreciation of the brightness a surface would otherwise have". (p. 251), appears to be supported by this experiment.

The data of Kruithof and Zijl (61) indicated that the edge of a 3.2^{o} circle can be blurred to 7' before contrast of the target had to be increased to maintain a threshold response. Similarly, the data from Middleton's (65) experiment indicates that the gradient between two brightness fields can be blurred to 5' before the contrast on one has to be increased for the S to report them as different. The results of the present study indicates that both of the above reports fail to provide an explanation of edge effects since they did not reveal the relative effect of edge across size.

Effect of Experimental Variables on Recognition

<u>Size</u>: The relative change in edge-gradient precluded analysis of variance across the size increase. Again, as with detection, the threshold decreases rapidly at first and then levels off. However, the contrast needed for 50 percent recognition is greater than that needed for detection. (Figures 5 and 6.)

Shape: The threshold data and the rate of change data were again analyzed by analysis of variance.

Bartlett's test indicated the X^2's for threshold and rate of change, variance were not significant.

Analysis of variance for thresholds (Tables X-A through XII-B) indicate that the figures do not differ significantly, except in one case (Table X-B). However, when the analysis of variance on the transformed contrast scores (Tables XIII-A through XV-B) are examined, the shape variance is seen to be highly significant in all cases except one (Table XIII-A).

It does not appear that the Gestalt concept of "simplicity" based on the perimeter to area ratio is adequate to predict the shape effects for these data. The Square and the Triangle appear to be the most efficient figures, while the Irregular figure, Cross and Star are much less effective.

Edge-gradient: The recognition threshold, as in the case for detection, followed the reduction in steepness of the edge-gradient with a systematic increase in threshold. This is borne out by both analyses of variance, for in all cases the edge effect was significant, usually at the 0.001 level. A glance at figures through indicates that the effect of decrease in edge sharpness on the contrast threshold is slightly more pronounced than for detection. Also, as in detection, the Cross and the Irregular figure appear to contribute the main portion of the variance attributable to shape.

Recently Day (19) attempted to explain form perception on

TABLE X-A

ANALYSIS OF VARIANCE FOR LOG RECOGNITION THRESHOLD DATA

SIZE I. SUBJECT: RM

Source	SS	df	MS	F
Figure	.395	5	.079	3.06
Edge	.232	2	.116	4.49*
Remainder	.258	10	.0258	
Total	.885	17		

*Significant at the .05 level of confidence.

TABLE X-B

ANALYSIS OF VARIANCE FOR LOG RECOGNITION THRESHOLD DATA

SIZE I. SUBJECT: EF

Source	SS	df	MS	F
Figure	.331	5	.066	23.57***
Edge	.346	2	.173	61.78***
Remainder	.028	10	.0028	
Total	.705	17		

***Significant at the .001 level of confidence.

TABLE XI-A

ANALYSIS OF VARIANCE FOR LOG RECOGNITION THRESHOLD DATA

SIZE II. SUBJECT: RM

Source	SS	df	MS	F
Figure	.193	5	.038	4.17*
Edge	.331	2	.165	18.15***
Remainder	.091	10	.0091	
Total	.615	17		

*Significant at the .05 level of confidence.
***Significant at the .001 level of confidence.

TABLE XI-B

ANALYSIS OF VARIANCE FOR LOG RECOGNITION THRESHOLD DATA

SIZE II. SUBJECT: EF

Source	SS	df	MS	F
Figure	.096	5	.019	1.03
Edge	.384	2	.192	10.65**
Remainder	.184	10	.0184	
Total	.664	17		

**Significant at the .01 level of confidence.

TABLE XII-A

ANALYSIS OF VARIANCE FOR LOG RECOGNITION THRESHOLD DATA

SIZE III. SUBJECT: RM

Source	SS	df	MS	F
Figure	.060	5	.012	2.50
Edge	.429	2	.214	42.50***
Remainder	.048	10	.0048	
Total	.537	17		

***Significant at the .001 level of confidence.

TABLE XII-B

ANALYSIS OF VARIANCE FOR LOG RECOGNITION THRESHOLD DATA

SIZE III. SUBJECT: EF

Source	SS	df	MS	F
Figure	.098	5	.0196	1.24
Edge	.462	2	.231	14.71**
Remainder	.157	10	.0157	
Total	.717	17		

**Significant at the .01 level of confidence.

TABLE XIII-A

ANALYSIS OF VARIANCE OF FREQUENCY OF CORRECT RECOGNITION RESPONSES

SIZE I. SUBJECT: RM

Source	SS	df	MS	F
Edge	1698.74	2	849.37	15.92***
Figure	398.07	5	65.61	
Contrast	20566.09	2	10283.04	192.85***
Interaction				
E X F	4694.73	10	469.47	8.80***
E X C	1599.19	4	399.79	7.49***
F X C	4703.30	10	470.03	8.81***
E X F X C	1066.52	20	53.32	
Total	34656.64	53		

***Significant at .001 level of confidence.

TABLE XIII-B

ANALYSIS OF VARIANCE OF FREQUENCY OF CORRECT RECOGNITION RESPONSES

SIZE I. SUBJECT: EF

Source	SS	df	MS	F
Edge	1842.67	2	921.33	22.68***
Figure	2049.15	5	409.83	10.17***
Contrast	22232.51	2	11116.25	275.90***
Interaction				
E X F	1750.29	10	175.02	4.34**
E X C	1503.82	4	375.95	9.33***
F X C	878.19	10	87.19	2.16*
E X F X C	805.91	20	40.29	
Total	31062.54	53		

***Significant at the .001 level of confidence.
**Significant at the .01 level of confidence.
*Significant at the .05 level of confidence.

TABLE XIV-A

ANALYSIS OF VARIANCE OF FREQUENCY OF CORRECT RECOGNITION RESPONSES

SIZE II. SUBJECT: RM

Source	SS	df	MS	F
Edge	10054.94	2	5027.47	62.81***
Figure	2991.18	5	598.23	7.47***
Contrast	42487.10	3	14162.36	176.96***
Interaction				
E X F	1175.30	10	117.53	
E X C	2283.14	6	380.52	4.75**
F X C	232.62	15	15.50	
E X F X C	2400.98	30	30.03	
Total	62574.11	53		

***Significant at .001 level of confidence.
**Significant at .01 level of confidence.

TABLE XIV-B

ANALYSIS OF VARIANCE OF FREQUENCY OF CORRECT RECOGNITION RESPONSES

SIZE II. SUBJECT: EF

Source	SS	df	MS	F
Edge	10142.93	2	5071.46	47.16***
Figure	2731.18	5	546.23	5.08**
Contrast	37771.13	3	12590.37	117.09***
Interaction				
E X F	624.87	10	62.48	
E X C	176.05	6	19.34	
F X C	1358.15	15	90.54	
E X F X C	3225.69	30	107.52	
Total	56030.00	53		

***Significant at the .001 level of confidence.
**Significant at the .01 level of confidence.

TABLE XV-A

ANALYSIS OF VARIANCE OF FREQUENCY OF CORRECT RECOGNITION RESPONSES

SIZE III. SUBJECT: RM

Source	SS	df	MS	F
Edge	19641.72	2	9820.86	214.52***
Figure	4081.91	5	816.36	17.83***
Contrast	32478.68	3	10826.22	236.48***
Interaction				
E X F	620.00	10	62.00	
E X C	1032.71	6	172.11	3.75**
F X C	428.29	15	28.55	
E X F X C	1373.67	30	45.78	
Total	59656.98	53		

***Significant at .001 level of confidence.
**Significant at .01 level of confidence.

TABLE XV-B

ANALYSIS OF VARIANCE OF FREQUENCY OF CORRECT RECOGNITION RESPONSES

SIZE III. SUBJECT: EF

Source	SS	df	MS	F
Edge	19498.79	2	9749.39	93.40***
Figure	4152.04	5	830.40	7.95***
Contrast	36481.72	3	12160.57	116.49***
Interaction				
E X F	656.72	10	65.67	
E X C	3199.16	6	533.19	5.10***
F X C	861.26	15	57.41	
E X F X C	3131.60	30	104.38	
Total	67981.29	53		

***Significant at .001 level of confidence.

the basis of the statistical theory of Marshall and Talbot. Day's account, however, is inadequate since forms can be recognized below the temporal level of 10 millisec. where nystagmic scan is of practically zero frequency. For example, Hartline (43) has shown that a brief flash of light, if bright enough, can maintain the frequency of impulses in the optic nerve tract at a high amplitude for nearly 60 sec. Furthermore, it is difficult to exolain how scanning an edge as wide as some used in this study (20') could generate a "ridge of excitation" about such a blurred contour. An energy rate discrimination response appears more olausable in the light of the known data.

The Relation of Detection to Recognition

Examination of Tables X-A through XV-B indicate that interaction effects are a function of size. For detection, interaction is least for the small size and then increases over the other two sizes. For recognition, this relationship is reversed. The interaction effect is greatest for the small size and falls to a low level for the other two sizes. The above indicates a qualitative difference between the two processes - a difference which must be considered in any theoretical attemot to predict recognition performance from detection data.

Effects of this interaction are brought out further by an evaluation of response categories utilized, (Tables XVI-A

TABLE XVI-A

RESPONSE FREQUENCY TO EACH STIMULUS CATEGORY

SIZE I. SUBJECT: RM

Stimulus Slide	Circle	Irreg. Figure	Square	Triangle	Cross	Star	Diamond	Dot	Yes	No	Total
111	42	3	9	1	-	-	-	-	20	50	125
112	38	1	6	1	-	2	-	-	18	59	125
113	19	-	15	-	3	-	-	-	27	61	125
121	-	58	-	-	1	2	-	-	18	49	125
122	-	54	1	3	2	2	-	-	13	50	125
123	2	52	-	-	-	-	-	-	25	46	125
131	1	1	46	2	1	1	-	-	17	56	125
132	6	-	48	1	-	-	-	-	22	48	125
133	2	-	23	-	1	1	-	-	34	64	125
141	1	2	-	60	-	-	-	-	12	50	125
142	-	5	-	53	1	3	-	-	8	55	125
143	-	1	1	32	6	-	-	-	17	68	125
151	-	-	1	-	52	2	-	-	13	57	125
152	-	-	-	-	53	2	-	-	13	57	125
153	1	-	-	1	26	5	-	-	22	70	125
161	-	-	-	1	24	26	-	-	10	64	125
162	-	-	1	1	29	28	-	-	6	60	125
163	-	-	-	-	34	19	-	-	14	58	125
	112	177	151	156	233	93	0	0	306	1022	2250

TABLE XVI-B

RESPONSE FREQUENCY TO EACH STIMULUS CATEGORY

SIZE I. SUBJECT: EF

Stimulus Slide	Circle	Irreg. Figure	Square	Triangle	Cross	Star	Diamond	Dot	Yes	No	Total
111	48	-	11	-	-	-	-	-	15	51	125
112	39	-	4	-	-	-	-	-	17	65	125
113	33	-	17	-	1	-	-	-	17	57	125
121	2	50	-	-	-	-	-	-	16	57	125
122	3	43	-	-	-	2	-	-	18	59	125
123	9	45	2	-	-	-	-	1	17	51	125
131	9	-	57	1	1	-	-	-	9	48	125
132	9	-	56	-	-	1	-	-	14	45	125
133	12	1	27	-	1	-	-	-	14	70	125
141	3	-	-	63	-	-	-	-	9	50	125
142	5	-	1	49	-	-	-	-	18	52	125
143	6	-	3	35	-	1	-	-	12	68	125
151	1	-	-	2	40	2	4	1	20	55	125
152	8	-	1	-	43	2	-	-	13	58	125
153	5	-	1	-	23	5	2	-	16	73	125
161	2	-	1	1	11	35	-	-	13	62	125
162	1	-	1	-	17	28	2	-	15	61	125
163	6	-	-	-	28	13	2	1	23	52	125
	201	139	172	151	165	89	10	3	276	1034	2250

TABLE XVII-A

RESPONSE FREQUENCY TO EACH STIMULUS CATEGORY

SIZE II. SUBJECT: RM

Stimulus Slide	Circle	Irreg. Figure	Square	Triangle	Cross	Star	Diamond	Dot	Yes	No	Total
211	81	-	-	-	1	-	-	-	1	42	125
212	63	-	-	-	-	-	-	-	1	61	125
213	50	-	1	1	-	2	-	-	10	61	125
221	-	64	2	-	-	-	-	-	6	53	125
222	-	50	-	-	-	-	-	-	2	73	125
223	-	38	1	-	-	-	-	-	12	74	125
231	1	-	76	4	1	-	-	-	2	41	125
232	3	-	67	1	-	-	-	-	5	49	125
233	11	-	36	-	-	-	-	-	8	70	125
241	-	-	-	86	1	-	-	-	2	36	125
242	-	-	-	81	-	-	-	-	-	44	125
243	-	-	-	49	1	-	-	-	5	70	125
251	-	-	1	-	63	4	-	-	6	51	125
252	-	2	-	1	60	1	-	-	4	57	125
253	-	1	-	2	31	13	-	-	7	71	125
261	-	-	-	-	6	70	-	-	3	46	125
262	1	2	-	3	7	67	-	-	3	42	125
263	-	1	-	-	9	30	-	-	10	75	125
	210	158	184	228	180	187	0	0	87	1009	2250

TABLE XVII-B

RESPONSE FREQUENCY TO EACH STIMULUS CATEGORY

SIZE II. SUBJECT: EF

Stimulus Slide	Circle	Irreg. Figure	Square	Triangle	Cross	Star	Diamond	Dot	Yes	No	Total
211	70	-	5	2	-	-	-	-	7	41	125
212	69	-	2	1	1	-	-	-	9	43	125
213	48	-	3	1	-	-	-	-	18	55	125
221	-	62	-	-	-	-	-	-	10	53	125
222	-	54	-	-	2	1	1	-	6	61	125
223	3	39	1	-	1	-	-	-	12	69	125
231	1	-	90	-	-	-	-	-	5	29	125
232	1	-	78	1	-	-	-	-	10	35	125
233	5	-	51	2	-	-	-	-	11	56	125
241	-	-	-	85	-	-	-	-	2	38	125
242	1	1	-	74	-	-	-	-	6	43	125
243	-	-	-	54	-	-	-	-	13	58	125
251	-	-	-	1	78	4	-	-	5	37	125
252	-	-	1	-	72	2	-	-	8	42	125
253	1	-	1	1	33	6	4	-	15	64	125
261	-	-	1	-	4	73	-	-	4	43	125
262	-	1	-	1	5	77	-	-	2	39	125
263	-	-	-	-	7	37	1	-	10	70	125
	199	157	233	223	203	200	5	0	153	876	2250

TABLE XVIII-A

RESPONSE FREQUENCY TO EACH STIMULUS CATEGORY

SIZE III. SUBJECT: RM

Stimulus Slide	Circle	Irreg. Figure	Square	Triangle	Cross	Star	Diamond	Dot	Yes	No	Total
311	75	-	-	-	-	-	-	-	-	50	125
312	59	1	1	1	-	-	-	-	2	61	125
313	30	-	3	-	-	-	-	-	9	83	125
321	2	42	-	-	-	-	-	-	10	71	125
322	3	37	-	-	-	-	-	-	2	83	125
323	3	9	1	1	5	-	-	-	8	98	125
331	-	-	67	4	-	-	-	-	1	53	125
332	1	1	64	2	-	-	-	-	2	55	125
333	13	-	15	2	-	-	-	-	6	89	125
341	-	1	-	73	1	-	-	-	-	50	125
342	-	-	-	58	-	1	-	-	1	65	125
343	-	-	-	26	-	1	-	-	3	95	125
351	-	-	-	-	56	1	-	-	3	61	125
352	1	-	-	-	46	1	-	-	4	73	125
353	-	-	-	1	11	13	-	-	9	91	125
361	-	-	-	-	1	69	-	-	-	55	125
362	-	-	-	-	4	56	-	-	1	64	125
363	-	-	-	2	8	14	-	-	6	95	125
	187	89	151	170	128	156	0	0	67	1292	2250

TABLE XVIII-B

RESPONSE FREQUENCY TO EACH STIMULUS CATEGORY

SIZE III. SUBJECT: EF

Stimulus Slide	Circle	Irreg. Figure	Square	Triangle	Cross	Star	Diamond	Dot	Yes	No	Total
311	61	-	1	-	-	-	-	-	2	61	125
312	49	-	1	-	-	-	-	-	9	66	125
313	23	-	4	-	-	-	-	-	8	90	125
321	-	48	-	1	-	-	-	-	8	68	125
322	-	27	-	-	-	-	-	-	7	91	125
323	1	4	1	-	-	-	-	-	13	106	125
331	-	-	69	-	-	-	-	-	3	53	125
332	-	-	60	-	-	-	-	-	2	63	125
333	4	-	23	-	1	-	-	-	5	92	125
341	-	-	-	70	-	-	-	-	2	53	125
342	-	-	-	57	-	-	-	-	3	65	125
343	1	-	-	26	-	-	-	-	-	98	125
351	-	-	2	-	64	3	-	-	3	53	125
352	1	-	-	-	47	2	1	-	7	67	125
353	2	-	-	-	8	6	1	-	14	94	125
361	-	-	-	-	1	70	-	-	2	52	125
362	-	-	1	-	3	53	-	-	1	67	125
363	-	-	-	-	4	20	-	-	8	93	125
	142	79	162	154	128	154	2	0	97	1332	2250

through XVIII-B). For size I, both Ss reported "nothing" and "yes" with almost equal frequencies. There were individual differences for figures, between the Ss, but the over all trends were quite similar. For example, both Ss reported Circles as "Squares" about as often as Squares were called "Circles". The same holds essentially for all sizes except for the extreme blurred Square. This figure was called "Circular" a slightly greater number of times - an outcome which is not surprising for stimuli with blurred contours. The Star tended to be confused with the Cross more often than the Cross with the Star. Aside from these two conditions the figures are essentially independent, in that, for the two larger sizes especially, few incorrect response categories were used, and the frequency of the "yes" response falls to a much lower level than for sizeI. The response to form appears to be independent of well defined contours in that correct categories were usually assigned when any discrimination was made. This seems to support Gibson's (34) position that the explanation of form perception requires a theory of how symbols are comprehended and utilized. In the present study, the correct category was reported even when cues from the edge were at a minimum.

The Prediction of Recognition Thresholds from Detection Data

The contrasts yielding thresholds of 50, 75 and 95 percent detection (as determined from the detection function) were fitted to the recognition functions and the predicted frequencies of recognition recorded. These relationships are presented in Tables XIX-A and XIX-B. It is apparent that the 50 percent thresholds for size I will predict low recognition performance. However, when we turn to size III the recognition level has rapidly approached that for detection. Thus, it appears that as size increases, recognition performance rapidly approaches detection performance as a limit.

Implications for Further Research

The approach of this study in manipulating stimulus for contour across size and shape of the target has implications for the following areas of research.

(1) At the physiological level there is a need to determine the relationship of edge-gradient change to the On/Off mechanism of the retina.

(2) Since form discrimination in lower animals has not been systematically manipulated, comparative studies in this area might prove relevant for comprehensive visual theory.

(3) The role of the edge-gradient would be critical for any account of the phenomena of figural after-effects. There is therefore a need to delineate whether contour is a relevant variable for establishing after-effects (Kohler and Wallack).

(4) In particular, studies are needed in which the area of the target is systematically impoverished in order to determine if discrimination is based on edge factors or on some edge-area combination.

TABLE XIX-A

RECOGNITION EFFICIENCY PREDICTED FROM 50, 75 and 95 PERCENT DETECTION THRESHOLDS

SUBJECT: RM

Stimulus Slide	SIZE I.			SIZE II.			SIZE III.		
	R_d 50	R_d 75	R_d 95	R_d 50	R_d 75	R_d 95	R_d 50	R_d 75	R_d 95
11*	3.0	8.0	18.0	31.0	50.0	71.0	50.0	72.0	95.0
12	0.0	0.4	2.5	31.0	61.0	93.0	43.0	54.0	74.0
13	0.5	0.2	1.0	4.0	10.0	22.0	19.0	30.0	54.0
21	24.0	26.0	44.0	29.0	43.0	68.0	24.0	54.0	91.0
22	15.0	20.0	26.0	15.0	36.0	66.0	20.0	58.0	93.0
23	8.0	13.0	26.0	14.0	34.0	64.0	1.4	10.0	40.0
31	1.5	4.0	17.0	32.0	49.0	64.0	36.0	70.0	92.0
32	0.3	0.9	7.0	20.0	40.0	66.0	40.0	46.0	54.0
33	0.8	1.2	3.0	5.0	13.0	39.0	2.0	5.0	16.0
41	13.0	22.0	64.0	42.0	54.0	74.0	48.0	72.0	95.0
42	1.6	4.0	7.0	48.0	70.0	95.0	50.0	74.0	95.0
43	3.5	9.0	2.5	34.0	62.0	87.0	21.0	56.0	90.0
51	16.0	30.0	56.0	3.0	15.0	52.0	38.0	50.0	62.0
52	13.0	20.0	30.0	20.0	34.0	55.0	24.0	38.0	70.0
53	1.0	2.0	5.5	5.0	20.0	48.0	0.9	2.5	11.0
61	1.8	3.0	7.0	18.0	26.0	38.0	49.0	72.0	95.0
62	8.0	14.0	16.0	15.0	22.0	34.0	35.0	50.0	74.0
63	7.0	10.0	19.0	0.4	1.6	7.0	10.0	36.0	84.0

*Code: circle, Edge I.

TABLE XIX-B

RECOGNITION EFFICIENCY PREDICTED FROM 50, 75 and 95 PERCENT DETECTION THRESHOLDS

SUBJECT: EF

Stimulus Slide	SIZE I.			SIZE II.			SIZE III.		
	R_d 50	R_d 75	R_d 95	R_d 50	R_d 75	R_d 95	R_d 50	R_d 75	R_d 95
11*	4.5	11.0	26.0	22.0	50.0	88.0	46.0	71.0	93.0
12	0.0	0.0	2.5	22.0	54.0	88.0	34.0	65.0	92.0
13	0.0	0.2	1.0	4.0	10.0	24.0	28.0	44.0	70.0
21	14.0	31.0	70.0	20.0	50.0	80.0	22.0	50.0	89.0
22	0.7	2.0	8.0	31.0	56.0	90.0	20.0	60.0	92.0
23	1.0	6.5	66.0	1.3	6.0	30.0	5.0	20.0	60.0
31	0.3	1.0	4.0	36.0	50.0	67.0	46.0	71.0	94.0
32	5.5	10.0	20.0	32.0	45.0	66.0	50.0	72.0	95.0
33	0.1	0.3	1.2	13.0	23.0	34.0	20.0	46.0	88.0
41	14.0	40.0	86.0	46.0	75.0	95.0	44.0	74.0	93.0
42	0.3	1.6	10.0	47.0	66.0	94.0	44.0	72.0	94.0
43	1.2	4.0	10.0	12.0	62.0	92.0	40.0	70.0	92.0
51	2.0	12.0	30.0	46.0	70.0	94.0	28.0	58.0	86.0
52	1.6	4.0	20.0	20.0	33.0	54.0	32.0	46.0	70.0
53	6.0	13.0	27.0	12.0	20.0	36.0	2.5	8.0	33.0
61	0.4	2.5	8.0	32.0	44.0	62.0	36.0	70.0	94.0
62	0.3	2.0	12.0	34.0	52.0	70.0	30.0	50.0	74.0
63	1.2	3.0	7.0	12.0	17.0	25.0	6.0	15.0	34.0

*Code: circle, Edge I.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Size, shape and edge-gradient of a visual stimulus are known to affect both detection and recognition.

Problem: This investigation was designed: First, to determine the effects of stimulus size, shape and edge-gradient on detection and recognition. Previously the affects of these variables were determined independently. Second, to determine whether recognition efficiency can be predicted from detection thresholds.

The brightness contrast thresholds for two Ss were determined for figures varying in their perimeter to area ratio. The figures, Circle, Irregular figure, Square, Triangle, Cross and Star were presented over three foveal sizes and three edge-gradient conditions for each size range.

The Findings:

I. Detection:

(1)Size. Increase in size decreases threshold at a decreasing rate.

(2)Shape. The stimulus shape did not affect detection thresholds for the smallest size targets. However, for the two larger sizes, stimulus shape does influence the detection threshold.

(3)Edge-gradient. Decreases in the steepness of the edge-gradient were systematically associated with increases in the detection thresholds.

II. Recognition:

(1)Size. Increase in stimulus size increases the frequency of correct recognition responses.

(2)Shape. The shape of the stimulus had a significant effect on the recognition threshold. The Irregular figure and the Cross had higher thresholds in general, than did the Circle, Square, Triangle, and S tar. Few "circle" responses were given to non-circular forms. This latter finding is contrary to predictions from the Gestalt theory. Predictions based on such physical parameters as area, amount of perimeter, of perimeter to area ratio could not adequately predict the present findings.

(3)Edge-gradient. A decrease in the steepness of the edge-gradient systematically increased the threshold for recognition. This increase was slightly more pronounced than found for detection. The use of incorrect response categories did not increase appreciably as the steepness of the edge-gradient decreased. In fact, the Ss stopped responding altogether to the very blurred figures.

III. Detection versus Recognition:

(1)A size of a stimulus increases, recognition thresholds regress on the detection threshold as a limit.

(2)The familiarity of stimulus forms appears to affect both detection and recognition functions. Non-familiar forms, eg, irregular shape, had higher thresholds than did figures like the Circle and Square.

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VISUAL DISCRIMINATION AS A FUNCTION OF STIMULUS SIZE, SHAPE AND EDGE-GRADIENT

Abstract of a Dissertation

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for the degree of Doctor of Philosophy

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The basic response of the visual mechanism is the discrimination of changes in luminous intensity in the visual world. This discrimination consists of (1) detecting the presence of a signal, and (2) assigning this signal to a category which has definitive class properties (recognition).

Detection: In the attempt to establish the characteristics of the stimulus for the detection response, amount of area and amount of edge of the object, have been advanced as determining factors. One group of investigators propose that as area is increased, the detection threshold will decrease systematically and that this response is independent of the shape of the object. These investigators have favored a view that as stimulus size increases a larger number of retinal receptors are fired and accordingly the detection threshold is reduced.

On the other hand, other investigators hold that the detection response is dependent upon the amount of edge or perimeter of the object. These investigators, however, are divided into two theoretical groups. One group proposes that the contrast disparity at the edge activates the post-retinal neural mechanism and that differential stimulation of a row of receptors will account for brightness discrimination. The other group has advanced the theory that brightness discrimination results from the retinal scanning associated with eye-movements.

Certain criticisms and gaps in our knowledge prevent the choice of any single theory at this time. For example, the scanning theory is inadequate since studies have shown that the detection response can occur at temporal intervals so small that the frequency of scanning movement is essentially zero. Similarly, the area explanation is deficient in that detection thresholds differ for stimuli equal in area but varying in shape. Finally, the lack of information on the relationship between changes in the edge-gradient and the detection threshold leaves the adequacy of the second theory undetermined.

Recognition: Gestalt theory would predict that the threshold for form will increase as the ratio of perimeter to area increases, providing area is constant. Accordingly, the circle is regarded as the simplist figure and should have the lowest detection and recognition thresholds.

In contrast to this approach, the data from other studies indicate that the role of shape is not clear. For example, other figures, such as the square and the triangle have been discriminated more readily than the circle. Furthermore, any theory of shape discrimination must specify the role of shape size in recognition. In this respect little systematic emperical information is available.

Whatever the theoretical position investigators have adopted, all agree that the contour of a figure is the "cue" or "information" carrier for shape identification. However, variations in the contour-gradient have not been systematically studied and at the present time the precise relationship between contour and recognition is uncertain.

The relation of Detection to Recognition: The relationship between recognition and detection has received little experimental attention. Nevertheless, it is apparent that a comprehensive account of form recognition must include some statement of the relationship of recognition to detection. For one thing, what is the relative contribution of such variables as area, and edge-gradient to recognition as opposed to detection? Furthermore, can detection measures be utilized to predict recognition performance?

Problem: The investigation was designed to determine the effects of size, shape and edge-gradient on detection and recognition. In addition, this study sought to determine whether recognition performance could be predicted from detection thresholds.

Method: A modified method of Single Stimuli was used to determine the brightness contrast thresholds for figures varying in their perimeter to area ratio. The figures, Circle, Irregular Shape, Square, Triangle, Cross, and Star, were presented over three foveal sizes and three edge-gradient conditions for each size range. The gradients were constructed by photographing the figures through various apertures placed in front of a camera lens. This procedure produced across the edge of the figures sigmoid-shaped gradients of different slopes.

Two young adults, with 20/20 acuity and no astigmatism, served as Ss. Viewing was done under daylight adaptation with ambient illumination controlled by enclosing the S's head and shoulders within a frame covered by a photographer's hood. The stimuli were presented in the center of four small orientation dots on a 21° background field (illuminated at 3 millilamberts). The Ss used their dominant eye and viewed the stimuli through a 2mm aperture.

The 54 stimulus combinations of target size, shape and edge-gradient were ordered in a random sequence, and the contrast increments assigned randomly to each condition. Seven preliminary lists were presented to familiarize the S with the experimental task. The Ss were asked (a)to report a change in stimulus conditions and (b)to identify this change without guessing. Daily morning sessions were run, with an occasional afternoon session, until 25 replications for each condition were obtained. A total of 6750 responses was obtained from each S after preliminary training.

The Findings:

I. Detection:

(1) Size. Increase in size of the stimulus decreases the threshold of detection at a decreasing rate.

(2) Shape. The stimulus shape did not affect detection thresholds for the smallest size targets. However, for the two larger sizes, stimulus shape does influence the detection threshold in that the Irregular Shape and the Cross have, in general, higher thresholds.

(3) Edge-gradient. Decreases in the steepness of the edge-gradient were systematically associated with increases in the detection thresholds.

II. Recognition:

(1) Size. Increase in the stimulus size increases the frequency of correct recognition responses.

(2) Shape, The shape of the stimulus had a significant effect on the recognition threshold. The Irregular Shape and the Cross had higher thresholds in general, than did the Circle, Square, Triangle, and the Star. Few "circle" responses were given to non-circular forms. This later finding is contrary to predictions from Gestalt theory. Furthermore, predictions based on such physical parameters as, area, amount of perimeter, and of perimeter to area ratio, could not adequately predict the present findings.

(3) Edge-gradient. A decrease in the steepness of the edge-gradient systematically increased the threshold for recognition. The use of incorrect response categories did not increase appreciably as the steepness of the edge-gradient decreased. In fact, Ss stopped responding altogether to the very blurred figures except at the brightest contrast increment.

III. The relation between Detection and Recognition:

(1) As size of a stimulus increases, recognition thresholds regress at a negatively decreasing rate on the detection thresholds as a limit.

(2) The recognition thresholds were slightly more affected (higher) by edge-gradient changes than were the detection thresholds.

(3) The threshold ranking for shape was essentially the same for both detection and recognition. Figures with lower detection thresholds, had lower recognition thresholds.

(4) The familiarity of stimulus forms appears to affect both detection and recognition functions. Non-familiar forms, e.g., Irregular Shape, had higher thresholds than did figures like the Triangle and Square.

IV. Implications for Further Research:

The approach of this study in manipulating the stimulus for contour across size and shape of the target has implications for the following areas of research:

(1) Studies are needed in which the area of the target is systematically impoverished in order to determine if discrimination is based on edge factors or on some edge-area combination.

(2) At the physiological level there is a need to determine the relationship of edge-gradient change to the On/Off mechanism of the retina.

(3) Form discrimination in lower animals has not been systematically studied. The experimental stimuli of the present study would permit comparative investigation which might prove relevant for a comprehensive visual theory.

(4) On the basis of the present results, it would appear that edge-gradient would be critical for any account of the phenomena of figural after-effects. There is a need to determine whether contour is a relevant variable for producing after-effects (Kohler and Wallack).

AUTOBIOGRAPHY

Wyatt R. Fox was born in Northumberland, New Hampshire, on November 11, 1924. He is a graduate of Littleton High School in Littleton, New Hampshire in 1942, and did his undergraduate work at Marietta College, Marietta, Ohio, and the University of Vermont, Burlington, Vermont, receiving the degree of Bachelor of Arts in 1951.

In 1951, he entered the University of Massachusetts at Amherst, Massachusetts, and received the degree Master of Science in Psychology in 1953. Since the Fall of 1952, he has been studying for a doctorate in Experimental Psychology at Boston University Graduate School.