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ELEMENTS

OF

VISUAL PERCEPTION

by

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ELEMENTS OF VISUAL PERCEPTION

by

Dudley B. Killam

Submitted to the Photographic Science and Instrumentation Division in partial fulfillment of the requirements for the Master of Science degree at the Rochester Institute of Technology

ABSTRACT

The roles of scale, contrast and spectral difference in visual detection and recognition was investigated. Geometrical target arrays were produced and projected using a rear projection apparatus. Scale was varied using combined photographic reduction and slide projection. Contrast levels were adjusted in projection of lithographic target arrays using neutral density filtration arrangements in the projection apparatus. Experimentally obtained cumulative probability of detection and combined detection and recognition was examined relative to established combinations of target scale, contrast and spectral difference. A method for the characterization of target pair differences was offered and analyzed. The relation of scale, contrast and perceptual target difference was analyzed and a hierarchy of scale importance in simple geometrical targets was clarified.

ACKNOWLEDGEMENTS

I should like to express my gratitude to all those who have assisted me or encouraged me over the course of my thesis research. In particular I would like to thank my advisor, Dr. Edward M. Granger, for his kind support and most willing counsel. Secondly, I should like to thank as a whole the most enthusiastic and kind people of the Eastman Kodak Company for their counsel, advice, assistance and participation in my thesis research.

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I. INTRODUCTION

The importance of vision to man in acquiring information about his environment is underscored by the fact that man acquires approximately 75% of the total information about his environment through the visual process[1]. Much research has been devoted to determining the mechanisms that characterize the visual process. The components of the vision system in man are complex and interrelated. Extensive studies have been performed to identify the relationships that exist among various components of the visual system of lower animals. The hope has been that by analogy the characteristics of the visual process in man can be deduced. However valuable such studies may be, it is necessary to supplement such information with data obtained from man himself, by whatever methods available.

The acquisition of visual information is characterized by a series of processes. This visual process continuum may be broadly divided into three tasks: detection, recognition, and identification. Relative to this tripartite visual process division, certain factors can be identified which appear to be important. There must be sufficient energy of appropriate spectral character for image detection. Additional stimulus parameters may affect the ability of man to detect and then recognize visual features. These parameters include size, shape, form, surrounding contrast, textural differences and sharpness.

The objectives of this experimental study have been to determine the role of size, contrast and image structure in the process of detection and recognition. While it is known that such factors are important in the visual process, previous studies involving these factors have not been entirely successful in characterizing the reasons for their importance. The goal of this experimental study was to demonstrate their importance in a controlled visual experiment and to identify the underlying reasons for their importance.

FOOTNOTES FOR CHAPTER I

1. Ian Overington, Vision and Acquisition (London: Pentech Press, 1976), 1.

II. EXPERIMENTAL PROCEDURE

The goal of the experimental procedure was to present a series of geometrical shape target arrays of known size and character at chosen contrast levels to individual observers. The observer's tasks were to examine the target arrays individually for differences in the target array and to identify if possible the geometrical figure associated with the difference. This was accomplished by projection of geometrical target array slides onto a plastic rear projection screen. The size of the geometrical shapes was varied using photographic reduction. The presentation contrast was controlled using neutral density filtration in the projector apparatus. The apparatus and display are illustrated in Figure 1.

TARGET PREPARATION

Targets

The target arrays consisted of a four point pattern of elements. The elements selected for use were circles, triangles, squares, hexagons and octagons. All elements were constructed so as to have equal areas. The four point patterns were assembled to consist of one element of interest and three null elements or circles. Four point patterns consisting of all null elements were also prepared. The element arrays are shown in Figure 2.

Figure 1. Projection Apparatus — Front and Rear.

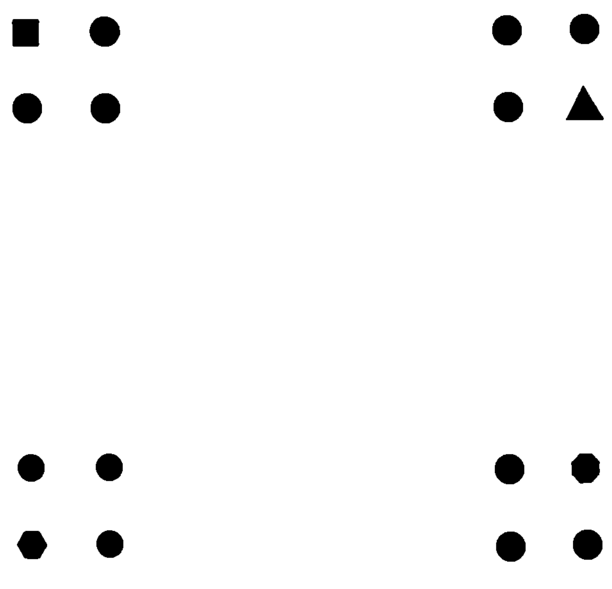

Figure 2. Target Arrays

Slide Preparation

The target arrays were photographically reduced to known, measured sizes using Kodalith Ortho film, Type 6556. The camera employed was a Mamaiya-Sekor 1000 DTL. Target illumination was provided using two 1500 watt tungsten photofloods at approximately 12 feet. Exposures, made at f/2.8, 1 second, yielded clear sharply defined images over the range of taking distances employed. Target films were processed in a Kodalith Film Processor using Kodalith MP developer at Kodak Park.

Projection Apparatus

The projection apparatus consisted of two Kodak slide projectors arranged in a vertical manner as shown earlier in Figure 1.

The lower projector was an Ektagraphic, equipped with a standard General Electric bulb, type DAH, with a relative brightness rating of 40% and rated life hours at low power of 800 hours[2]. Its purpose was to provide flare light to the display for contrast variation. Loaded with only a blank slide mount, it was equipped with an Ektanar Zoom lens, f/3.5, set to yield a magnification of about 6 at the display. The illumination provided by the flare projector was adjusted using Kodak neutral density filters inserted into a holder mounted at the end of the projection lens. Filter values employed for the three contrast levels employed were 1.0, 1.5 and 2.0.

Additional filtration over both the upper target projector and the lower slide projector was provided by hanging large sheets of neutral density material, values 0.4 and 0.1, from the apparatus structure just

in front of the projector lens apertures. The function of this additional filtration was to assure that average illumination levels at the lower contrasts matched that available at the uppermost contrast obtained with the 2.0 filtration of the flare projector.

The upper projector was a Carousel Model 850H with auto-focus and remote slide changer control. It was equipped with a Sylvania bulb, type ELH, with a relative brightness rating of 65% and rated life-hours at low power of 140 hours[3]. It served as the image projection source and was fitted with an Ektanar Zoom lens, f/3.5. The lens aperture was modified with a circular aperture mask into which was cut a half inch hole. The mask served to attenuate the illumination provided in projection and also to eliminate a secondary image formed via reflection from the glossy rear of the projection screen. The lens was set to provide a measured magnification of 6 at the display.

The image projector was placed level on a plywood stand above the flare projector. The flare projector display was made to coincide with that of the image projector by elevating the flare projector slightly, about an inch. The plywood stand was assembled so as to allow this adjustment, minimizing the lens separation while allowing for necessary ventilation of the lower projector.

Contrast Measurement

Display contrast was varied as previously indicated using neutral density filtration techniques. Consideration had been given to using polarizer materials for this purpose. This method was rejected due to the color shift towards the blue inherent in crossing the polarizer materials on the flare projector aperture.

Contrast was measured using a Spectra Brightness Spot Meter produced by the Photo Research Corporation and made available by Eastman Kodak. Output of the meter assembly was read in footlamberts on a General Electric meter. The illuminance provided by the flare projector alone and both projectors together was alternately measured for each contrast arrangement. For these measurements, the image projector was loaded with a slide containing clear film base. During the measurements, background illumination was provided to the rear of observer's position by an overhead projector covered with heavy paper. The room was otherwise darkened. The meter was oriented so as to be directed at the center of the display screen, and was positioned at the observation distance of two meters.

Target Mensuration and Selection

The size of the images on the target slides was determined using a microscope equipped with a stage accurate to .0001 inches. The size of the circular null objects in the target slides ranged from about 21 to 277 mrad visual subtense at two meters viewing distance. This amounted equivalently to a range of angular subtense for the geometric figures of 33 to 431 mrad for the triangle, 26 to 347 mrad for the square, 23 to 305 mrad for the hexagon and 22 to 292 mrad for the octagons.

The total range of sizes available were not used for each figure however. In a preliminary screening experiment, the following ranges were selected: triangle, 33 to 205 mrad; square, 45 to 165 mrad; hexagon, 40 to 305 mrad; and octagon, 53 to 292 mrad. The preliminary study indicated that such chosen angular subtense ranges would yield re-

sults from threshold level to certainty for the detection and recognition tasks required of the observer.

Target Presentation

The targets were presented to each observer separately. The location of the non-null geometric target within the four point array was uniformly varied so as to preclude any right versus left or top versus bottom subject display bias from systematically biasing the detection and recognition task. The order of presentation of the slides was randomized for each observer by starting at a different slide each time over the three contrast treatments. The order of the contrast treatments presented to the observers were randomized as well. With each change in contrast, the observer was allowed to adapt to the presentation contrast. At the beginning of the first contrast treatment, a series of larger targets were presented so that each observer would become familiar with the target array scheme and also to verify that each observer was capable of distinguishing between geometrical shapes at essentially gross scale levels. A set of images on paper were also made available to each observer when the experiment was explained.

The responses were recorded for each observer and the slides advanced as each decision task was completed. There was no time limit placed on observation time, yet the average length of view time for the total slide sequence was about 15 to 20 minutes. Each observer was encouraged to make an affirmative choice to the best of his or her ability with each presentation. No indication was given the observer whether a "correct" response had been given. However, encouragement was given for all affirmative answers as well as answers of no difference in the presentation array.

In addition to recording the responses of each observer, this experimenter also recorded accessory information concerning the techniques which each observer used in viewing the slide presentations. No constraint was placed on any observer other than a respect for the "foul line" at the two meter observation distance. Each observer was urged to indicate any anomalous appearance in each target presentation. Where the observer was fitted with corrective lenses, a general history of vision was solicited and recorded. Observer preference as to contrast treatments was queried as well as any general impressions concerning the degree of difficulty in recognizing or detecting the different geometrical shapes. The contrast levels employed in the presentation were 0.86 (C1), 3.30 (C2) and 13.69 (C3). Corresponding mean illumination provided at each of the treatment combinations was 193 footlamberts (C1), 198 footlamberts (C2) and 181 footlamberts (C3).

FOOTNOTES FOR CHAPTER II

2. Eastman Kodak, Projection Distance Tables and Lamp Data for Kodak Slide and Motion Picture Projectors (Rochester, N.Y.: 1975).

3. Ibid.

III. EXPERIMENTAL DESIGN AND FACTOR ANALYSIS

The basic design of this study was a three factorial type. The factors involved were visual scale, contrast, and figure type. While the structure of the design was maintained over the course of the experimental study, certain modifications were required.

Visual Scale

First, as indicated in Chapter II, a preliminary experiment demonstrated that different visual scale ranges for each geometric figure were required to cover observer recognition and detection capabilities. This was expected. However, the scale ranges required for the figures employed were different than those theoretically expected. Relative to such differences, all available appropriate scales for the figures were employed. This difference in target type scale factors made it necessary to augment a planned geometric ratio variation in target sizes to be presented. The number of scales for each figure were thus different.

The degree of uncertainty involved in scale range for each figure also impacted on intended replication within the design. It was desired to limit the duration of the experiment to approximately 15 minutes. Replication of treatment combinations made this requirement difficult to satisfy while assuring that necessary information on figure scale was to be obtained. In a tradeoff of these factors, replication was decided to be least important. Replication was accomplished at selected scale levels for each figure type for potential use in evaluating possible interaction between scale and contrast factors.

Contrast

The selection of contrast levels was dictated by available, convenient values of neutral density filtration. What appeared to be appropriate output contrasts at three filtration selections may not have been entirely satisfactory.

Latent Variables

Although latent variables had been considered and controlled regarding display color temperature variation and overall presentation illumination levels, the control aspects of illumination level might have been more judiciously considered. This latter latent factor appeared to have negated in large part aspects of contrast difference. This did not manifest itself until data analysis was performed however.

Accessory contributions of figure position and orientation within each display were averaged over the experiment by the randomization method described in experimental procedures. Insofar as the data gathered in this experiment indicated, the randomization procedures employed were successful.

Response Variable

The nature of the response variable also had substantial bearing on the conduct of the experiment. The response variable was of a twofold nature, relating to the detection and recognition aspects of each observer's task. For each observer, the tasks involved were of a binomial character. Either one saw a difference in a given presentation or one did not. Given that a difference was perceived, the observer either could or could not identify a geometrical figure with the perceived difference.

Summing the total correct observations in each case, a percent correct was obtained for each treatment combination at the detection and recognition levels.

IV. RESPONSE ANALYSIS

For the detection and recognition tasks required of the observers in this experimental study, cumulative percent correct response were obtained. The unreduced raw response character for the detection and the detection-recognition tasks is illustrated for the geometrical elements of interest in Figures 3 and 4.

Normality Transformation

The nonlinear nature of the response curves was not unanticipated. Various models were considered in the initial course of analysis. The response curves indicated that a normal approximation was justified from the standpoint of both intuition and the information which could be extracted from the data set with this approximation.

The raw response data was plotted for each figure of interest and for the three contrast levels employed on normal probability paper. The generally linear nature of the data plotted this way indicated that this approach had sufficient merit to warrant continuation of the analysis tactic. The complete approach then consisted of the imposition of a linear scale on the ordinate probability axis, followed by the application of systematic linear regression to all treatment group plots obtained this way[4]. Consideration of such results indicated that a linear transformation appeared sufficiently accurate to represent all data obtained in the study.

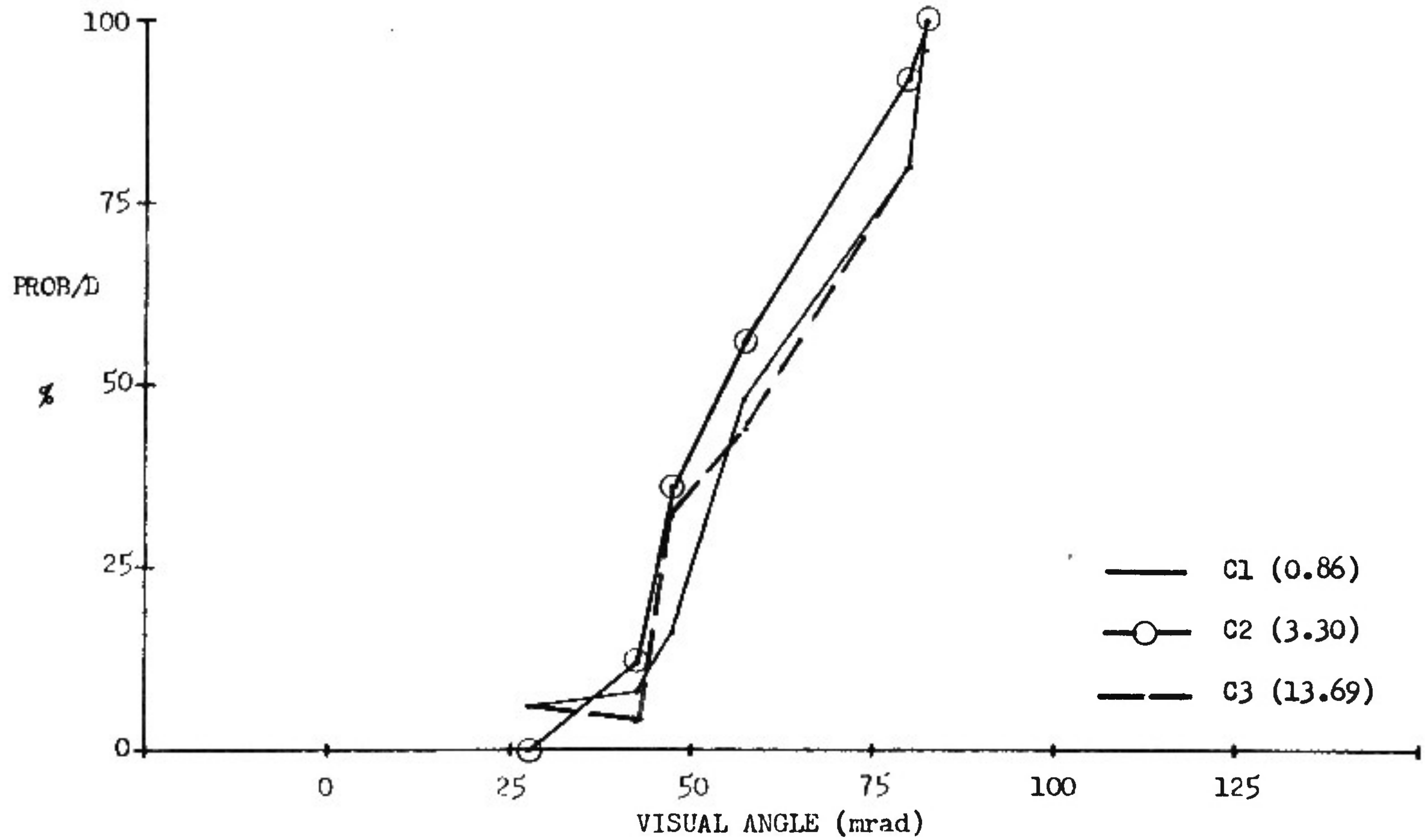

Figure 3. Uncorrected Probability of Detection — Square (S) Vs Visual Angle

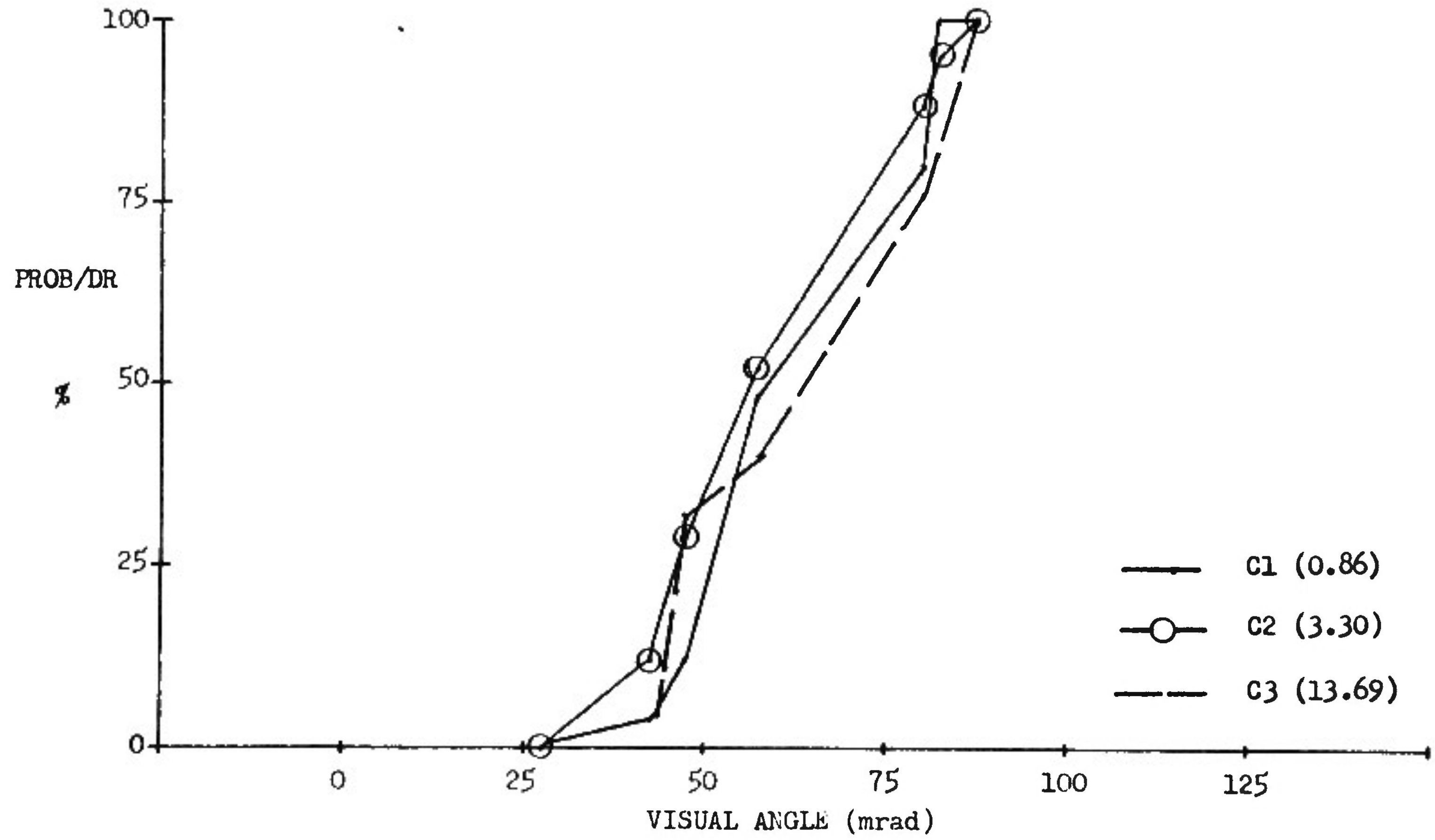

Figure 4. Uncorrected Probability of Detection and Recognition — Square (S) Vs Visual Angle

Correction for Chance

The importance of chance detection or recognition events was then allowed by applying standard corrections for chance to the raw data set[5]. The applicable formulation for such corrections is given by

$$P_{CORRECT} = \frac{P_{RAW} - P_{CHANCE}}{1 - P_{CHANCE}}$$

In the case of detection, it was assumed that the probability of chance detection (P_{CHANCE}) of any given figure of interest was on the average 25 percent. For the case of recognition, the task was judged to consist of two events, difference detection and figure recognition. As a first order approximation, chance detection was set a priori at a continued 25% level. For recognition, the probability of chance identification of an element was set a priori at 20%, there being five figures of interest over all detection treatments. In this way, the chance probability correction for detection was set at 5 percent corresponding to the product of the two event probabilities.

While one could argue that such assigned a priori probabilities might well vary with the figure of interest, it was judged that, with no firm evidence of this, the selected chance probabilities were fair estimates. The effect of such a correction was greatest in threshold probability areas for each observer task. That is, it was a transformation which eliminated threshold noise in the data sets. Considering the small data set (n=25), this was felt realistic.

Scale and Contrast

The significance of relative object scale in the detection and recognition tasks was clearly evident from even the raw response plots.

The expected significance of contrast in the experimental study tasks was not clear in the raw data and initial corrected probability response curves. This is indicated for the detection and combined detection-recognition tasks for each of the geometrical shapes in Figures 5, 6, 7 and 8. The presence of crossings as in the figures would have normally indicated the possibility of interactions between contrast and scale. However, the pattern of these figures as well as that similarly obtained for the combined detection and recognition task did not indicate a consistent feature to either an interaction or, more importantly, to a significant variation in response with contrast.

The importance of contrast in this study was evaluated using analysis of variance (ANOVA) and by application of Duncan's Multiple Range test. The results served to substantiate that the effect of contrast in this experiment was weak at best and evidently had been obscured by some other factors in the experiment. For triangles, contrast levels employed appeared not significant at all. For other figures, the role of contrast was more closely significant but not as had been expected in the experiment.

The reasons for this lack of contrast importance may be found in the mean level of illumination for each contrast level obtained with the projector apparatus used in this experiment. As measured, the mean illumination provided for each of the contrast levels was 193 footlamberts for low contrast; 198 footlamberts for middle contrast and 181 footlamberts for high contrast or about 187 footlamberts on the average. At this level, it appeared that, regardless of the perception of contrast change by any given observer, contrast played an insignificant role in detection and recognition

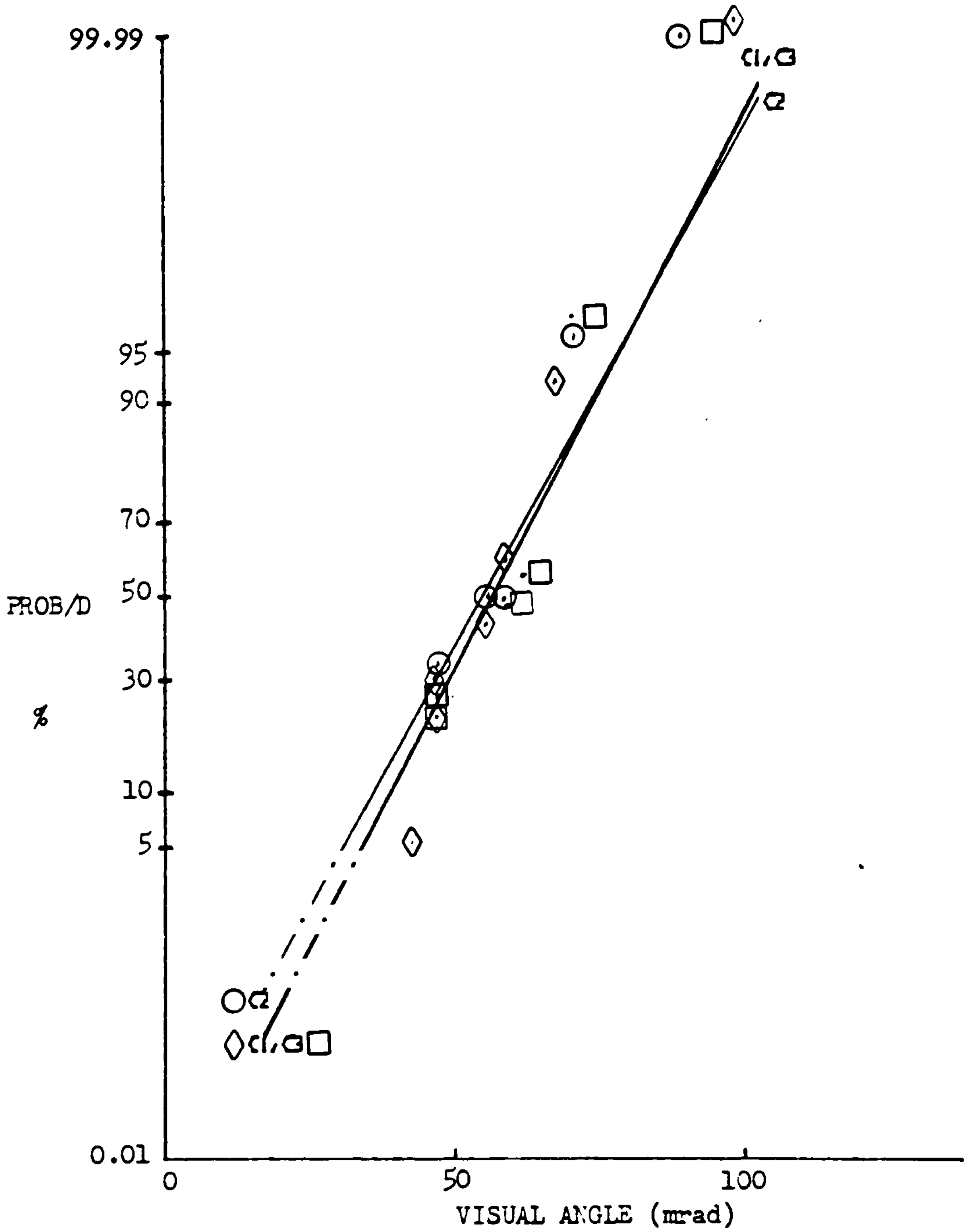

Figure 5. Uncorrected Probability of Detection — Triangle (T) Vs Visual Angle

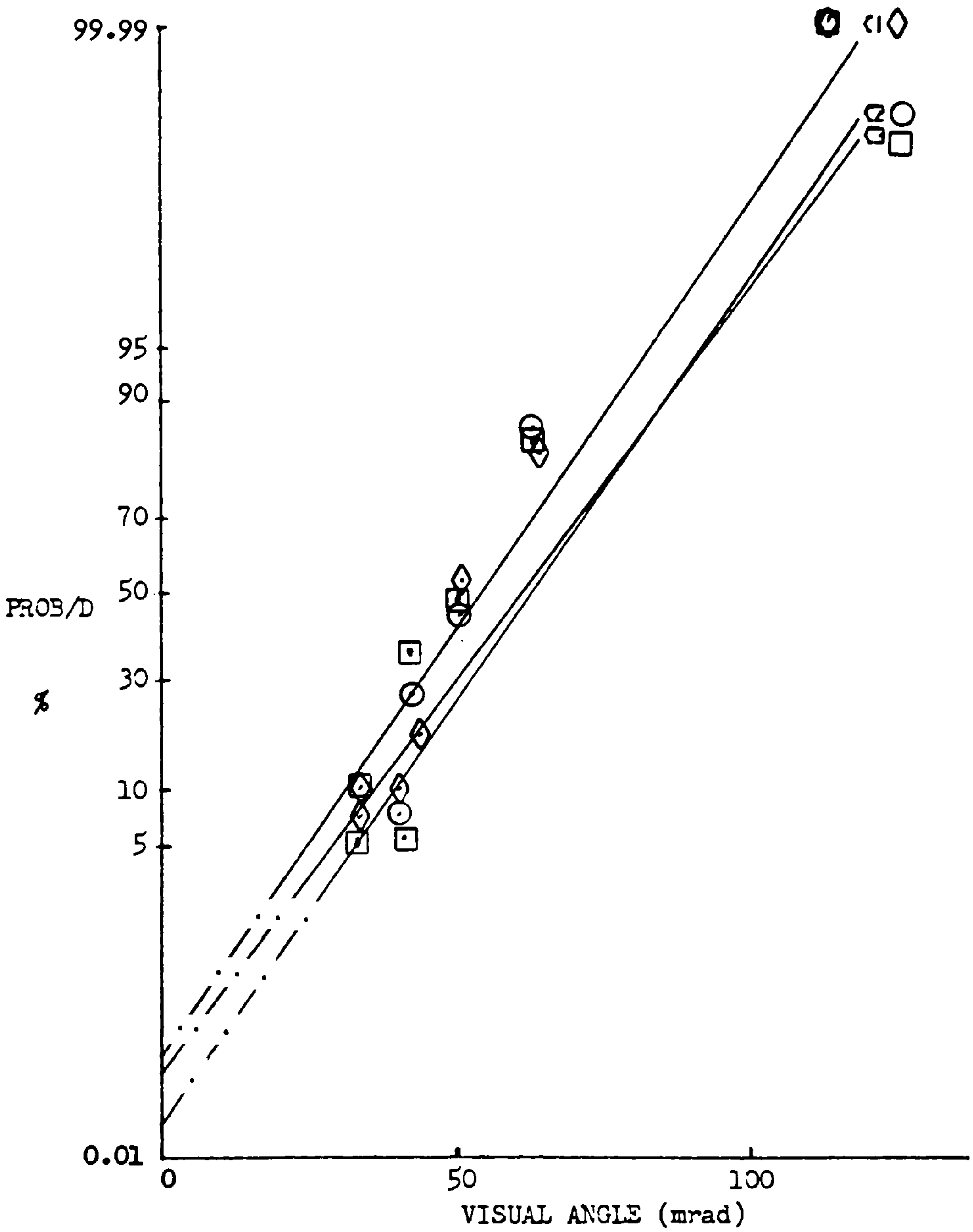

Figure 6. Uncorrected Probability of Detection — Square (S) Vs Visual Angle

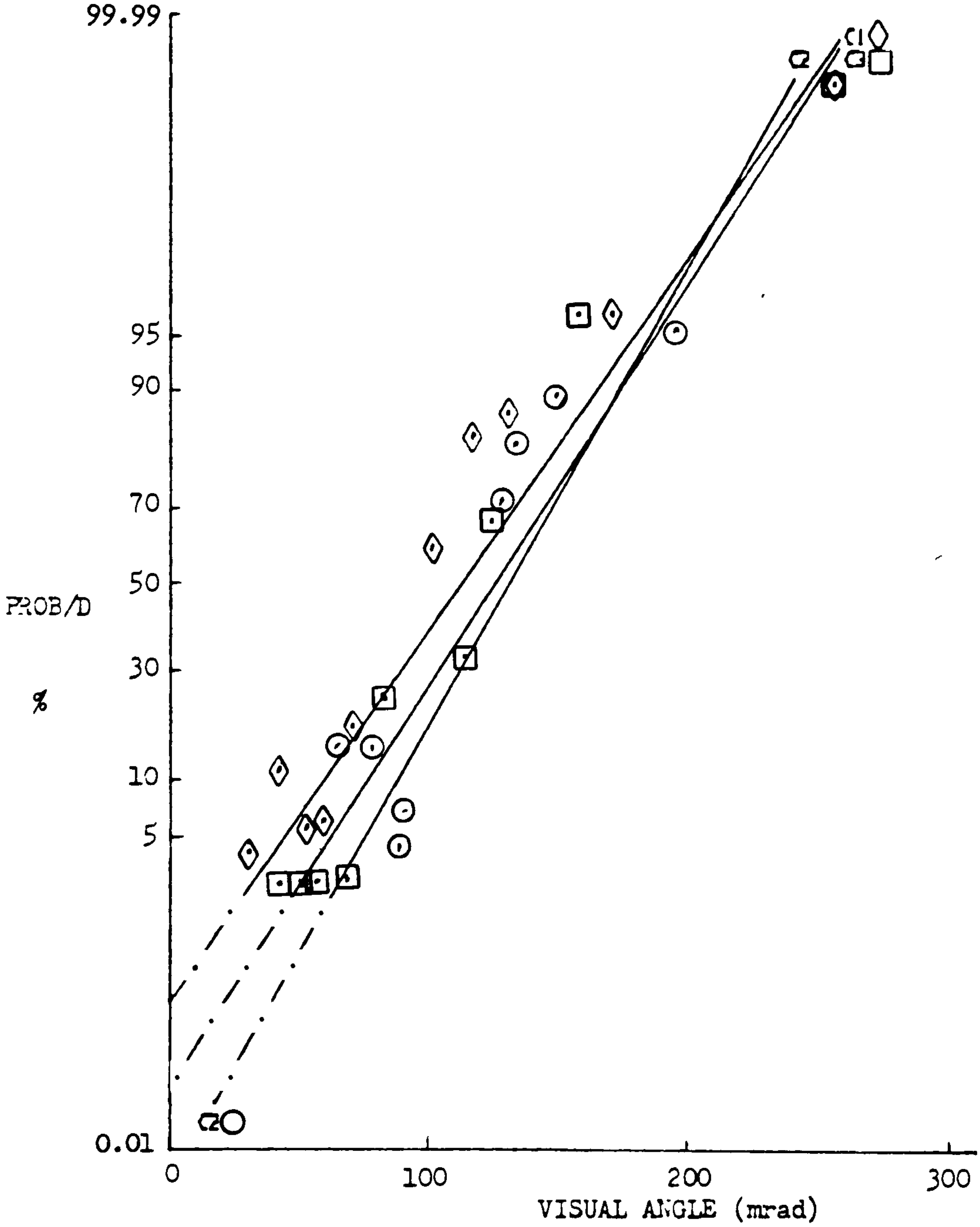

Figure 7. Uncorrected Probability of Detection — Hexagon (H) Vs Visual Angle

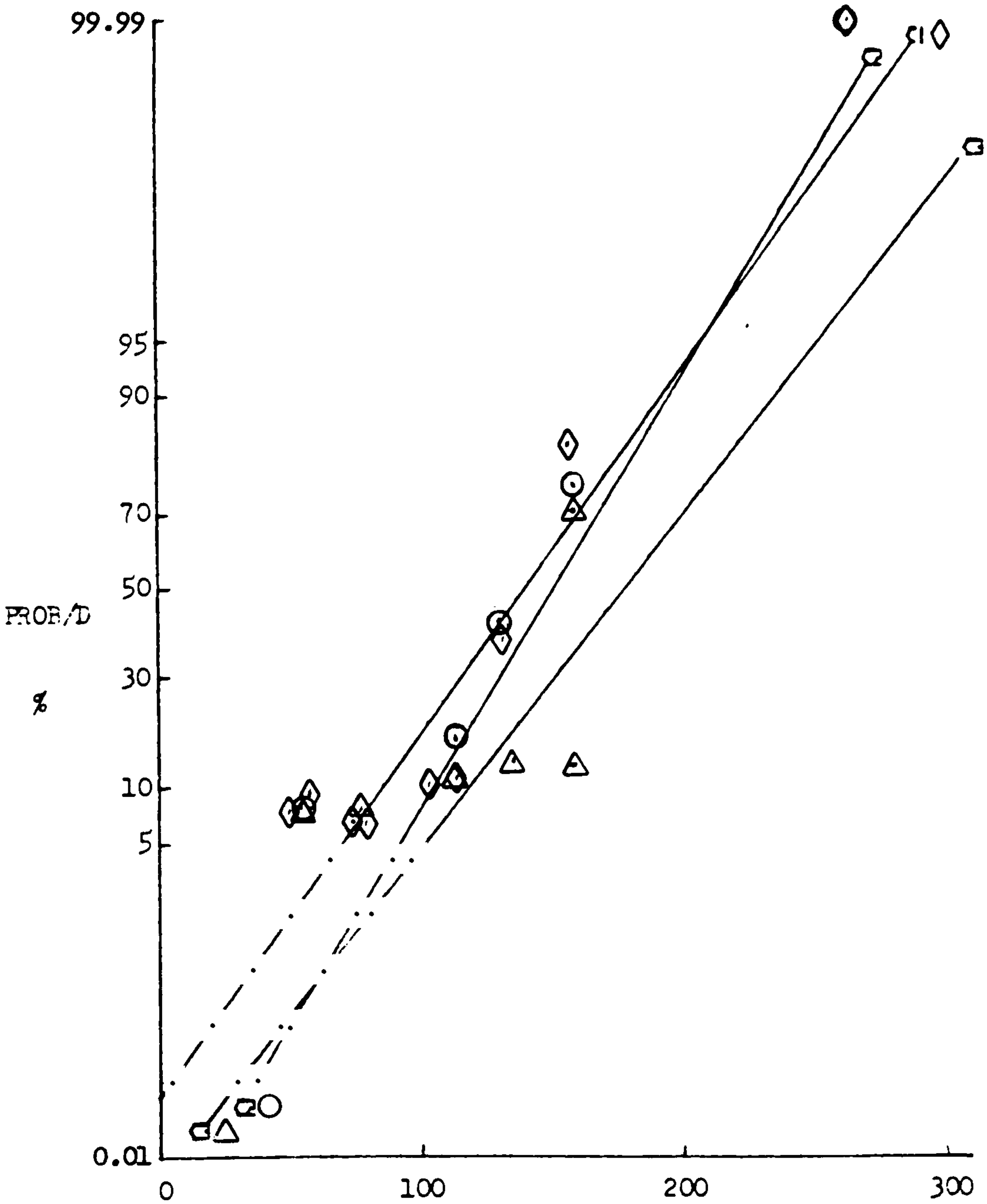

Figure 8. Uncorrected Probability of Detection — Octagon (O) Vs Visual Angle

tasks. Thus, for the purposes of subsequent analysis, the contrast level treatments were treated as replicates of sorts.

FOOTNOTES FOR CHAPTER IV

4. Owen L. Davies, ed., The Design and Analysis of Industrial Experiments (New York: Hafner Publishing Company, 1967), 46.

5. Lucien M. Biberman, Perception of Displayed Information (New York: Plenum Press, 1973), 189.

V. THE CONCEPT OF DIFFERENCE SPECTRA

The variation in response due to the geometrical figures employed in this experiment was clearly significant. The reasons for such significant variation have not been identified precisely, for in this factor the transitional visual capability between simple detection and combined detection and recognition occurs. Whether one has accepted a Gestalt global view of cortical recognition or the simpler perhaps retinal view of recognition, the characterization of the real difference cues in visual objects cannot be easily ascertained[6].

The figures in this study were of equal area but different complexity obviously. The hierarchy of relative difficulty in recognizing the targets used here varied as the degree to which the target considered approached the character of circular null objects.

The Difference Hypothesis

It was hypothesized from the onset of this experiment that retinal processes are more important than the Gestalt view central processes in establishing the differential character of such images as have been employed here. While some researchers have considered that perspective or linear convergence in target arrays may be important in establishing baselines for visual cues in varying target types[7], other baseline determinants have also been proposed.

Findings and conclusions relative to this shape factor aspect of recognition have not been agreed upon by assorted researchers. Helson and Fehrer

as well as others have demonstrated that among geometrical forms including rectangles, equilateral triangles, discs and squares of equal area and assorted contrast, rectangles and triangles respectively were the more easily recognized geometrical forms[8].

In this experiment, the geometrical figure hierarchy was seen to consist of triangles, followed by squares, hexagons and octagons. An intuitive explanation for such a hierarchy was evident in the relative amplitude of triangular pattern portions of these figures extending beyond the null object circumference. In order to depict this hierarchy, the percent correct identifications (for detection as well as combined detection and recognition) was plotted versus the relative size of the circular null object in each case. A summary of the results for uncorrected and corrected cases of detection and detection and recognition are shown in Figures 9, 10, 11 and 12. In these cases, the effect of contrast has been averaged over the figures involved.

The Fourier Approach

The intuitive difference of the figures used in this experiment can be more precisely specified using Fourier transform methods. The assumption is that the retinal mosaic can be considered and understood as a series of receptors. From this assumption, the meaning of a two dimensional Fourier transform takes on analytical significance in terms of what can be considered the difference spectrum. Performing a two dimensional Fourier transform on the figure combination shown in Figure 13 can be expected to yield a power spectrum difference having characteristics which are directly interpretable in terms of the properties of the retinal mosaic of the human visual system.

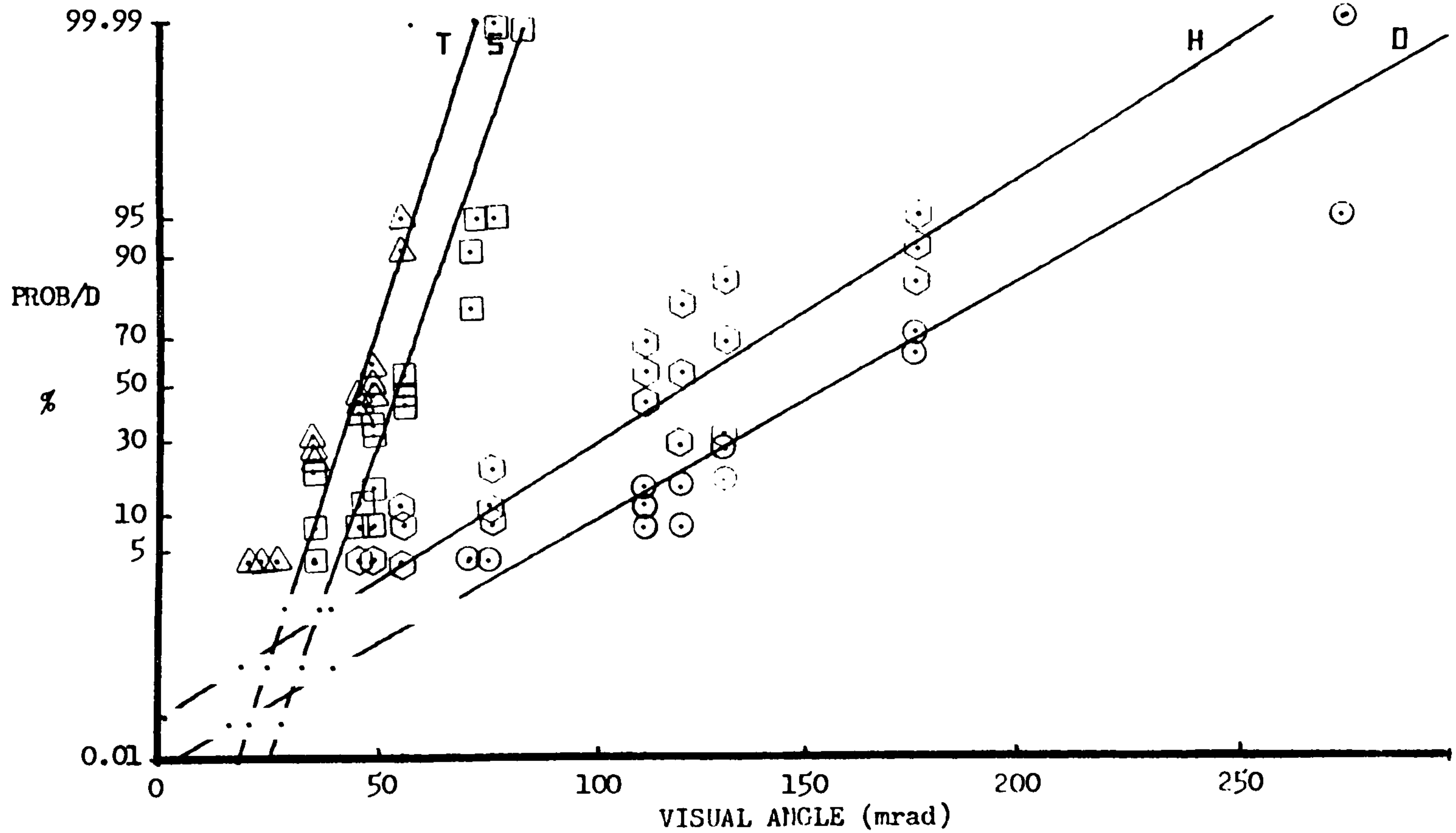

Figure 9. Uncorrected Probability of Detection Vs Visual Angle

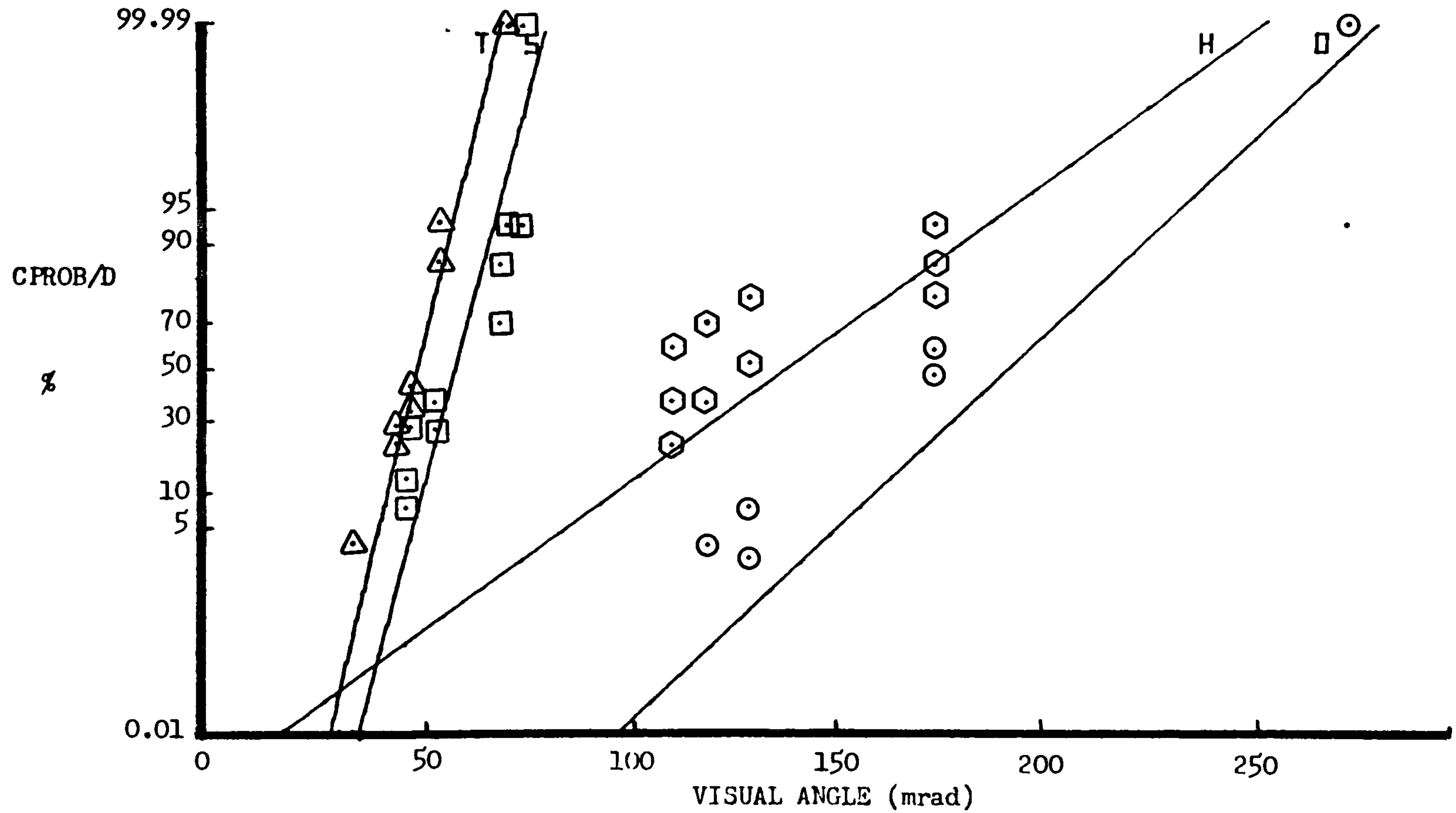

Figure 10. Corrected Probability of Detection Vs Visual Angle

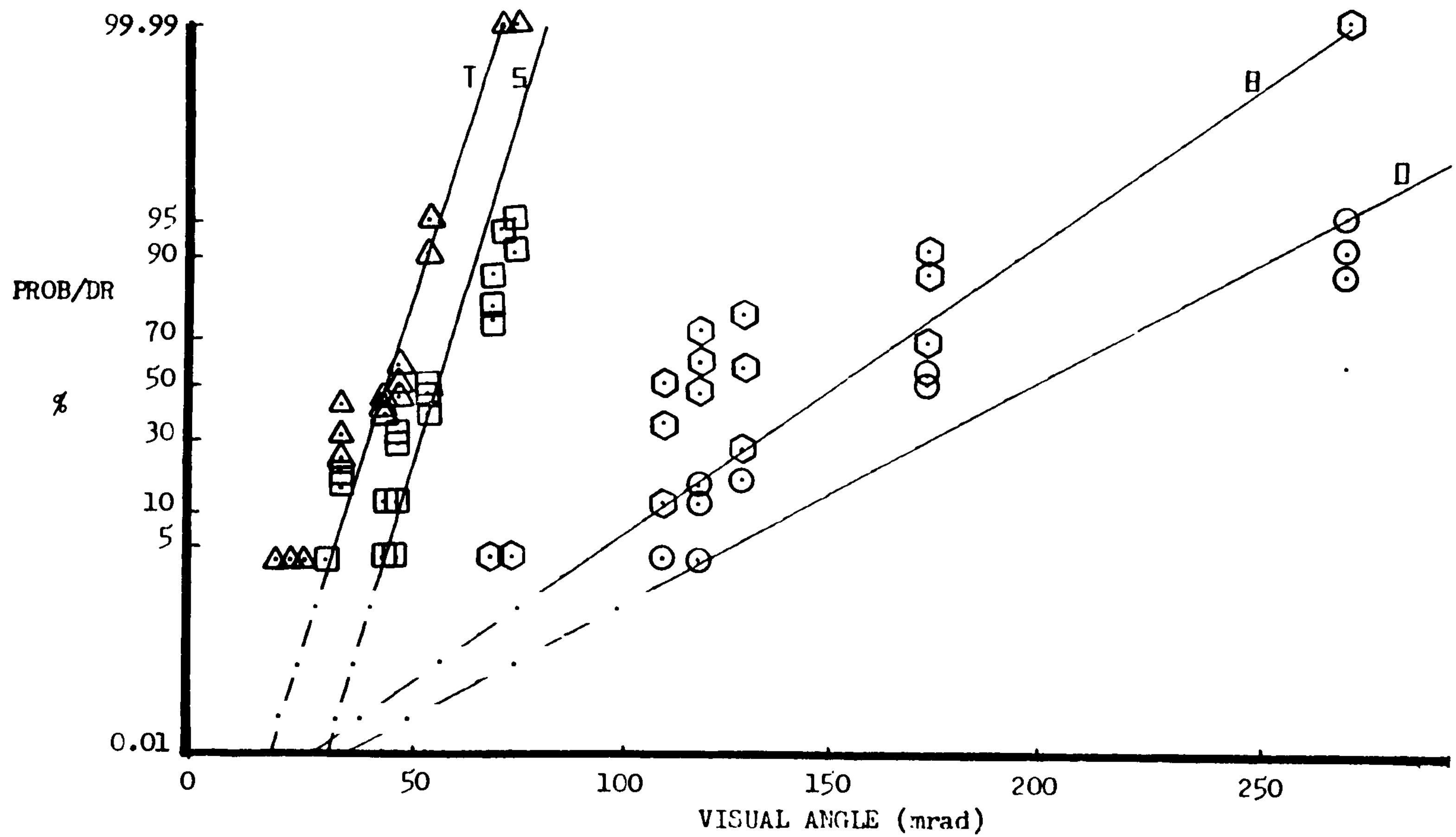

Figure 11. Uncorrected Probability of Detection and Recognition Vs Visual Angle

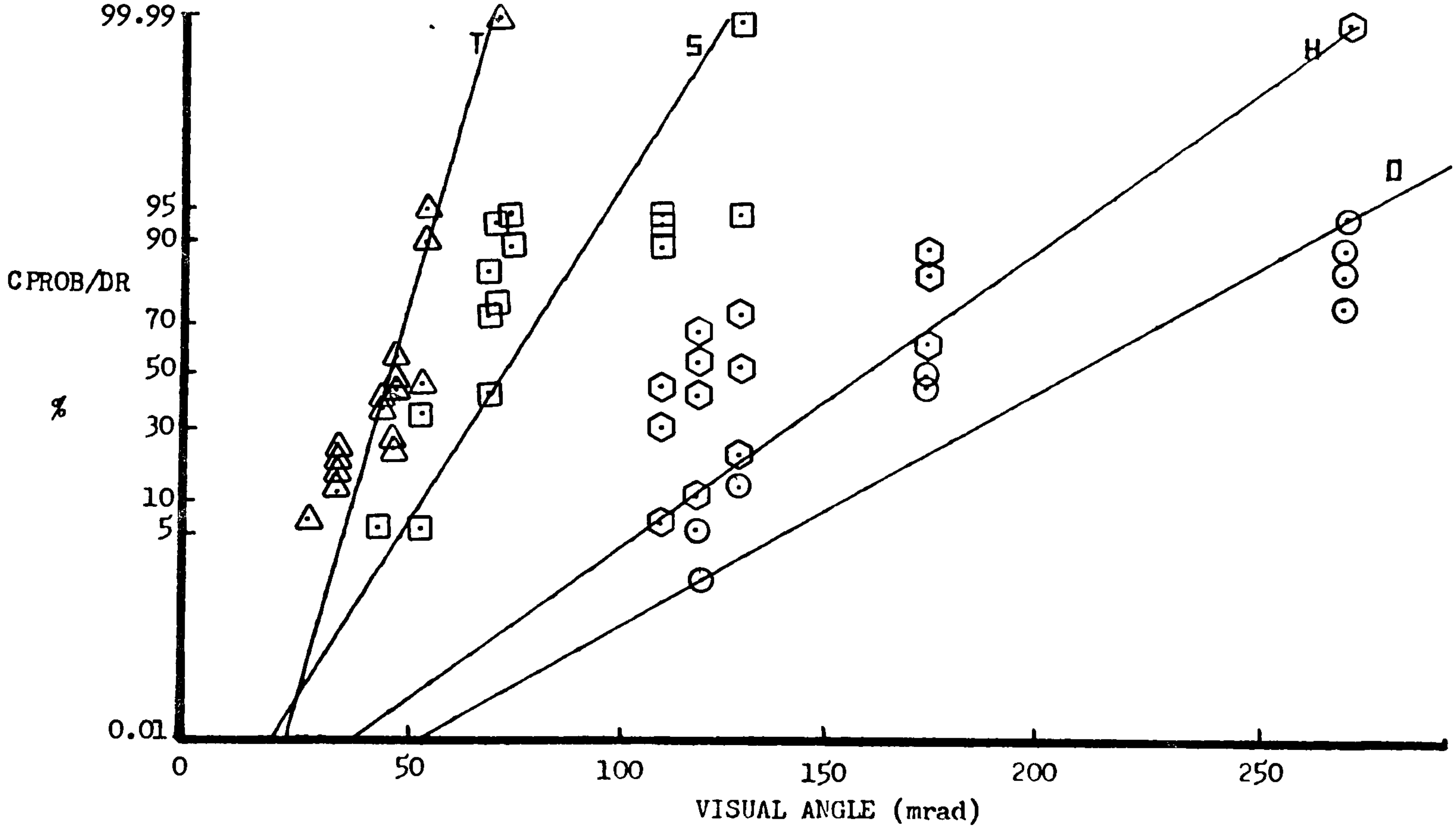

Figure 12. Corrected Probability of Detection and Recognition Vs Visual Angle

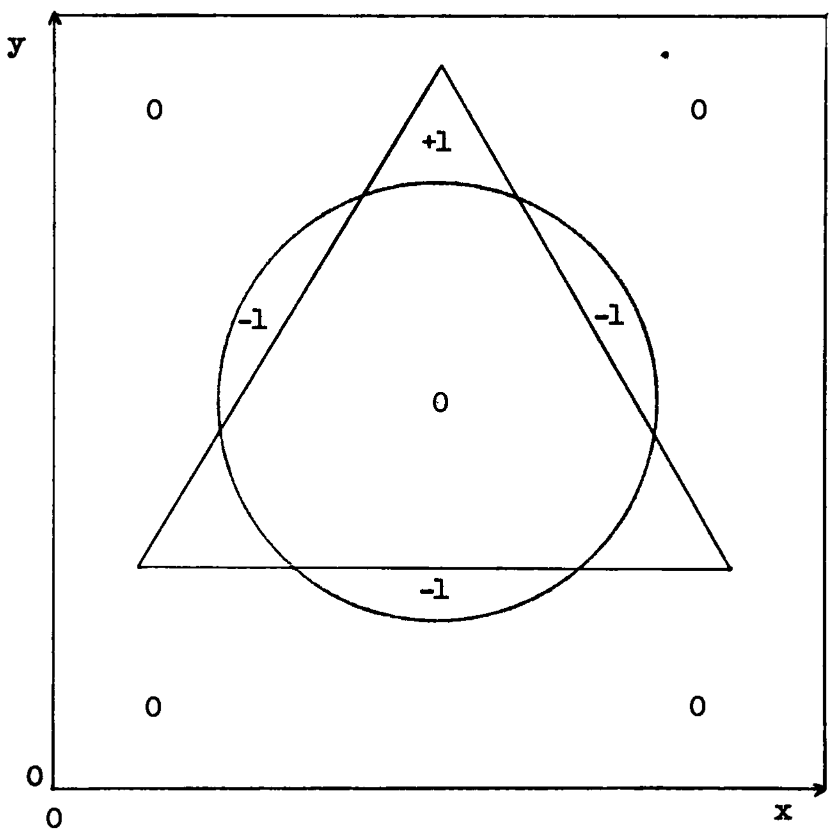

Figure 13. Fast Fourier Transform Encoding Circle — Triangle Comparison f(x,y)

The symmetry of the target types employed in this study leads directly to the notion of a power spectral difference as the real quantifier of comparison between two more or less related geometrical figures. The power spectra is much more likely to be a worthy predictor variable than geometrical figure parameters as perimeter, area or ratios of similar parameters.

The method by which the power spectral difference may be determined is fairly straightforward but demands the use of computer facilities with large capacity to carry out the required two dimensional Fourier transforms. In this experimental study, it had been planned to perform such transforms for the geometrical figures utilized. Computation difficulties coupled with limitations in available computer time and finite financial resources have made this goal unrealizable. Nevertheless, the method is described here and the results to be obtained can be specified with what is considered a high degree of confidence[9]. (See also Appendix.)

Considering Figure 13 which depicts the circle triangle combination of equal area overlaid center for center, one must assign values to the triangular projections and circular sector areas of +1 and -1 respectively (or vice versa). Other areas within the bounds of the two figures and outside such bounds in a defined 2^n grid system are assigned a value of 0. The grid system character is required for the two dimensional Fast Fourier algorithm. The accuracy of the method will be greater with respect to exact Fourier solutions as the value of n is increased.

Difference Spectra Predictor Variables

The output of such a two dimensional Fourier analysis may be considered as the power spectral difference between two compared targets.

The similarity or dissimilarity of the compared targets will be reflected by the method described as a characteristic "fingerprint" difference spectrum. Such a fingerprint power spectrum may be considered somewhat simplistically, perhaps in one dimension or more properly one angular orientation of such paired targets. Fourier comparisons averaged over all such angular orientations can be expected to yield power spectra in which target pairs differentiability is determined by the characteristic spectral difference of such paired target types. The ability of human observers to detect differences in such paired targets can be considered in terms of a filtering action implied by the morphology of the human retinal receptor array and by higher order cortical integrative mechanisms also important in the visual process[10]. The nature and consequences of such a bandpass frequency character in human vision has been studied in various contexts[11]. The applicability of such a concept has been demonstrated for practically oriented pictorial photography by Granger and Cupery[12] as well as in somewhat less practical experimental circumstances in the recent literature[13].

FOOTNOTES FOR CHAPTER V

6. Overington, Vision and Acquisition, 81.

7. Ibid, 82.

8. Ibid, 82.

9. Edward M. Granger, "Specification of Color Image Quality" (unpublished Ph.D. dissertation, The University of Rochester, 1974), p 4.

10. Ibid, p 5.

11. Otto H. Schade, "An Evaluation of Photographic Image Quality and Resolving Power,", JSMPTE, 73 (Feb., 1964), 81-119.

12. E. M. Granger and K. N. Cupery, "An Optical Merit Function (SQF), which Correlates with Subjective Image Judgements," Photogr. Sci. Eng., 16, 221 (1972).

13. G. Hanske, U. Lupp and W. Wolf, "Matched Filters — A New Concept in Vision," Photogr. Sci. Eng., 22, 59 (1978).

VI. SUMMARY AND CONCLUSIONS

This experimental study has shown that the ability of human observers to detect and recognize different given target forms varies as a function of scale and target pair complexity. The known and well-studied variation in human visual capability with variation in presentation contrast was not a statistically significant contributor to the measurements made in this study.

A method has been described by which the differences in target pair complexity may be categorized using Fourier analysis. More importantly, the likely relation of such difference spectra and human visual capabilities has been addressed and important questions in this regard implied but left unanswered in this work.

The ability of human observers to detect and to recognize known geometrical figures employed in this study has been shown to be ordered in a hierarchal manner. This hierarchy is most likely related to an inherent capability of the human visual system. Such a capability appears to be a more or less ordered continuum which is functionally relatable to fundamental differences in Fourier derived difference spectra for target pairs considered. Proper interpretation of such difference spectra may lead to a clearer understanding of perceptual differences within target type classes and among varying configuration targets as well. Such an understanding might well serve to indicate the bounds under which given target classes may be used to evaluate optical systems intended for a

specific purpose. It might well be possible that, for a given optical system product, certain target types are more representative of given required detection and recognition tasks expected of human observers than other target types. If this could be shown as the case, it would follow that at least a portion of the correlation discrepancy between optical system testing and evaluation and human visual capabilities to interpret the end products of such optical systems would be eliminated. This in itself would constitute a very desirable result.

VII. RECOMMENDATIONS FOR FUTURE WORK

The results obtained in this study indicate that considerable merit lies in examination of the relationship between human visual system capabilities and target types of relatively simple, known character using techniques of Fourier analysis.

Numerous opportunities present themselves for further study in this area. Clearly, the experimental approach employed in this study should be able to address previously established characteristics of human visual response as a function of contrast level. With the hierarchy of target-type detection and recognition shown in this study, a more detailed study of contrast effects at appropriately lower illumination levels is desirable. Equally attractive as a subject of further study would be the assessment of human visual capabilities when imagery subject to known optical degradations is presented.

Perhaps most important in the opinion of this experimenter, the relationships between commonly employed photo optical test targets and the properties of the human visual system can be apparently successfully explored experimentally in a controlled fashion using relatively simple presentation techniques, routine statistical analysis tools and most powerful Fourier analysis techniques. The relation of simple test imagery to real imagery may also be explored within a framework limited by the capability of the human visual process.

VIII. APPENDIX

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By way of example, the magnitude spectral difference for two of the figure comparisons was computed using a 32 by 32 grid system. The comparisons selected were the circle-triangle and circle-hexagon figure pairs.

As shown in Figure 14a, the circle-triangle pair yielded with this analysis a relative magnitude spectral difference of apparent sinusoidal character. The main elements of the difference pattern and the predominant spectral difference content of the pair was concentrated within a region close to the array origin in frequency space. This was true of the magnitude spectral difference pattern taken axially in both of the frequency space directions, f_y and f_x, as illustrated in Figures 14a and 14b.

For the circle-hexagon figure pair, the same analysis procedure yielded a much more diffuse magnitude spectral difference pattern taken axially in both of frequency space directions, f_y and f_x, as is illustrated in Figures 15a and 15b. No predominant concentration of magnitude spectral difference was found near the array origin in either of the axial slices.

In these two figure pair comparisons, the different character of the two is clearly shown. Moreover, it can be expected as noted earlier in this paper that such contrasts would be heightened by the use of a finer grid analysis in each case. Most importantly, the characteristic difference in any figure pair case relative to the capabilities of the human visual system is depicted in the analysis. It is these differences which

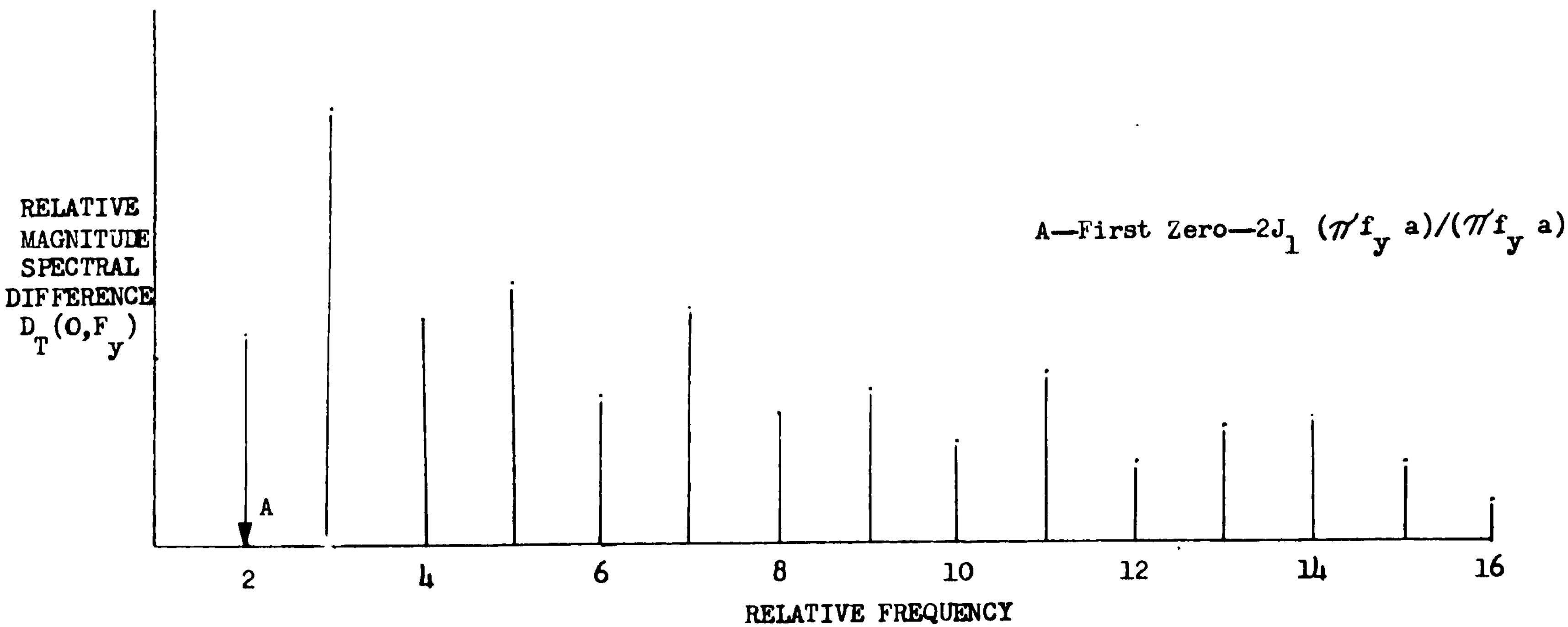

Figure 14a. Relative Magnitude Spectral Difference Vs Relative Frequency (fy) — Circle-Triangle

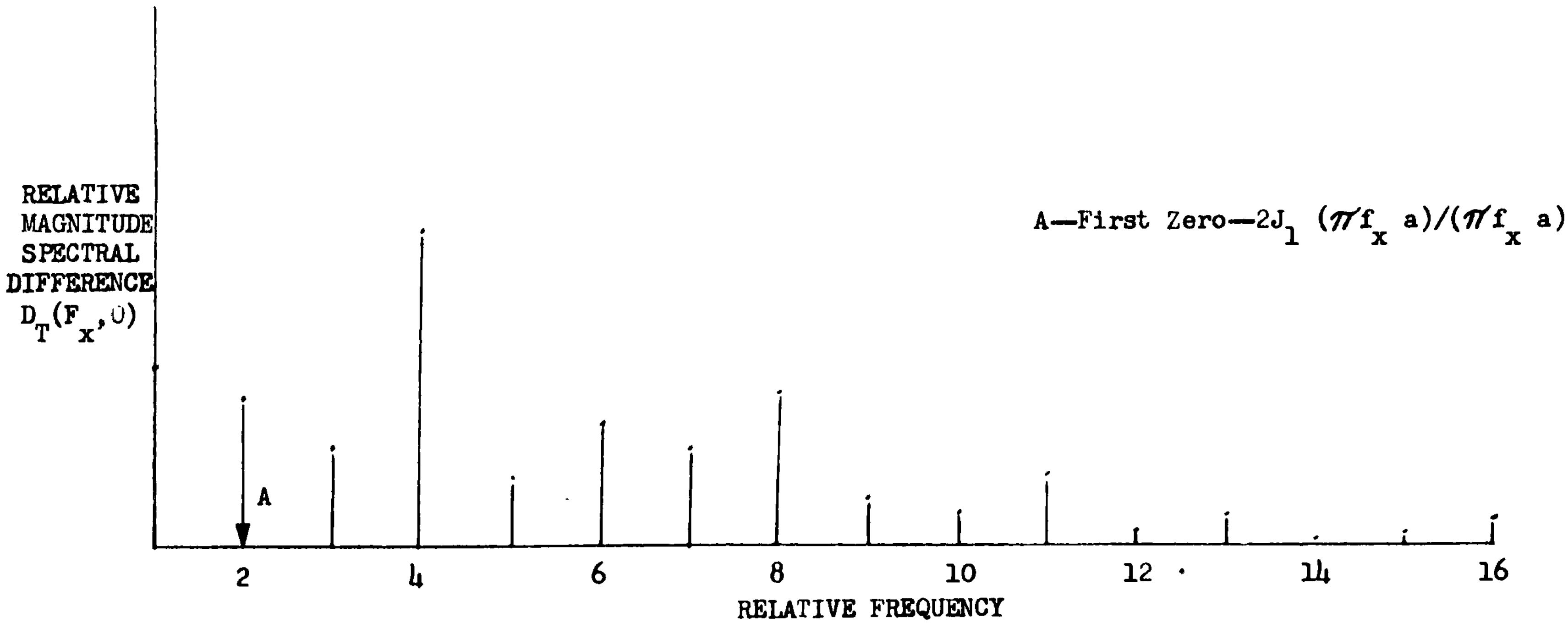

Figure 14b. Relative Magnitude Spectral Difference Vs Relative Frequency (fx) — Circular-Triangle

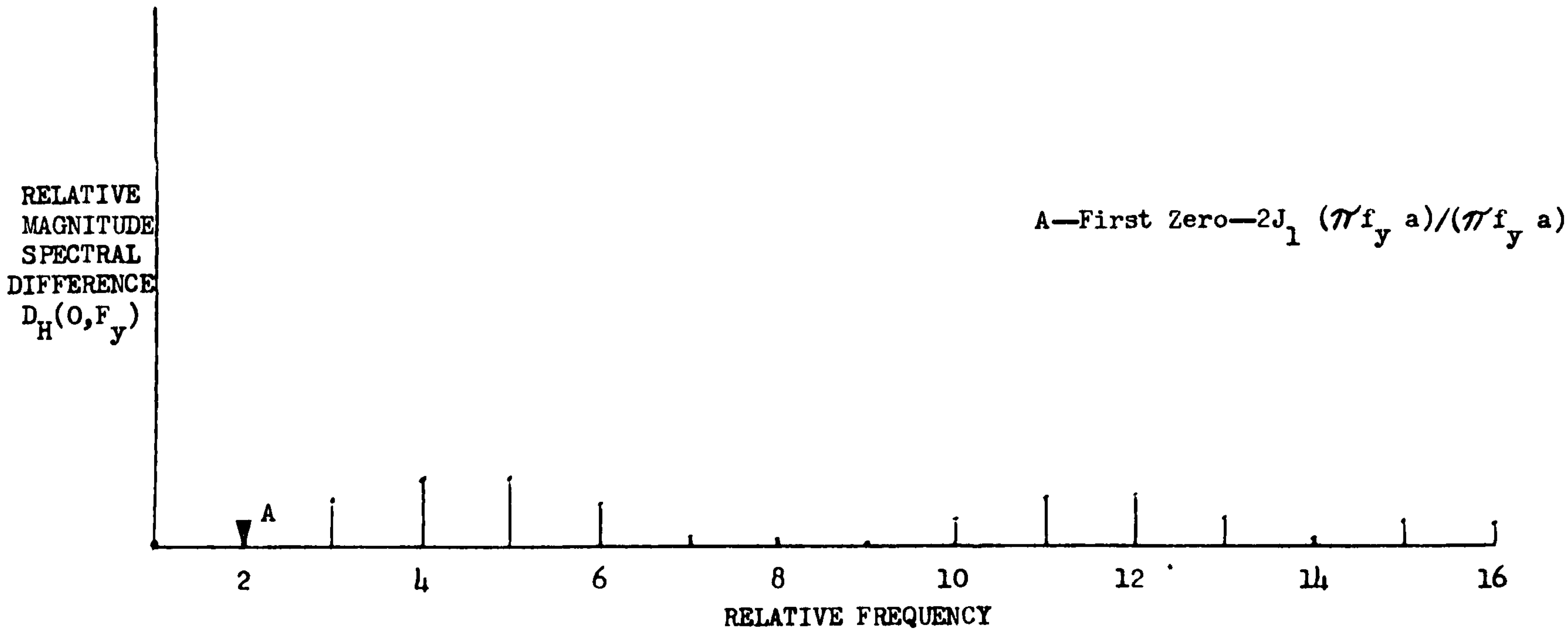

Figure 15a. Relative Magnitude Spectral Difference Vs Relative Frequency (fy) — Circle-Hexagon

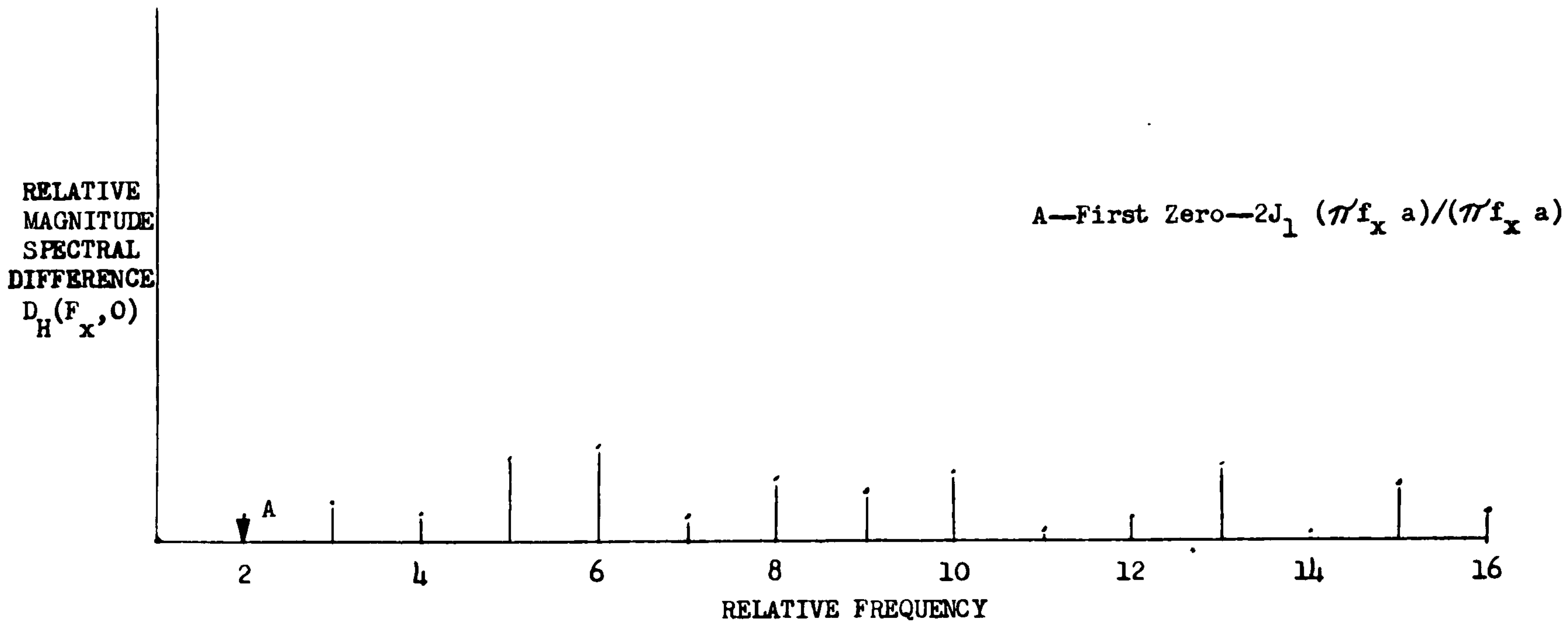

Figure 15b. Relative Magnitude Spectral Difference Vs Relative Frequency (f_x) — Circle-Hexagon

can be considered as a likely underlying cause of variable comparative facility in the separate detection and recognition tasks required of the observers in this study.

The comparative differences in the figures depicting detection and recognition tasks can be related to the location of the predominant spectral differences in the figure pairs. That is, one figure pair relative to another may be closer to the frequency space origin or more concentrated over that frequency space range which is characteristic of the human visual system capabilities. Similar frequency space patterns of variation for other figure pairs can be shown to be related to the detection and recognition scale continuum as well.

One method of relating such figure pair measures, one to another, and of relating the comparison to the human visual system is clear. Entering the cumulative distribution plots for the figure pairs of interest, the ratio of abscissal intersects for each of the figure pairs considered will be analogous to the ratio of abscissal distances required to encompass predominant power spectral contents of the pairs of interest. Using such a tactic, the filtering action of the human visual system can be included in consideration and the intuitive relative recognizability of certain figure pairs clarified.

It must be recognized here that a fine level of analysis is desired both in establishing the location and separation of detection and recognition distribution for each figure pair being studied. Equally desirable is the use of a grid system of finer character than 32 by 32, giving a more accurate depiction of the difference spectrum involved in each case.

Even at the analysis level here, the differences in the respective figure pairs become evident. This is a significant result.