AD-778686

1. Report No. CG-D-78-74	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SHAPE CODING FOR DAYMARKS		5. Report Date March 1974
		6. Performing Organization Code
7. Author(s) J. H. Hill & C. N. Abernethy		8. Performing Organization Report No. DOT-TSC-CG-72-4
9. Performing Organization Name and Address Department of Transportation Transportation Systems Center Kendall Square Cambridge MA 02142		10. Work Unit No. R2081/CG 208
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation United States Coast Guard Office of Research and Development Washington DC 20590		13. Type of Report and Period Covered Final Report 1 July 1971-30 June 1972
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Three experiments were conducted on form discrimination to select and evaluate forms for shape coding of daymarks. The discriminability of the forms was measured by the frequency with which each form was identified correctly and the frequency with which each form was confused with the other forms under evaluation. The form, in addition to the presently used can and nun, that was found sufficiently discriminable for use as a shape code for daymarks is the hourglass or a cylinder of equal aspect ratio.

17. Key Words Form Discrimination Daymarks	18. Distribution Statement DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22151.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	42	

PREFACE

The work described in this report was performed as a part of the Buoy Detection and Recognition Studies project sponsored by the United States Coast Guard, Office of Research and Development. The object of this work was to evaluate a number of shapes as potential shape codes for navigational daymarks.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Preceding page blank

LIST OF TABLES

1.0 INTRODUCTION

Navigational buoys designed for use in daylight are shape coded in order to convey to the mariner specific information about the water in the immediate vicinity. The nun and the can daymarks, which are about equal in number, account for almost 95 percent of the daymarks now in use. The other five percent of the daymarks are a mixture of shapes which have evolved over the past two hundred years or so, and for which the meanings of their shape codes are not definitively established. Although the number of these daymarks is relatively small, the problem of establishing a formal shape-code for them is a real one, since these daymarks play a very important role in the safety of navigation.

In addition to the requirement of being easily recognized, shapes used for coding daymarks must fulfill construction and operational handling requirements[1] as follows:

1. Daymarks, to be omnidirectional, must be rotationally symmetrical about the vertical axis.
2. For a given effective range of visibility, the silhouettes of all daymarks must have the same area.
3. Any form used for coding daymarks must provide for enclosing a radar reflector and for mounting a light atop the daymark.
4. To ensure ease of handling by the buoytenders, no part of the daymark can have a lateral dimension greater than that of the base width.
5. The basic shape against which all others are to be evaluated is the sihouette of a can daymark, a rectangle with a height to width ratio of 2:1.

With these requirements in mind, the literature on recognition of geometric forms was reviewed for guidance on the selection of (1) the geometric forms most likely to be applicable in the design of daymarks, and (2) the measure to use for the evaluation of the recognizability of the forms selected.

2.0 LITERATURE REVIEW

The measures of recognizability used in previous studies can be divided into two classes: direct and indirect. The indirect measures that have been used include reaction time[2] and sorting time,[3] whereas the direct measures require the observer to name the shape presented, and the frequency of errors or correct responses is taken as the measure. For purposes of this study on the shape coding of daymarks, a direct measure was used, since knowledge of the extent to which the various forms are confused must be determined. The correct recognition of a form depends not only on the form itself, but also on the other forms from which it must be discriminated.[3,4]

The dearth of geometric forms applicable to the coding of daymarks was revealed by the review of the literature. The reasons for this are immediately apparent when the general conclusions that have been derived from previous work are considered. The information contained in a form is concentrated at its contours and is further concentrated at those points on the contours where their directions change most rapidly.[6] Form discrimination varies inversely with the relative quantity of information contained in the form; for shapes of a given area, difficulty of discrimination increases with the length of the perimeter.[5] The amount of information that can be used effectively for purposes of shape coding is limited by man's perceptual capacity, and any excess information is perceived as "noise".[6] Complex forms have also been found to be more difficult to remember[7,8] and more difficult to name[7,9] than simple forms. In view of their finding, complex forms are contraindicated for shape coding daymarks which must be easy to remember and easy to name.

In view of these conclusions, simple geometric forms such as the circle, triangle and rectangle appeared the most likely candidates for shape codes. In previous investigations, however, circular figures were found to be much less readily recognized than polygons,[4,10,11] and figures with more than four sides were found to be confused with circles and with each other.[11]

On the basis of these findings and within the restrictions established by the construction and operational handling requirements, the seven basic forms shown in Figure 1 were devised. Stimulus-Forms 1 through 5 are composed of various combinations of isosceles triangles and rectangles which should be most likely candidates for shape codes for daymarks. Insufficient data were found in the literature, however, to give unqualified support to this conclusion. For example, no data were found on the discrimination of isosceles triangles from rectangles as a function of the apex angle of the isosceles triangle. The absolute discrimination of isosceles triangles of equal areas, however, was found to vary with the size of the apex angle, whereas the absolute discrimination of rectangles under the same conditions was found not to vary with the aspect ratio.[5]

Before isosceles triangles and rectangles of specific dimensions could be selected for use in the composition of forms for coding daymarks, it was deemed necessary to determine the effects of apex angle and aspect ratio on the discrimination of isosceles triangles from rectangles. With these data in hand, potential code forms composed of appropriately selected isosceles triangles and rectangles would be evaluated as potential coded daymarks.

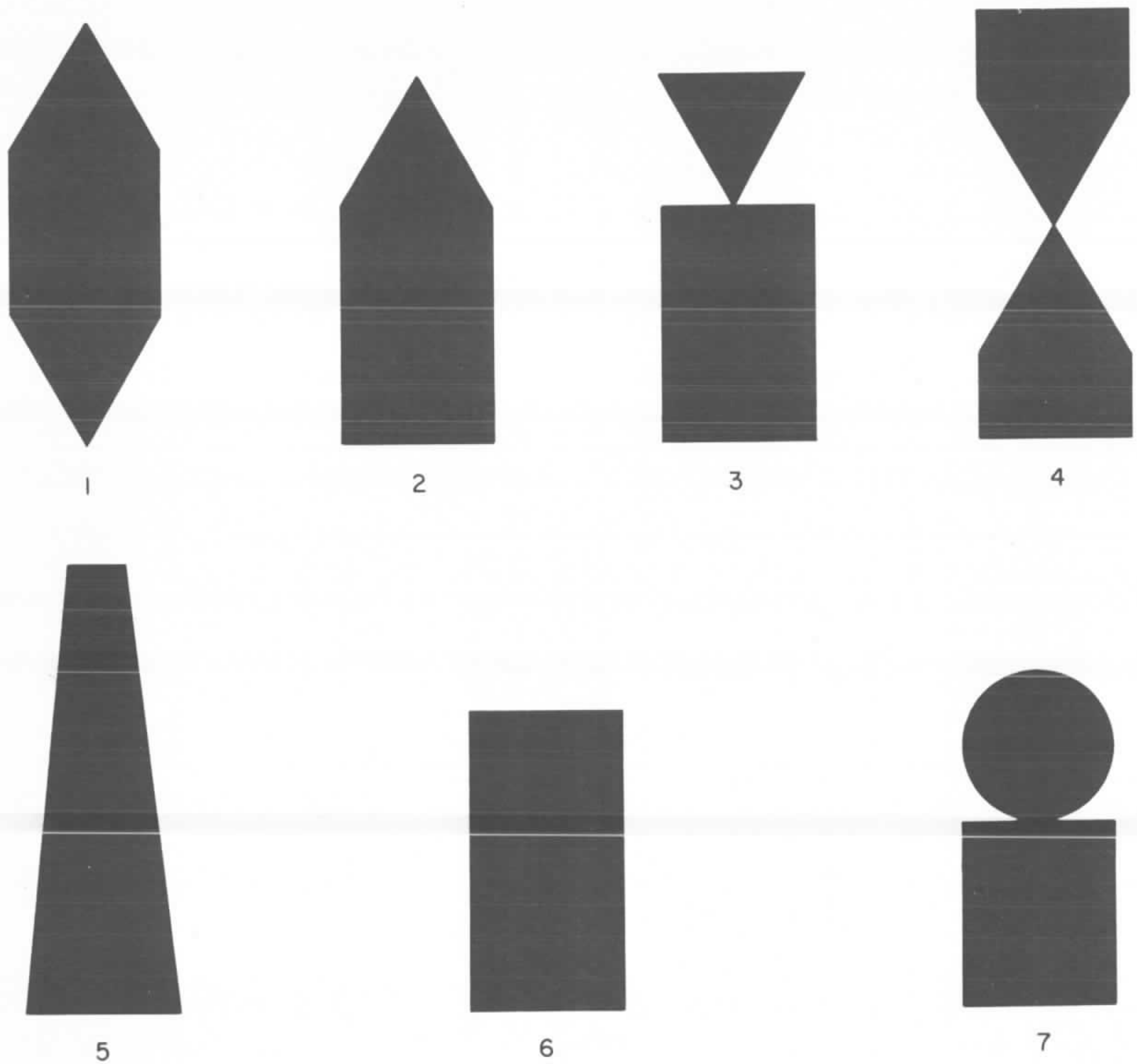

Figure 1. Seven basic forms to be evaluated as codes for daymarks.

3.0 EXPERIMENT I

3.1 PROBLEM

The purpose of Experiment I was to determine the effects of the apex angle of isosceles triangles and the aspect ratio of rectangles on the discrimination of these two forms. The frequencies of right and wrong response-forms were recorded as a function of the luminance of the stimulus-form presented. These data were used to determine for each form the luminance required for 75 percent right responses which was defined as the form-discrimination luminance threshold. The percentage of times each incorrect response-form was made for each stimulus-form presented was defined as the confusion index.

3.2 STIMULUS-FORMS

The 15 stimulus-forms used in Experiment 1 are shown in Figure 2. The bases of the five triangles are all equal, and, when presented to the subject, they subtended a visual angle of 30 minutes of arc. The increments in the heights of the triangles are equal and form apex angles of 60, 40, 30, 25 and 20 degrees. The other ten stimulus-forms are two sets of five rectangles. One set of five rectangles is of correspondingly equal areas and bases and the other set of five rectangles is of correspondingly equal areas and heights. The triangular and rectangular forms were drawn, photographed and appropriately reduced in size for mounting in 35 millimeter slide holders. Thus, five high-contrast white on black transparencies were made of each form for a total of 75 transparencies in all. To control the transmission of the transparencies, each of the five transparencies of each form was sandwiched with a Kodak Wratten neutral density filter of 0.1, 0.2, 0.3, 0.4, or 0.5 log units density which allowed each of the 15 stimulus-forms to be presented at five luminances.

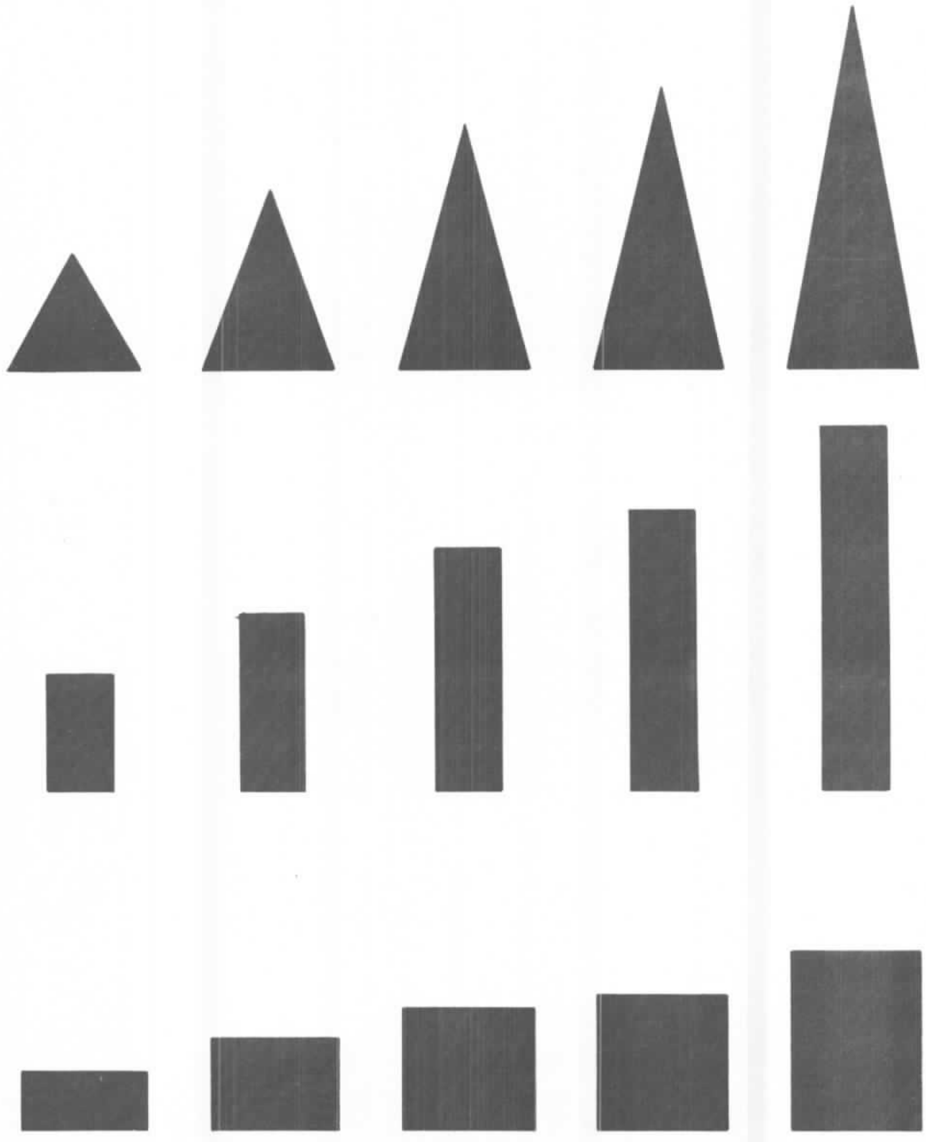

Figure 2. The 15 forms used to evaluate the effect of apex angles on the discrimination of isosceles triangles from rectangles of equal areas and bases and rectangles of equal areas and heights.

3.3 APPARATUS

A random access Kodak Ektagraphic Projector, Model RA-960, was used to present the forms to the subject. The projection lamp was operated at 3.5 amperes dc to provide ripple free illumination of the transparencies. To ensure even illumination across the transparency in the projector, one sheet of flashed opal glass was mounted between the condenser lenses and another was mounted after the condenser lenses of the projector. As a result, the luminance distribution of the light projected on the screen was constant within ± 0.02 log millilamberts, as measured with a Spectra Spot meter. A Linhof Technika shutter was mounted on the end of the lens barrel of the projector and set for a shutterspeed of 1/100 seconds. The accuracy and reliability of the shutter speed was confirmed by measuring the flash duration with a 1P39 phototube and a Tecktronic type 547 oscilloscope. A Wratten neutral density filter of appropriate density was mounted in front of the shutter to adjust the overall flash luminance as required by the subject's threshold. The stimulus forms were presented to the subject by back-projecting them on a screen made of Keuffel and Esser Albanese tracing paper.

The subject was seated 12 feet in front of the projection/ adapting screen. The screen, as viewed by the subject, was a white disc 12 degrees in diameter with a neutral gray rectangular surround which subtended 37 degrees in the vertical and 19 degrees in the horizontal. The white adapting screen and the gray surround were front illuminated by 12 GE Cool White florescent tubes operated at 3.5 amperes dc. The florescent tubes were mounted six to a side 45 inches in front of and even with the vertical edge of the gray rectangular surround. No variation could be detected in the luminance of the white screen.

3.3.1 Subjects

Two subjects, A and B, participated in Experiment 1. Both subjects had normal visual acuity; one wore corrective lenses.

3.3.2 Procedure

The subject was seated in the dark, 12 feet in front of the adapting screen and allowed to dark adapt for ten minutes. The adapting screen was then illuminated and the subject was allowed to light adapt for five minutes. During this second period, the subject was given the following instructions.

> "This experiment is a study of form discrimination. You are asked to identify a number of shapes as they are flashed on this projection screen in front of you. Each time the experimenter says "ready", you will present a shape to yourself by pulling on this shutter-release string when you are fixated and accommodated on the center of the screen. The form flashed in the center of the screen will be one of three kinds: a triangle, a "thin" rectangle, or a "fat" rectangle. You must make a choice after each flash and report your choice to the experimenter. The experiment will consist of a series of sessions each lasting approximately an hour with a rest period after about a half hour. Are there any questions?
>
> We will now begin with a series of flashes to familiarize you with the forms and to establish the light levels required for you to see the forms."

Following the five minute period of light adaptation, a practice series of at least 20 trials was run to familiarize the subject and to determine the value of the neutral density filter required to adjust the overall flash luminance as required by the subject's threshold. Then the appropriate Wratten neutral density filter was mounted in front of the shutter of the slide projector, and the regular series of trials was started.

On each trial one of the 75 35-millimeter slides of the forms in the random access projector was selected by the experimenter, the shutter was cocked, and the subject was given the "ready" signal. When the subject was appropriately accommodated and fixated on the center of the screen, he released the shutter and reported his judgment of triangle, thin rectangle, or fat rectangle. This procedure was repeated for each trial of the series. The series for each subject consisted of 1000 presentations of the forms, that is, ten replications of each of the ten rectangular forms at each of five luminances and 20 replications of each of the five triangular forms at each of the five luminances. The 1000 trials of each series of trials were arranged in a computer-generated random sequence.

3.4 RESULTS

The threshold for form discrimination was defined as the luminance required for 75 percent correct recognition. The average threshold luminance for the three types of forms are shown as a function of area of the forms in Figure 3. Although in general the thresholds for the thin rectangles were higher than those for the fat rectangles and the thresholds for the triangles were higher than those for the thin rectangles, the differences are so slight as to be of little or no practical significance.

When it was found that the luminance thresholds were of little practical value, the incorrect response-forms made for each stimulus-form were tabulated for all five luminances of presentation. From these data confusion indices were calculated for all forms. The extent to which the three types of forms were confused by both subjects is shown in Table 1. Each entry in Table 1 is the percent of the responses-forms that were triangle, thin, or fat in response to the presentations of each of the 15 forms. The data for the wrong responses to the presentation of the triangles are also shown graphically in Figure 4. As can be seen in Figure 4, the percent confusion for the thin and fat responses combined is minimal when the apex angles were between 30 and 60 degrees.

The data for the wrong responses of triangle and thin or fat rectangle to the presentation of the fat and thin rectangles are shown graphically in Figures 5 and 6 respectively. The straight lines were fitted by the method of least squares. In all cases, the amount of confusion varies inversely with the height of the forms.

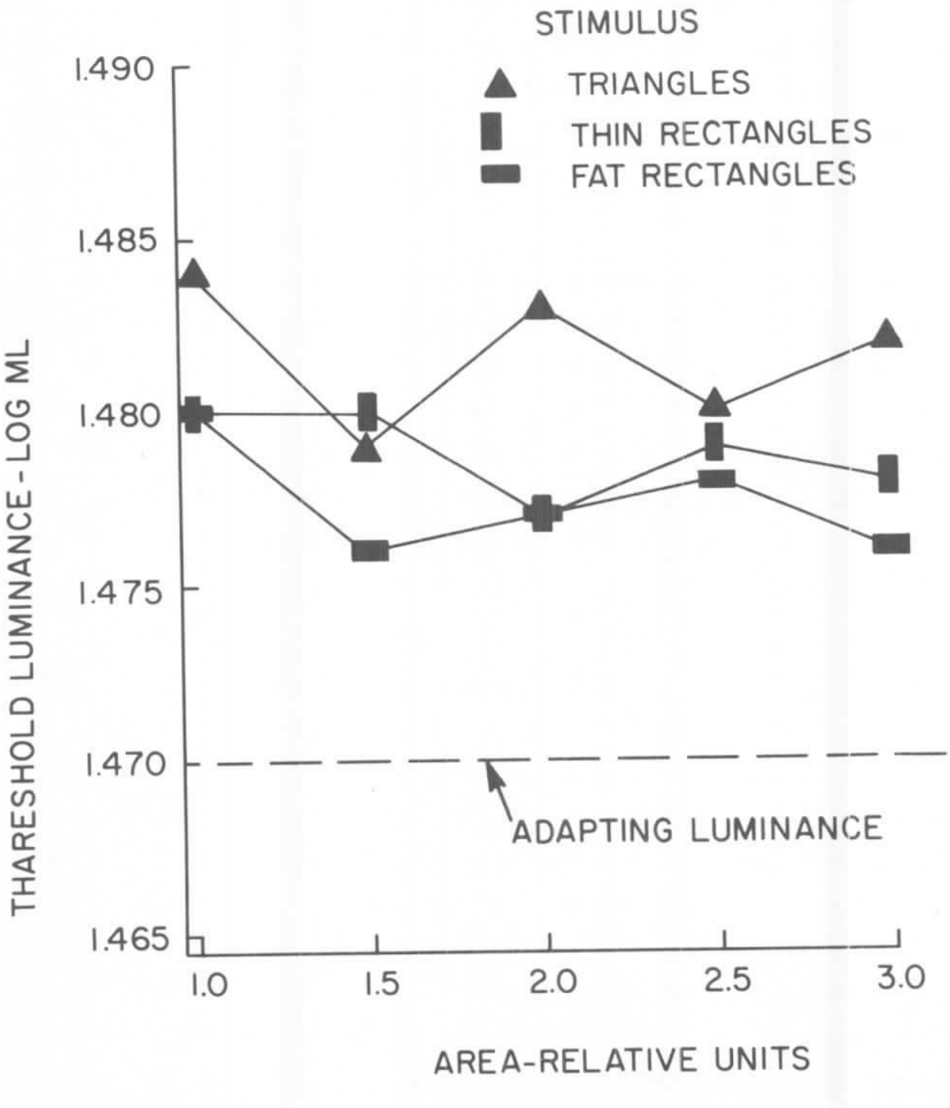

Figure 3. The discrimination threshold-luminances for isosceles triangles, thin rectangles, and fat rectangles as a function of the areas of the forms.

TABLE 1. THE PERCENT RESPONSES OF "TRIANGLE", "FAT", AND "THIN" AS A FUNCTION OF THE STIMULUS-FORM PRESENTED IN EXPERIMENT 1.

RESPONSE-FORM PERCENT	STIMULUS-FORM PRESENTED														
	TRIANGLE					FAT RECTANGLE					THIN RECTANGLE				
AREA	1.0	1.5	2.0	2.5	3.0	1.0	1.5	2.0	2.5	3.0	1.0	1.5	2.0	2.5	3.0
"TRIANGLE"	68.0	68.0	65.2	62.0	55.0	18.0	17.0	17.0	16.0	13.0	27.3	22.0	12.0	17.0	11.0
"FAT" RECTANGLE	16.0	13.0	11.0	11.0	4.0	66.0	73.0	67.0	78.0	80.0	14.2	6.0	9.0	8.0	4.0
"THIN" RECTANGLE	16.0	19.0	23.8	27.0	41.0	18.0	10.0	16.0	6.0	7.0	59.5	72.0	79.0	65.0	85.0

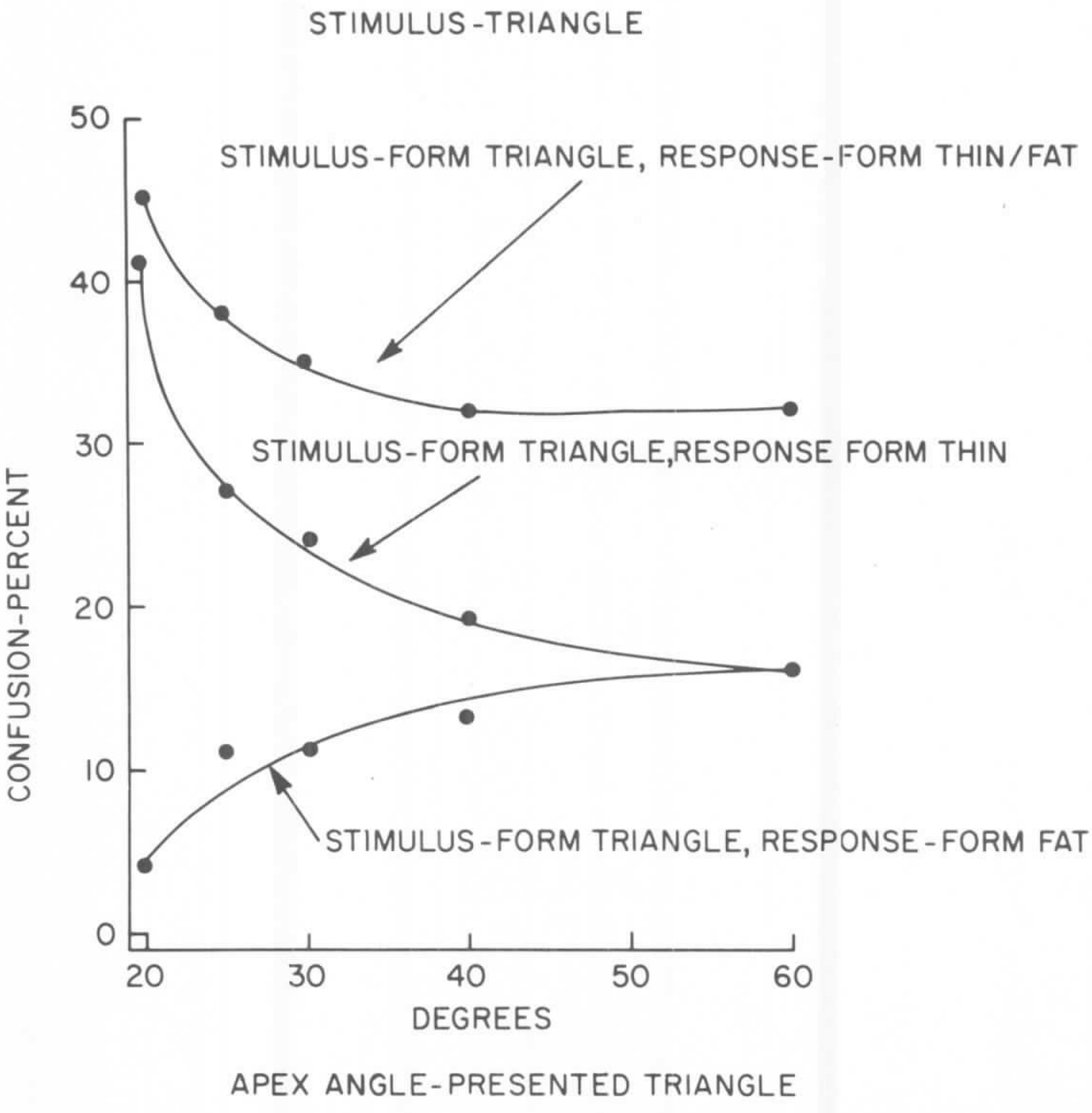

Figure 4. The confusion of isosceles triangles with thin and fat rectangles as a function of the apex angle of the triangular form presented.

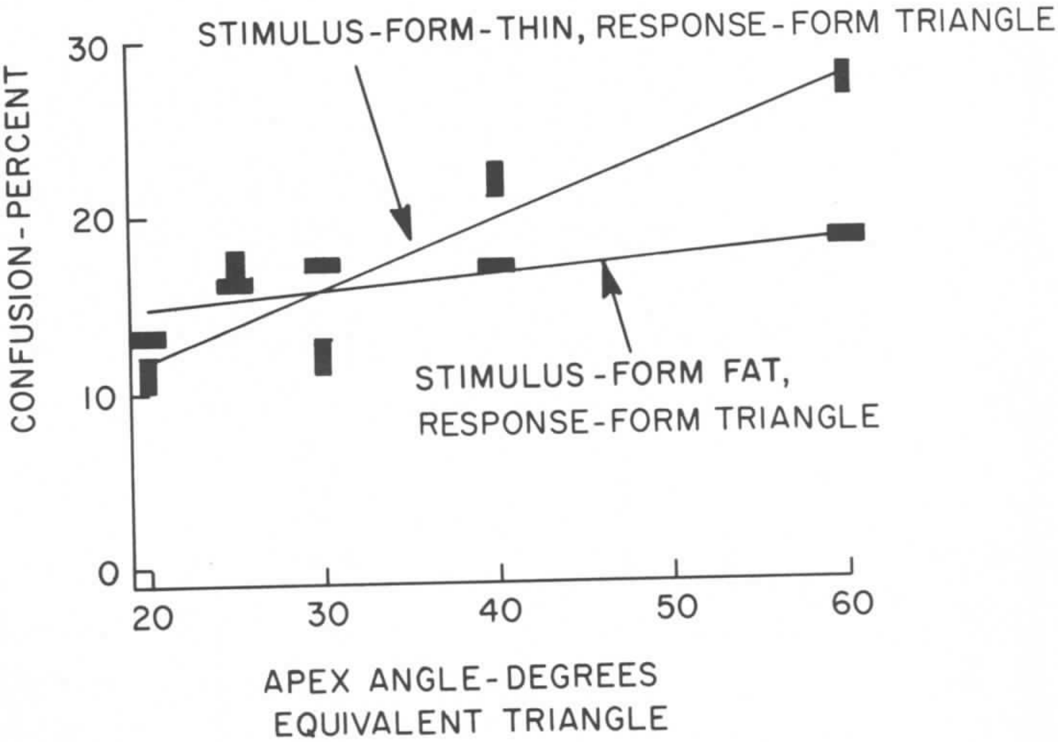

Figure 5. The confusion of thin and fat rectangles as triangles as a function of the apex angle of the triangular forms of equal area.

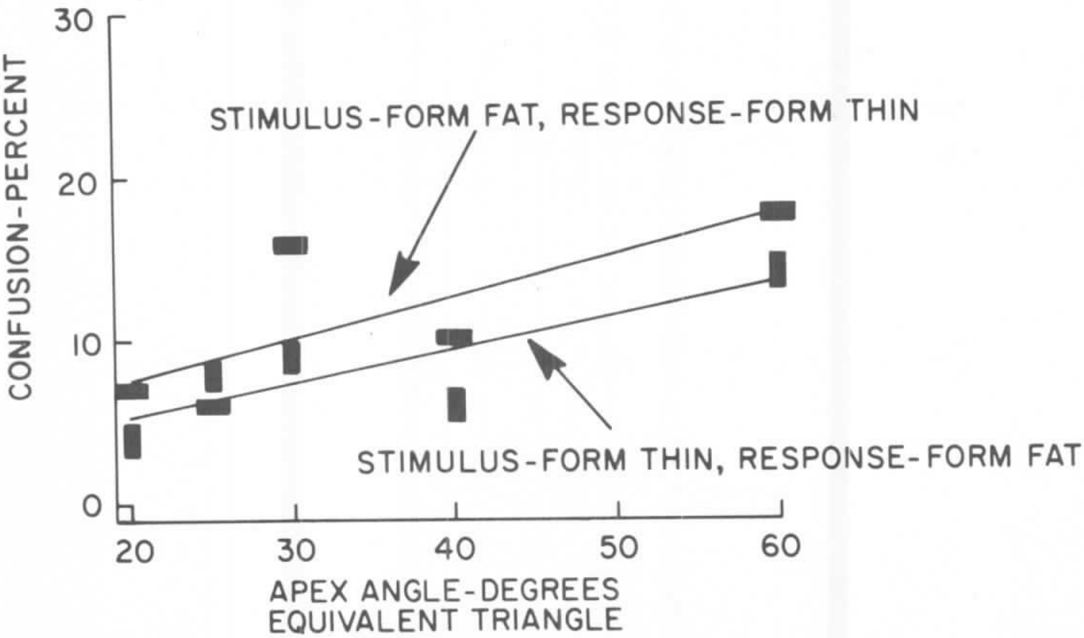

Figure 6. The confusion of thin as fat rectangles and fat as thin rectangles as a function of the apex angles of the triangular forms of equal area.

3.5 DISCUSSION

The selection of the size of the apex angle for maximum discrimination of isosceles triangles is not aided by the threshold luminance data for these three types of geometric forms. The differences are just too small. On the basis of the confusion indices obtained, however, there is no question that discrimination of isosceles triangles is maximal for triangles with apex angles of from about 30 degrees to 60 degrees.

The confusion indices further indicate that height, width and apex angle all play a part in the discimination of geometric forms. Since triangles with apex angles of less than 60 degrees were more likely to be perceived as thin rectangles than they were as fat rectangles (See Figure 4), height is presumably a more dominant cue than base width. The differences in the two types of errors (triangles perceived as thin rectangles) vary inversely with apex angle; apparently there is an interaction between the heights and widths in the discrimination of these figures. This interaction can be seen in Figure 5. The perception of the fat rectangle as a triangle varies very little as a function of height whereas the perception of a thin rectangle as triangle shows a considerable increase. That is, a thin rectangle is less likely to be seen as a triangle as its height increases (See Figure 5). This conclusion is further supported by the data shown in Figure 6. Thin and fat rectangles are less likely to be confused when the height to width ratio is high, and as this ratio decreases the confusion increases.

4.0 EXPERIMENT 2

4.1 PROBLEM

In view of the slight variation found in Experiment 1 in the discrimination of isosceles triangles with apex angles of between 30 and 60 degrees and the importance of context or frame-of-reference in form discrimination[3,4], further determinations of the effects of apex angle on the form recognition of isosceles triangles were considered necessary. The purpose of Experiment 2 was to determine the effects of the size of the apex angle of isosceles triangles used in the composition of forms as potential shape codes for daymarks. The frequencies of right and wrong response-forms were recorded for each of the stimulus-forms presented.

4.2 STIMULUS-FORMS

Three variations of four basic stimulus-forms were used in Experiment 2. These stimulus-forms are shown in Figure 7. Isosceles triangles with apex angles of 30, 40, and 60 degrees were used in the composition of the three variations in each type of form. These 12 stimulus forms were prepared and used in Experiment 2 in exactly the same way as in Experiment I.

4.3 APPARATUS, SUBJECTS AND PROCEDURE

The apparatus, subjects and procedure used in Experiment 1 were also used in Experiment 2. Each subject made 1200 judgments in the course of this experiment.

4.4 RESULTS

The extent to which the three variations of the four types of basic forms were confused by both subjects is shown in Table 2. Each entry in the body of Table 2 is the frequency of each response for each of the stimuli presented. The total number of errors for each stimulus form is shown below the body of the table along with between-types errors.

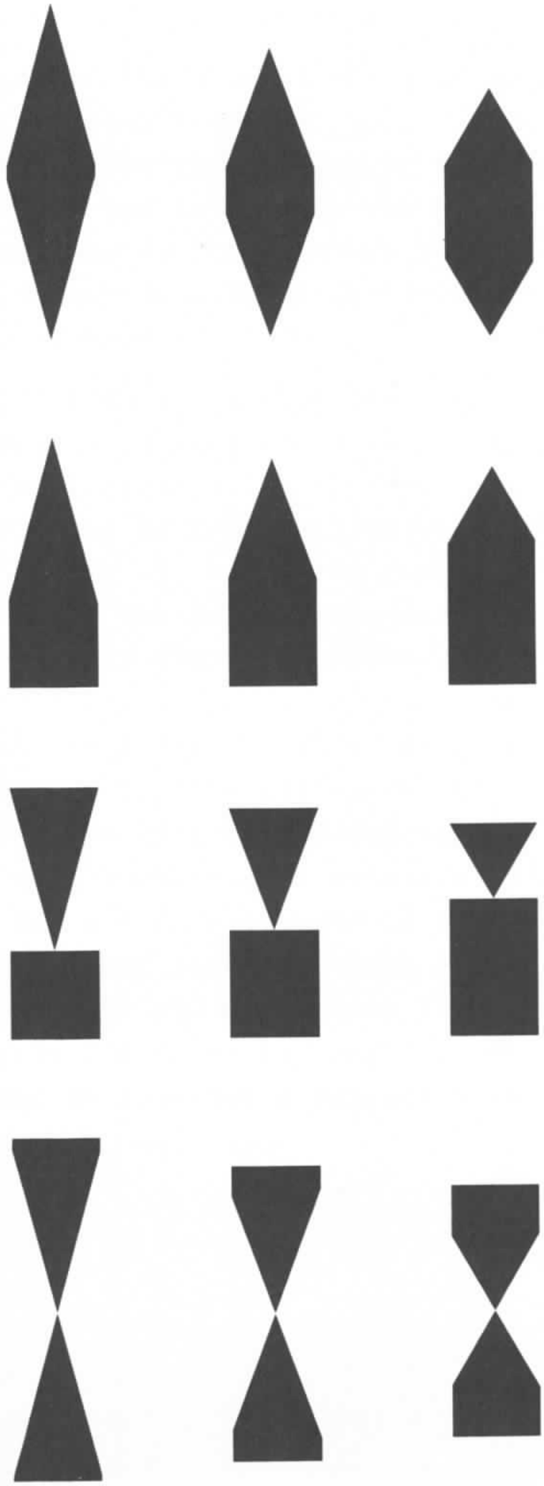

Figure 7. The three variations of the four basic stimulus-forms used in Experiment 2.

TABLE 2. THE FREQUENCY OF RESPONSE-FORMS AS A FUNCTION OF THE STIMULUS-FORM PRESENTED IN EXPERIMENT 2.

			STIMULUS-FORM PRESENTED											
			1			2			3			4		
			30°	40°	60°	30°	40°	60°	30°	40°	60°	30°	40°	60°
RESPONSE-FORM FREQUENCY	1	30°	111	15	1	1	0	0	0	1	0	3	0	0
		40°	76	148	21	2	6	1	0	1	1	0	1	0
		60°	4	26	148	1	5	7	0	1	2	0	0	0
	2	30°	6	5	1	135	18	6	1	5	2	2	1	0
		40°	2	3	11	46	124	56	0	2	4	0	0	1
		60°	0	2	7	6	44	111	0	0	3	1	0	0
	3	30°	1	0	1	1	1	0	96	7	1	3	6	3
		40°	2	0	4	4	5	5	61	141	31	0	3	17
		60°	1	0	5	1	4	10	4	28	150	0	2	3
	4	30°	0	0	0	1	1	0	5	1	0	151	30	0
		40°	0	1	1	2	2	0	26	4	2	32	153	26
		60°	0	0	0	0	0	2	11	9	4	0	2	150
BETWEEN TYPES ERRORS			12	11	30	13	24	55	43	24	18	9	13	24
TOTAL ERRORS			88	52	52	65	86	87	108	59	50	40	45	50

4.5 DISCUSSION

The extent of the confusion among the four basic types of stimulus forms is shown by the data presented in Table 2. On the basis of these data four stimulus forms, one of each of the four basic types, were selected for further study as potential shape codes for daymarks. Selected were the Stimulus-Form 1-40, 2-30, 3-60, and 4-30. The data indicate, however, that the four stimulus forms are not all equally likely to be acceptable for coding daymarks. Furthermore, it has long been known that recognition of an object is more dependant on its upper portion than its lower portion[12]. With this in mind, the confusion found between Stimulus-Forms 1 and 2 and between Stimulus-Forms 3 and 4 is understandable. The confusion that was found between Stimulus-Forms 2 and 3, however, cannot be similarly explained, the upper portions of these forms are as different as the upper portions of Stimulus-Forms 1 and 4 for which effectively no confusion was found. Possibly the lack of a "common name" for Stimulus-Form 3 was the problem even though all the forms were always referred to by number and never by name throughout the course of the experiment.

5.0 EXPERIMENT 3

5.1 PROBLEM

The purpose of Experiment 3 was to determine the recognizability of and the confusion among the seven stimulus-forms shape which have been proposed as shape codes for daymarks. The frequencies of right and wrong response-forms were recorded for each of the stimulus-forms presented.

5.2 STIMULUS-FORMS

The stimulus-forms evaluated in Experiment 3 were the four found least confusing in Experiment 2 plus the three others as shown in Figure 8.

5.3 APPARATUS, SUBJECTS AND PROCEDURE

Except for the replacement of subject B by subject C, all conditions of Experiment 3 were the same as in the preceding two experiments. A total of 1050 judgments was made by each subject in the course of the experiment.

5.4 RESULTS

In the body of Table 3 are the frequencies (and standard errors) of right and wrong responses by both subjects for each stimulus-form presented. The extent to which each of the seven stimulus-forms is recognizable is indicated by the frequency of right responses. Response bias, however, inflates the frequencies of right responses and a greater degree of recognizability is indicated than is actually the case. Therefore, corrections for bias must be made if frequencies of right responses are to be used as a measure of recognizability.

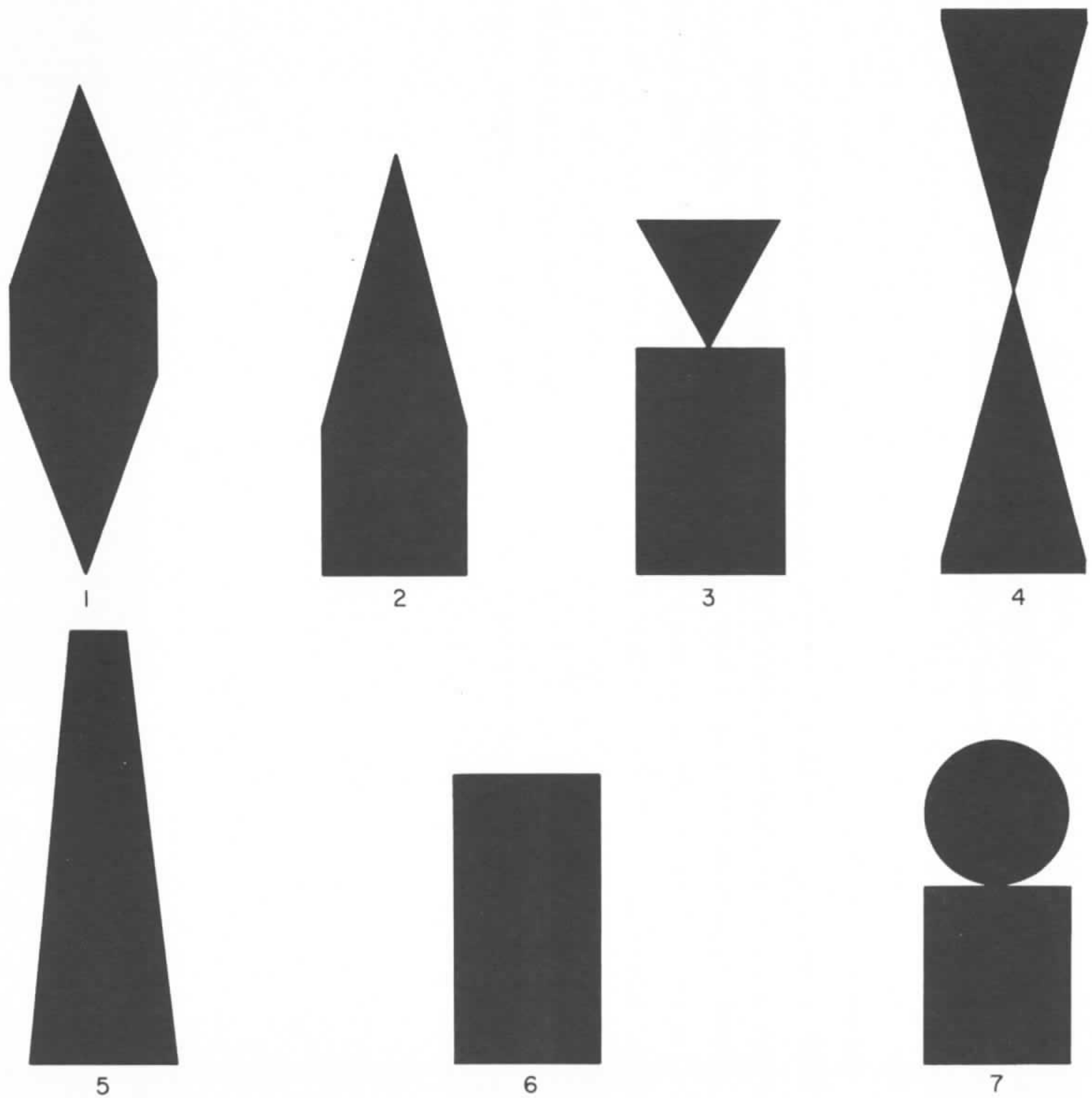

Figure 8. The seven shapes selected to be evaluated as potential codes for daymarks.

TABLE 3. THE FREQUENCY OF RESPONSE-FORMS AS A FUNCTION OF THE STIMULUS-FORM PRESENTED IN EXPERIMENT 3.

		STIMULUS-FORM PRESENTED							
		1	2	3	4	5	6	7	TOTAL RESPONSE BIAS
RESPONSE-FORM FREQUENCY	1	245 ±5.47 (232)	20 ±0.28	5 ±0.04	5 ±0.04	8 ±0.07	4	4	291 -9
	2	33 ±0.60	260 ±5.10 (235)	33 ±0.60	2	79 ±2.01	6 ±0.05	18 ±0.25	431 +131
	3	7 ±0.06	3	221 ±5.62 (204)	0	1	26 ±0.42	50 ±1.08	308 +8
	4	1*	1	2	288 ±3.26 (288)	6 ±0.05	1	1	300 0
	5	9 ±0.09	14 ±0.17	8 ±0.07	4	203 ±5.48 (193)	2	8 ±0.07	248 -52
	6	5 ±0.04	0	14 ±0.17	1	1	254 ±5.28 (243)	77 ±1.94	352 +52
	7	0	2	17 ±0.23	0	2	7 ±0.06	142 ±4.09 (132)	170 -130
TYPE ERRORS		55	40	79	12	97	46	158	487

*Frequency too small to compute standard error

The frequency of right responses for each stimulus-form was corrected for bias*, and the corrected frequencies are shown in parentheses. The total number of wrong responses for each stimulus-form is shown below the body of the table. The total number of responses for each response-form and the response-form bias are shown to the right of the body of the table.

5.5 DISCUSSION

On the basis of the frequency of right responses when corrected for bias, the seven stimulus-forms are shown in order of decreasing discriminability in Figure 9. Correcting the frequency of right responses for bias interchanged the ranking of two stimulus-forms, 2 (nun) and 6 (can). In view of the importance of frame-of-reference in form discrimination, however, the wrong responses are much more interesting for our purposes.

Stimulus-Form 4 is not only the most readily discriminated of the seven stimulus forms but it was not confused with any of the other forms with the possible exception of Stimulus-Form 5. This high discriminability of Stimulus-Form 4 is most likely attributable to the aspect ratio of the form as a whole rather than the particular shape of the form. A rectangle with a like aspect ratio would probably be discriminated just as readily as indicated by the results obtained Experiment 1. The confusion indices for the discrimination of rectangles from triangles and from other rectangles decreased as the aspect ratio increased.

On the other end of the scale are Stimulus-Forms 7 and 5 to which the two subjects showed considerable negative bias. Stimulus-Form 7 was confused mainly with Stimulus-Form 6 and Stimulus-Form 3. Stimulus-Form 5 was confused with Stimulus-Form 2. These two forms account for more than 50 percent of the incorrect responses made in the course of the study and should be eliminated from consideration as potential daymarks.

*Correction for frequency of report was obtained by $(Rc_z = Tx - \frac{W_z}{1-Px})$ where RC_z = corrected number of right responses for form X; T_X = total number of form X presented; W_z = number of form X wrong; P_X = proportion of total errors made on all forms which were called form X.[10] p. 671.

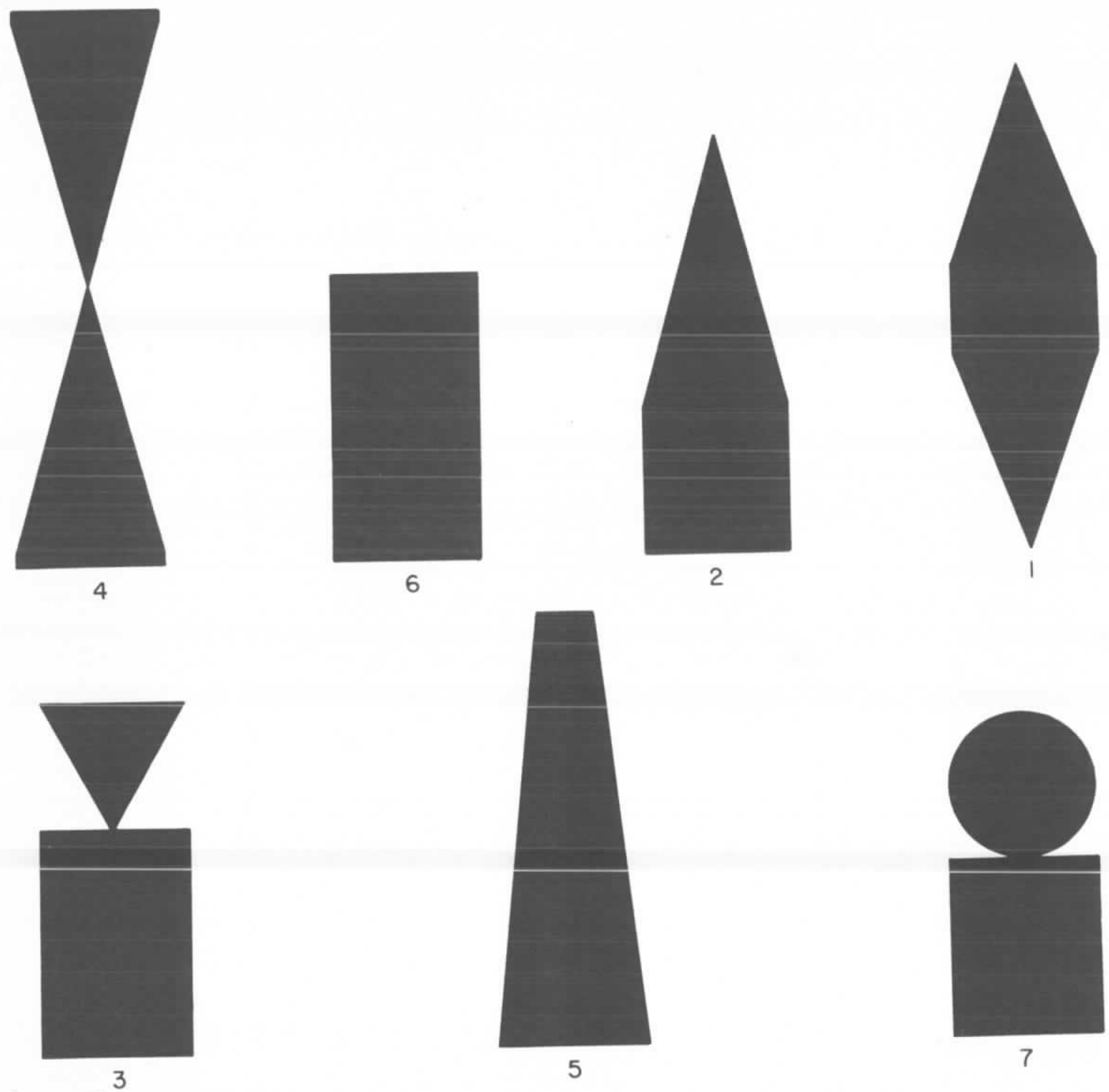

Figure 9. The seven forms evaluated as codes for daymarks are shown in order of decreasing discriminability.

Stimulus-Forms 1, 2, 3, and 6 are all confused to some degree with each one or another; however, little or no confusion occurred between Stimulus-Forms 2 and 6. Confusion did occur between Stimulus-Form 1 and 2 with Form 1 called 2 more often than the reverse. Stimulus-Form 3 was not only perceived as Stimulus-Form 2 but also to a lesser degree as Stimulus-Form 6.

What are the implications of these data with respect to the selection of forms for coding daymarks? Since a set of daymarks are an information coding system for the mariner, it is more appropriate to determine the significance of the results of this experiment in terms of information transmitted by the set of stimulus-forms than in terms of the traditional statistics.[13]

The information analysis performed (see Appendix A) disclosed that with a set of seven stimulus-forms 1.54 bits of information were transmitted. This amount of information is almost exactly the number of bits of information transmitted in a three choice situation. Thus, on the basis of the data obtained, the stimulus forms used were sufficiently discriminable to select three forms but not a fourth as coding forms for daymarks.

Whether further effort should be made to find a fourth form suitable for coding daymarks can be determined by applying this same information analysis. If there were four forms each perfectly discriminate and each with an equal probability of occurrence, the coding system would transmit two bits of information. In actuality, however, the assumption of equal probability of occurrence of each type of form would be untenable. The nun and the can, about equal in number, account for about 95 percent of the daymarks now in use. Of importance here is the fact that the discriminability of a stimulus-form has been shown to vary directly with its probability of occurrence.[14]

How much information could be delivered by two daymark forms in addition to the present nun and can? An analysis (see Appendix B) was performed assuming perfect discriminability and probabilities of occurrence of 47.5 percent each for the nun and the can and 2.5 percent each for the two other forms. The analysis disclosed that only 1.31 bits of information can be transmitted under these conditions. This same amount of information can be transmitted in a three choice situation. With the high probability of occurrence for the nun and the can nothing is to be gained from adding a fourth daymark form to the coding system. Until such times as the probability of occurrence is about 35 percent each for the nun and the can and 15 percent each for the third and fourth form of daymark would a search for a fourth form be warranted. With perfect discriminability assumed, four forms with these probability of occurrence would transmit 1.88 bits of information which is enough to warrant the use of the fourth form (see Appendix C).

Provided it meets the construction and operational handling restrictions, Stimulus-Form 4 or a cylindrical form of at least the same aspect ratio should make a good addition to the nun and can. The selection of a fourth form for daymarks from among the seven forms evaluated is not warranted on the basis of the data obtained.

6.0 CONCLUSIONS

Three experiments were conducted on form discrimination to select and evaluate forms for shape coding of daymarks. The discriminability of the forms was measured by the frequency with which each form was identified correctly and the frequency with which each form was confused with the other forms under evaluation. The form, in addition to the presently used can and nun, that was found sufficiently discriminable for use as a shape code for daymarks is the hourglass or a cylinder of equal aspect ratio.

REFERENCES

1. Clark, G. P., Recognition Characteristics Study for Buoys. USCG FTDC Rep., 1970, No. 503

2. Cheatham, P. G., Visual Perceptual Latency as a Function of Stimulus, Brightness and Contour Shape. Journal of Experimental Psychology, 1952, 43, 369-380.

3. Sleight, R. B., The Relative Discriminability of Several Geometric Forms. Journal of Experimental Psychology, 1952, 43, 324-328.

4. Hyman, R. & Hake, H. W., Form Recognition as a Function of the Number of Forms which can be Presented for Recognition. USAF WADC Tech. Rep., 1954, No. 54-164.

5. Krauskope, J., Duryea, R. A. & Bitterman, M. E., Threshold for Visual Form: Further Experiemnts. American Journal of Psychology, 1954, 67, 427-440.

6. Attneave, F., Some Informational Aspects of Visual Perception. Psychology Review, 1954, 61, 183-193.

7. Attneave, F., Symmetry Information, and Memory for Patterns. American Journal of Psychology, 1955, 68, 209-232.

8. Fehrer, E. V., An Investigation of the Learning of Visually Perceived Forms. American Journal of Psychology, 1935, 47, 187-221.

9. French, R. S., Identification of DOT Patterns for Memory as a Function of Complexity. Journal of Experimental Psychology, 1954, 47, 22-26.

10. Casperson, R. C., The Visual Discrimination of Geometric Forms. Journal of Experimental Psychology, 1950, 40, 668-681.

11. Smith, S. W., Time Recognition for Target Detection in Complex Abstract Visual Display. University of Michigan. Inst. Sci. Technology, Memo. Proj. Mich., No. 2900-235-R, April 1961.

12. Huey, E.B. The Psychology and Pedagogy of Reading. New York: The Macmillian Company, 1908.

REFERENCES (CONT'D)

13. Garner, W.R. & Hake, W.H., The Amount of Information in Absolute Judgements. Psychology Review, 1951, 58, 446-459.

14. Hyman, R., Stimulus Information as a Determinant of Reaction Time. Journal of Experimental Psychology, 1953, 45, 188-196.

APPENDIX A

TABLE A-1. INFORMATION ANALYSIS[13] OF THE DATA PRESENTED IN TABLE 3, EXPERIMENT 3, ON THE DISCRIMINATION OF SEVEN POTENTIAL CODING FORMS FOR DAYMARKS.

STIMULUS-FORM (S_k)

RESPONSE-FORM (k_j)	1	2	3	4	5	6	7	
1	245 ∇ 0.117 ∞ 0.3622 ¶ 0.020 § 0.1129 T	20 0.010 0.0664 0.020 0.1129	5 0.002 0.0179 0.020 0.1129	5 0.002 0.0179 0.020 0.1129	8 0.004 0.0319 0.020 0.1129	4 0.002 0.0179 0.020 0.1129	4 0.002 0.0179 0.020 0.1129	291 Ψ 0.139 >
2	33 0.016 0.0955 0.029 0.1481	260 0.124 0.3734 0.029 0.1481	33 0.016 0.0955 0.029 0.1481	2 0.001 0.0100 0.029 0.1481	79 0.038 0.1793 0.029 0.1481	6 0.003 0.0251 0.029 0.1481	18 0.009 0.0612 0.029 0.1481	431 0.205
3	7 0.003 0.0251 0.021 0.1170	3 0.001 0.0100 0.021 0.1170	221 0.105 0.3414 0.021 0.1170	0 0.000 - 0.021 0.1170	1 0.000 - 0.021 0.1170	26 0.012 0.0766 0.021 0.1170	50 0.024 0.1291 0.021 0.1171	308 0.147
4	1 0.000 - 0.020 0.1129	1 0.000 - 0.020 0.1129	2 0.001 0.0100 0.020 0.1129	288 0.137 0.3929 0.020 0.1129	6 0.003 0.1624 0.020 0.1129	1 0.000 - 0.020 0.1129	1 0.000 - 0.020 0.1129	300 0.143
5	9 0.004 0.0319 0.017 0.0999	14 0.007 0.0501 0.017 0.0999	8 0.004 0.0319 0.017 0.0999	4 0.002 0.0179 0.017 0.0999	203 0.097 0.3265 0.017 0.0999	2 0.001 0.0100 0.017 0.0999	8 0.004 0.0319 0.017 0.0999	248 0.118
6	5 0.002 0.0179 0.024 0.1291	0 0.000 - 0.024 0.1291	14 0.007 0.0501 0.024 0.1291	1 0.000 - 0.024 0.1291	1 0.000 - 0.024 0.1291	254 0.121 0.3687 0.024 0.1291	77 0.037 0.1760 0.024 0.1291	352 0.168
7	0 0.000 - 0.012 0.0716	2 0.001 0.0100 0.012 0.0716	17 0.008 0.0557 0.012 0.0716	0 0.000 - 0.012 0.0716	2 0.001 0.0100 0.012 0.0716	7 0.003 0.0251 0.012 0.0716	142 0.068 0.2637 0.012 0.0716	170 0.081
	300 Φ 0.143 Λ	300 0.143	300 0.143	300 0.143	300 0.143	300 0.143	300 0.143	2100 ←

∇ the frequency (N_{jk}) of the Response-Form (R_k) made to the Stimulus-Form (S_k)

Ψ the row totals - $N_{j.}$

Φ the column totals - $N_{.k}$

← the total number of events in the matrix - N

∞ $p(j,k) = \frac{N_{jk}}{N}$: Probability of the joint occurrence of stimulus category, k, and response category, j.

> $p(j) = \frac{N_{j.}}{N}$: Probability of occurrence of j.

Λ $p(k) = \frac{N_{.k}}{N}$: Probability of occurrence of k.

¶ $p(j,k)\log_2 p(j,k)$

§ $P(j,k) = p(j)p(k)$

T $P(j,k)\log_2 P(j,k)$

The information transmitted:-

$$I_t = -\sum_{j=1}^{R}\sum_{k=1}^{S} P(j,k)\log_2 P(j,k) + \sum_{j=1}^{R}\sum_{k=1}^{S} P(j,k)\log_2 p(j,k)$$

$$= 5.5405 - 3.9970$$

$$= 1.5435 \text{ bits}$$

APPENDIX B

TABLE B-1. THE ANALYSIS OF THE AMOUNT OF INFORMATION THAT CAN BE TRANSMITTED WITH A DAY-MARK CODING SYSTEM COMPOSED OF NUNS AND CANS EACH WITH A PROBABILITY OF OCCURRENCE OF 47.5 PERCENT AND TWO OTHER FORMS EACH WITH A PROBABILITY OF OCCURRENCE OF 2.5 PERCENT, PERFECT DISCRIMINATION IS ASSUMED.

STIMULUS-FORM (S_k)

RESPONSE-FORM (R_j)	1 (NUN)	2 (CAN)	3	4	
1	0.475 ∞ 0.5102 ¶ 0.2256 § 0.4849 T	0.2256 0.4849	0.0119 0.0766	0.0119 0.0766	0.475 >
2	0.2256 0.4849	0.475 0.5102 0.2256 0.4849	0.0119 0.0766	0.0119 0.0766	0.475
3	0.0119 0.0766	0.0119 0.0766	0.025 0.1330 0.0006 0.0100	0.0006 0.0100	0.025
4	0.0119 0.0766	0.0119 0.0766	0.0006 0.0100	0.025 0.1330 0.0006 0.0100	0.025
	0.475 Λ	0.475	0.025	0.025	

∇ the frequency (N_{jk}) of the Response-Form (R_k) made to the Stimulus-Form (S_k)

Ψ the row totals - $N_{j.}$

Φ the column totals - $N_{.k}$

← the total number of events in the matrix - N

∞ $p(j,k) = \frac{N_{jk}}{N}$: Probability of the joint occurrence of stimulus category, k, and response category, j.

> $p(j) = \frac{N_{j.}}{N}$: Probability of occurrence of j.

Λ $p(k) = \frac{N_{.k}}{N}$: Probability of occurrence of k.

¶ $p(j,k)\log_2 p(j,k)$

§ $P(j,k) = p(j)p(k)$

T $P(j,k)\log_2 P(j,k)$

The information transmitted:-

$$I_t = -\sum_{j=1}^{R}\sum_{k=1}^{S} P(j,k)\log_2 P(j,k) + \sum_{j=1}^{R}\sum_{k=1}^{S} P(j,k)\log_2 p(j,k)$$

$$= 2.5924 - 1.2864$$

$$= 1.3060$$

APPENDIX C

TABLE C-1. AN ANALYSIS OF THE AMOUNT OF INFORMATION THAT CAN BE TRANSMITTED WITH A DAYMARK CODING SYSTEM COMPOSED OF NUNS AND CANS EACH WITH A PROBABILITY OF OCCURRENCE OF 35 PERCENT AND TWO OTHER FORMS EACH WITH A PROBABILITY OF OCCURRENCE OF 15 PERCENT. PERFECT DISCRIMINATION IS ASSUMED.

STIMULUS-FORM (S_k)

RESPONSE-FORM (R_j)	1 (NUN)	2 (CAN)	3	4	
1	0.35 ∞ 0.5301 ¶ 0.1225 § 0.3711 T	0.1225 0.3711	0.0525 0.2232	0.0525 0.2232	0.35 >
2	0.1225 0.3711	0.35 0.5301 0.1225 0.3711	0.0525 0.2232	0.0525 0.2232	0.35
3	0.0525 0.2232	0.0525 0.2232	0.15 0.4105 0.0225 0.1223	0.0225 0.1223	0.15
4	0.0525 0.2232	0.0525 0.2232	0.0225 0.1223	0.15 0.4105 0.0225 0.1223	0.15
	0.35 Λ	0.35	0.15	0.15	

∇ the frequency (N_{jk}) of the Response-Form (R_k) made to the Stimulus-Form (S_k)

Ψ the row totals - $N_{j.}$

Φ the column totals - $N_{.k}$

← the total number of events in the matrix - N

∞ $p(j,k) = \frac{N_{jk}}{N}$: Probability of the joint occurrence of stimulus category, k, and response category, j.

\> $p(j) = \frac{N_{j.}}{N}$: Probability of occurrence of j.

Λ $p(k) = \frac{N_{.k}}{N}$: Probability of occurrence of k.

¶ $p(j,k)\log_2 p(j,k)$

§ $P(j,k) = p(j)p(k)$

T $P(j,k)\log_2 P(j,k)$

The information transmitted:-

$$I_t = -\sum_{j=1}^{R}\sum_{k=1}^{S} P(j,k)\log_2 P(j,k) + \sum_{j=1}^{R}\sum_{k=1}^{S} P(j,k)\log_2 p(j,k)$$

$$= 3.7692 - 1.8812$$

$$= 1.8780 \text{ bits}$$