Effects of figural complexity on the identification of different solid and outlined shapes[1]

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Forty-eight Ss responded in a paper-and-pencil figure-cancellation task to both solid and outlined histoforms and polygons. Three levels of complexity were provided by use of four-, six-, and eight-element constrained metric figures. Perceptual performance, in terms of speed of figure identification, was generally better on polygons than on histoforms, and better on outlined than on solid figures. More importantly, figural complexity was found to interact significantly with these variables: perceptual performance was relatively better on outlined than on solid figures at low levels of complexity, and increases in complexity were less disturbing with polygons than with histoforms.

Past research has consistently shown that the simpler a physical shape or pattern, the easier it is for man to perceive its form correctly (for a summary of pertinent studies, see Vernon, 1952, pp. 46-80). More recently, form perception has been described as an information-reduction process permitting a variety of specific shapes or patterns to be grouped into a limited number of classes (cf. Attneave, 1954; Fitts et al, 1956; Alluisi, 1960; Evans, 1967a; Thurmond & Alluisi, 1967). This information-reduction view of form perception implies that the lower the uncertainty of the stimulus, the more likely are differences between shapes to be perceived rapidly and accurately. Numerous studies have indicated that this is indeed the case; for example, identification performance is apparently inversely related to stimulus complexity (Fitts & Leonard, 1957; Baker & Alluisi, 1962) and to perturbations of figures by visual noise (Alluisi et al, 1964; Alluisi & Thurmond, 1968). These studies were conducted with a single class of figures, i.e., they were conducted with "metric histoforms" that look like solidly contoured bar graphs. They are figures that have been (and are being) used by a number of researchers concerned with the investigation of visual form perception (e.g., Alluisi & Hall, 1965; Evans, 1967b; Gould, 1967; Thurmond, in press).

Prior evidence, however, also suggests that perceptual performance does not decrease monotonically as a function of increases in figural complexity, at least with use of polygons. Rather, a U-shaped function has been obtained with both men and animals in a number of studies relating ease of discrimination of pairs of random polygons and their complexity; namely, perceptual performance seems to be superior with polygons having about six or seven sides relative to the performance obtained with polygons having a lesser or greater number of sides (Crook, 1957; Fisher, 1959; Brown et al, 1962; Michels et al, 1962). Apparently, then, for some classes of shapes (polygons), the increase in discriminative cues provided by the larger amount of informational content of more complex stimuli is *beneficial* to perceptual performance up to a point.

In the present study, identification performance was compared at three levels of stimulus complexity on two types of figures, i.e., between metric histoforms and metric polygons. Metric polygons look like the polygons constructed by line drawings of the type proposed by Attneave & Arnoult (1956) and currently used by numerous research workers in form perception (see Brown & Owen, 1967). However, metric polygons have been quantified with use of a logic identical to that employed for specifying the uncertainty characteristics of metric histoforms. Since these two figure types are analogs of each other, they are equated in informational content at specified levels of complexity, and their use permits the variation and control of other equated stimulus parameters (Thurmond & Alluisi, 1967).

Attneave (1954) has demonstrated empirically that the information in a figure is concentrated along contours and is further concentrated at the points on a contour where contour direction changes most rapidly (i.e., the angles or peaks of curvature). Thus, it is reasonable to assume that the use of shapes that are outlined in form as opposed to solidly dark forms on a white background should have essentially no effect on identification performance (cf. Thurmond, in press). In order to test the validity of this assumption, the present study was designed to compare identification performance on both solid and outlined histoforms and polygons.

METHOD

Two kinds of shapes (polygons and histoforms) appeared as both solid and outlined figures at three levels of stimulus complexity to provide 12 different experimental conditions. One sample of 24 different metric histoforms was drawn from each of the three populations generated by an underlying 4 by 4, 6 by 6, and 8 by 8 cell matrix (providing figures of four-element, six-element, and eight-element levels of complexity, respectively). Likewise, polygon analogs for each metric histoform were constructed by drawing one sample of 24 metric polygons from each of three populations generated by circular matrices containing four, six, and eight radii. All six samples of figures appeared as both solid and outlined in form, and they were constrained in that each of the possible column heights (or radial extents) appeared once and only once in each figure. Thus, the figures represent a random sampling of each of the two kinds of shapes from three different stimulus populations. The four-element matrix defines a population of 4! or 24 constrained metric figures, as contrasted with 6! or 720 and 8! or 40,320 constrained metric figures in the populations defined with the six-element and eight-element matrices, respectively.

The size of detail was constant for all figures (approximately 0.04 cm sq); therefore, the overall size of the four-element figure was one-fourth the area of the eight-element figure. The stimulus figures were accurately drawn with the use of graph paper, photographed, and reproduced by offset printing on 8½ x 11 in. white paper. The 24 sampled figures of a given experimental condition appeared as target figures on three different sheets, each sheet consisting of eight rows of figures. Each row, or problem, consisted of a target figure on the left and three choice figures on the right; two figure widths separated left from right, and one figure width separated both the choice figures and the rows. Three sheets of a given kind of target figure (histoform or polygon) of either solid or outlined form at one of the three levels of complexity were stapled together to form a subtest. The order of pages was balanced across the subtests, whereas the order of target figures and correct responses was balanced within each subtest. Twelve subtests, one for each of the 12 samples of figures (or experimental conditions), were stapled to form a test booklet, their orders being balanced across the tests.

The tests were administered to 48 psychology students (26 males and 22 females) at the University of Louisville; Ss ranged in age from 18 to 65 years, with a median of 23.

The first- (left-most) and second-choice figures were metric figures of the same type as the target figure, whereas the third-choice figure was in all cases an open square equal in overall area to the matrix used to construct

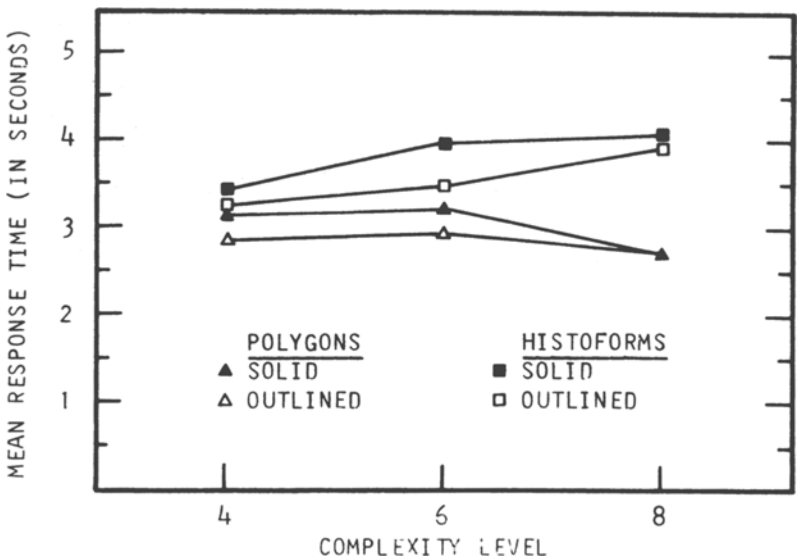

Fig. 1. Mean response time per identification (in seconds) as a function of the complexity of solid and outlined histoforms and polygons.

the figures. The task required S to look at the target figure on the left of each row and then to cross out either the first- or the second-choice figure if it was identical to the target, or the open square if neither of the first two choice figures matched the target.

Elpased time from the beginning of testing was written in 5-sec intervals on a blackboard in front of the group-testing room by E; the digits were large and clearly visible to all Ss. Each S recorded this time at the bottom of each page as it was completed and immediately proceeded to the following page. Thus, each of the 48 completed test booklets consisted of 24 cancellation responses for each of the 12 experimental conditions, or 288 responses in all, and also of 36 elapsed time recordings, one on each of the 36 sheets of the test booklet.

RESULTS

The mean percentage of errors has not been presented as a criterion of performance because so few errors were made. The overall mean percentage of incorrect figure cancellations made in responding in the task was 5.5. The mean response times (in seconds) per cancellation are given for each of the 12 experimental conditions in Fig. 1. A four-factor analysis of variance was computed on the basis of these data. The four factors were: Ss, form–histoform vs polygons (F), type of figure–solid vs outlined (T), and complexity level (C).

The analysis indicated that (a) polygons were more quickly identified than histoforms ($F = 59.412$, $df = 1/47$, $p < .001$), (b) generally longer response times were required to identify solid figures than outlined figures ($F = 20.300$, $df = 1/47$, $p < .001$), and (c) response time generally increased as complexity increased from the four-element to the eight-element level ($F = 10.625$, $df = 2/94$, $p < .001$). In addition, the two first-order interactions of form (histoforms vs polygons) and type of figure (solid vs outlined) with complexity level were statistically significant (for the F by C interaction, $F = 43.504$, $df = 2/94$, $p < .001$; for the T by C interaction, $F = 5.970$, $df = 2/94$, $p < .005$). No other effects were statistically significant.

The two interactions may be interpreted with reference to Fig. 1: (a) Response times with histoforms increase monotonically as complexity increases, whereas response times with polygons are not much affected by increases in figural complexity and even decrease at the eight-element complexity level. (b) Response times with outlined histoforms and polygons are briefer than with solid figures at relatively low levels of complexity; however, at the higher eight-element complexity level, differences in response times to outlined and solid figures are not apparent.

DISCUSSION

The data of the present study replicate and extend previous findings concerning the identification performance on solid metric histoforms across complexity levels ranging from 4 by 4 to 8 by 8. Specifically, constrained eight-element metric histoforms sampled from a population generated with an 8 by 8 matrix require a longer response time for their identification than similar four-element figures generated with a 4 by 4 matrix (cf. Alluisi & Hall, 1965; Baker & Alluisi, 1962). At the lowest level of complexity (four-element figures) essentially no differences in performance are apparent; this result agrees with the findings of a previous study that compared perceptual performance on four-element histoforms and polygons (Thurmond & Alluisi, 1967). However, as the level of complexity increased in the present study, performance in the identification of metric polygons was affected little, if at all, whereas the identification performance of metric histoforms tended to decrease monotonically. This effect is especially prevalent at the highest level of complexity (figures constructed with eight-element matrices) and was found to be true whether the shapes were solid or outlined in form. Thus, for both solid and outlined metric histoforms, the inverse relation between stimulus complexity (or uncertainty) and perceptual performance implied by the information-reduction view of form perception appears to have been supported. On the other hand, comparable increases in the complexity of metric polygons had little, if any, effects on performance.

Thus, the findings of this study suggest that increases in stimulus complexity have different effects on perceptual performance depending on the distinctive details provided by the contours of particular kinds of shapes. It seems reasonable to assume that man does not process all of the information in a figure when perceiving form, but rather that he is more likely to make discriminations on the basis of contour details that most readily distinguish one shape from another (cf. Baker & Alluisi, 1962). In the case of the histoforms–characterized by a base at the bottom and bars rising–any changes in contour features providing cues for discriminating differences between shapes occur in close spatial proximity. As the complexity of the histoforms increases (e.g., from a four-element figure to an eight-element figure), the number of potential cues for discriminating differences between shapes also increases–not only in terms of the number of elements free to vary, but also in terms of the elements' greater degrees of freedom to vary from each other. However, any particular cue (i.e., any particular element) is *embedded* in the histoform's contour immediately adjacent to neighboring cues or elements. Thus, as the histoform's complexity increases, the probability also increases that a distinctive cue (or cues) for discriminating differences between shapes will be masked by adjacent elements.

The distinctive contour features of the polygons, on the other hand, are not immediately adjacent to each other; rather, the cues (or elements) for discriminating differences between these shapes are spaced around the contour. Evidently, as the complexity of the polygons increases, the beneficial effects of the contours' providing an increasing number of cues for discriminating between shapes effectively counteracts—or even overcomes—any detrimental effects of increasing the number of elements in the shapes. Thus, the amount that any particular discriminative cue in the figure's contour is masked by other elements in the contour is apparently less for polygons than for histoforms at comparable levels of complexity (at least within the relatively narrow range of complexity employed here). It is important to note that size detail was held constant in the present study; hence, the areas of all eight-element shapes were twice as large as those of four-element shapes, and the contour details were therefore spaced proportionally as complexity increased.

These interpretations are admittedly tentative, and their implications must be substantiated with further experimentation. It may be that four-element histoforms represent a level of complexity that is near the peak of performance efficiency for this particular class of shapes. If this is the case, then perceptual performance with less complex histoforms (e.g., two- or three-element histoforms) should be worse than performance with four-element histoforms. Specifically, on the basis of prior evidence and the results obtained in the present study, it is hypothesized that perceptual performance is a U-shaped function of complexity for both histoforms and polygons. It is further hypothesized that peak performance efficiency changes location along the complexity continuum as a function of (a) the distinctiveness of the figures' contour details, and (b) the degree to which these cues for discriminating differences between shapes are spaced around the contour.

An attempt to clarify the applicability of the information-reductive approach to form perception appears to be in order. Specifically, it seems reasonable to assume on the basis of the evidence to date that information reduction does indeed occur in the absolute identification of form, or in tasks requiring the S to reproduce shapes or patterns from form-perception memories. The information-reduction approach also seems applicable to the perception of differences between visual forms as figural complexity is increased from a relatively high initial level (i.e., beyond the peak of performance efficiency). On the other hand, it is difficult to see how an information-reduction view of form perception could account for the beneficial effects of increasing figural complexity from zero to a level of peak perceptual performance efficiency (the rising part of the curve relating perceptual performance and figural complexity).

In the case of both histoforms and polygons, perceptual performance was better on outlined than on solid figures at low complexity levels (four-element and six-element). However, the two functions describing perceptual performance on solid and outlined figures converge at the eight-element level of complexity in the case of both classes of shapes (see Fig. 1). These data are interpreted generally as supporting the notion that the information relevant to the identification of visual forms is concentrated in the contour of the form (cf. Attneave, 1954). Furthermore, the use of outlined contours apparently enhanced performance by making the contour more distinctive, perhaps by providing a "double-edged" cue regarding those points on the contour where contour direction changes most rapidly. No clear interpretation can be offered for the lack of difference obtained in the perceptual performance on solid and outlined figures at the eight-element complexity level. Perhaps the increase in the number of cues for discriminating between shapes at the eight-element complexity level effectively eliminated any potential stimulus discriminability provided by the outlined contours.

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NOTE

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