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Distinctive local features of visual patterns

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Random polygons were generated in a manner that permitted tests of whether unfamiliar patterns were discriminated on the basis of their longest lines or most complex local features. Results showed that subjects tended to base discrimination on the most complex local features of complex visual patterns. This tendency may reflect the greater variability and higher information content of those features.

Following early investigations of the metrics of form by Attneave (1954) and Attneave and Arnoult (1956), symmetry, orientation compactness, complexity, jaggedness, elongation, and "information content," variously defined, have been shown in one instance or another to aid the observer in differentiating between simple visual patterns (Zuzne, 1970). Recent investigations have shown that discriminations are often based on such global characteristics, but that local characteristics may also play an important part in discrimination (Foster, 1978; Hoffman, 1980; Kimchi & Palmer, 1982). This result was anticipated by Gibson (1969), who first suggested that individual patterns were discriminated primarily on the basis of "distinctive features," which could be either global—symmetry, compression, orientation—or local and limited—a break in contour or a single line's being curved instead of straight. Gibson hypothesized that comparison of a series of such characteristics usually provided the basis for discrimination of one pattern from another.

The present research represents an effort to discover what types of local features are most likely to be involved in the discrimination of visual patterns. It seems unlikely that all kinds of local features would be equally important. When discriminations are based on local features, two types of local contour characteristics are likely to be involved: the most complex parts and longest lines.

The most complex parts of a visual pattern's contour could be the local features most used for discriminating that pattern from other patterns. A rationale for this is that a complex section of contour has more degrees of freedom than a simple section of contour has and thus is more likely to contain unique configurations. Pasnak (1971) showed that parts of the contour that are most unique and idiosyncratic to each pattern are most utilized by the perceiver in discriminating the pattern. Hence, in the case of patterns that are complex enough to realistically approximate those encountered in the natural world, the most complex portions of contour would, because they would be unique more often than other parts, be discriminated more often.

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Alternatively, discrimination may be based on the longest lines in a pattern's contour. Under impoverished viewing conditions—low illumination, peripheral vision, brief viewing durations—the longest lines are the ones that can best be seen. Thus, Krauskopf, Duryea, and Bitterman (1954) long ago showed that the threshold for discrimination of a visual pattern is determined by its "critical detail"—its longest line segments. Also, more contour could be more efficiently processed by directing attention to the longer lines. If, as Attneave (1954) suggested, the perceptual system responds primarily to discontinuities of contour (angles and bends), then more of the pattern's contour would be perceived if the observer attended to those discontinuities that demarcated the longest lines.

A more intuitive reason that discrimination might favor longest lines is that they are retinally biggest. Thus, Kimchi and Palmer (1982) showed that larger local features were more likely than small ones to determine the shape of visual patterns.

The following experiment was designed to test whether longer lines, which are presumably easier to detect, or the most complex sections of contour, which are presumably most likely to be unique, are used to discriminate patterns. The definitions of contour "complexity" and of "longer lines" were necessarily relative. If two parts of a pattern's contour each have a given length, and one part contains 12 angles and the other contains only 3, the first is defined to be four times as complex as the second. This is true whatever the given length may be, and does not change at all if the pattern becomes larger or smaller or if the viewer moves nearer or farther away. Likewise, if the line segments in one section of contour are four times as long as those in another section, they are relatively longer, and will continue to be so in exactly the same proportion regardless of the unit of length involved.

The experimental hypotheses were tested by generating polygons whose contours were divided into sections of equal length. Some of these sections were relatively complex, others had relatively long lines, and others were intermediate. A discrimination paradigm was employed to determine the relative importance of these types of contour as distinctive local features for the polygons.

METHOD

Subjects

The subjects were 20 experimentally naive undergraduate students.

Apparatus

An American Optical opaque projector Model 1000 equipped with an Ilex tachistoscopic shutter was employed in this experiment.

Stimulus Materials

A standard (St) random polygon was generated on a grid marked in polar coordinates. The grid was divided into nine equal sections by radii emanating from its center at 40° angles. A point on each radius was chosen randomly. These points were then connected by series of straight lines, generated via a restricted randomization, to form a closed polygon. The contours for each of three sections consisted of 12 .25-in. (6.35-mm) lines, for each of three other sections consisted of 6 .5-in. (12.7-mm) lines, and for the remaining three sections consisted of 3 1-in. (25.4-mm) lines (see Figure 1). These lines were generated by sequentially connecting points on the grid according to a random numbers table, with the restrictions that each point be at the prescribed distance from its neighbors and that the contour be closed. This procedure resulted in a complex polygon whose contours had three sections containing a few long lines, three complex sections with many angles per unit contour, and three sections of intermediate line length and complexity. Thus, for the standard polygon shown in Figure 1, Sections 1, 4, and 7 are complex, Sections 2, 5, and 8 have the longest lines, and Sections 3, 6, and 9 are intermediate in these characteristics. Note that each section contains exactly the same amount of contour; only the number of segments into which the contour is broken (i.e., the angles per unit contour) is a variable.

Nine comparison polygons (Co) were generated. Each was identical to the St in eight of the nine sections of contour. The first Co differed only in Section 1, which was recast via a new sequential random selection of points defining line segments of the proper length that closed the figure. The point on the boundary of Sections 1 and 2 and the point on the boundary of Sections 1 and 9 were retained. The second Co polygon differed from the St only in Section 2, which was recast randomly by the method described above, the third in Section 3, and so forth. Hence each Co differed from the St in a different section, and in only 1/9 of its total contour.

To control for idiosyncracies that might be associated with any one St and to control for position effects that might be associated with Sections 1-9, two more standards were generated randomly by the method described previously. For the second St, Sections 2, 5, and 8 were complex, Sections 3, 6, and 9 had the longest lines, and Sections 1, 4, and 7 were intermediate. For the third St, Sections 3, 6, and 9 were complex, Sections 1, 4, and 7 had the longest lines, and Sections 2, 5, and 8 were intermediate in these characteristics. Nine Co polygons were generated randomly for each of these standards. Each Co differed from its St in a different one of the nine contour sections.

The patterns were reversed and mounted on black backgrounds, so that the grids and the radii separating the contour sections were not visible.

Procedure

The subjects were seated 5.49 m from the screen. Projected polygons subtended a visual angle of 12° 55′. Luminance of the polygons was 545 cd/m², and luminance of the screen background was 298 cd/m², as measured by an SEI photometer.

The subjects were told that pairs of random polygons would be presented and were told to write whether the polygons were identical or different on the answer sheet provided. First, a St was presented for 1 sec; after 5 sec, during which the screen was blank, a Co was presented for 1 sec. In the following 5 sec, the subjects were to write whether the members of each pair were "identical" or "different," and were required to guess even if they were uncertain.

Half of the 54 trials consisted of presentations of a St twice in succession in order to equalize the effectiveness of guessing "different" with that of guessing "identical." The other 27 trials consisted of single pairings of each St with the Co patterns appropriate to it. The order of trials was randomized for each set of subjects.

RESULTS

Table 1 presents the results. A randomized block analysis of variance was performed in which different line lengths (short, intermediate, long) served as the independent variable and correct discrimination of the St and Co stimuli served as the dependent variable. The main effect of line length, or alternatively, complexity, was significant [$F(2,38) = 9.58$, $p < .01$]. Contrasts between means revealed that accuracy was significantly greater when the differentiating section contained many short lines (complex) than when it contained only a few long lines (simple) [$F(1,38) = 6.59$, $p < .01$]. The latter two conditions did not differ statistically [$F(1,38) = .66$, $p > .05$]. A signal detection analysis, the results of which are presented in the lower part of Table 1, further reveals that response bias, reflected in the Betas, had no important role in these results.

Table 1
Means and Standard Deviations for Correct Identification of Different St/Co Pairs and d′ and Beta for Each Type of Contour

	Contour Type		
Complexity	High	Intermediate	Low
Line Length	Short	Intermediate	Long
Mean	6.15	4.90	5.20
SD	1.36	1.48	1.86
d′	1.00	.62	.72
Beta	1.03	1.14	1.12

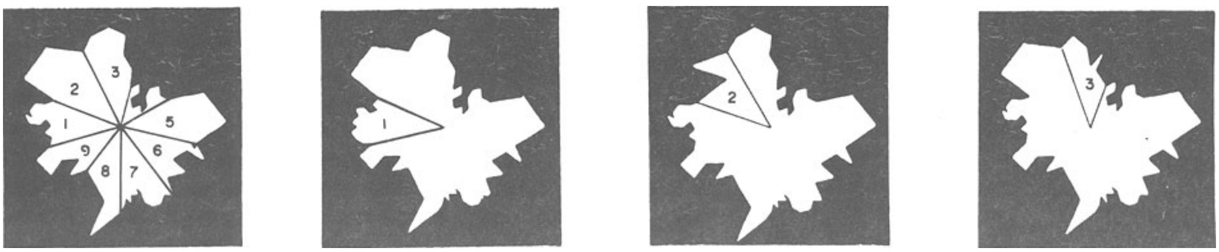

Figure 1. The standard polygon is shown to the left. Comparison polygons differ from the standard in complex, long, and intermediate line areas. (Internal lines and numerals were not visible to the subjects.)

DISCUSSION

Some of the results of this experiment can be accounted for in terms of information content. If information content is defined as the number of angles per unit of contour that differ between contours, then the complex contour sections (nine short lines) contain the most information and the simple contour sections (three long lines) contain the least. On the basis of the redundancy of the contours, one would predict an ordinal relationship between complexity and accurate discrimination. Hence, it is not surprising that the most accurate discriminations were made for those polygons whose most complex contour sections differed from the St. However, the ordinal relationship did not persist, because the subjects did not make the next most accurate discriminations when polygons differed from St in contour sections of intermediate information content. Instead, the contour sections containing three long lines and equal sections containing six lines of intermediate length were equally poor as discriminative stimuli, and discrimination was little better than chance.

This may reflect the difficulty of the discrimination—viewing time was restricted, patterns had a high overall level of complexity, and Co patterns had the same global configuration as the St pattern. It appears that, under such conditions, those local features that are the most complex—and therefore the most variable and the highest in information content—are preeminent in the discrimination of one shape from others having the same prototype.

REFERENCES

Attneave, F. (1954). Some informational aspects of visual perceptions. *Psychological Review*, **61**, 183-193.

Attneave, F., & Arnoult, M. D. (1956). The quantitative study of shape and pattern perception. *Psychological Bulletin*, **53**, 452-471.

Foster, D. H. (1978). Visual comparison of random-dot patterns: Evidence concerning a fixed visual association between features and feature-relations. *Quarterly Journal of Experimental Psychology*, **30**, 637-654.

Gibson, E. J. (1969). *Principles of perceptual learning and development.* New York: Appleton-Century-Crofts.

Hoffman, J. E. (1980). Interaction between global and local levels of form. *Journal of Experimental Psychology: Human Perception and Performance*, **6**, 222-234.

Kimchi, R., & Palmer, S. E. (1982). Form and texture in hierarchically constructed patterns. *Journal of Experimental Psychology: Human Perception and Performance*, **8**, 521-535.

Krauskopf, J., Duryea, R. A., & Bitterman, M. E. (1954). Threshold for visual form: Further experiments. *American Journal of Psychology*, **67**, 427-440.

Pasnak, R. (1971). Pattern complexity and response to distinctive features. *American Journal of Psychology*, **84**, 235-245.

Zusne, L. (1970). *Visual perception of form.* New York: Academic Press.

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