Dimensionality of judgments of visual patterns varying in amount of symmetry and formal similarity

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This experiment explored the dimensionality of judgments of visual patterns varying in form and amount of whole and part symmetry. The study compared judgments made by independent subjects on scales of symmetry, balance, pleasingness, goodness, simplicity, organization, and dispersion. All judgments showed very high reliabilities. A principle factors analysis of the interscale correlation matrix yielded a substantial single factor of symmetry/pleasingness upon which all scales but one (dispersion) were very highly loaded. The structure of the main factor indicates that, regardless of the nominal scale instructions to raters, the results are very closely equivalent. Dispersion judgments were highly reliable but were uncorrelated with the main factor.

Recent research has met with some success in manipulating the Gestalt concept of figural goodness and in demonstrating under a variety of conditions that good figures are processed faster and reproduced more accurately than are poor ones (e.g., Garner, 1974; Howe, 1980). The Gestalt formulation (Koffka, 1935) urged that, among other figural properties, symmetry was a key determinant of perceptual organization and hence of the goodness of a stimulus pattern (e.g., Hochberg, 1974). Most experiments dealing in any way with pattern goodness have adopted the empirical expedient of having subjects simply rate patterns along a scale of goodness defined at the bipolar extremes by the words "good" and "poor." When this is done, it is observed that patterns are judged to be better ones if they come from smaller rotation and reflection subset sizes (Garner, 1974, 1979)—that is, if they contain more components of main axial symmetry—or if they contain more components of part symmetry between quadrants of the total pattern (Howe, 1980).

Although the positive relationship between amount of objective symmetry and judged goodness is thus clear enough, a question is raised about what the subject is primarily doing when pattern goodness is assessed. Since goodness is presumably an affective response having the same sorts of fundamental properties as does Osgood's Evaluation (Osgood, 1962, 1964), it ought to have numerous subjective as well as objective correlates. One purpose of this methodological inquiry was, therefore, to inspect the question of whether other types of judgments

(e.g., symmetry, complexity, organization) of patterns systematically varying in both form and amount of objective symmetry are correlated with goodness. A second question was whether there are separable aspects of a pattern that the rater ignores during the judgment of goodness. Should this turn out to be the case, the concept of goodness may thereby be sharpened. One such possible dimension is the degree of dispersion of elements within a pattern. Several recent investigators have pointed to compactness as a factor in pattern processing (e.g., Akin & Chase, 1978; Glushko, 1975; Shepard & Podgorny, 1978).

Toward these ends, a set of dot patterns was judged by independent groups of subjects along a series of hypothetical scale dimensions, and the factorial dimensionality of judgments was established.

METHOD

Patterns

The patterns are shown in Figure 1. Since their construction was described in considerable detail elsewhere (Howe, 1980, Experiment I), only a brief summary is presented here. The first row of patterns in each half of Figure 1 contains the prototypes. Patterns having a rotation and reflection (R & R) subset size of 1 [R & R(1) patterns] are completely symmetrical about the four main axes and remain isomorphic under all $4 \times 2 = 8$ transformations respectively involving rotation and reflection. The three R & R(8) patterns appearing beneath each R & R(1) prototype were successively derived by displacing just one dot to an adjacent cell, to produce respectively high (2 or 3), medium (1), and low (0) components of part symmetry between pairs of quadrants (diagonally, horizontally, or vertically). All R & R(8) patterns are nonisomorphic under any transformation of the whole about a main axis. The R & R(2) prototype patterns have a subset size of 2 and contain only two main axes of symmetry. They remain isomorphic under both reflection and 180-deg rotation. Their derivatives were constructed in the manner just described. R & R(4) patterns are symmetric about a single main axis and are isomorphic only under reflection. The

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R&R Subset Size	Degree of Part Symmetry (in R&R) Patterns	R&R(1) Prototype Patterns and Derivatives								R&R(2) Prototype Patterns and Derivatives							
1																	
		6.25	6.95	6.60	6.80	6.60	6.25	6.65	6.35	5.45	5.25	4.90	5.10	4.30	4.60	4.80	5.20
4																	
		4.30	5.60	4.80	5.20	4.65	3.45	4.55	4.20	3.60	3.00	3.90	3.15	3.40	3.45	3.00	4.20
8	High																
		3.90	3.40	3.50	4.35	3.60	3.00	3.90	3.15	2.90	2.70	2.60	2.85	3.40	3.45	3.00	4.20
8	Medium																
		3.40	3.45	3.00	4.20	2.70	3.45	2.60	2.85	2.90	2.70	2.60	2.85	3.40	3.45	3.00	4.20
8	Low																
		3.40	3.45	3.00	4.20	2.70	3.45	2.60	2.85	2.90	2.70	2.60	2.85	3.40	3.45	3.00	4.20

Figure 1. Patterns, identity codes, and mean judged amount of symmetry. More complex patterns were derived from prototypes (Row 1) having a rotation and reflection subset size of either 1 (a) or 2 (b).

numbers 1-36 appearing under the patterns served as pattern-identification codes. The decimal number under each pattern was the mean scale judgment of amount of pattern symmetry (see below).

Scales

The patterns were judged on six new scale dimensions: asymmetrical-symmetrical, unbalanced-balanced, unpleasing-pleasing, complex-simple, unorganized-organized, and compact-dispersed. In each case, the first and second adjectives were placed, respectively, at the low (1) and high (7) ends of the scale. Firm goodness scale values were already available for the present sample of patterns (Howe, 1980) and were included in the quantitative analyses.

Procedure

Each pattern was projected onto a screen for 5 sec, and the subjects entered ratings of each pattern opposite the numbers 1-36 on page 1 of a booklet. Following a 60-sec interval, the subjects rated "patterns 37-49" on page 2. These 13 patterns were actually numbers 1-13 repeated. Items 1-3 were immediately discarded. Items 4-13 and 40-49 were used for within-subject reliability checks.

Experimental Design

Twenty subjects were assigned to each of the six new rating scale conditions. Every set of 20 subjects was tested in four subgroups of 5 each, each subgroup judging all 36 prototypical patterns in both a different orientation (0 deg, as in Figure 1, 90, 180, or 270 deg) and a different sequence. Four different sequences, consisting of four Latin square variations of a basic random arrangement, were used. Following computation of the within-subject reliability coefficients, data for items 4-13 were discarded. All other statistical procedures were carried out only on rating booklet items 14-49.

Subjects

All 120 participants were unselected undergraduate students satisfying an introductory psychology course participation requirement at the University of Missouri-St. Louis.

RESULTS

Reliability of Individual Ratings

Within-subject reliability coefficients assess over 10

repeated patterns were obtained for each individual subject x scale condition. (It should be noted that, for each scale condition, four different sets of 10 items were repeated.) The median values of the 20 coefficients for each scale condition ranged from .715 to .885 and yielded a grand median $r = .827$ (all $df = 8$, $p < .01$). The median value for the dispersion scale was .832. The intraclass correlation coefficient, r_{kk} , for each scale was also obtained. These coefficients ranged from .957 to .980 (all $df = 34$, $p < .0001$). The r_{kk} coefficient indicates the probable correlation with a hypothetical set of averaged ratings obtained on a second occasion. There is thus no question about the reliability of the basic data.

Interscale Correlations and Factor Analysis

A mean scale value for each of the 36 patterns was obtained for each of the new scale conditions, to which goodness values reported in Howe (1980) were added. The between-scale Pearson intercorrelation matrix was obtained from the 7×36 rectangle of means. The general pattern of these results indicated that the dispersion scale was independent of the other six scales, since it yielded nonsignificant correlations with them (all $r \leq .275$, $df = 34$, $p > .05$). The positive manifold among symmetry, balance, pleasingness, goodness, simplicity, and organization scales, on the other hand, yielded r s from .810 to .963 (median $r = .917$, $p < .0001$). While the factorial implications of these findings are rather obvious, the intercorrelation matrix was factored by the principal factors method. Squared multiple correlations were used as initial communality estimates, and the solution was iterated until the communalities stabilized. Only one factor actually showed an eigenvalue above unity, and by that criterion it can be concluded that there was just a single major common factor, here characterized as one of symmetry/pleasingness. Dispersion, on the other hand, could at best be considered a minor specific factor, at least within the restricted context of the set of scales used here. Whereas the factor loading for dispersion was $-.197$ ($h^2 = .039$), the other six factor loadings ranged from .873 to .975 (h^2 ranged from .762 to .951).

Amount of Objective Symmetry and Judgment on Scales

Table 1 presents the grand mean judgments, under each scale condition, by R & R subset size and degree of part symmetry among R & R(8) patterns. The values for all six Factor 1 scales are uniformly very high for R & R(1) patterns, and decline systematically with increasing subset size (i.e., with lower main axial symmetry) and with diminishing degrees of part symmetry. In fact, the rank order correlation is 1.00 between the six descending amounts of objective symmetry and the scores on each scale.

For each set of scale data, a two-factor analysis of variance was performed on the entire set of ratings of 36 patterns x 20 subjects. The 36 patterns constituted

Table 1
Mean Scale Values as a Function of Rotation and
Reflection (R & R) Subset Size and Degree of
Part Symmetry in R & R(8) Patterns

Scale Condition	R & R Subset Size				Degree of Part Symmetry		
	1	2	4	8	High	Medium	Low
Symmetry	6.65	6.46	5.18	4.57	3.60	3.18	
Balance	6.98	6.87	4.91	4.49	3.30	2.89	
Pleasingness	6.40	6.00	4.80	3.63	3.17	2.80	
Goodness*	6.41	5.94	4.94	4.25	3.71	3.27	
Simplicity	6.13	5.86	4.72	4.08	3.11	2.91	
Organization	6.83	6.66	5.11	4.51	3.44	2.83	
Dispersion	4.30	4.03	4.63	4.42	4.74	4.78	

*Data from Howe (1980, Experiment II).

the repeated measures factor. The independent factor is defined as follows. Recall that within each scale group of 20 subjects, four subgroups of 5 subjects judged all 36 patterns under just one of the four possible rotational orientations. These four orientation conditions of judgment were now permitted to constitute the independent factor in the analysis of variance. For all six variables that loaded on Factor 1, highly significant values of F occurred: for R & R subset size, $F_{(3,105)} \geq 140.640$, $p \leq .0001$, $MSe \leq .412$; and for degree of part symmetry within the R & R(8) category, $F_{(2,105)} \geq 5.050$, $p \leq .01$, $MSe \leq .412$. Partitioning of the variance attributable to these 2 sources showed that the percentages accounted for by R & R subset size are—in the respective order listed in Table 1—approximately 62.2%, 70.8%, 75.0%, 77.0%, 75.8%, and 82.8%. Degree of part symmetry accounts for an average of about 2.7% of the variance.

In sharp contrast, although for dispersion judgments the influence of R & R subset size was actually marginally significant [$F_{(3,105)} = 5.961$, $p < .001$, $MSe = .348$], still the R & R variable now accounted for only 3.5% of the total variance. Furthermore, the degree of part symmetry did not influence dispersion judgments [$F_{(2,105)} = 1.48$, $p > .05$]. In fact, 74.1% of the variance among dispersion judgments was distributed among the 36 patterns themselves. These two sets of results are complementary.

Figure 2 presents approximate two-dimensional locations of the 36 patterns using symmetry and dispersion ratings as coordinates. It is easy subjectively to predict the rank order of dispersion scores within each of the nine rows of four equivalent patterns in Figure 1 and to verify the prediction in Figure 2.

DISCUSSION

These data collectively support the notion that there exists a primary dimension of pattern evaluation, here labeled symmetry/pleasingness, that is statistically and psychologically substantial. The positive manifold among scales of goodness, pleasingness, balance, symmetry, simplicity, and organization suggests that

the various scale conditions may tap a nonspecific representation to which there are multiple avenues of access. Alternatively, it is possible that the subjects perceived the Factor 1 scale names as having much the same meaning and rated the patterns simply on the basis of their most salient differential properties. In any event, regardless of the nominal instructions to raters, the functional consequences were essentially the same. It is of some interest that pleasingness has appeared as a robust negative correlate of judged complexity in numerous experimental studies of aesthetic judgment (e.g., Berlyne, 1971; Berlyne, Ogilvie, & Parham, 1968; Day 1967) and that judged complexity has been observed to follow several criteria of objective complexity, of which a substantial one was amount of symmetry (Chipman, 1977).

On the other hand, although the dispersion scale is a solitary one, its reliability is equal to that of the other scales used here, and its independence from Factor 1 is evidence that it deals with a veridical property that is uncorrelated with objective symmetry and subjective goodness. In this regard, using 17 of Garner and Clement's (1963) prototypical patterns in a multidimensional scaling study of similarity, Glushko (1975) demonstrated primary clustering of patterns on the basis of R & R subset size, and a secondary dimension that he tentatively interpreted as one of dispersion. The resemblance between Glushko's outcome and ours is striking.

Finally, although liberal processing times were accorded our subjects, patterns of the type used here have been evaluated for pattern goodness with very good reliability following constrained information processing times far too short to yield even remotely significant immediate pattern recall (Howe, 1980). Pattern goodness must thus rest upon very primitive structural properties and is thus most probably precategorical (Howe, 1980). The representation of dispersion is also likely to be precategorical, although no direct data on that question are available at the present time.

Figure 2. Two-dimensional locations of patterns using symmetry and dispersion as defining scales.

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