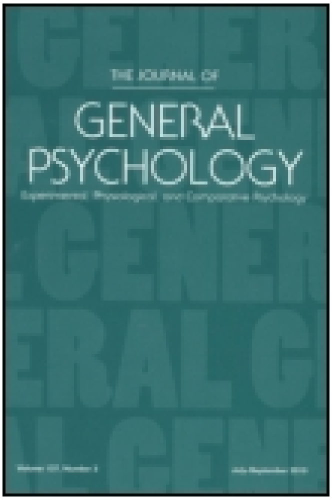

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AN EXPERIMENTAL STUDY OF AESTHETIC PREFERENCE FOR POLYGONAL FIGURES*

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A. INTRODUCTION

Fechner (10), the founder of experimental aesthetics, proposed a fundamental law of aesthetic preferences; in his words, "the principle of aesthetics may be briefly summarized by saying that human beings, in order to enjoy contemplation of some object, require to find herein a kind of unified variety" (10, p. 54). He went on to exemplify his meaning by reference to polygonal figures (10, p. 73) and stated explicitly that "pleasure grows in proportion to the degree of a clear feeling of unity, extending through a greater variety (*Mannigfaltigkeit*)." His whole discussion makes it clear that within limits, which he carefully defines, aesthetic pleasure is a function of both order and complexity elements. Unfortunately his plan to work out an aesthetics *"von unten"*—i.e., on an experimental basis—did not lead him to study empirically preference judgments for polygons; his experiments are largely confined to different aspects of the "golden section." He did, however, attempt to give some tentative definitions of what the concepts "order" and "variety" or "complexity" could mean in relation to polygons; number of sides, size of angles, etc., are explicitly mentioned by him in this connection.

Birkhoff (3) attempted to enumerate all the elements which make up order and complexity in polygons; he also formulated a general formula for beauty which he calls the "Aesthetic measure" (M). According to him, $M = O/C$ —i.e., aesthetic pleasure derived from a polygon, or any other object, is a *direct* function of the number of order elements (symmetry, equal sides, equal angles, etc.) and an *inverse* function of the number of complexity elements (number of sides, re-entrant angles, etc.). In his book are printed 90 polygons, in order of M; the highest value is given to a simple square, which according to him should be the most liked polygon. His set of polygons has figured in many experimental studies and has been used in the experiment described below; reference to individual polygons will therefore use the numbers given

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them in his book. Birkhoff himself never carried out any experiments to verify his theory, which contradicts Fechner's by relating C inversely rather than directly to M.

Eysenck (6) summarized the large literature available on the relationship between Birkhoff's formula and actual preference judgments made by different groups of subjects; he also reported on various experiments of his own. Correlations between Birkhoff's order and that observed empirically are not usually high and may drop to almost zero; there is no doubt that his formula gives only a poor approximation to the true order. Eysenck suggested an empirically derived formula for M which gave much higher correlations with subjects' actual rankings; he also suggested that Birkhoff's formula for M was fundamentally wrong, and should be rewritten: $M = O \times C$. Eysenck also found that some people showed a definite preference for simple figures—i.e., polygons in which O elements predominated—while others preferred complex figures—i.e., polygons in which C elements predominated—and he suggested, along the lines of his previous work (7, 8), that this direction of preference might be linked with personality, particularly with extraversion-introversion (9).

This hypothesis was taken up by several writers, particularly by Barron (1) and by Barron and Welsh (2), who produced the Barron-Welsh Art Scale (1, 15, 17). Other writers have introduced points of view associated with information theory into this field (4, 11, 14, 16, 18). These workers were not concerned with personality correlates of preference for order and complexity, but rather with the more precise definition of these concepts in relation to preference judgments. Nor have they restricted themselves to polygonal figures; other types of drawings have also been used, often produced by using the principle of the "random walk."

B. Method

The present study was concerned with certain specific questions, mainly directed to making more specific the bases of preference judgments for the Birkhoff polygons. Subjects for the study were 160 industrial apprentices, nearly all of them 16 years of age, and all male. These were individually tested; each was presented with two sets of 45 polygons in succession, with the instruction to rank them in order of preference. The first set was made up of Birkhoff polygons 1 to 45, the second set of numbers 46 to 90. All polygons had been photographed in black on white background—in Birkhoff's book (3) the polygons are printed in blue—and the separate copies of the cards containing the polygons, which were square, could be individually manipulated by the subjects. The linear size of the reproductions was approximately twice that of the originals. The number of polygons obtaining each rank was fixed: the two best-liked ones were given a 1, the next five a 2, the next nine a 3, the next 13 a 4, the next nine a 5, the next five a 6, and the two least liked a 7. Thus a roughly normal distribution was forced on the subjects; this eliminated absolute differences in preference, but leaves intact the relative preference judgments between one polygon and another which we intended to analyze.

For the purpose of analysis the two sets of rankings were combined; it would no doubt have been preferable had all 90 polygons been ranked in one sitting, but it was soon found that the task was too difficult for the subjects, and they began to get careless. Two small subsets, with a lengthy pause between rankings, seemed experimentally preferable, although the possibility cannot be ruled out that this division may have introduced certain artefacts. The nature of the results makes it unlikely that such artefacts could have produced serious distortions.

Product-moment correlations were calculated between all 90 polygons, and a factor analysis by principal components was carried out, extracting all 90 factors. Inspection of the latent roots suggested that only between 10 to 15 of the factors were large enough for interpretation, and after several rotations with varying numbers of factors it was decided to settle on 13; it would have made little difference to the results had a different number been chosen. These factors were then rotated by means of the Promax method of oblique rotation (12) into simple structure, and higher-order factors extracted subsequently. Details of the findings are given below.

C. PRIMARY AND HIGHER-ORDER FACTORS

Table 1[1] shows the factor loadings of the 90 polygons for the 13 factors extracted. The nature and meaning of these factors can be discerned by considering the polygons having the highest loadings on each factor, and an attempt to do so is made below. An arbitrary limit of .40 has been used to reduce the number of loadings to be considered, and the polygons representing each factor are given in order of size of loading. In several factors there are polygons which have loadings exceeding the limit by a small amount, but which have signs opposite to those polygons which characterize the factor. The interpretation of such isolated polygons must of course be that they exemplify the

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[1] Tables 1 and 2 have been deposited as Document number 9924 with the ADI Auxiliary Publications Project, Photoduplication Service, Library of Congress, Washington, D. C. 20540. A copy may be secured by citing the Document number and by remitting $1.25 for photoprints, or $1.25 for 35-mm microfilm. Advance payment is required. Make checks or money orders payable to Chief, Photoduplication Service, Library of Congress.

opposite characteristic to that which has produced the factor, but such polygons have only been included in our discussion when their presence helps to clarify the nature of the factor. The factors are not discussed in their order of extraction, which is of no psychological interest in any case, but the numbers of the factors reflect their order of extraction. It must be borne in mind, in considering these factors, that the names given to the factors are arbitrary; the writer has made an effort to extract what is common to the polygons with high loadings, but this feature is often very difficult to put into words, and the reader may obtain a much better idea of the nature of the factor by studying the actual polygons which go to make up that factor.

Factor 3: The highest loadings on this factor occur on items 11, 1, 3, 2, 70, 55, and 4, reproduced respectively in normal reading order in Figure 1(A). These are all simple, familiar polygons, like triangles, squares, rectangles, and diamonds; this factor closely resembles Birkhoff's conception of "order," and indeed the four polygons which have the highest M scores—1, 2, 3, and 4—are all included in the list.

Factor 6: This is a "rotational symmetry" factor—i.e., all the polygons can be rotated without changing their aspect. Item numbers in order are 53, 84, 88, 89, 90, and 69. One might also regard this factor as the opposite of Factor 3 because it embodies Birkhoff's notion of complexity very consistently; thus the factor includes only items low on M—particularly 84, 88, 89, and 90. Figure 1(B) shows the nature of this factor clearly.

Factor 2, shown in Figure 1(C), is made up of items 30, 48, 10, 12, 16, 21, 5, and 7; all the polygons approach the circle in shape, differing only in the number of straight sides and the size of the angles. One might call this a "circle" factor.

Factor 4, shown in Figure 2(A), is made up of items 32, 20, 60, 63, and 33; all the polygons approach the ellipse in shape, differing only in the number of straight sides and the size of the angles. One might call this an "ellipse" factor.

Factor 1, shown in Figure 2(B), is made up of items 73, 71, and 75; item 58 has a high loading opposite in sign to the others and is included here because it throws some light on the nature of this factor. Characteristic of this factor seems to be an elongated projection or protuberance, somewhat like a steeple; provisionally one might call this the "steeple" factor. Item 58, which has a sign opposite to the other items, also has a projection, but a small one; clearly the characteristic feature of this factor is the *size* of the projection. It might be interesting to test sex differences in preference for this factor.

Factor 5: This factor is made up of items 50, 13, 25, and 24; Figure 2(C) shows that all the items are elaborations of the "cross" motive. It is interesting that items 9, 29, and 49, shown in Figure 2(D), have only rather low loadings on this factor, although they seem to embody this theme comparatively clearly.

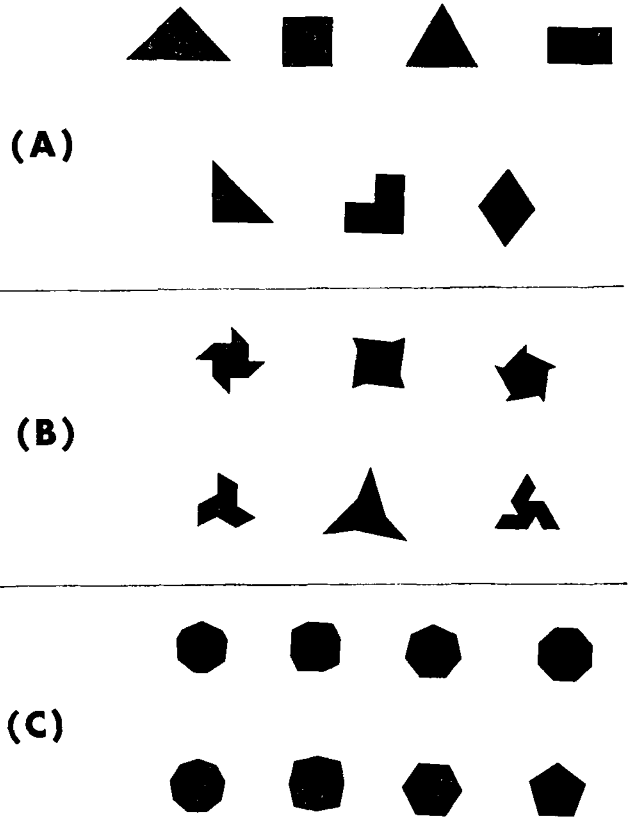

FIGURE 1
Adapted by permission of the publishers from *Aesthetic Measure* by George D. Birkhoff, Harvard University Press, Cambridge, Massachusetts, 1933.

Obviously the elaboration of the simple cross motive plays an essential part in the nature of this factor.

Factor 10: Items 44, 62, 26, and 66—Figure 3(A)—do not define a very clear factor, although in three cases out of the four it would appear that we are dealing with some variation on the theme of a "U." We may perhaps provisionally call this a "U-shape" factor, but without much confidence in our understanding of its nature.

Factor 12: Items 35, 28, 14, 17, 15, and 86 are all variants of a triangle elaborated in various ways; Figure 3(B) shows these variations quite clearly. There seems to be little doubt about the identification of this factor.

Factor 13: This factor may perhaps be called a "pillar" factor; items 34, 64, 54, 38, and 81, which define it, suggest some variant on this theme (with the exception of 54, which does not seem to fit in very well with the other polygons). Figure 3(C) shows the polygons in question.

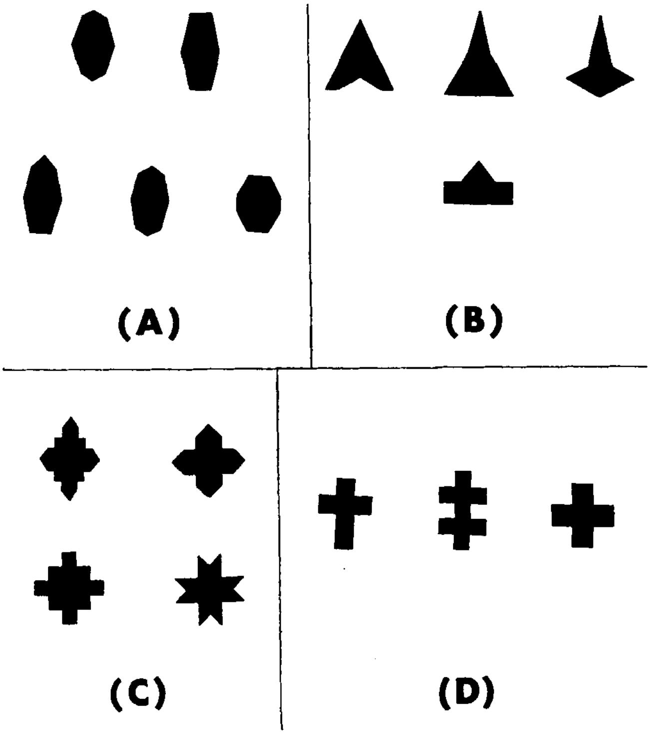

FIGURE 2
Adapted by permission of the publishers from *Aesthetic Measure* by George D. Birkhoff, Harvard University Press, Cambridge, Massachusetts, 1933.

Factor 7: Items 85, 45, and 74, which make up this factor, are very similar, as Figure 3(D) shows quite clearly. The factor may perhaps be labelled an "S-curve" factor.

Factor 9, which is made up of items 37, 19, and 82, is somewhat difficult to define. The three polygons shown in Figure 4(A), particularly item 37, suggest a three-dimensional structure and recall such well-known figures as the

Necker cube. We felt little confidence in this identification, but suggest it here for the purpose of future research which may support or disprove this notion.

Factor 8, made up of items 83, 57, and 59—Figure 4(B)—and Factor 11, made up of items 78, 67, and 79—Figure 4(C)—are impossible to interpret and may not be anything but statistical artefacts. No attempt will be made here to speculate on possible similarities between the items shown for each factor.

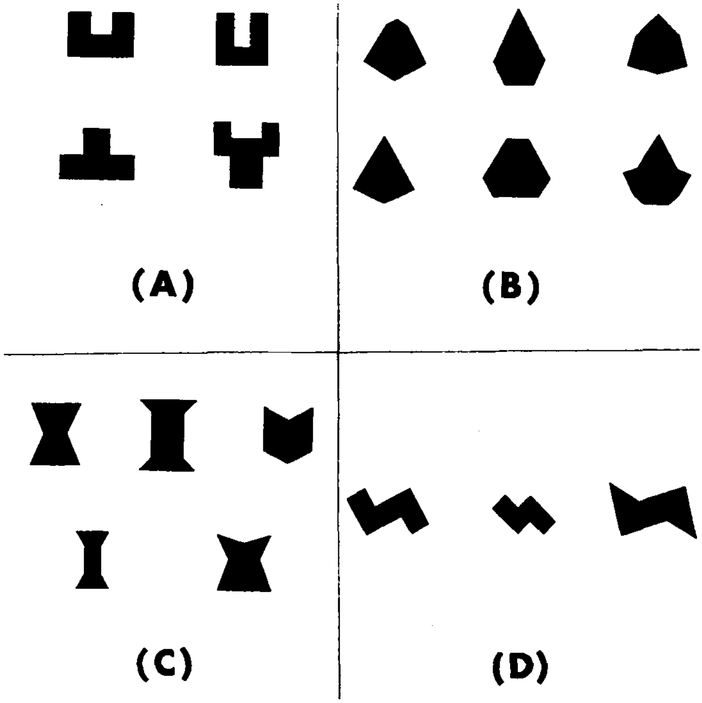

FIGURE 3
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Readers may feel that many of these factors are just variants on some common theme, and that the complex procedure of statistical analysis employed has not produced results which could not have been obtained by simple inspection and grouping of polygons on the basis of the characteristics suggested by intuition. This point is probably not well taken. Consider the "cross" factor, where we have found that simple cross designs had only very low loadings; this could not have been anticipated on the basis of intuition. Or consider

Figure 4(D); this brings together three star-shaped designs—6, 8, and 40—which might have produced a "star" factor but did not in fact do so. Intuition *ex post facto* is relatively easy, but cannot compare with factual, statistical analysis.

The 13 factors extracted from the matrix are of course not orthogonal, but oblique, and the intercorrelations between them are given in Table 2.[2] Extraction of higher-order factors proceeded through a four-factor oblique solution to a third-order single bipolar factor whose loadings are given in Table 1. The intermediate second-order factors are not of great interest as they simply mirror progression to the final third-order factor, and as they are difficult if not impossible to interpret discussion of them is here omitted. The nature of the third-order factor, however, is fortunately very clear; Figure 5 shows the polygons having the highest positive loadings in order of size of loading, and Figure 6 shows the polygons having the highest negative loadings, also

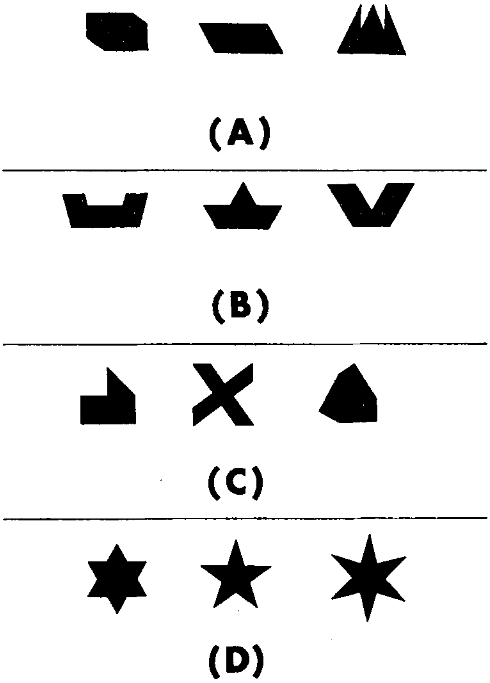

FIGURE 4

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[2] See footnote 1.

in order of size of loading. Arbitrarily we have selected the 16 polygons having highest positive and negative loadings; the reason for this choice lay in the fact that two sets of 16 items result in a reliable test of this factor, as will be shown below.

This factor is clearly one opposing simplicity to complexity; it may be of some interest to indicate the objective features which are characteristic of each. The group of simple polygons is characterized by right angles, small number of nonparallel sides, and familiarity; the group of complex polygons is characterized by angles other than right angles, large number of nonparallel sides, and lack of familiarity. By familiarity is meant that figures like squares, rectangles, diamonds, and triangles have been encountered frequently; so have letter-like figures (H, T, I, X), and so have arrows and crosses. Unfamiliar figures are essentially new to the subject; they are unlikely to have been encountered. These simple rules would seem to account completely for the polygons most characteristic of this factor.

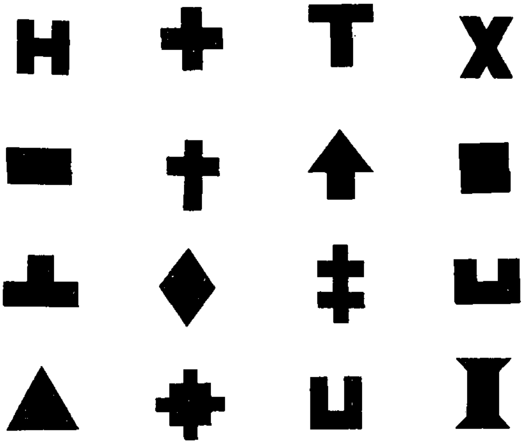

FIGURE 5

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How closely is preference for any of these shapes determined by the O *vs.* C factor? An attempt was made to answer this question by using the generalized Kuder-Richardson Formula 20 (13) in relation to the 16 O polygons, the 16 C polygons, and the two combined. The reliabilities for the two sets of 16 polygons were .79 and .82, respectively. The correlation between preference for order and preference for complexity is —.78, and the reliability of the combined score (order-complexity), derived from 32 polygons, is .89. This is an unusually high value, showing that the factor defined by the polygons shown in Figures 5 and 6 can be very reliably measured and exerts a very strong influence in polarizing subjects' preference judgments. Clearly the other, primary factors discussed before are of very much less importance than this all-embracing super-factor.

D. Preference Orders and Formula

We may now turn to the actual preference judgments made by our subjects; means and standard deviations are given in Table 1, and Figures 7 and 8 show the best liked polygons in order of preference (Figure 7), and also the least liked polygons, with the least liked coming last. Arbitrarily we have again chosen 16 polygons in each case to represent the good and bad shapes, respectively; this number is sufficient to discuss general rules, but not so large that it becomes impossible to print the actual sequence of polygons.

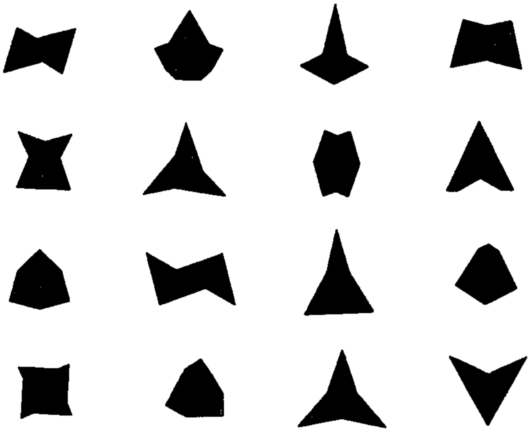

FIGURE 6
Adapted by permission of the publishers from *Aesthetic Measure* by George D. Birkhoff, Harvard University Press, Cambridge, Massachusetts, 1933.

It is clear that the disliked figures are similar in many respects to the "simple" factor; they have few nonparallel sides, right angles, and are familiar. The liked figures, on the other hand, have many nonparallel sides, nonright angles, and are unfamiliar. It is also noticeable that every one of the well-liked polygons has several re-entrant angles, while few of the disliked polygons do; those that do have exclusively 90° re-entrant angles, which are almost totally missing in the well-liked group of polygons. Of course, the two features of having many nonparallel sides and having angles departing from 90° are related; right angles imply parallel sides. Symmetry is another feature which may be important; several of the ill-liked polygons are lacking in vertical, horizontal, and rotational symmetry, which none of the well-liked ones does.

We have three values for each polygon: (*a*) M, Birkhoff's Aesthetic Measure, which purports to represent the O/C value of each figure; (*b*) R, the actual rating of the aesthetic value of each polygon, averaged over all our subjects; and (*c*) F, the factor loading of each polygon for the complexity-simplicity factor. According to Birkhoff, we would expect M to correlate highly with R; according to the experimental evidence summarized by Eysenck (6), we would expect at best a relatively slight correlation. The actual correlation is .13, which is not statistically significant; as expected, Birkhoff's formula fails to predict actual aesthetic judgments of our group. M does, however, correlate significantly with F: $r = .51$. This is of course not unexpected; O/C should correlate positively with a factor which gives positive loadings to simple designs and negative loadings to complex designs. It is perhaps a little surprising that the correlation is not higher; clearly Birkhoff's definition of O and C is not identical with the basis of judgment adopted by the subjects of this experiment. The correlation between R and F is also significant, but much lower: $r = .29$. This indicates that preference judgments show a slight preference for O as opposed to C, but this tendency is too slight to give us much help in predicting the aesthetic value of any particular polygon.

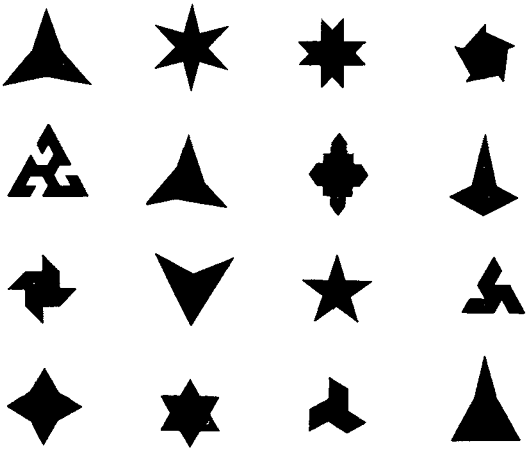

FIGURE 7

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Our theoretical analysis of M as a function of both O and C (M = O × C) suggests a simplification of the empirical formula worked out by Eysenck (6) which has 12 weighted elements and is both clumsy and awkward to work with. Order elements boil down essentially to some form of symmetry (vertical, horizontal, or rotational); presence of any form of symmetry is given 20 points. Complexity may be measured by the number of sides and the presence of angles other than 90°; we give 20 points for the latter quality and add the actual number of sides. (Thus item 70 would score 3 points for its three sides, and 20 points for having angles which depart from being right angles; total score = 23.) The only complication which appears necessary relates to non re-entrant angles which are near 90° or 180°; these carry a penalty of 20 points. We now multiply the O elements with the C score, to obtain our M score. The highest score obtained by any of our 16 "bad" polygons is 240; the lowest score obtained by any of our 16 "good" polygons is 480. The mean of the "bad" polygons is 100, that of the "good" ones is 675. These figures suggest that this simple formula derived from our theory regarding the monotonic relation between both O and C, on the one hand, and M, on the other, has predictive value; it derives from Eysenck's empirical formula, but enormously simplifies it. It is not unlikely that considerable improvements are still possible in deriving such a formula, but the main possibility of progress seems to lie (*a*) in the study of the scores of different groups of people (naive, knowledgeable with respect to art; bright, dull with respect to intelligence), and

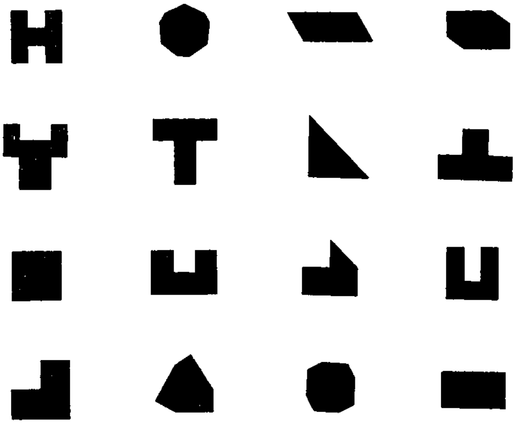

FIGURE 8
Adapted by permission of the publishers from *Aesthetic Measure* by George D. Birkhoff, Harvard University Press, Cambridge, Massachusetts, 1933.

(*b*) in the study of the relation between preference for O *vs.* C elements and the personality dimension of extraversion-introversion.

The value of the mean order of ratings, psychologically speaking, must be regarded as a function of the hypothetical ability of individual subjects to give "good" judgments, and to do so reliably. In other words, if there were only a weak tendency for individuals to agree strongly, weakly, or not at all with the average rating of the polygons, then the average would be of little interest and would quite likely differ from sample to sample. If, on the other hand, individuals showed strong tendencies to demonstrate good or bad "taste" consistently, then the mean ratings of groups of subjects would be of considerable interest and value. The term "taste," as applied here to the degree of a person's agreement with the average, may not go uncriticized, but on past occasions the writer has tried to justify its use both theoretically and experimentally (5, 9), and as suggested there the letter "T" will be used to designate this hypothetical trait in the individuals making up our sample.

Following previous practice (5), we have used the correlation of an individual subject's ratings of the 90 polygons with the average ratings furnished by the whole group of 160 apprentices as that individual's score. To obtain an estimate of the reliability of that score, the polygons were divided into two groups, those with odd numbers and those with even numbers in Birkhoff's collection; separate scores were then calculated for each individual for each set of polygons, and these two scores were then correlated over the 160 subjects. The (corrected) reliability turned out to be .82, which is astonishingly high considering the very homogeneous nature of the group; it seems clear that meaningful and reliable judgments regarding the aesthetic value of polygons can be made even by quite untutored young men like those who served as subjects in this experiment. Furthermore, it is quite clear that, while they were homogeneous with respect to age, personality, intelligence, and social class, they differed profoundly with respect of "T." Consider for example subject 4, whose correlations with the average order were —.14 and —.25, or subject 32 (—.31 and —.40) as contrasted with subject 63, whose correlations with the average order were .82 and .83, or subject 109 (.85 and .89). There is obviously a marked difference in the aesthetic abilities of the first two subjects, as contrasted with the other two; the fact that "T" is very reliably measured in this group suggests that the same may be true of other groups as well, although it does not of course follow that other groups will have the same rankings on the average as did this group. Our finding merely suggests that rankings or ratings furnished by different groups can with advantage be compared, as they are probably highly representative of the populations of which they constitute a sample.

We may conclude that Fechner and Birkhoff were right in emphasizing the importance of order and complexity elements in the genesis of preference judgments, at least as far as polygons are concerned. While several primary factors also emerged from our analysis, these were clearly of much less importance than the general, higher-order factor of order/complexity, which seemed to lie at the basis of the general preference judgments of our subjects. Judgments were lawful, and highly reliable; this finding gives us hope that further work with other groups may enable us to study the influence of such factors as sex, age, training, and intelligence on preferences for order and complexity elements, respectively.

E. Summary

Preference judgments on 90 polygons were obtained from 160 industrial apprentices. The judgments were intercorrelated and the 90 × 90 matrix was factor analyzed by Promax. A number of meaningful primary factors were extracted, as well as a powerful higher-order factor of order *vs.* complexity. Preference judgments showed no correlation with Birkhoff's predictive formula, but agree rather with the writer's tentative formulation of aesthetic preference as being the product of order and complexity elements; a formula based on this hypothesis showed good agreement with fact. Preference judgments were scored for individual subjects in terms of their agreement with the mean order of preference, and high reliabilities obtained for these scores. It was concluded that preference judgments for polygons are lawful and are legitimate and useful topics for psychological analysis.

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