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motor training with considerably more generalization than do high stratum Ss. The higher amount of generalization for the low stratum group could well account for the higher level of error making on motor trials. If this is so, *transfer* for high stratum Ss should be greater in a positive direction than for low stratum Ss. If transfer effects can be shown to be comparable for high and low strata, no harm should be done in treating averaged data. If transfer effects are importantly different from one stratum to another, however, the treatment of transfer effects for each stratum separately will not only be a statistical necessity, but also a potential advantage in a theoretical sense.

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Figure 1. Mean performance by trials on verbal pretraining and criterion tasks, employing strata based on pretraining scores.

An Investigation of the Judged Complexity of Stimuli With High Information Content

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Abstract. The complexity of stimuli with high "constructed complexity" was judged by 40 subjects on an equal-appearing intervals scale. Earlier studies had employed stimuli of lower constructed complexity, and it was felt that the judgment task would prove more difficult when the constructed complexity was increased. Results showed that subjects experienced no difficulty in making the judgments—as constructed complexity increased, so did judged complexity. It was suggested that magnitude estimation might be a more appropriate means of assessing judged complexity than equal-appearing intervals for future studies.

Attneave (1954) first postulated the application of an information theory model to form perception. The model represented a realistic attempt to quantify and operationalize form and the generation of stimuli. Later, Attneave (1955) found that information is concentrated at changes in contour. In a subsequent paper, Attneave & Arnoult (1956) presented a series of methods for constructing randomly derived stimulus shapes, which may contain as many changes of contour, or sides, as one chooses. This

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variation in number of sides may be termed "constructed complexity".

Whereas the amount of information in a shape can be controlled through its constructed complexity, the present concern is with how this information is processed in a perceptual task. One such task requires subject to judge the degree of complexity which they perceive in a series of shapes at varying levels of constructed complexity.

In separate studies, Attneave (1957) and Arnoult (1960) explored the relationship between judged complexity and various physical characteristics of the stimuli. Both sets of data indicate that constructed complexity accounted for approximately 80% of the variance in the ratings. The stimuli used in these studies were relatively simple; their maximum level of constructed complexity was twelve sides. In both studies, judged complexity increased as the number of sides increased. Edelman *et al.* (1961) investigated an extension of this work and found a similar tendency for judged complexity to increase as number of sides increased when the stimulus sample included levels up to twenty-four sides.

Although this relationship between judged and constructed complexity has been shown to be a positive one, it is reasonable to expect that subjects will experience greater difficulty in discriminating between shapes when the complexity levels are increased. The present study attempts a further investigation of this problem by extending the range of constructed complexity levels in the stimulus sample.

Method

Subjects

The subjects used in this experiment were 40 volunteer members of an introductory psychology course at Iowa State University, who received extra credit in the course for taking part in the experiment. They ranged in age from 18 to 21 years, and none had had previously participated in a psychological experiment.

Stimuli

The stimuli employed were constructed by the Type I method proposed by Attneave and Arnoult (1956). The stimuli consisted of 8 stimuli of the same complexity level, defined by the number of sides, in each of 6 categories ranging from 20 sides, increasing at five side intervals to 45 sides. These stimuli were mounted on white cardboard and were cut from black construction paper. The 48 stimuli were then randomly arranged so as to control for any possible order effects and coded for rapid identification. Five white cards, approximately the same size of the stimuli, were numbered from 1 to 5 and used as the five categories. These five category cards were taped to the table top for convenience. The instructions for sorting the stimuli were tape recorded.

Procedure

Each subject was led into a small room which contained the taped instructions for sorting the cards. The subject was also provided with a printed copy of the exact instructions which were on the tape recorder. This enabled the subject to re-read any portion the taped instructions had not made clear. The subject was then led from the instruction room to a cubicle where the judgment task was performed. The subject was instructed to look through the stimuli in order to become familiar with the type of stimuli he was to judge and to begin only when he considered himself ready. The method of equal-appearing intervals (Edwards, 1957) was used to obtain judgments of complexity for the stimuli. The Ss were instructed to sort all 48 shapes into five piles. Those shapes which appeared most simple to the Ss were placed on the first pile; those shapes which appeared most complex were placed on the fifth pile. Piles two and four represented less extreme degrees of simplicity and complexity, respectively, and pile three those shapes which appeared neither very simple nor very complex. After a subject had completed the task, the experimenter recorded each stimulus at each category and reorganized them into the pre-arranged random order using the coded values on the reverse side of the cards.

Scoring

The distribution of the judgments for each shape was tabulated. Upon the completion of all judgments, the median, or "scale value", for each shape was determined. A scale value of one indicated that the shape was judged to be very simple; a value of five denoted that it was perceived very complex. Scale values between these extremes indicated varying degrees of perceived complexity or simplicity.

A procedure devised by Wolins Edelman (*et al.*, 1961) was used to compute the indices of dispersion. For each item, the differences between 75th and the 50th and between 50th and 25th percentiles were computed and the one chosen as the index of dispersion was the larger of the two. This method was designed to augment the effects of skewness in the dispersions of the individual distributions. The mean dispersion values for the stimuli were then plotted against the number of stimulus sides.

RESULTS

Figure 1 shows the average dispersion values for the stimuli plotted against the number of stimulus sides. From previous studies, it would be expected that average dispersion values would be small at the extremes and larger for the categories near the center. That is, it should be easier to judge stimuli which are very simple or very complex than to discriminate among intermediate levels of complexity. Figure 1 indicates that this expectation is born out in the present study. However, this does not imply that judgments are less variable in one set of shapes than in another; rather, this is a statistical artifact produced by the scaling procedures involved. Extreme scale values from equal-appearing interval judgments can not have large dispersion values. Results similar to these are always found when using this method.

Figure 2 illustrates the judged complexity of stimuli, on the equal-appearing interval scale, as a function of the number of sides. Judged complexity increases as the number of sides increase. This result is similar to those obtained by Attneave (1957), Arnoult (1960) and Edelman, *et al.* (1961). These similarities occurred despite the fact that both Arnoult and Attneave used different stimuli, a different technique of presentation and

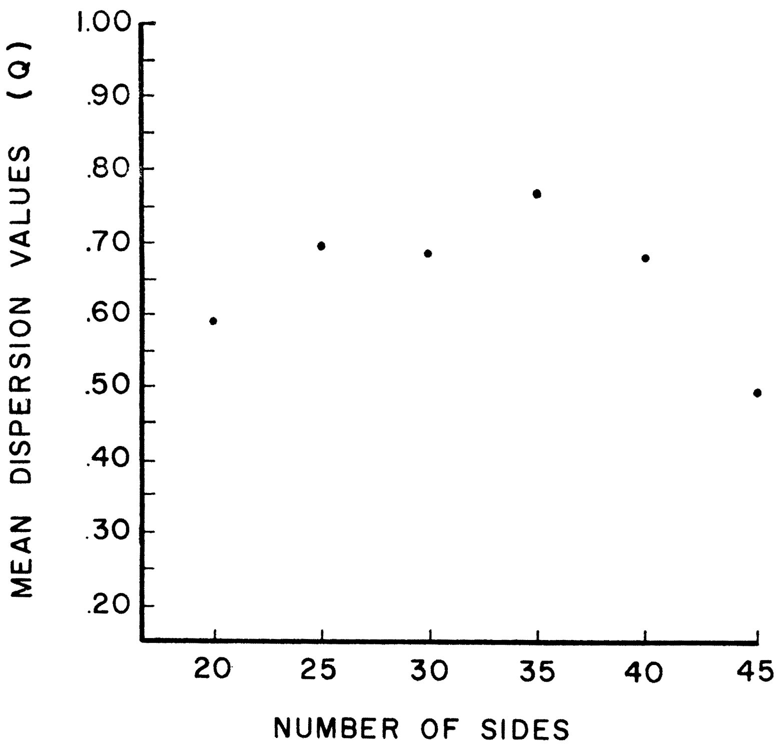

Figure 1. Relationship between dispersion values and number of sides.

different methods of judging. The relationship may thus be considered highly reliable.

In order to determine whether or not the subjects could discriminate between levels of complexity at the upper extreme, judgments of the 40 point and the 45 point stimuli were subjected to a Mann-Whitney rank test. Significance between the two categories was found beyond the .01 level.

Discussion

The principle concern of this study was to extend the range of complexity beyond that employed by Attneave (1957) and Edelman, *et al.* (1961), in order to further evaluate the effect of increased stimulus complexity upon form perception. The increasing function found in the previous studies has also been demonstrated in the present study, and the evidence suggests

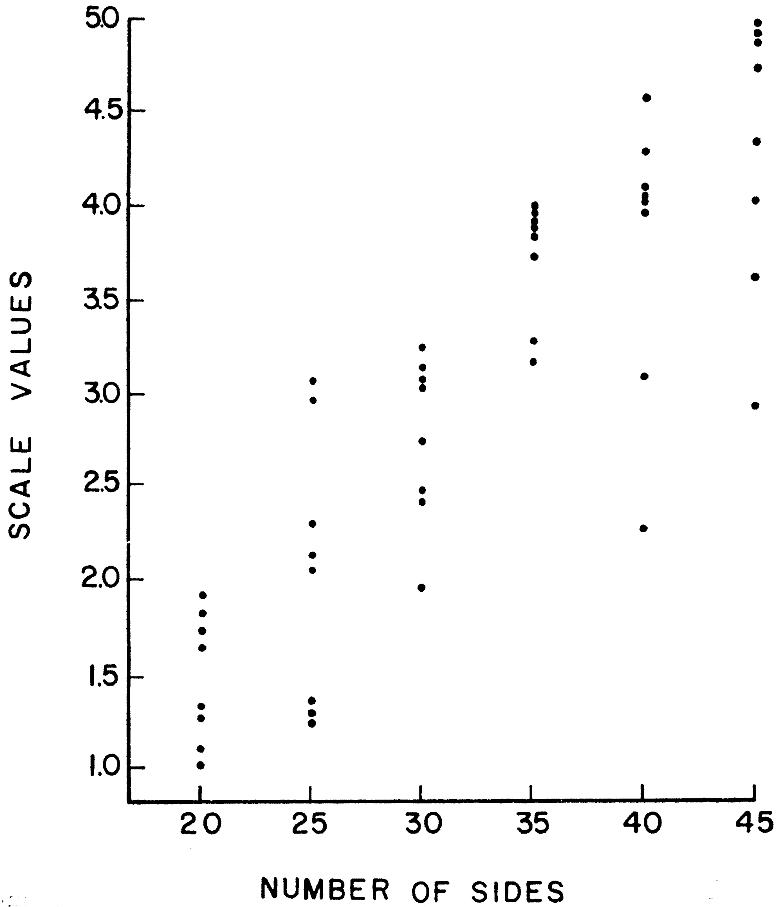

Figure 2. Judged complexity as a function of the number of sides.

As one ascends the scale of constructed complexity it is reasonable to expect that subjects will experience more and more difficulty in discriminating between shapes of different complexity levels. In fact, as the number of sides are increased indefinitely, the judgment of complexity may become confounded with the subject's reaction to a different quality in the stimulation. For example, brightness may be judged up to a certain point that this relationship persists at least up to 45 sides. The ability of the subjects to discriminate between the two most extreme classes of shapes indicates that one has yet to reach a point on the psychophysical continuum which will produce a less exact correspondence between amount of information and the processing of that information. Eventually, it is believed, such a point will probably be reached, but this study has not accomplished this.

beyond which any increase in stimulation produces an increase in pain and not an increased brightness. It is not possible at this time to tell what this emergent quality will be in form perception but it may be hypothesized:

a) that the relationship between subject variables (i.e., visual acuity) and performance on the perceptual task will be most noticeable at that range of stimulus complexity in which the emergent quality begins to appear;

b) that judgments of complexity for shapes beyond this range will be lower. The implication here is that additional information (complexity) added to a shape beyond this range will achieve a level which is not easily processed will force subjects to group bits of information, resulting in their perception of a less complex figure.

This analogy between judgments of brightness and of complexity has further significant implications, in that the evidence suggests that such judgments are prothetic in nature, as are many psychophysical dimensions. This is to say, as one increases the number of sides, one is essentially adding complexity to the figure as a whole; which it is believed implies *adding* stimulation to stimulation. Prothetic continua may be differentiated from metathetic continua in that the latter involve substituting one stimulation for another stimulation (Stevens, 1957).

The major disadvantage of prothetic continua stems from the fact that they do not allow for the application of parametric statistics, nor in some cases even non-parametric statistics when such stimuli are scaled by the equal-appearing interval procedure. Essentially prothetic continua produce variances which are non-homogenous and non-normal on the equal-appearing interval scale. The resulting curve is also non-linear with respect to any transformation of the physical dimension. As one can see from an inspection of the data (Fig. 2) the mean of the medians and the variances of these medians covary in an unsystematic fashion. Thus this evidence suggests that the equal-appearing intervals procedure produces non-additivity. Since there is no transformation possible on this prothetic continuum for equal-appearing interval values, to obtain additivity, the next best alternative would be to use magnitude estimation. Magnitude estimation results in additivity and the resulting error distribution therefore should be normal. Thus one should be able to use distribution free statistics with respect to the normal.

Judging complexity is a relatively simple perceptual task. Certainly other tasks involving more complex perceptual processes will result in less exact correspondence between information and information-processing. A study is in progress which attempts to apply the stimuli used in this study in a more complex task, that of association. Also, this project will continue its attempts to further increase complexity levels in the judgmental situation.

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