Abstract

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The ability of adults to process visual information varying on the dimensions of color, symmetry, and information load, was investigated in the present study by means of a recognition task. The subjects were 15 males and 17 females associated with the University of North Carolina at Greensboro. Prior to the onset of the actual experiment, all subjects were given familiarity with stimulus slides, similar to, but different from those used in the study. During training the subjects' task was to simply look at each slide as it appeared on the screen, noting its colors, symmetry, number, and position of stripes filled in with color in each pattern. During the recognition part of the experiment, each subject was required to state whether or not he recognized a stimulus slide out of five alternatives. If the subject responded "yes" for recognizing the stimulus slide, he then made a first and second choice as to which two, out of the five alternatives, were first and second most likely to be the stimulus slide. If the subject responded "no" for not recognizing the stimulus slide, he still made one selection out of the five alternatives as to which one was most likely to be the stimulus slide. The results of the study indicated that information load was important in recognition and that subjects utilized perceived similarity among stimulus items in addition to specific stimulus dimensions.

SOME METHODOLOGICAL CONSIDERATIONS AND STRATEGIES FOR PROCESSING OF VISUAL INFORMATION

by

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Introduction

Some parameters which define the conditions under which perception will occur have been investigated and have yielded some stable principles. Attneave and Arnoult (1956) pointed out that shape is a multidimensional variable, although it had often been considered a dimension. In addition, they maintained that the number of dimensions necessary to describe a shape is not fixed or constant, but increases as a function of the amount of information contained in the stimulus. It was indicated also that there remain a number of problems in using various types of stimuli. Even if the number of dimensions which are necessary in a given case is known, the choice of particular terms (i. e., reference axes in the multidimensional space in the specific case) remains a problem; it seems that some such terms have more psychological meaningfulness than others.

In order to reduce substantially the effects of such a problem so that stimuli could be systematically quantified and varied, Attneave and Arnoult proposed a number of methods for constructing random "nonsense" shapes. Each procedure is, in actuality, a set of rules by which points are plotted and connected in accordance with values obtained from a table of random numbers. Each method determined a domain of stimuli. This procedure was one of the first attempts to study perceptual learning in terms of quantified and exact variables. Although the amount of information contained in each stimulus could be ascertained, there were evidently some problems. As the stimulus increased in informational load, the figure's meaningfulness also increased; that is, its approximation to objects and shapes in the real world increased as a function of its perceived complexity or informational load. In addition, such figures were only increasing functions of complexity with respect to the number of angles or "turns" contained in them; thus implying that the patterns could not control for the amount of light and dark areas.

Information Processing Approaches to Perceptual Learning

Munsinger and Kessen (1964) have proposed a theory which suggests that environmental information (variability) can be quantified by information theory, and that a human being has a limited cognitive structure to handle variability. They postulated that humans prefer a level of uncertainty at or just above their processing limit, and that the tendency to prefer stimulation of high variability is related to a subject's ability to code or process variability. Moreover, continued testing, which provided short-term experience, resulted in increased preference for stimuli of high variability. It should be mentioned that variability was operationally defined in terms of number of independent turns of shapes, and thus is subject to the same problems as the forms of Attneave and Arnoult (1956).

Schroder, Driver, and Steufert (1967) conceived of an organism as a device for processing information input in the computer sense of the term. They observed that the independent variable, stimulus information or complexity, has two aspects: (a)number of dimensions of information presented in a given time span, and (b)diversity of information and of alternatives each unit of information adds. Further, it was pointed out that an increase in input complexity should first raise and then lower the level of information processing. It seemed, therefore, that an organism can only process an amount of information below a maximum load, and that if this amount is too "weighty" the excess information will not be processed. According to this theory, it is conceivable that processing of visual information would increase to a certain optimal level; then decrease as the amount of information continues to increase. This would yield an inverted "U" shaped function. Support for these concepts has been reported by Munsinger and Kessen, (1964), Dorfman and McKenna (1966), and Vitz (1966).

The notion that learning and memory are a type of data sorting implies that the nervous system performs substantial alterations of the physical image received by the sense organs. These transformations extract information about color, size, distinguish pitch and loudness, and determine the spatial and temporal relationships of visual and acoustical signals. Employing the terminology of Eleanor Gibson (1969), this data sorting can be seen to encompass the following: (a)abstraction of differential properties of stimuli, (b)filtering out of irrelevant variables of stimulation, and (c)selecting out or selectively attending of the kind described as exploratory activity of the sense organs. These transformations are of great use to the nervous system in that they simplify tremendously the information that must be transmitted to higher level analyzing or filtering systems.

Munsinger (1966) attempted to study strategies of assimilating information in visual stimuli from a behavioral standpoint. Subjects varied in age from approximately seven to 22 years. He found that young children and adults may approach variability (complexity) of stimuli in different ways. It appeared that adult subjects code or structure information in the stimuli in ways that children do not. In this 1966 study, moreover, Munsinger proposed that children merely sample the stimulus. Further, he was able to show that this strategy changed as a function of age. In a 1967 study, Munsinger found some interesting results which gave further insight into the problem of strategies and information processing: (a)redundancy of stimuli aided recall, (b)adults were better able to use reduction of information to aid recall than children, and (c)adults were differentially aided, as compared to children, by the color-coding to the redundant features of the stimuli. Munsinger went on to say that these results support the notion of two distinct processes contributing to the recall of redundancy. At low levels of numerousness (i. e., the number of black and blue squares in each stimulus pattern) a simple perceptual-memory process, not related to age, is functioning, while at higher levels of numerousness, age differences occur. This suggested to Munsinger a complex coding and storage process which develops through experience.

In order to analyze information processing in an experimental setting, it is necessary to be able to quantify and systematically vary units of information called bits. In 1953, George Miller indicated how information transmission, in terms of bits, related to a classical discrimination learning curve. He defined channel capacity as the maximum amount of information which could be processed by an individual. In an article entitled "The Magical Number Seven, Plus or Minus Two (1956)," he elaborated on the application of the concept of channel capacity to the studies of memory and absolute judgments. On the basis of studies, he concluded that there exists a consistently obtained limit for processing information about the numerousity of a stimulus variable. The channel capacity was maintained to comprise around seven pieces of information or approximately 2.58 bits. Miller further noted that the channel capacity could be increased by an efficient grouping of old items into new ones. This process he termed chunking. Chunking defined a procedure for giving structures to the environment, reducing the number of alternatives to be cognized, and thus, increasing the amount of information which can be processed. In other words, chunking is a process for reducing uncertainty and thus emphasizing the critical differences among stimulus objects for effective discrimination.

Cybernetics has proposed that the human brain functions in a manner of a stable control system of servomechanisms; that is, procedures of control and communications in physical systems are said to parallel in certain fashion the working of the human nervous system. This represents quite a change in conception from the functional unit of the nervous system as a reflex-arc to a complex feedback loop. With the beginning of control systems with the ability to correct themselves in this manner, a much needed improvement arose. The "Computer Age" with its specialized machines (e. g., analog and digital computers), brought with it new models for interpreting behavior (Newell, Shaw, & Simon, 1958). The TOTE mechanism, an alternative to the reflex-arc was proposed by Miller, Galanter, and Pribram in 1960. The notion of a TOTE mechanism supported the idea of an active organism, attending, testing, and selecting stimuli from the environment. Such functional operations and mechanisms are proposed to exist and have locations within the brain. Moreover, it is quite evident that this system, in selecting stimuli, must deal with input which varies along a complexity dimension--assimilating only that information which is congruent with the organism's ability to process it. Although a simplistic model, the TOTE mechanism showed that the organism must test and retest in order to achieve congruent meaning and input. Finally, in obtaining the required order about the environment, the system "exits," and the organism makes an appropriate response. However, it is not enough to know that the organism tests. Psychology must attempt to delineate the processes involved in information processing, and further, must investigate the observable behaviors which also indicate how a testing strategy is operating.

Lane (1968) maintained that in studies which have been reported in the past, there has been a wide variation in peak complexity preferences among individuals. Thus, whereas most subjects prefer an intermediate value of complexity, that value will be highly variable within any group of subjects across any range of complexity (Dorfman & McKenna, 1966 with matrix grains; and Vitz, 1966 with random shapes). Lane discussed the use of a computer derived set of stimuli called histoforms which have the advantage over those of Attneave and Arnoult, (1956) that more precise specifications and quantifications of some of the variables relevant to subjective complexity are possible. The method used to formulate the stimuli is described by Evans and Mueller (1966), and is based on deviations from a prototype design. Increased complexity is defined in terms of deviations above the baseline (prototype design), and decreased complexity in terms of deviations below the baseline. Generally, patterns are seen to vary in terms of redundancy. In other words, Lane assumed complexity and redundancy to be synonymous. Using this method, Lane found that degree of preference is an increasing linear function of stimulus complexity and that the variation in peak preferences across intermediate points in the range of complexity, reported by Munsinger and Kessen, 1964; Dorfman, 1965; Dorfman and McKenna, 1966; and Rump, 1968, was not present. Furthermore, Lane's results deviate from what would be expected from information theory (Schroder et al., 1967). It appears that a possible explanation for the difference in results is that Lane assumes that increasing the amount of information through redundancy results in an overload of information. In actuality, however, redundancy reduces the amount of information input. The subject is required to look at less or part of the pattern in order to achieve a knowledge of the whole.

Motivational Considerations

There has been a great deal of emphasis on the motivational significance of stimulus complexity and the closely related concepts of stimulus unexpectedness and stimulus variation. Dember and Earl (1957) postulated that stimulus complexity is a primary determinant of attention and, as such, is a major independent variable in the control of exploratory, manipulatory, and curiosity behavior. Their study also suggested that a subject has a preferred level of handling a given level of information. The amount just greater than this amount, a "pacer" stimulus, is determined by the complexity of the stimulus and the subject's past experience. They maintained further that the greatest attention will be paid to the pacer stimulus as compared to stimuli with lesser or greater complexity values. Lynn (1966) also suggested that stimulus complexity may elicit orienting reactions more readily than stimulus simplicity. Support for this observation is found in several investigations (Berlyne, 1958a, b; Frantz, 1958a, b).

In one experiment Berlyne (1958a) noted to which stimulus a subject looked first. In human infants, aged three to nine months, it was the one with the greatest amount of contour. Fantz (1958a, b) reported similar findings with infants and chimps. With human adults, Berlyne (1958a) found that more complex or incongruous pictures were fixated longer than were congruous or less complex figures. Complexity was introduced by irregularity in arrangements of the parts of patterns, by increasing the number of parts of figures, by making the parts heterogeneous, or making their shapes irregular. These experiments are supposed to indicate that subjects orient themselves to stimuli in accordance with such properties of stimuli which may be called novel, incongruous, or complex. There exist, however, a number of problems with these investigations: (_a_)looking time or fixation should not be employed singly as a measure of preference for a particular stimulus array. There appear to be cases in which looking time is correlated with dislike or, at least, negatively correlated with verbally expressed preference. Further, eye fixation seems to be indicative of cognitive processing; in that the greater the informational load, the greater the duration of the eye fixation, (b)it is questionable whether Berlyne's figures vary along a complexity level continuum, (c)meaningfulness of figures is not adequately controlled, and (d)in Berlyne's study (1958b) the figures were not scaled according to the amount of light and dark (brightness) or the amount of contour irregularity between a black and white half of a card. Thus, it may be implied that preference may be a function of brightness or irregularity rather than complexity. In any case it is evident that ambiguity surrounds the independent variables.

Developmental Factors

The developmental aspects of preference for visual complexity were investigated by Osles and Kofsky (1968). They presented each of three concepts, form, color, and size, at three levels of informational load, that is, with none, one, or two of the other dimensions irrelevant. The total number of subjects was 270 children; four, six, and eight years old. The four-part experimental procedure consisted of pretesting, pretraining, concept attainment, and intelligence assessment. At all levels of stimulus complexity, the eight year olds, then the six year olds, and lastly the four year olds were able to cope successfully with the task, suggesting that the ability to process increasingly complex materelial increases with age. Osles and Kofsky pointed out that the improvement in performance with age might be due to improved memory or to a difference in strategy which changes the memory load. This result supports the data of Munsinger (1966) which indicated that, as age increases, there is a shift from an increasing monotonic function to an inverted "U" shaped curve, due to the change of strategy from stimulus sampling to coding and structuring of information. Further, Munsinger (1967) found that adults were better able to use reduction in information to aid recall, and they were differentially aided (with respect to children) by color-coding of the redundancy.

Other studies which have dealt with preference for visual complexity are somewhat conflicting: (a)subjects prefer symmetrical shapes (Eisenman, 1967), (b)subjects prefer complex symmetrical shapes (Eisenman & Gellens, 1968), (c)subjects prefer symmetry regardless of complexity preference (Eisenman & Rappaport, 1967), and (d)less complex figures are preferred over more complex ones (Lawrence, 1962), although subjects preferred to look at the more complex patterns for longer periods of time.

Signal Detection Approach to Perceptual Learning

The investigation of perception of visual stimuli in terms of signal detection theory has not received much attention in the past. Yet, an analysis which has dealt with this topic has disclosed how fully an observer can distinguish and rank sensory events. It has usually been assumed in applications of detection theory that sensory events can be ranked throughout the range of liklihood ratios. In testing this hypothesis, Swets, Tanner, and Birdsall (1961) utilized a spot of light of fixed intensity presented on a uniformly luminated background. Each trial consisted of four temporal intervals. The subject was asked to choose the interval most likely to contain the signal, and then choose the interval he believed second most likely to have contained the signal. In the experimental situation, a four-alternative forced choice task was employed. The results indicated that subjects responded well above chance on their second guess; for these conditions, if the subject's first choice was incorrect, his second choice would be correct with a probability of .33, the chance probability. The data yielded a second choice probability of .46. These results seem to refute the notion of absolute sensory threshold, and imply that subject's sensitivity to stimuli which are irrelevant is greater than was suspected in the past. Further, it can be inferred that subjects assimilate more information than just what is supplied by the signal. In other words, information from background "noise" does get processed on some level, although it may be possibly attenuated.

Estes and Taylor (1964) proposed a model of visual detection. This model assumed that at some point in a subject's response system, the elements of a display must be reacted to singly. Thus, although the elements of a configuration are initially registered in parallel on the retina, they must pass at some point through a channel which permits passage of only one element at a time. This paradigm assumed the following: (a)when a display containing D elements is exposed for a short interval, a subset of elements is registered in the receptor apparatus, (b)following the exposure, the traces of the display in the nervous system fade exponentially in such a way that following the display, there is some fixed probability that the traces of the display will have passed below the threshold level at which they can influence behavior, (c)during and following the display, until the stimulus traces pass below threshold, the registered elements are scanned, one at a time. As each element is scanned, it is classified as either signal or noise; and if the former, it leads to a report as to the critical element detected, most importantly, (d)if the stimulus traces fade below threshold before the critical element is scanned, the subject gives a report at random.

Parks (1966) applied psychophysical signal detection theory to recognition-memory performance. Old items in the test list were considered to be analogous to "signals" while new items were analogous to "noise only." He postulated the existence of a psychological continuum according to which each decision to respond "old" or "new" is made. This dimension was thought of as representing the degree of familiarity associated with test items. Thus, it was assumed that the subjects' decisions were based on a dimension not directly related to the actual stimulus dimension involved. In other words, this theory predicts that a subject will say "new" or "old" based on the perceived difference between test items. It can thus be inferred that the more similar the test items are to the signal, the more he will respond "old." If the test items are very different from the signal, the greater will be the subject's tendency to respond "new." If the test items are very similar to one another and to the signal, the greater the tendency to respond randomly.

Basically, signal detection theory makes possible a separation of the criterion and the sensitivity of a subject and provides some powerful tools for analyzing these processes. Murdock (1965) attempted to study the problems of short-term memory utilizing the methods of signal detection. Murdock presented all subjects with 54 trials, each trial consisting of a presentation of six A-B word pairs followed by a recognition test for one of the six pairs. The recognition test consisted of presenting either an A-B or an A-X pair; the subject was required to respond with either a "yes" or "no" and, in addition, give a confidence judgment. An A-B pair represented a proper pair, while an A-X pair was an improper pair; that is, two words which had not been paired during the list presentation. The results of this study seemed to disrepute the idea of a high threshold in short-term memory, above which one can make correct recognitions and below which one responds by chance. Instead, recognition in short-term memory appeared to be more analogous to the continuous process postulated by signal detection theory with the individual capable of varying his criterion over a wide range.

It has been implied that perception is an active process requiring attention and cognitive functioning. Further, it has been indicated that there are many approaches to the study of problems in perception. Many studies have yielded significant gains in the understanding of the processes involved in perceptual learning, while others have simply shown that subjects of all ages respond differentially to the stimulus field. Procedures such as looking time, verbally-expressed preferences, rating scales, and questionnaires are, in many cases, unreliable indices of behavior. In addition, such techniques vary so widely across experiments that inferences based on the data are not generalizable. Further, there seems to be a definite lack of definition and precision of independent and dependent variables. A major need exists to define in precise operational terms what is meant by "complexity" so that procedures and findings may be replicated by future investigators.

It is clear that at least the following are needed: (a)both independent and dependent should be scaled, (b)a more precise measure of the dependent variable should be used, (c)attenuation of individual differences should be accomplished by the selection of subjects for relevant past experience, or by training, and instructions, (d)stimuli should be constructed which control for brightness, excessive meaningfulness, color (or lack of it), degree of intricacy within the outline of the general figure, and (e)repeatable operational procedures should be utilized.

The present study was an attempt to evaluate the possible relationships among the following variables: (a) color, (b)symmetry-asymmetry, (c)informational load, and (d)second-choice recognition. While at issue with some of the previously mentioned studies, the following predictions have been generated: (a)during recognition, subjects who respond incorrectly on their first choices, should respond above chance on their second choice, (b)where color is associated with asymmetry, recognition should be hindered, (c)where color is associated with symmetry, recognition should be facilitated, (d)in terms of Parks' theory (1966), the greater the similarity of the noise patterns to the signal, the greater the tendency to respond "yes" in a recognition task, (e) as informational load increases, recognition should be hindered, and (f)as symmetry increases, recognition should be facilitated.

Method

Subjects. The subjects participating in the present study were 15 male and 17 female graduate students and faculty who had volunteered to participate. The subjects were all affiliated with the University of North Carolina at Greensboro.

Stimulus Materials. All stimuli were 32-centimeter squares which were divided into four equal quadrants. Each quadrant was then filled with a particular number of stripes, depending on the informational load (level of complexity). The number of stripes in each quadrant was either four, six, or eight. Of these four, six, or eight stripes, either two, three, or four stripes respectively were filled in with color. For the conditions of symmetry[1], either two or three quadrants were filled in following Munsinger's (1967) procedure for asymmetrical redundancy. There were four conditions of color: (a)all filled in stripes were black, (b)all filled in stripes were red, (c)symmetry was delineated in black and asymmetry in red, and (d)symmetry was denoted by red and asymmetry by black. One of the four quadrants was selected randomly, and either two, three, or four stripes filled in with color.

[1] The term symmetry is used in the present paper to denote exact repetition of certain dimensions within the same stimulus pattern.

Whether these stripes were horizontal or vertical was also determined randomly. The color of these stripes was dependent on the color-code condition. After the first quadrant had been designed, either one or two more randomly selected quadrants were set up exactly like the first quadrant; thus, producing either a two or three quadrant symmetry. The random quadrant(s) had the same number of stripes as the other quadrants, except that the opposite orientation of the symmetrical quadrants and the patterns were random and unrelated to the other quadrants. Although the matrices of Munsinger (1967) solved many of the problems already discussed, they could not be utilized in the present study due to the non-constant brightness factor and probably greater level of meaningfulness. The stimuli that were employed in this investigation control for constant luminosity and reduce meaningfulness to a large extent. For an example of a stimulus slide see Figure 1.

During training subjects were shown a series of 12 patterned slides, divided into groups of fours separated by a blank slide; i. e., when nothing was shown on the screen. The first group of four slides contained only items with two stripes filled in with color for a particular level of color and symmetry. The second group of four slides contained only slides with three stripes filled in with color for the same condition of color and symmetry. The last group of four slides contained only those slides with four stripes filled

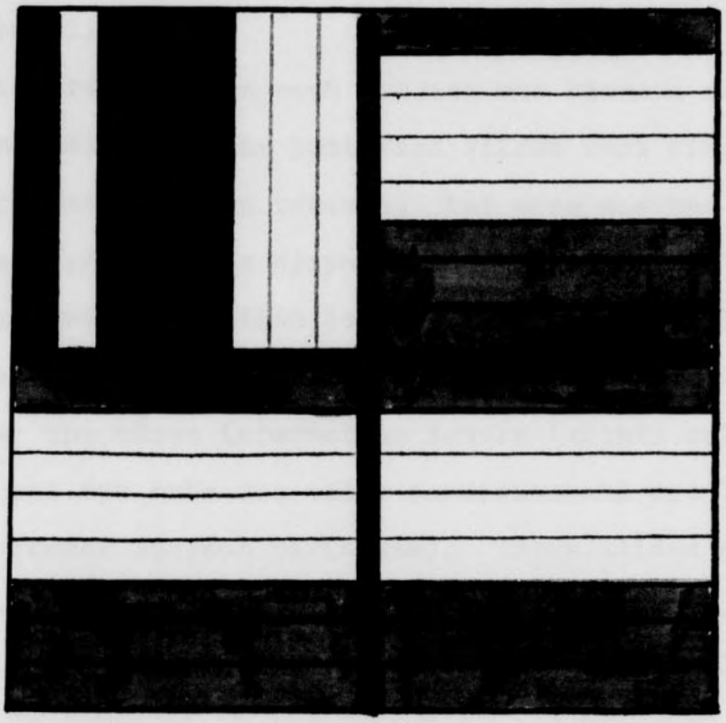

Figure 1. An example of a stimulus slide: red symmetrical black with four stripes filled in with color in each quadrant and three quadrants symmetrical.

in with color for the same condition of color and symmetry. These series of slides are referred to in the present paper as "training slides."

During recognition each subject was shown a series of six patterned slides. The patterned slides were similar to the ones presented during training, but none was the same slide. The series of six slides was composed of two examples of each level of information (complexity) for a particular condition of color and symmetry. All subjects saw slides varying over the three information levels (within subjects variable), but saw only one color condition and one level of symmetry (between subject variables). These slides are referred to in the present study as "stimulus slides."

Following the presentation of each stimulus slide, another slide appeared on the screen (a "recognition slide"). This recognition slide contained five patterns, one of which was the stimulus slide just presented, plus four others similar, but not the same as the stimulus slide. All five patterns were randomly positioned side by side. Under each pattern the letters A, B, C, D, and E appeared from left to right. The stimulus slide appearing in this group of five slides constituted a correct slide. The other four denoted incorrect slides.

The four incorrect slides were systematically designed to represent four types of errors: (a)color error, (b)information error, (c)symmetry error, and (d)position error. A color error pattern was exactly the same as the correct (stimulus) slide, but had the opposite colors associated with the stripes filled in with color (i. e., where black appeared in the correct slide, red appeared in the incorrect slide, and vice versa). An information error slide was designed such that if the correct slide contained two stripes filled in with color in each quadrant, the incorrect slide contained three stripes filled in with color in each quadrant. If there were three stripes filled in with color in each quadrant of the correct slide, there were four stripes filled in with color in each quadrant of the incorrect slide. Lastly, if there were four stripes filled in with color in the correct slide, there were three stripes filled in with color in each quadrant in the incorrect slide. The isomorphism of the correct slide was always maintained in the designing of the information error slide. A symmetry error slide was constructed such that if the correct slide contained two symmetrical quadrants, the incorrect slide contained three symmetrical quadrants, the two already in the correct slide plus one other randomly selected. The fourth quadrant remained the same as the one in the correct slide. If the correct slide contained three symmetrical quadrants, the incorrect slide contained two symmetrical quadrants. The quadrants chosen were always two forming a vertical or horizontal symmetry. A diagonal symmetry did not occur in the incorrect slides. The next quadrant (not part of the symmetry of the correct slide) was preserved on the incorrect slide, and the last quadrant (the third symmetrical quadrant for the correct slide) was completely redesigned at random. A position error slide was designed such that the symmetrical quadrants from the correct slide were preserved on the incorrect pattern, but one stripe from the non-symmetrical quadrants was selected randomly and moved to an adjacent stripe position.

Procedure. The stimuli were projected to the front of a screen positioned approximately six feet from the subjects. The experimenter, operating the slide projector, was seated behind the subjects. The subjects participated in the study in randomly assigned groups of two. All subjects were involved for only one session which was composed of a training part and a recognition part. Each session ran for approximately 15 minutes.

Prior to the onset of the actual experiment, all subjects were given exposure to training slides similar to, but different from, items used in the actual study. The order of presentation of these training slides was maintained constant for all subjects over all conditions of color and symmetry. All subjects were instructed that the patterns which were to appear on the screen were divided into four quadrants with a certain number of stripes filled in with color in each quadrant. They were also told that there was color associated with some of the stripes and that some of the quadrants in each pattern were symmetrical; i. e., that some of the quadrants were identical to some other quadrants. The subjects' task during training was simply to look at the slides as they were presented on the screen, and try to notice the color, symmetry, and number of stripes filled in with color in each quadrant. All training slides were shown consecutively three times through so that subjects would have the opportunity to see all the attributes of the patterns. Each slide was presented for five seconds with a .8-second interval between slide presentations.

During the recognition part of the session each stimulus slide was presented for four seconds with a .8-second time interval between showing of successive slides followed by a recognition slide presented for 20 seconds. The order of presentation of stimulus slides was determined randomly and independently for each group. When the recognition slide appeared on the screen, the subject's task was to mark on his answer sheet whether or not he recognized one of the five patterns as being the stimulus (correct) slide. A "yes" response constituted recognizing the stimulus slide. After a subject responded "yes," he then made a first and second choice as to which pattern (A, B, C, D, or E) was the slide he had just seen (stimulus slide). Each subject, if he responded "yes," was required to select the pattern most likely to be the correct one, and the pattern second most likely to be the correct one. If the subject responded "no" for not recognizing the correct slide, he then chose A, B, C, D, or

E as being most likely to be correct (a second choice selection). A "no" response constituted a first choice selection, since the subject was, in essence, saying that neither A, B, C, D, nor E was the stimulus slide. Subjects had the entire time that the recognition slide was on the screen to mark their responses (20 seconds). Two seconds prior to the offset of the recognition slide, the experimenter said "ready" as a cue for the subjects to complete their responses and look at the screen for the presentation of the next stimulus slide. Subjects were also instructed not to leave any blank answers, but to guess if they were unsure of an answer. Lastly, the lights in the room were turned off and blinds partly drawn to give enough light for subjects to mark answers and, at the same time, reduce any after-image effects.

Results

The number of correct recognitions on first choice data for each subject under each condition was tabulated. This was accomplished by noting if a subject initially responded "yes" for recognizing the correct (stimulus) slide. If the subject did initially respond "yes," then the letter corresponding to the slide he selected for his first choice was matched to an answer key containing the correct responses. Only the number of correct first choices was used in this initial analysis. If the subject responded "no" for not recognizing the correct slide, his second choice of a particular letter (A, B, C, D, or E), corresponding to a slide which the subject thought most likely to be the correct one, was disregarded for this first analysis.

In summary, the design of the present investigation included (as between-subject conditions) four levels of color (all black, all red, black-symmetrical red, and red-symmetrical black), two types of redundancy (two quadrants symmetrical and three quadrants symmetrical). As within-subject conditions, all subjects saw matrices with either two, three, or four stripes filled in with color in each quadrant. Of the four quadrants in each stimulus pattern, two or three quadrants were symmetrical to each other, and the other two (one) quadrant(s) were (was) randomly constructed independently of the others. For each subject, two examples of each level of information were presented individually, so that there could be a possible total of six correct first choice responses for each subject. The number of correct responses for each level of information at each condition of color and symmetry was entered into a split plot analysis of variance to assess the effects on recognition attributable to color, symmetry, and level of information.

Only one main effect, information level, was significant beyond .05 level. Number of correct responses for all subjects decreased as the level of information increased, $\underline{F}\ (2,48) = 3.31$, $\underline{p} < .05$ as shown in Figure 2. Those stimuli which contained four stripes filled in with color produced more errors in recognition than did those stimuli which contained two or three stripes filled in with color. The condition of symmetry was not significant and did not seem to affect recognition ($\underline{F} = 1.55$, 3,24$\underline{df}$, $\underline{p} < .25$). The main effect of redundancy through symmetry was not significant, $\underline{F}\ (1,24) = 1.28$, $\underline{p} < .50$, seemingly did not affect recognition appreciably. Where the symmetrical quadrants were associated with one color and the random quadrants with the other color, recognition seemed to be assisted by symmetry. The all black and all red conditions did not show this trend. This result, although not significant, is shown in Figure 3.

A trend analysis performed on the number of correct responses as a function of information level indicated a

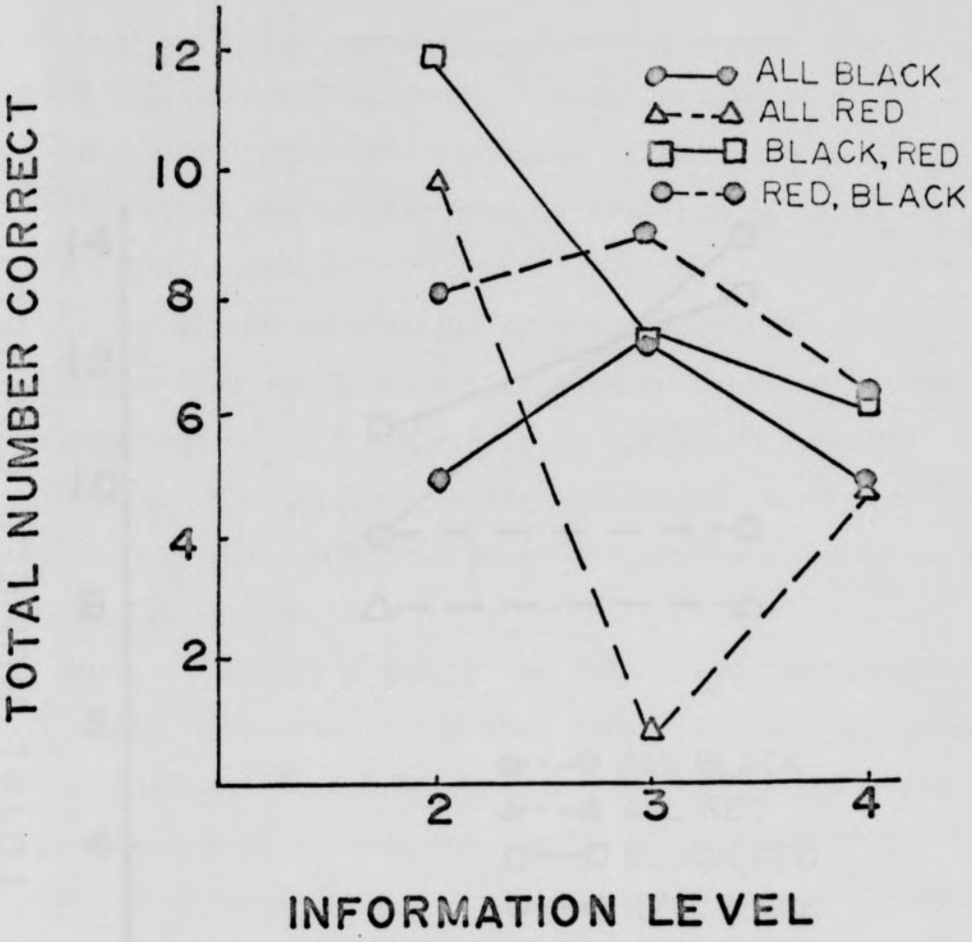

Figure 2. Total number of correct responses for all subjects at each level of information (number of stripes in each quadrant which were filled in with color).

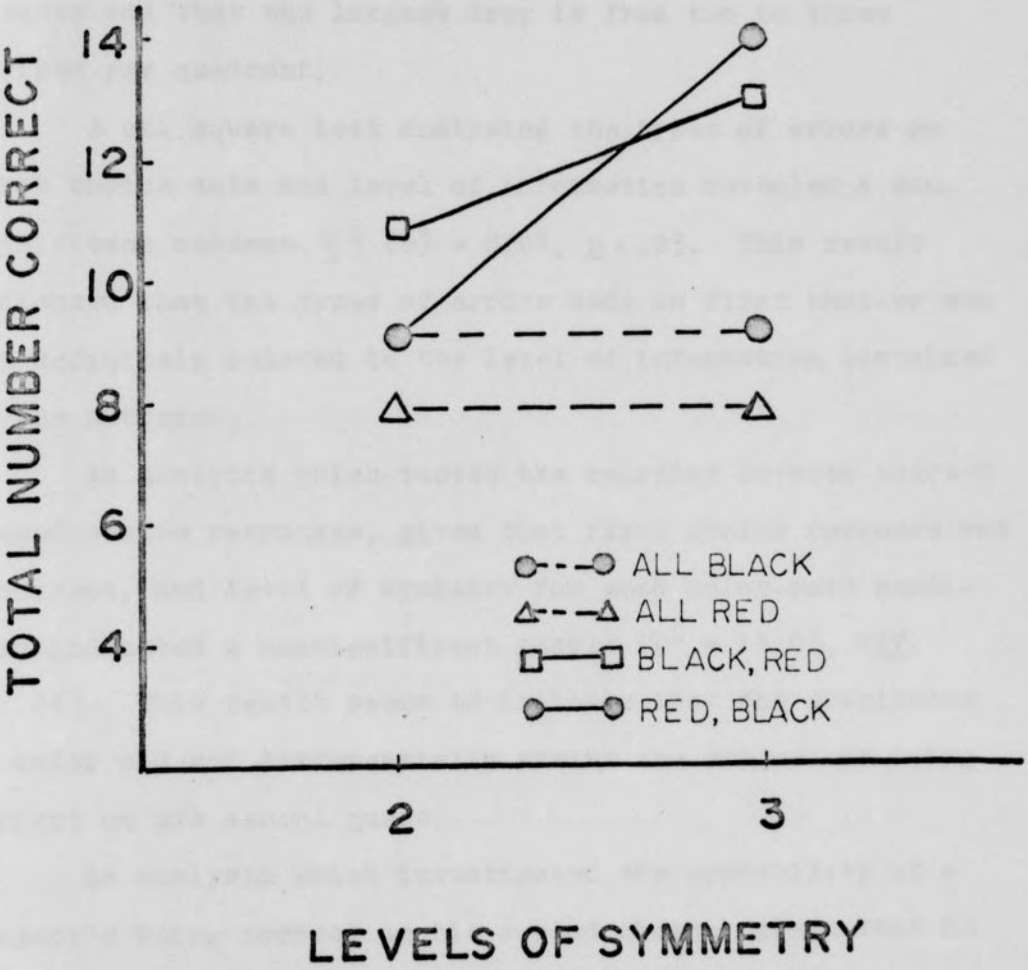

Figure 3. Total number of correct responses for all subjects at each level of symmetry (two quadrants redundant and three quadrants redundant).

significant linear trend, F (1,29) = 15.41, $p < .01$, and a significant quadraric trend (F = 16.28, df = 1,29, $p < .01$). Figure 4 illustrates this trend. It can be seen that the number of correct responses decreases as information increases and that the largest drop is from two to three stripes per quadrant.

A chi square test analyzing the types of errors on first choice data and level of information revealed a nonsignificant outcome, χ^2 (6) = 8.04, $p < .25$. This result indicated that the types of errors made on first choices was not definitely related to the level of information contained in the patterns.

An analysis which tested the relation between correct second choice responses, given that first choice response was incorrect, and level of symmetry for each color-code condition indicated a nonsignificant result (χ^2 = 14.06, 7df, $p < .06$). This result seems to indicate that the attributes of color did not differentially assist the subject in being correct on his second guess.

An analysis which investigated the probability of a subject's being correct on his second choice, given that he was incorrect on his first choice, revealed that subjects respond correctly with a probability of .58 which is significantly greater than chance of .25, $z = 7.84$, $p < .001$.

A comparison between correct and incorrect responses on second choice, given the first choice was incorrect, and the

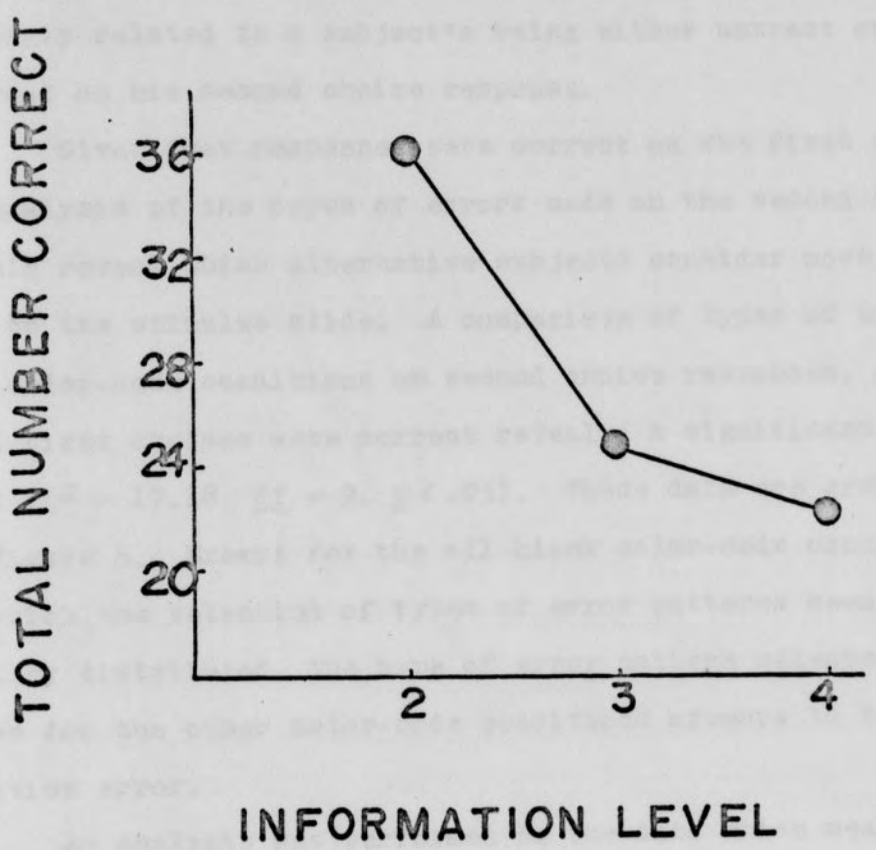

Figure 4. Total number of correct responses for all subjects at each level of information (number of stripes in each quadrant which were filled in with color) collapsed over all conditions of color and symmetry.

four color-code conditions revealed a nonsignificant result ($\chi^2 = 7.12$, $df = 3$, $p < .10$). It appears that color is not strongly related to a subject's being either correct or incorrect on his second choice response.

Given that responses were correct on the first choice, an analysis of the types of errors made on the second choice should reveal which alternative subjects consider most similar to the stimulus slide. A comparison of types of errors and color-code conditions on second choice responses, given that first choices were correct revealed a significant result ($\chi^2 = 17.18$, $df = 9$, $p < .05$). These data are graphed in Figure 5. Except for the all black color-code condition in which the selection of types of error patterns seems to be equally distributed, the type of error pattern selected most often for the other color-code conditions appears to be a position error.

An analysis was performed on the data which measured the number of correct responses on first choice data for the first and last (sixth) items presented during the experimental session versus the middle two items (items three and four) in the same series. The reason for this analysis was to test the specific hypothesis that the middle items might be more difficult to learn than the end items. The focus of this test was the case where two examples of the same level of information occurred in positions three and four of the series and appeared not to be learned. A repeated-measure analysis

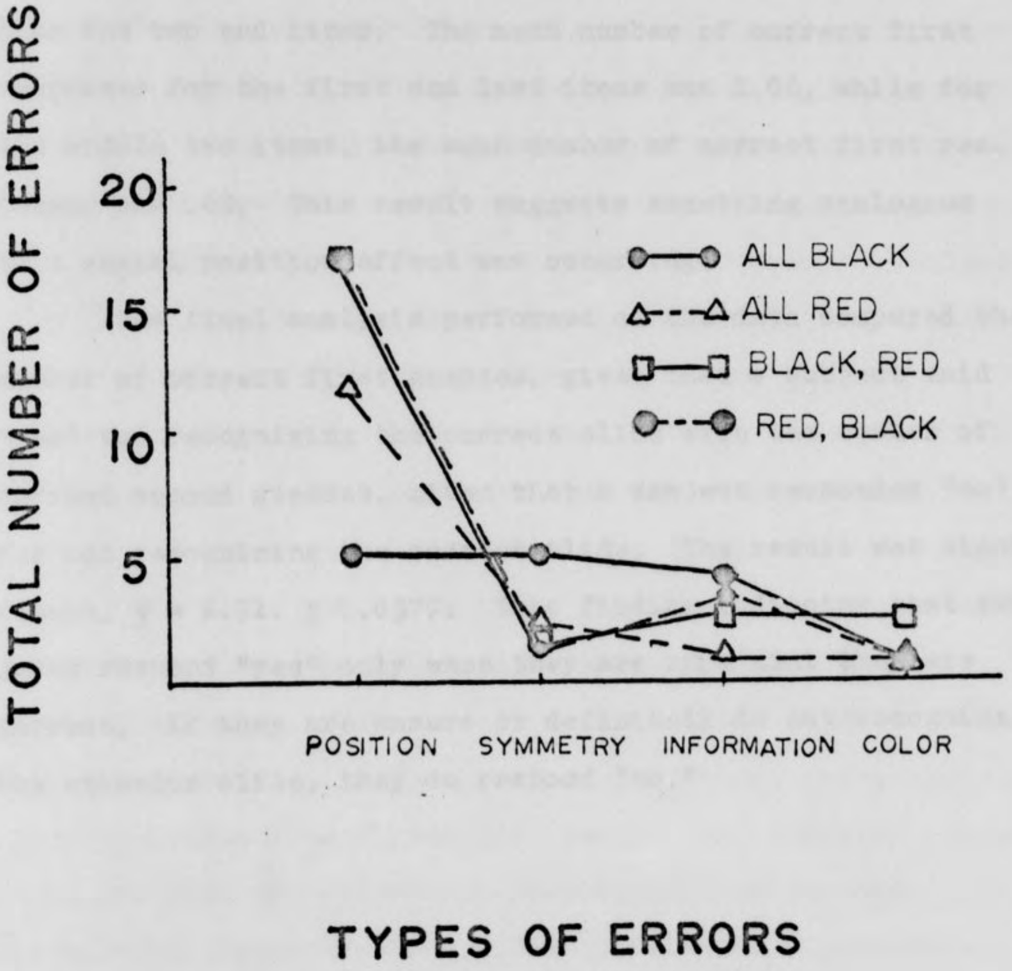

Figure 5. Total number of selections of each incorrect alternative on second choice responses, given that first choice selections were correct.

of variance on these correct responses revealed a significant result ($\underline{F} = 7.11$, $\underline{df} = 1,62$, $\underline{p} < .01$). This finding showed that the two middle items were more difficult to learn than the two end items. The mean number of correct first responses for the first and last items was 1.06, while for the middle two items, the mean number of correct first responses was .68. This result suggests something analogous to a serial position effect was occurring.

The final analysis performed on the data compared the number of correct first guesses, given that a subject said "yes" for recognizing the correct slide with the number of correct second guesses, given that a subject responded "no" for not recognizing the correct slide. The result was significant, $\underline{Z} = 1.91$, $\underline{p} < .0377$. This finding indicates that subjects respond "yes" only when they are sure that they are correct. If they are unsure or definitely do not recognize the stimulus slide, they do respond "no."

Discussion and Conclusions

The present experiment adds to our knowledge of the factors inherent in a stimulus pattern which influences human information processing. The result that number of correct responses decreased as information level increased was not unexpected. The notion of channel capacity (Miller, 1956), derived from similar data, would lead one to expect this. It appears that human beings do indeed possess a limited ability to process information efficiently within a given time span. It also seems that where redundancy through symmetry should reduce uncertainty and facilitate recognition, it only did so in the cases where one color was associated with symmetry and the other color was associated with the random quadrants. Where both symmetrical and random quadrants were filled in with stripes of the same color, recognition was not facilitated (See Figure 2). The role of stimulus redundancy has been the subject of many studies which often have found contradictory results. Fitts, Weinstein, Rappaport, Anderson, and Leonard (1956) indicated that symmetry aided in recall, but hindered discrimination. Munsinger and Forsman (1966) found that in a tachistoscopic identification task, which required the subject to match a stimulus item to a sample, the addition of symmetry to randomly generated shapes generally facilitated subjects' performance. Munsinger (1967) explored the effect of stimulus redundancy in a task which required absolute judgments of a set of stimuli; groups of subjects were asked to estimate the numerousness (level of information) of 8 X 8-cell matrices. The findings of this study showed that added redundancy (three vs. two submatrices redundant) interfered with estimation performance. The notion that color, when associated with symmetry, facilitates recall (Munsinger, 1967) might be applicable to recognition.

The finding that the most frequent error on second choice data, given that subjects' first response was correct, was a position error seems to suggest that subjects perceive a position error pattern as most closely resembling the stimulus slide, although similarity was not operationally defined in terms of stripe position, nor was position error independent of the other types of errors. However, the results tend to support Parks' theory of familiarity (1966). It seems evident that very often subjects responded "yes" for recognizing the stimulus slide, basing their decision on a position error. This might be analogous to responding "old" on the basis of perceived, not actual, similarity.

The indication that subjects respond correctly with a probability of .58 on second choice responses given incorrect first choices reveals something about subjects' strategies of processing information and decision-making. Since there were only four possible answers following a first choice selection, each one the remaining slides had an a priori probability of .25 of being chosen. If subjects were able to eliminate two slides as being very different in configuration (namely the symmetry error, color error, or information error slides), from the stimulus slide, there remained only two alternatives, the two most seemingly similar items, namely the position error slide and the correct one. At this point subjects responded at random between the two alternatives--an a priori probability of .50, quite similar to the obtained value of .58 ($\underline{Z} = 1.52$, $\underline{p} < .07$). This observation in addition to some memory for stimulus dimensions accounts for the data well for it seems as though the most frequent combination of first and second choice responses was position error--correct selection or vice versa. Subjects were indeed able to eliminate the incorrect attributes of the patterns, even though they were often wrong on their first choice responses. It appears that some "noise" does get processed by the nervous system along with some of the dimensions to be learned. This interpretation supports the finding of Swets et al. (1961).

The theory of Estes and Taylor (1964) maintained that if the stimulus traces fade below threshold before the critical element is scanned, the subject gives a report at random. According to the present study, the only time a subject responds randomly is when he has narrowed his alternatives down to two very similar items, and this process of elimination is not random, but is based on a familiarity rule similar to Parks' (1966) model. In other words, the critical element in Estes and Taylor's paradigm is familiarity under Parks' theory. The present study is in accord with Parks' notion of decision-making in that subjects appear to make judgments on the basis of a dimension not directly related to the actual dimension involved. The decision seems to be founded on a perceived difference between test items, in addition to some memory of the critical elements of color, symmetry, and information.

The finding of a strong serial position effect might suggest the necessity of counterbalancing the stimulus slides so that each slide appears in every position. This would insure that the results of this study and others would not be confounded by such an effect and, thus, might yield clearer and more meaningful data.

Finally, it is suggested that in a future investigation some of the recognition slides be made up of all noise items (incorrect slides) or that the recognition patterns be presented singly and successively with a yes-no recognition task so that such measures as d of signal detection theory could be calculated.

Summary

The responses of 15 male and 17 female subjects to a perceptual recognition task provided a test for the hypothesis that there exists a relationship between the independent variables of color-coding, symmetry, and information and the dependent variable, identification of a previously presented visual pattern from among four alternatives similar in all dimensions but one to the stimulus (correct) pattern.

Most of the following conclusions of the present experiment are supported by the results of Parks (1966) and Munsinger (1967) on decision-making and information processing.

1. The idea of a limit on the processing of information is strongly implicated.

2. Where the symmetrical and random quadrants of the stimulus patterns are associated with different colors, recognition seems to be facilitated.

3. Parks' theory of familiarity in addition to some memory for stimulus dimensions seems to account for the data well.

4. The strategies of subjects indicate that some "noise" does get processed by the nervous system, and that subjects do not respond randomly but on the basis of elimination.

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