THE EFFECTS OF THREE PHYSICAL PROPERTIES

OF VISUAL PATTERNS ON THE ATTENTIONAL

RESPONSE OF THE SQUIRREL MONKEY

By

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Bachelor of Arts

Muhlenberg College

Allentown, Pennsylvania

1965

Submitted to the faculty of
the Graduate College of
the Oklahoma State University
in partial fulfillment
of the requirements
for the degree of
MASTER OF SCIENCE
July, 1968

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PREFACE

The present experiment was one of a series of studies conducted under the direction of Dr. Larry Brown to determine the effects of various physical properties of visual patterns on the attentional behavior of humans and squirrel monkeys.

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CHAPTER I

INTRODUCTION

The questions of what physiological mechanisms and what stimulus dimensions underlie an organism's selection of relevant sensory information with the simultaneous exclusion of insignificant signals have remained vital for many years. For a long time responses to the question of what stimulus properties are selectively utilized have centered around the principles of perceptual organization offered by Gestalt psychologists. That is, properties such as contour, symmetry, and general figure "goodness" were regarded as the relevant factors in stimulus selectivity. Only within the last fifteen years, however, have answers to this question been advanced which have aroused the interest of most quantatively orientated psychologists. Awakened by the new developments in the psychology of motivation revealing that organisms not only strive to reduce drive states, but also at times seek out stimulation, psychologists began to attempt to define the stimulus characteristics related to many behaviors, including attentional behaviors, formerly considered too mentalistic to deal with. In particular, the research activities in the area of attention have mainly fallen within three categories—attempts to define the physiological mec-

namisms underlying diverse attentive behaviors, attempts to discern the role of attention in discrimination learning, and attempts to correlate attention with various physical parameters of stimuli.

Falling in the latter category, the present study was designed to examine the effects of three stimulus dimensions, viz., area, completeness, and "proximity variance", on the visual attention given to various random patterns by the squirrel monkey. Based on the proposition that certain aspects of the environment are more salient than others, it was hypothesized that the attentional response to the various experimental patterns should vary according to the informational characteristics of the stimulus dimensions represented in the patterns. Moreover, by the use of carefully quantified patterns and controlled methods of stimulus presentation it was hoped that some further light might be shed on the question as to the means whereby an organism selects relevant sensory information.

CHAPTER II

REVIEW OF THE LITERATURE

Physiological Mechanism of Attention

A large amount of research has established that the
reticular activating system is the functional unit which
controls the overall level of central nervous activity and
an important part of the ability to direct attention toward
specific areas of stimulation. Existing as a diffuse col-
lection of fibers interspersed with nuclei, this system ori-
ginates within the cervical region of the spinal cord and
extends through the medulla, pons, and mesencephalon, termi-
nating finally within the diencephalon. Physiologically,
with the exception of a small portion in the ventromedial
medulla, the entire complex acts largely as an excitor.
The initiation of the system's excitatory influences results
either from collateral stimulation accompanying sensory im-
pulses passing to the cerebrum or from centrifugal stimula-
tion derived from the cerebrum itself. Qualitative differ-
ences have been found to exist, however, between the arou-
sal capacities of the several portions of the system. Elec-
trical stimulation of mesencephalic portions has been found
to evoke generalized arousal throughout the entire brain,
thus suggesting in accord with the findings of Gastaut and

associates (1957), that mesencephalic components of the reticular formation maintain a state of normal wakefulness. On the other hand, electrical stimulation of single thalamic portions of the system has been shown to elicit activity in topically isolated areas of the cerebrum, providing evidence that thalamic components function both as relays for mesencephalic arousal and as sources of specific activation of particular areas of the cortex. Moreover, studies have shown that the interaction of thalamic induced activity and oscillating facilitation and inhibition from the cerebral cortex seems to enable selective attention (Jasper and Ajmone-Marsan, 1952; Jasper, 1958).

The anatomical complex of interconnecting neural pathways in the reticular formation also seems to provide a coordinating mechanism both within individual cerebral hemispheres and between one hemisphere and the other. The nature of these interconnecting pathways suggests, in addition, that the reticular formation may function similar to the "programming" and "scanning" units in a computer (Guyton, 1966). The proposed programming function derives from knowledge of the close connection of various thalamic portions of the system with specific cortical areas which when activated would enable the release of previously stored information or the processing of information supplied by immediate sensory input. The ability to scan the total store of information to locate some dictated item(s) apparently involves a complex interaction of corticofugal projections with

thalamic components which in turn project to defined areas
of the cortex where the given information may be stored.
Obviously, though, such operations are exceedingly complex,
and little is known about the mechanisms involved. Similar-
ily, except for a few generalized areas, little is known
concerning the specific location or locations within the
system related to the capacity to attend to a particular
feature of the environment. Nevertheless, recent evidence
suggests that besides functioning in general arousal and
alerting, the reticular formation also serves in perception
as a monitor for incoming sensory input, selecting and focu-
sing those messages which are "important" enough to be re-
layed to the cerebral cortex (Lindsley, 1958).

Attentional Aspects of Discrimination Learning

Quite independent from the neurophysiological investi-
gation of attention has been the advent of a formidable
amount of data illuminating attentional components in the
discrimination-learning process. An immediate outgrowth of
the research activity responsible for these data has been
the development of several theories employing attention as a
central construct (Lovejoy, 1965; Mackintosh, 1965; Suther-
land, 1959a; Zeaman and House, 1963). Despite variations in
the terminology applied to specific concepts and assumptions
by different theorists, the basic premises of all such the-
ories are similar. Fundamentally, discrimination learning
is conceived of as a two-stage process: first, as an analy-

zing response to some relevant stimulus dimension defined by a general class of cues possessing a given common characteristic; and second, as the establishment of an instrumental response to the cues of the relevant dimension. The actual mechanism underlying both of these stages is further conceived of as being largely one of trial-and-error. Thus, according to the general theory, in successive intervals of the discrimination the probability of selecting a given cue associated with the relevant dimension will increase, while that associated with irrelevant dimensions will decrease. It is notable that despite difficulties in quantifying learning during the analyzing phase, this two-stage conception of the discrimination-learning process has been considerably bolstered by several confirmations of quantitatively derived predictions made on the basis of the general theory (Lovejoy, 1966; Zeaman and House, 1963).

Quantitative Studies of Visual Perception and Attention

A third category of attentional reseach, also arising independently from investigations in neurophysiology or in discrimination learning, has dealt with the physical characteristics of the stimulus as they relate to attention. Unfortunately, the bulk of the studies making up this category has involved topics which are related but ancillary to the specific problem of determining what properties of visual patterns are important to attention. According to their primary purpose, these studies may be further subdivided

roughly into those attempting to quantify relations between perception and physically specified stimulus parameters, those investigating the stimulus dimensions governing the ability of different classes of animals to discriminate among various shapes and patterns, and those dealing directly with the stimulus determinants of attention.

Quantitative Studies of Form Perception

Hochberg and McAlister (1953) were perhaps the first investigators to make a significant contribution toward quantifying visual-shape and pattern perception. Using Kopfermann "cubes" as stimulus patterns, it was found that the relative time devoted to viewing the bidimensional phase of patterns was related to the information (number of different items that must be given in order to specify a pattern along one or more dimensions that may be abstracted from the pattern) contained in the pattern. Specifically, the probability of making a bidimensional response to a stimulus was inversely related to the number of angles and number of line segments contained in the pattern.

Paralleling the initiative of Hochberg and McAlister, numerous other investigators have attempted to relate a wide variety of perceptual capacities to specific physical characteristics of the stimulus array.

In an early discussion dealing with the informational qualities of visual patterns, Attneave (1954) indicated that perceived information was primarily located along the con-

tours of a shape and was especially related to points of contour change, as at angles and the peaks of curves; low information, correspondingly, was associated with redundancy either in color or direction of slope. With random polygons constructed according to several methods outlined earlier by Attneave and Arnoult (1956), Attneave (1957) further demonstrated that forms judged to be highly complex contained a larger number of turns (angles or curves), more symmetry in comparison to asymmetrical shapes with an equal number of independent sides, and greater angular variability (the average of the differences between adjacent angles of the polygon's contour) than forms rated less complex. Arnoult (1960), moreover, not only was able to substantiate Attneave's findings concerning the relationship of various physical parameters to judged complexity, but also suggested the importance of symmetry and curvature to perceived familarity and meaningfulness. Using nonsense shapes varying in their sidedness, area, symmetry, curvature, and several other physical dimensions, it was found that the largest amounts of the variance in perceptual judgments of familarity and meaningfulness could be accounted for in terms of the symmetry and curvature of the stimuli.

Several investigators have reported that with humans and squirrels an increase in the complexity (sidedness) of the shapes comprising various patterns facilitates discrimination performance up to some optimum level determined apparently by the inherent limits of the observer's sensory

processing capacities (see Miller, 1956), but indicated that properties of axial rotation (the angular rotation of the shape from its vertical axis) and asymmetry also aided in the discriminations (Brown et al., 1962; Hitchcock et al., 1963; Michels et al., 1962). Seiler and Zusne (1967) demonstrated further that the ability to correctly judge the complexity of tachistoscopically presented random shapes varied according to the complexity of the shapes, 24-sided shapes being most incorrectly judged and 6-sided shapes being most accurately judged, and according to the amount of viewing time permitted. Thus, either placing constraints upon information processing behavior in the form of decreased time or increased information load served to impair discrimination performance.

Using rhesus monkeys as experimental subjects, Polidora and Thompson (1964, 1965) found that the ability to discriminate various patterns was closely related to the disparity in area, disparity in contour, and number of redundant and unique elements of the patterns. Contrary to humans and squirrels, however, the monkey's ability to discriminate patterns appeared to be inversely related to the sidedness of the component shapes (Polidora, 1965).

Dealing with a somewhat different quality, viz., geometricity, Zusne and Michels (1962a, 1962b) reported that the subjective judgment of "geometric form" was based primarily upon the parameters of symmetry and compactness (ratio of the area to the perimeter squared). Compactness,

more recently, was also found to be an important parameter for the accurate discrimination of tachistoscopically presented random shapes (Forsyth and Brown, 1967).

Although the studies cited above represent only a small sampling of those attempting to quantify visual perception, it seems important to note, nevertheless, that despite widely proliferated research activity and repeated attempts to synthesize existing findings (Brown and Owen, 1967; Egeth, 1967; Michels and Zusne, 1965), too few studies using comparable methods have dealt with any one variable to permit a very reliable evaluation of the role of a given parameter in the perception of a particular multidimensional pattern. As emphasized by a recent study by Nash and Michels (1966), at least one vital problem that has yet to be thoroughly investigated is the complex manner in which specific variables of the pattern may interact.

Shape and Pattern Discrimination in Animals

Numerous studies have been done with animals attempting to discern the capacities of a particular class of animals for making a given kind of visual form discrimination. In that the visual forms used in these studies varied in certain physical characteristics, these studies are similar to those already described. A distinction may be made, however, since these studies have used relatively more molar dimensional measurements. For example, measurements such as those of the relative ease of discriminability between a circle

and a square have been employed. (A circle and a square may be distinguished along several more molecular dimensions, such as the number of sides, degree of curvature, and several other dimensions.)

Sutherland conducted a series of experiments to determine the ability to discriminate orientation and shape by octopuses. Using outlined rectangular forms it was found that octopuses were readily able to discriminate between rectangles in vertical and horizontal orientations but had considerably more difficulty discriminating between obliquely orientated rectangles (Sutherland, 1957a, 1958a). An increase in the rectangles's size, irregardless of their orientation, also appeared to aid discrimination (Sutherland and Carr, 1963). With discriminations involving other forms Sutherland (1957b, 1958b, 1959b) found that squares were more readily discriminated from triangles than diamonds from triangles, but that squares and circles had about the same discriminability as squares and triangles. A study of the discrimination of horizontal and vertical mirror images suggested further that, at least for the octopus, the horizontal extent of the shape was of most significance. Up-down pairs of T-shapes and U-shapes were consistently discriminated with greater ease than were pairs of left-right U- and T-shaped stimuli. Interestingly, recent studies with humans (Attneave and Oldson, 1967) and with monkeys (Riopelle et al., 1964) have revealed similar evidence for the importance of the horizontal extent of the shape to discrimination.

Studies have also been done on the discrimination of various shapes by rats. Lashley (1938) conducted a comprehensive study of the rat's ability to detect visual detail. Despite criticisms that Lashley's use of solid figures may have brought about discriminations based on brightness instead of the properties of the shapes themselves, the general finding that rats tended to isolate certain elements from the total stimulus complex and respond primarily on the basis of these elements has been widely supported by contemporary studies. Contrary to Lashley's finding that rats cannot discriminate a square from a circle, however, Dodwell (1957) demonstrated that rats could make a circle-square discrimination following prior discrimination training with vertical and horizontal striations. With the inclusion of triangles among the discrimination objects, Dodwell (1960) further noted that rats were as readily able to distinguish circles from triangles as they were circles from squares. Similar to earlier findings with octopuses, rats were also found to be able to readily distinguish horizontal from vertical rectangles (Sutherland, 1961). On the other hand, a study by Sutherland and Carr (1962) found, contrary to the findings with octopuses, that no reliable distinction could be made between the rat's discrimination of horizontal and vertical forms as opposed to non-horizontal and non-vertical forms. For example, X- and V-shaped forms in various orientations were discriminated with as equal facility as were T- and H-shaped stimuli. Comparable

discriminative ability with vertical, horizontal, and obli-
que figures, however, was also indicated in later reports of
shape discrimination by cats (Sutherland, 1963) and by var-
ious fishes (Sutherland, 1964).

Fantz conducted a series of studies which were closely
related to the investigations of shape discrimination with
octopuses and rats. Dealing with the development of visual
perception rather than discrimination ability itself, how-
ever, these studies were designed to measure the initial
preference for various shapes by several classes of animals.
With newly-hatched domestic chicks, Fantz found that initial
pecking was directed adaptively toward shapes of natural
food sources; specifically, chicks were found to prefer
round forms over non-circular forms despite variations in
color, background, degree of contrast, orientation, or depth
cues (Fantz, 1961, 1967), and despite variations in size
(Fantz, 1958). Differing from the chick's preference for
simple circular forms, the preference of infant monkeys sub-
jected to eight weeks of light deprivation was in all cases
for more highly patterned stimuli, that is, checkerboards
over squares, stars over circles, and black-and-white squa-
res and newsprints over larger red squares (Fantz, 1958,
1965). In studies with human infants, preferences were also
found to exist for more complex patterns, bull's-eye patterns
being preferred over striped targets and checkerboards being
preferred over uniform squares (Fantz, 1961).

Study of the Physical Determinants of Attentional Behavior

In contrast to those studies previously cited, several studies by Brown, singly and in association with others, are probably the only ones directly concerned with quantifying the attentional aspects of visual perception in terms of specific, physically defined stimulus parameters. Brown and Farha (1966), following the methodological suggestions given earlier by Brown (1964), carried out an investigation of the effects of various instructional sets upon the viewing time (the measure of attention) of patterns with shapes differing in area, number of turns (complexity), and color. Results showed that larger shapes, irrespective of their color, evoked significantly longer viewing times under all set conditions than smaller shapes. Significant interaction also occurred between instructional set and both area and number of turns. Area was of greater importance under interesting and pleasing sets than under the neutral sets. Viewing times increased with the number of turns characterizing the shapes under both the pleasing and interesting sets; however, a decrease was found under the pleasing sets. A later study (Brown and O'Donnell, 1966) dealing with attentive behavior in both humans and squirrel monkeys found further that with human subjects increased attention was related to increases in the number and angularity of the pattern elements, whereas with monkeys increased attentiveness seemed due only to the addition of pattern components.

Supplementing these findings, Brown and Lucas (1966) also provided evidence for the importance of the dissimilarity of the pattern-components' border widths to the attentional response of humans. Recently, in a study designed to evaluate the effects on attention of several other pattern parameters, Brown (1967) found that with humans attention was significantly related to the elevation and dissimilarity in hue of the pattern components; with monkeys, attention increased with the curvature and elevation of the components. Thus, a general hypothesis suggested by all of these studies is that informational variables seem to have greater importance to attention than noninformational variables, both for humans and monkeys.

CHAPTER III

METHOD

Subjects

Eight male and two female adult squirrel monkeys, Sai-
miri sciurea, served as subjects. All had been used in at
least one previous discrimination learning experiment (see
Brown, 1967) and thus were acquainted with the testing appa-
ratus and the type of task to be performed.

Apparatus and Stimulus Objects

The apparatus was a miniaturized WGTA (Wisconsin Gen-
eral Test Apparatus) scaled in size for use with the squir-
rel monkey (see Cross and Brown, 1965, for a complete des-
cription). Patterned after the standard WGTA, it consisted
of a rectangular chamber divided into two compartments by
several horizontal bars. The front compartment was lighted
and contained a movable three-well test tray on which sti-
mulus objects could be presented to the subject located in
the rear compartment. An extension of the track on which
the tray moved also permitted the tray to be brought out
from the front compartment for easy accessibility during
arrangement of the test problems. The wall of the compart-
ment facing the experimenter had a one-way mirror and thick

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black curtain to obscure the subject's view of the activities of the experimenter. Dried currents were used to prompt entry to and exit from the apparatus and to reward performance throughout the experiment.

Stimulus objects presented to the subjects were of three types. Those used during pretraining were multidimensional "junk" objects attached to small wooden bases. The experimental objects were white wooden wedges having an inclined surface of 5-cm. X 5-cm. to which a pattern of the same size was glued. An additional wedge, used as a control, bore no pattern and thus was uniformly white.

Stimulus Patterns

Eight stimulus patterns representing differing levels of the three parameters of area, completeness, and proximity variance were constructed according to the following procedures.

Six cells, defined by coordinates obtained from a table of random numbers, were selected within a 14-cm. X 14-cm. grid graduated at one-centimeter intervals. The distance from each cell to its closest neighboring cell was measured, and from these measurements the proximity variance (PV) and mean proximity of the six cells were computed. That variance resulting from a random selection of cells was arbitrarily set as the measure of high PV. (Actually several random sets of cells were plotted and that set containing the highest PV was used.) The mean proximity and PV of the

six cells were 3 cm. and 4 cm., respectively. The grid containing these six cells served as a template for organizing patterns having a high PV.

The template for low PV (zero variance) was made by randomly choosing three cells from the high PV template and randomly selecting three additional cells on the grid in positions such that each cell was separated from its closest neighboring cell by 3 cm. Since each cell was situated 3 cm. from its closest neighboring cell, the mean proximity of both templates was equated at 3 cm., but the PV of the low PV template was 0 cm.

Using Method I of Attneave and Arnoult (1956) three random quadrilateral shapes were drawn as prototypes for use with the two templates. Two copies of each of these shapes was assigned at random to two of the six cells of the high PV template and to two cells of the low PV template.

For two of the experimental patterns, the shapes were reduced in area to 500 mm.^{2}, centered by eye in a vertical orientation (see Erown and O'Donnell, 1966) over the cells to which they were assigned in both the low- and high-PV template patterns, and drawn in outline with black ink on sheets of heavy white paper. (In some instances it was necessary to move a shape slightly from its cell to prevent its overlapping an adjacent shape.) In a similar manner, the shapes were reduced in area to 200 mm.^{2} and drawn on sheets of white paper to produce two further experimental patterns. Four additional patterns were also drawn in a manner identi-

cal to those already constructed, except that the arms of the angles of each shape were cut off by a distance equaling 30% of the shorter arm of each individual angle. The eight 14-cm. X 14-cm. patterns resulting from these procedures were finally reduced photographically to an area of 5-cm. X 5-cm. and printed on matte paper. The prints were glued to the inclined surfaces of the wooden wedges described previously. After the final reduction in size, each large shape had an area of approximately 62.5 mm.^{2} and each small shape had an approximate area of 25 mm.^{2} (The experimental patterns, slightly reduced in size, are shown in Figure 1.)

Procedure

Since the procedure used in this experiment was essentially the same as that employed earlier by Brown and O'Donnell (1966) and Brown (1967), the rationale underlying the procedure can best be described by a quotation from one of these earlier studies.

> It has been shown that two-choice discrimination learning in the squirrel monkey is facilitated by the prior presentation of one of the objects, appropriately baited or unbaited . . . . Now, if one stimulus property should be of greater "attentional" importance to the squirrel monkey than another, it might be expected that the first in a single-object presentation would be detected with greater probability than the presence of the second and, hence, would have greater overall effect on subsequent discrimination performance. If, for example, large stimuli elicit visual orientation with shorter latency or for longer periods of time than smaller stimuli, it might be assumed that in a discrimination problem involving size as the critical cue prior presentation of the large stimulus would be of greater over-all benefit than prior presentation of the smaller stimulus . . . . (Brown and O'Donnell, 1966, pp. 712-713).

Figure 1. Arrangement of experimental pattern-pairs according to opposing levels of the three stimulus parameters, area, completeness, and proximity variance.
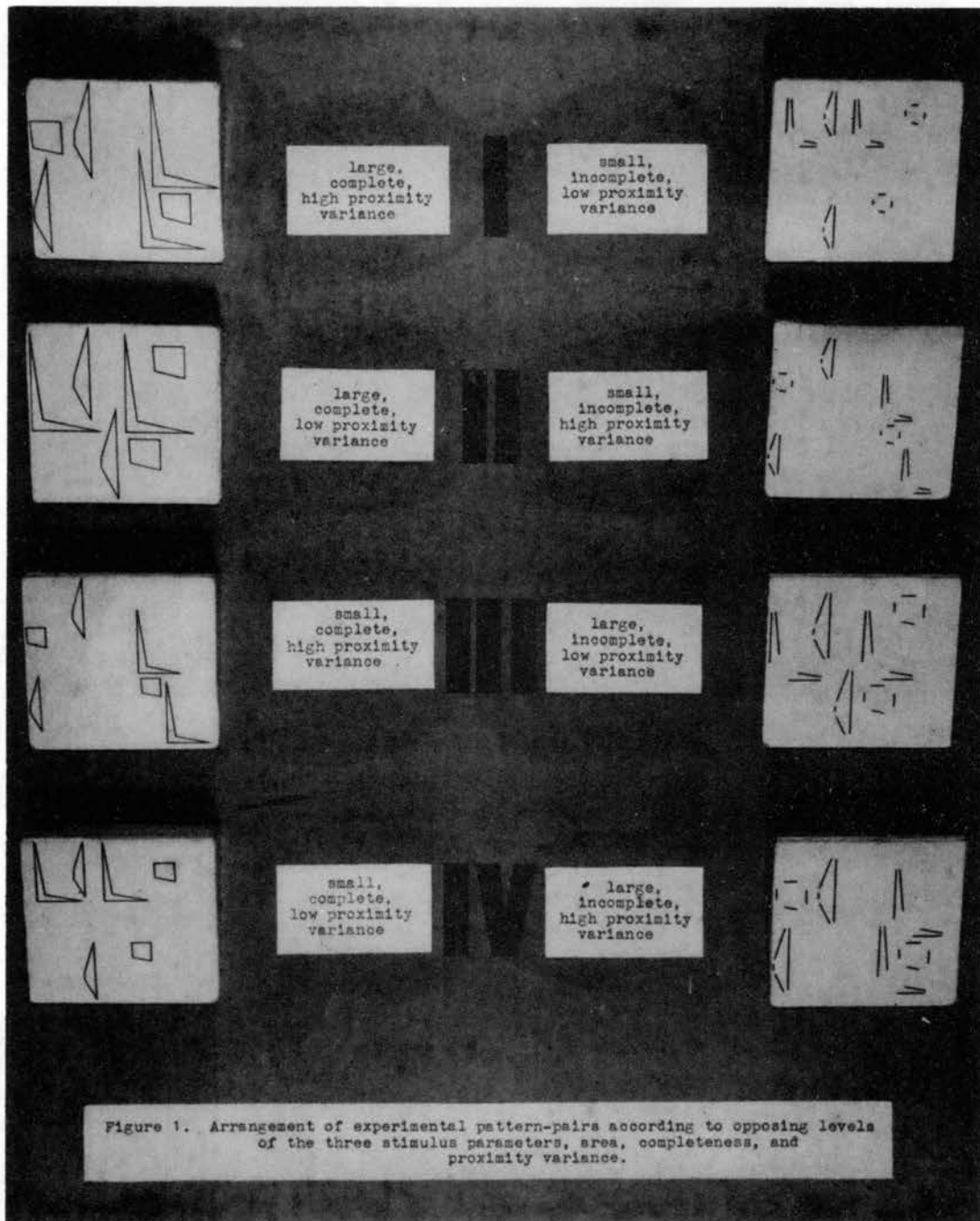
Each experimental pattern was paired with its opposite
in all dimensions to form four object pairs (see Figure 1).
Since each member of a pair could serve as a rewarded pat-
tern during any given presentation, 8 basic problems were
thus formed. Furthermore, since these same 8 basic problems
were used to assess both "attention" and "preferences," a
total of 16 experimental problems resulted. Each experimen-
tal problem consisted of three consecutive presentations of
a single wedge over the center food well, followed by two
presentations of a particular pair of patterns over the side
food wells. Wedges presented on Trials 1-3 were always
baited, whereas only the positive wedge was baited on Trials
4 and 5. In attention (A) problems the pattern used during
the single-object presentations was the positive pattern
used during Trials 4 and 5. In preference (P) problems the
single object was always the white wedge. The reason for
including assessments of preference in the discriminations
can be seen in the following quotation from a study employ-
ing a procedure similar to that of the present study, but
using curvature as one of the parameters.

> The P problems . . . were used to control for
> the possibility that choices on Trials 4 and 5 might
> reflect simple stimulus preferences rather than the
> effects of the single-object presentations. For
> example, if in one $\underline{/A\underline{/}}$ problem a curved pattern
> were presented on Trials 1-3 and S chose the cor-
> rect (i.e., the curved) pattern on Trials 4 and 5,
> and, if in another $\underline{/A\underline{/}}$ problem an angular pattern
> were presented on Trials 1-3 and S chose the in-
> correct (i.e., the curved) pattern on Trials 4 and
> 5, it might be concluded that S benefited more from
> the prior presentation of the curved pattern than
> from that of the angular pattern and, hence, that
> curved patterns have greater attentional value than

angular patterns. However, the consistent choice
of the curved pattern might reflect nothing more
than a mere preference for curved over angular
forms (Brown, 1967, pp. 402-403).

Since the experimental patterns were very similar, and
since the inter-problem interval was only about 30 seconds,
an equal number of filler problems was used to minimize the
effects of transfer. The 16 filler problems, constructed
from four pairs of multidimensional "junk" objects, were
presented in the same fashion as the experimental problems.

Problems were presented to subjects in four blocks,
with each block containing 16 experimental and 16 filler
problems. Each block was presented at the rate of eight
problems per day for four successive days; a one-day rest
interval was allowed before the start of each new block of
problem presentations. Problems were presented in a differ-
ent random order for each animal, and the positioning of
positive stimulus patterns during Trials 4 and 5 was gover-
ned by the Gellermann series with the one restriction that
right and left food wells receive an equal number of bait-
ings for each block of problems. The noncorrection method
was used during all presentations. An interval of approxi-
mately 15 seconds was maintained between trials with a given
problem.

CHAPTER IV

RESULTS AND DISCUSSION

For each stimulus property present in the positive pattern on a given problem one A (or P) score was recorded for both performance on Trial 4 and performance on Trials 4 and 5 combined. The A (or P) score on a given property for each animal was the total number of correct responses on Trial 4 (or Trials 4 and 5 combined) on all A (or P) problems in which the property appeared in the positive pattern. Since there were six properties, since two scores were computed for each property on a given problem (one for Trial-4 responses and one for responses on both Trials 4 and 5), and since there were two types of problems (A or P), each monkey received 24 scores (6 X 2 X 2). Scores for a property representing one level of a stimulus dimension were compared with the scores for the property representing another level of the $\underline{same}$ dimension by means of $\underline{t}$ tests for matched observations; 12 $\underline{t}$ tests were therefore made on the data. Since each property appeared in the positive pattern in four of eight A (or P) problems within each 4-day block, and since there were four 4-day blocks, the maximum A (or P) score possible for each property was 16 for one-trial (Trial 4) data and 32 for two-trial (Trial-4 and Trial-5) data. Per-

formance on the filler problems was not evaluated.

A summary of the results of the 12 t tests is shown in Table I. As can be seen from the table, the properties of "smallness" and "incompleteness" appear to be significantly related to learning. On the other hand, smallness and incompleteness also appear to be significantly related to preference behavior. It might therefore appear that the performance noted with these dimensions during learning may largely be assumed to be a function of stimulus preference. That performance on both learning and preference problems failed to show differences based on level of PV also tends to support such a conclusion.

The effects of small, incomplete patterns on discrimination performance may further be seen by analyzing performance relative to pattern pairings 1 and 2 and pairings 3 and 4, respectively. Since in pattern pairs 1 and 2 the properties of smallness and incompleteness, properties which tend to increase the frequency of correct response, were acting together, it might be expected that such a combination would have resulted in a maximal performance difference. As can be seen in Table II such an expectation is borne out. Similarily, when the dimensions of smallness and incompleteness were placed in opposition with each other, as in pattern pairs 3 and 4, the performance differences would have been expected to be minimal. The results shown on Table II also substantiate this expectation. It is noteworthy that in both of these analyses the maximizing and minimizing of

differences apply both to attention and preference problems, thus suggesting in conjunction with the overall analysis of problems that stimulus preferences exerted an important effect.

TABLE I

ANALYSIS OF THE EFFECTS OF THE STIMULUS DIMENSIONS,
AREA, COMPLETENESS, AND PROXIMITY VARIANCE, ON
VISUAL PATTERN DISCRIMINATIONS INVOLVING
ATTENTIONAL AND PREFERENCE BEHAVIOR

STIMULUS DIMENSION	ATTENTION				PREFERENCE			
	Trial 4		Trial 4-5		Trial 4		Trial 4-5	
	Mean	t	Mean	t	Mean	t	Mean	t
AREA large	7.9	2.32*	15.8	2.66*	7.8	1.64	15.1	2.40*
small	10.3		19.8		9.8		18.6	
COMPLETE-NESS complete	7.8	3.12*	16.1	2.87**	7.3	3.67**	14.6	7.40***
in-complete	10.4		19.6		10.3		19.0	
PROXIMITY VARIANCE high	9.1	0.0	17.6	0.69	8.1	1.63	16.2	1.47
low	9.1		18.0		9.5		17.6	

     *   P$<$.05
    **   P$<$.01
   ***   P$<$.001

TABLE II

ANALYSIS OF THE EFFECTS OF PATTERN PAIRINGS ON DISCRIMINATIONS INVOLVING
ATTENTION AND PREFERENCE WITH RANDOM VISUAL PATTERNS REPRESENTING
DIFFERING LEVELS OF THE STIMULUS DIMENSIONS, AREA,
COMPLETENESS, AND PROXIMITY VARIANCE

STIMULUS DIMENSION	PATTERN PAIRS	POSITIVE LEARNING				PREFERENCE			
		TRIAL 4		TRIALS 4-5		TRIAL 4		TRIALS 4-5	
		Mean	t	Mean	t	Mean	t	Mean	t
AREA	Pairs 1-2 large	3.3	3.56**	7.2	3.41**	3.5	4.04**	6.9	4.82**
	small	5.8		11.0		6.0		10.9	
	Pairs 3-4 large	4.6	-.16	8.7	.24	3.8	-.06	8.2	-.71
	small	4.5		8.9		4.3		7.7	
PROXIMITY VARIANCE	Pairs 1-2 high	4.6	-.17	8.7	1.24	4.1	3.08*	8.0	3.38*
	low	4.5		9.5		5.4		9.8	
	Pairs 3-4 high	4.5	.15	8.9	-.25	4.0	.14	8.2	-.96
	low	4.6		8.7		4.1		7.7	
COMPLETE-NESS	Pairs 1-2 complete	3.3	3.56**	7.2	3.41**	3.5	4.04**	6.9	4.82**
	incomplete	5.8		11.0		6.0		10.9	
	Pairs 3-4 complete	4.5	.16	8.9	-.24	3.8	.60	7.7	.71
	incomplete	4.6		8.7		4.3		8.2	

* P<.05
** P<.01

Although the results with preference problems were found to be statistically significant for the properties of smallness and incompleteness, it may still be questioned whether the effects noted could not be due to the greater importance of these properties to attention. The concept of attention, it may again be recalled, refers to the selection within a class of cues of those properties which are of greatest significance and responding on the basis of these select properties. Given the current results, that statistical significance was obtained both with learning and preference problems, it appears that rather than responding on the basis of several select stimulus properties, discriminations occurred at a more molar level (i.e., manual preference) and hence, may or may not have reflected the sole control of one or more stimulus properties: for example, preference responses may be subject to the control of "fear" and other non-stimulus factors. Presumably, if the measure of attention could have been refined, it would have been possible to detect those attentional factors which may or may not have been operating. However, under the current conditions, all that can reliably be noted is that elevated performance with smallness and incompleteness appeared to be based on manual preference for stimulus objects having these properties.

That proximity variance failed to show significant effects on performance, although being an informational variable, can probably be accounted for in part by the technique

of pattern construction. Since, as indicated previously, it was not always possible to center a particular experimental shape over its prescribed cell during pattern construction, it is conceivable that the physical difference in proximity variance may have been reduced. Furthermore, the perceptual difference between high and low proximity patterns, being rather small at the outset, may well have become diminished as the original patterns were reduced to a 5-cm. X 5-cm. area.

The preference for incomplete patterns may have been due in some degree to the initial association value (e.g., secondary reinforcement value) attached to the patterns. Unfortunately, since studies have not been done with monkeys comparable to those with humans on the association value of random shapes (Vanderplas and Garvin, 1959), and in view of the obvious difficulties of obtaining a measure of a random shape's association value with non-human subjects, no estimate can be made of the role that this factor may have played in the present discriminations.

Considering difficulties inherent in the measure of sub-human attention, including the probable "insensitivity" of behavioral measures, advances in the neurophysiological investigation of attention appear worthy of additional consideration. Techniques have already been devised for recording the manner in which information derived from the color, contour, and form of a shape is processed neurally by receptors in the visual system (DeValois, 1966). Techniques

have also been used to measure the electrical responses from electrodes implanted in particular areas of the reticular activating system, the system believed to be intimately related to attentional capacity, during shape discrimination by monkeys (Lindsley, 1958). Perhaps by combining techniques of these types, it would be possible to obtain a more direct measurement of the sensory information transmitted to higher centers of the nervous system as an organism responds to a given visual shape or pattern. By comparing sensory input and changes in input at various levels of the nervous system associated with the response to a given shape, it may be possible to determine those shapes or properties of shapes which deliver the greatest amount of central information. Those properties of shapes having neuroelectrical concomitants found to be relatively undiminished in the passage to higher neural centers might be assumed to have greater importance to attention than properties having associated input which shows significant reduction. Certainly the inclusion of such measures would not obviate attempts to obtain measures of those stimulus properties most associated with overt attentive behaviors; it might, however, provide a more accurate gauge of the information an organism actually receives from a particular dimension and is thus able to process.

Finally, the results of recent work by Polidora (1966) seem relevant to an analysis of the results of the present study. In a multidimensional analysis of the relation of

fifteen different stimulus dimensions to visual pattern dis-
crimination by monkeys it was found that performance was
almost exclusively determined by the number of unique ele-
ments (the total number of spatially corresponding elements
in lighted-unlighted states) of the patterns. Although var-
iables such as sidedness and contour disparity formerly
identified as significantly related to discrimination per-
formance were also found important in this study (Polidora,
1965a, 1965b), these variables appeared to be almost en-
tirely subsumed under the more basic variable, unique ele-
ments. Thus, in the present study the dimensions of area,
proximity variance, and completeness may or may not have
been "basic" dimensions. The implication is that where sev-
eral stimulus dimensions are simultaneously involved, it is
imperative to establish which variable(s) is more fundamen-
tally related to behavior before it can be determined which
property (or properties) has the greatest importance to at-
tention.

CHAPTER V

SUMMARY

Eight male and two female squirrel monkeys served as
subjects in an experiment designed to evaluate the effects
of three stimulus dimensions, area, completeness, and proxi-
mity variance, on the visual attention given to eight random
patterns. Each pattern, representing a given level of each
of the three stimulus dimensions, was paired with that pat-
tern opposite to it in all properties and presented as a
simultaneous discrimination problem involving either a mea-
sure of attention or stimulus preference. Paired presenta-
tions involving the measurement of attention were preceded
by three training trials with the positive pattern from the
pattern-pair; presentations involving the measurement of
preference were preceded by training with a non-patterned
stimulus. The significance of the three dimensions to
learning following single-object presentations with patter-
ned stimuli, and to preference following single non-patter-
ned presentations, was evaluated in terms of the total num-
ber of correct responses each subject made for a given level
of a stimulus dimension in comparison to that obtained for
the other level of the same dimension. Analysis of the re-
sults revealed that the contributions of "smallness" and

"incompleteness" were statistically significant to attention
(P <.05), but that these same properties also elicited sig-
nificant preferences (P< .01). Analysis of the results with
patterns in which smallness and incompleteness acted togeth-
er or in opposition revealed that such combinations signifi-
cantly increased or decreased, respectively, the frequency
of correct responses. That the effect of proximity vari-
ance, an informational variable, failed to reach statisti-
cal significance in both analyses lent further support to
the finding that stimulus preference was an important factor
in elevated performance with small, incomplete patterns. In
view of the possible "insensitivity" of the behavioral mea-
sure of attention employed, suggestion was made of a tenta-
tive means whereby a more direct measure might be obtained
of the information an organism actually receives while
overtly responding to visual shapes or patterns.

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