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HIGH-ORDER CONCEPT FORMATION IN THE PIGEON[1]

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After 30 days of operant training, with pecking responses to aerial photographs containing man-made objects reinforced with food, and no food reinforcement for pecking on photographs not containing man-made objects, a discrimination to the two classes of photographs was obtained. The discriminative response generalized to photographs with which the pigeons had no previous experience. This study demonstrates that pigeons are capable of forming relatively high-order concepts. Some possible stimulus properties controlling the discrimination are discussed.

When an organism gives the same response to a set of stimuli varying on a particular dimension, but not to other stimuli that lack that stimulus dimension, that behavior is said to be an example of concept formation. It has long been recognized that animals are capable of forming simple concepts, *i.e.,* where the stimulus dimension is easily specifiable.

As pointed out by Malott and Siddall (1972), the concepts include: size (Klüver, 1933), color (Weinstein, 1945), triangularity (Andrews and Harlow, 1948), numbers (Hicks, 1956), novelty (Brown, Overall, and Gentry, 1958; Brown, Overall, and Blodgett, 1959), patterns (Kelleher, 1958), guided missile targets (Skinner, 1960), bad parts on an assembly line (Verhave, 1966), and matching (Malott, 1969; Malott and Malott, 1970). In addition, it has been shown that dogs can be trained to respond to certain classes of explosives and tunnels (Carr-Harris and Thal, 1969).

More recently, the work on concept formation in animals has been extended to more complex stimulus dimensions, ones that the experimenter cannot specify in stimulus terms but are nevertheless highly reliable classifications on the basis of object qualities. In particular, several recent papers have reported on the ability of pigeons to form high-order abstract visual concepts (Herrnstein and Loveland, 1964; Malott and Siddall, 1972; Siegel and Honig, 1970). These studies examined the ability of the pigeon to discriminate between the class of visual images described as containing a person and another class characterized by the absence of a person.

The present study was designed to investigate the ability of pigeons to form concepts more complex than that of human *versus* nonhumans; namely, to discriminate between photographs containing man-made objects and those containing no man-made objects.

METHOD

The apparatus employed was similar to that described by Lubow and Stevens (1964). The main components included a sound-attenuated compartment, a food hopper, a pecking key onto which stimuli were back-projected, a sound source, a 35-mm slide projector with a circular magazine, scheduling equipment, and a numerical printout recorder. The hopper delivered grain when the pigeon made a correct key-pecking response. An auditory signal (1200 Hz, 72 dB at 2 ft) followed an incorrect key-pecking response.

The following four scheduled contingencies were in effect throughout the experiment: (1) If the subject pecked the positive slide within 2 sec from onset, the food hopper was presented. The hopper and slide remained on for a total of 1.5 sec from the time of response and were then followed by the next slide. (2) When

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the subject did not respond to the positive slide, the slide remained on the key for 2 sec and was then followed by the next slide. (3) If the subject pecked the negative slide within 2 sec from onset, the tone was presented. The tone and slide remained on for a total of 6 sec from the time of response and were then followed by the next slide. (4) When the subject did not respond to the negative slide, the slide remained on the key for 2 sec and was then followed by the next slide. A correct response was either pecking a positive slide or not pecking a negative slide. Conversely, an incorrect response was either pecking a negative slide or not pecking a positive slide.

The slides were of two different sets, one containing man-made objects (positive slides) and the other containing no man-made objects (negative slides). All were black and white aerial photographs. The positive slides included cities, highways, plowed fields, and orchards. The negative slides included natural terrain under various conditions, mountains, canyons, forests, and water. The photographs were obtained from several different books and varied in altitude, brightness, angle of regard, *etc.* It was assumed that the only consistent difference between these two sets of photographs was along the dimension(s) relevant to this study.

The subjects were four experimentally naive male White Carneaux pigeons, approximately 2 yr old. They were reduced to 80% of their normal baseline weight and then trained to peck at the key when it was illuminated. When this response became stable, 80 slides were introduced, 40 positive and 40 negative. The pigeon received three runs of the 80 slides each day in the same order of presentation. Acquisition training continued for 30 days.

To test for generalization, 10 new slides (five positive and five negative) replaced 10 acquisition slides on the thirty-first day. These new slides were randomly placed within the original series of 80. Each pigeon received two presentations of this series.

Since the slides were always presented in the same order during acquisition, a test for serial position effects was necessary. On the thirty-second day, the order of presentation of the original 80 acquisition slides was changed. This order continued for six days. On the thirty-eighth day, a new test for generalization was given. Again, 10 new slides replaced 10 acquisition slides, being randomly placed in the series previously presented. On the thirty-ninth day, a second test for serial position was given. This was similar to the first test except that the slides were arranged in a new order. This new order was presented for one day only.

RESULTS

Performance of one of the four pigeons did not improve during the initial training or during any of the following tests. Data from this bird are not included in the results. However, the remaining three pigeons did discriminate between the two sets of slides. Figure 1 shows the percentage of key-pecking responses to each slide over the last 10 days of acquisition training. This represents the percentage of correct key-pecking responses to the positive slides and the percentage of incorrect responses to the negative slides. For example, in the case of Pigeon F, only two slides containing no man-made objects (negative) were pecked at more than 50% of the time, and five slides containing man-made objects (positive) were pecked at less than 50% of the time. For this graph and the succeeding ones, the slides were rank-ordered for number of responses. The percentage of responses was plotted as a function of the rank order. A perfect score on all 80 slides would result in two parallel lines maximally displaced, one high for the 40 positive slides and one low for the next 40 negative slides. These graphs clearly show a difference in the number of responses to the two sets of slides. A few slides were responded to incorrectly most of the time. These slides were, generally, the same slides for the three pigeons.

Figure 2 represents the percentage of responses to each slide for the combined first and second serial position tests. Only the data from the first day of the first test and the first day of the second test were used. The data show that the two sets of slides were responded to differentially, thus ruling out the possibility that the pigeons were learning the serial presentation of the slides. Most of the slides responded to incorrectly were again the same for all three pigeons, and the same ones that were responded to incorrectly during the initial training.

The results of the two generalization tests are shown in Figure 3. The separation of the

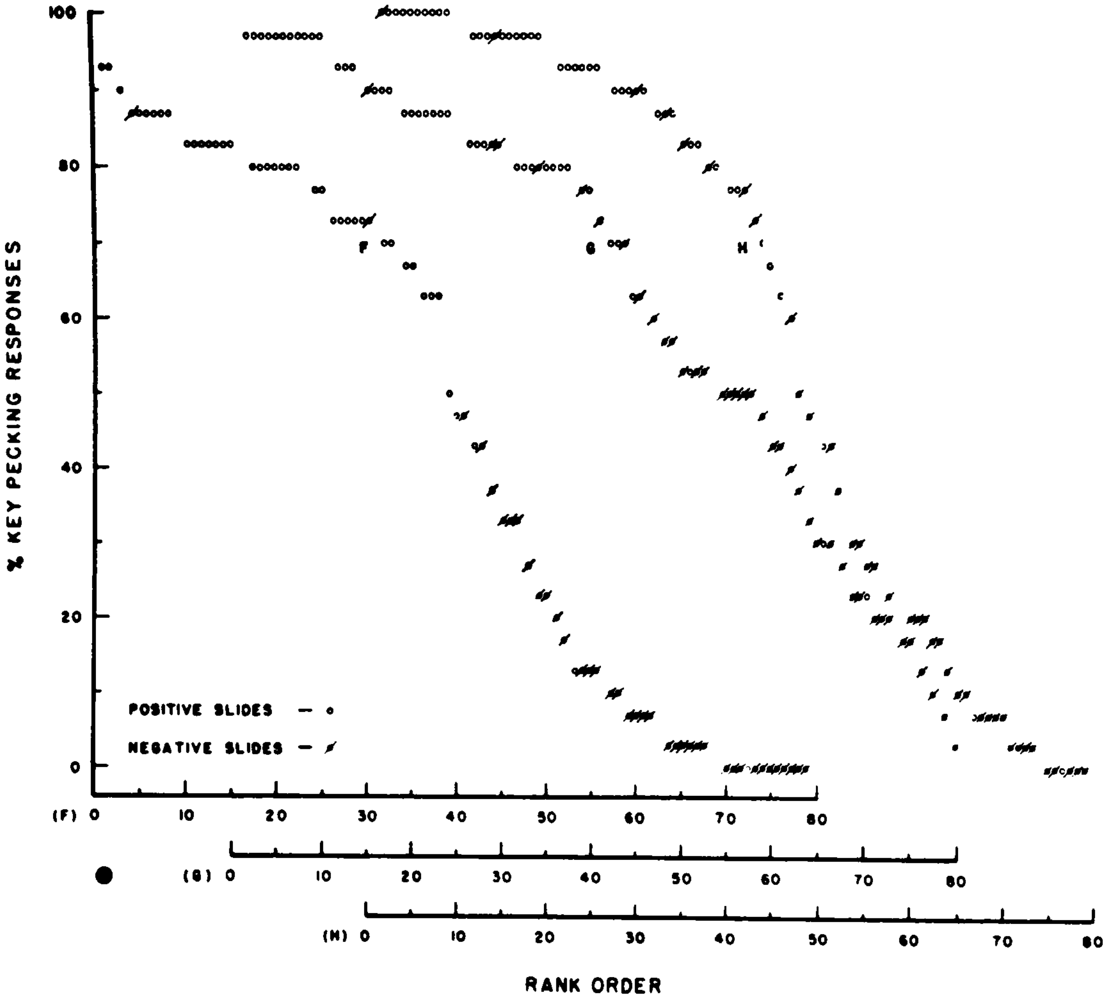

Fig. 1. Percentage of key-pecking responses to individual slides over the last 10 days of acquisition. Abscissas are displaced in order to present the data for individual subjects.

two sets of slides on the basis of the number of responses is not as clear as in the preceding graphs, and a statistical analysis (χ^2 test for one sample) was run on these data. The results for two of the pigeons, G and H, were significant ($p < 0.05$). The third pigeon, F, did not do as well ($p < 0.15$), although the results for its first generalization test were significant ($p < 0.05$).

All training and testing then ceased for 52 days, although the subjects remained on a food deprivation schedule. Following this period, acquisition training was resumed, followed by new tests for serial position effect and generalization. The generalization tests were performed with new stimuli. The results of this replication were comparable to that of the first experiment. The three subjects reacquired the discrimination between man-made and non-man-made stimuli, the discrimination was not based on serial position effects, and the discrimination generalized to new stimuli.

DISCUSSION

The present results indicate that pigeons are capable of discriminating higher-order visual stimuli. They apparently discriminated successfully between photographs containing man-made objects and those containing no man-made objects. It would seem that they isolated one or more stimulus properties common to photographs of man-made objects. From quite another point of view in psychol-

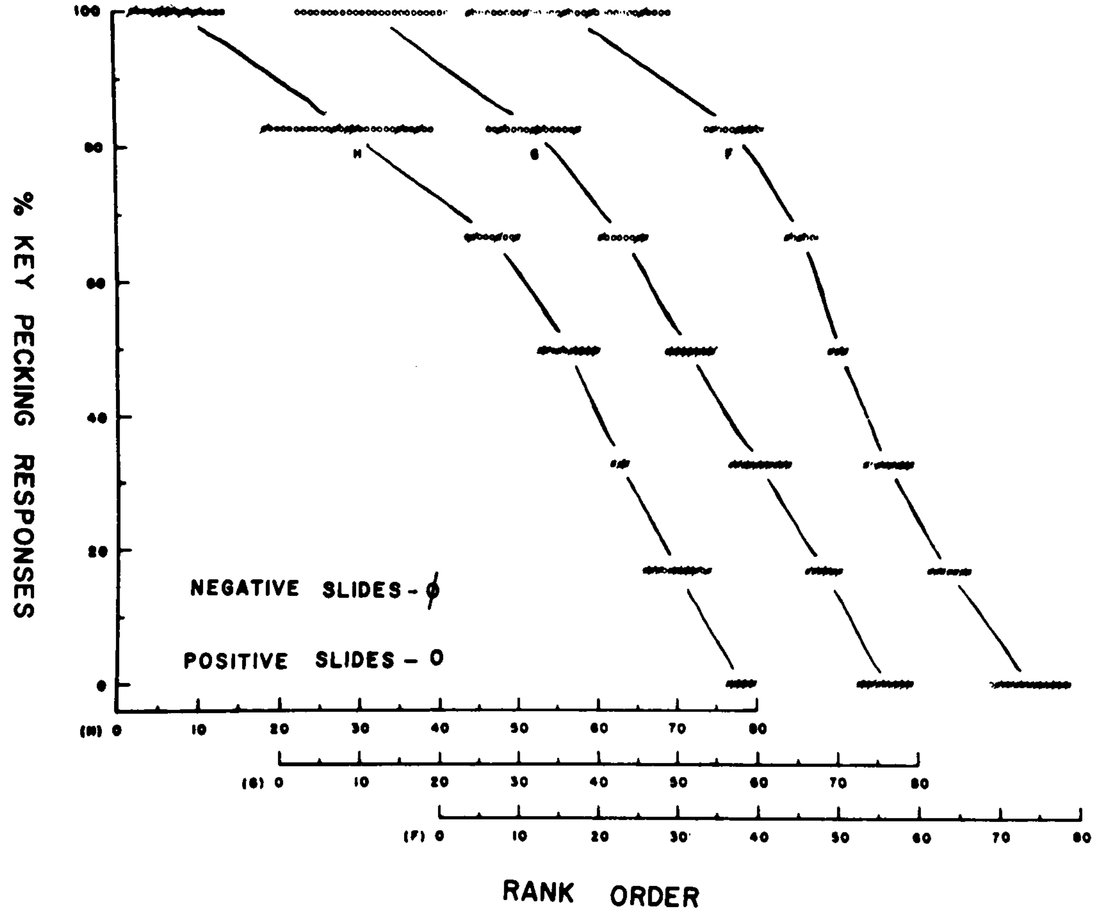

Fig. 2. Percentage of key-pecking responses to individual slides over both the first and second serial position tests. Abscissas are displaced in order to present the data for individual subjects.

ogy, it may be of interest to determine the invariant stimulus properties that the bird extracted (*cf.* Gibson, 1966).

Figures 4 and 5 display some representative samples of the photographs used. Figure 4 is a selection of photographs, containing man-made objects, to which the pigeons reliably responded. Items j, k, and l were taken from the generalization tests, the remainder from acquisition. Figure 5 is a selection of photographs, containing no man-made objects, to which the pigeons reliably did not respond. Items v, w, and x were taken from the generalization tests, the remainder from acquisition.

By examining separately all those slides that the birds responded to significantly and that they avoided significantly, several hypotheses were induced to account for the stimulus basis of the discrimination. These hypotheses were:

I_p The pigeons responded to slides containing the presence (p) of straight lines and/or approximately 90° angles.

II_p The pigeons responded to slides that contain all of the following characteristics—light and dark areas distributed throughout the slides, high contrast between the light and dark areas, and approximately half of the total area of the slides being light, and half dark.

III_p The pigeons operated under both Hypothesis I and Hypothesis II.

The converse of each of these hypotheses must also be considered, *e.g.*, not responding is under control of the absence (a) of straight lines and/or approximately 90° angles. To test each of the hypotheses, the 100 slides from acquisition and the two generalization tests were segregated on the basis of whether or not the slide was responded to on 70% or more of the

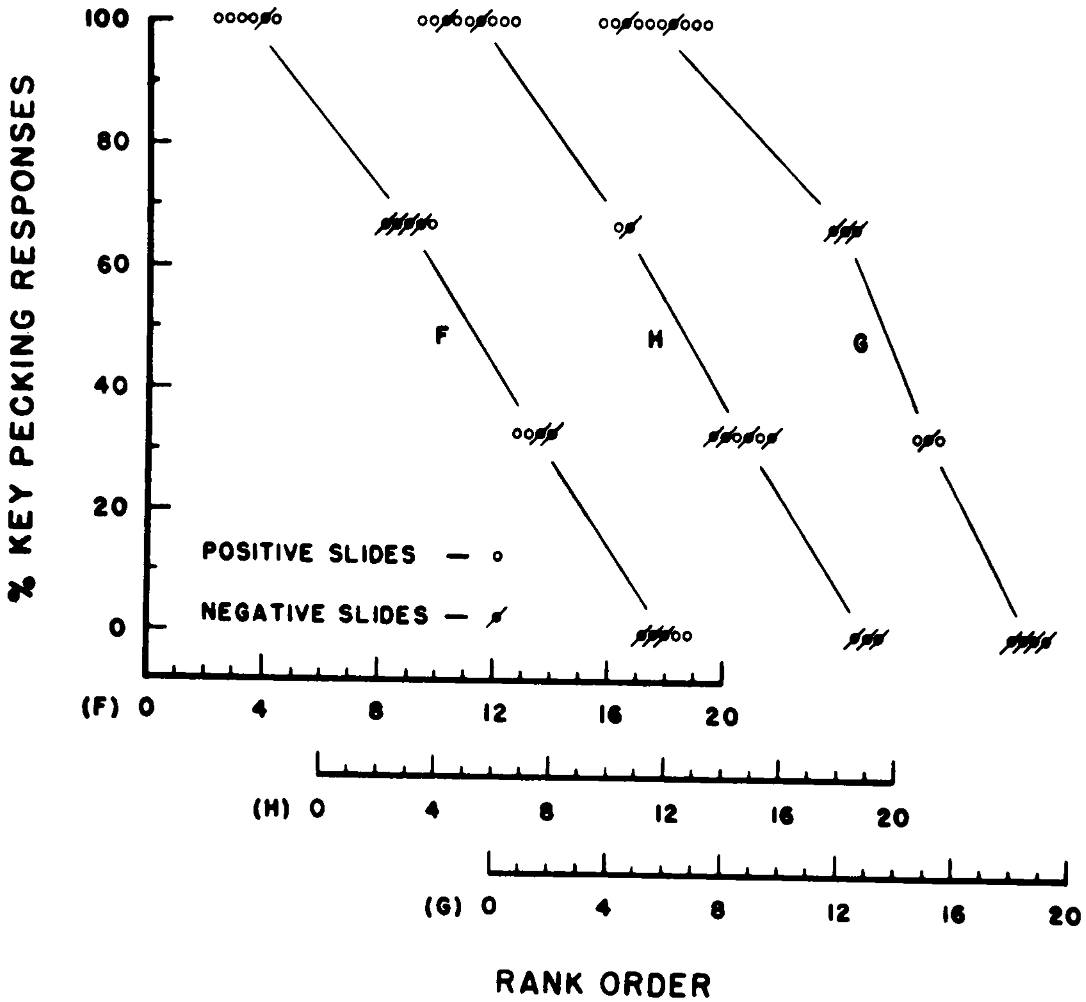

Fig. 3. Percentage of key-pecking responses to individual slides over both the first and second generalization tests. Abscissas are displaced in order to present the data for individual subjects.

trials. This was done separately for each bird. A similar procedure was followed for not responding on 70% or more of the trials. This division was done independently of whether the slide was positive or negative. Therefore, a small number of false positives and false negatives are included in each sample. Following this, an independent observer, not knowing anything about the experiment, was given the description of the hypothetical properties to which the birds were responding, and asked to indicate the presence or absence of each property in photographs similar to Figures 4 and 5, but ungrouped.[2] The correspondence of his judgement with that of the birds' responding is shown in Table 1.

Table 1 answers the question of what percentage of the slides that were responded to consistently had a particular stimulus characteristic. Thus, it is clear that of the two major hypotheses concerning the control of key-pecking responses, Hypothesis I_p, concerning the presence of straight lines and/or right angles, is the more potent. However, by itself, it still does not account for 16 to 28% of the slides to which the birds responded. With the addition of Hypothesis II_p, only 2% to 8% of the slides remain unaccounted. It should be noted that there is not a considerable overlap between I_p and II_p; either one may occur in the absence of

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[2] An additional two raters were used afterwards to check on the reliability of the judgements. It was found to be almost perfect.

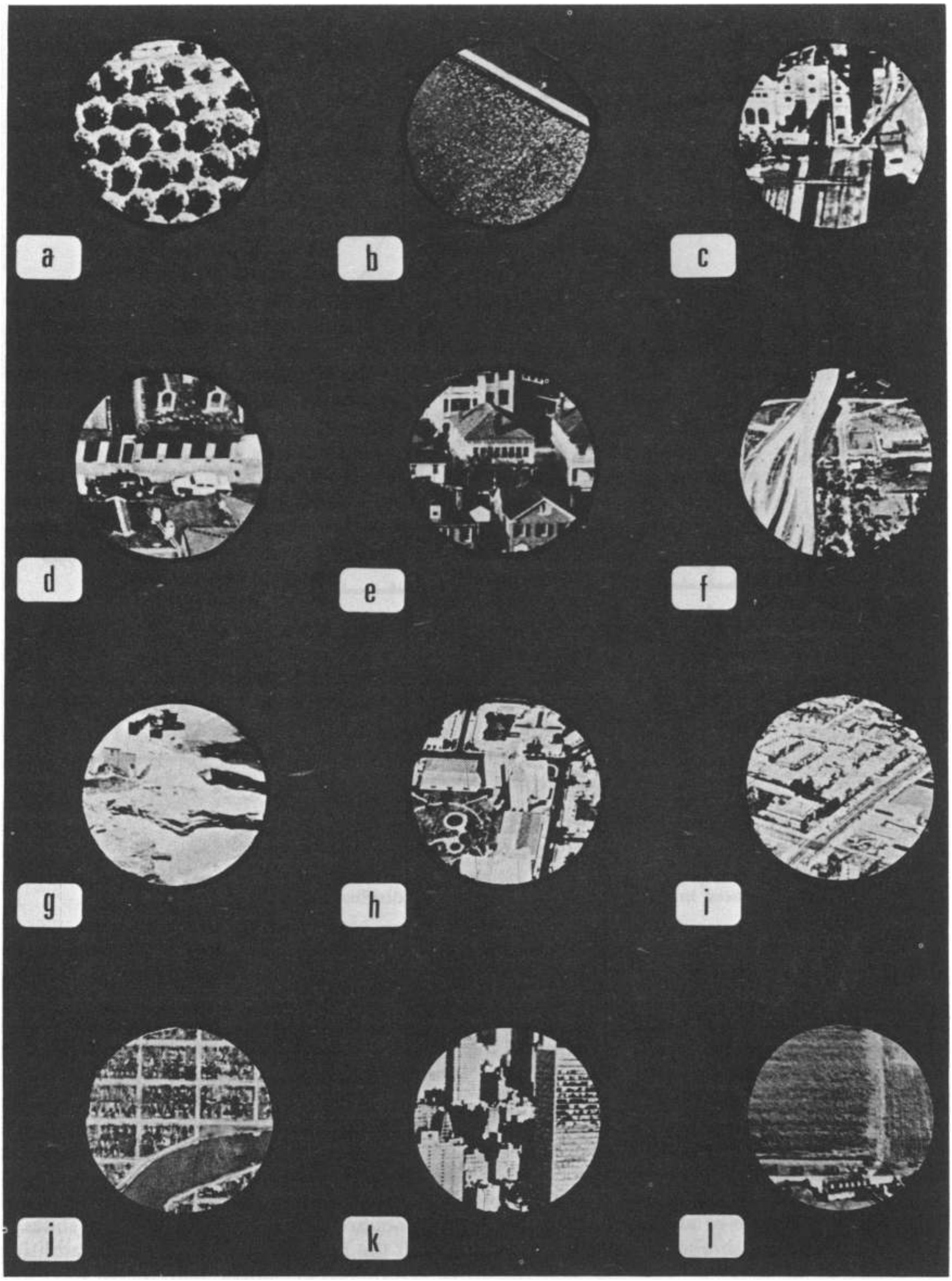

Fig. 4. A selection of slides with man-made objects.

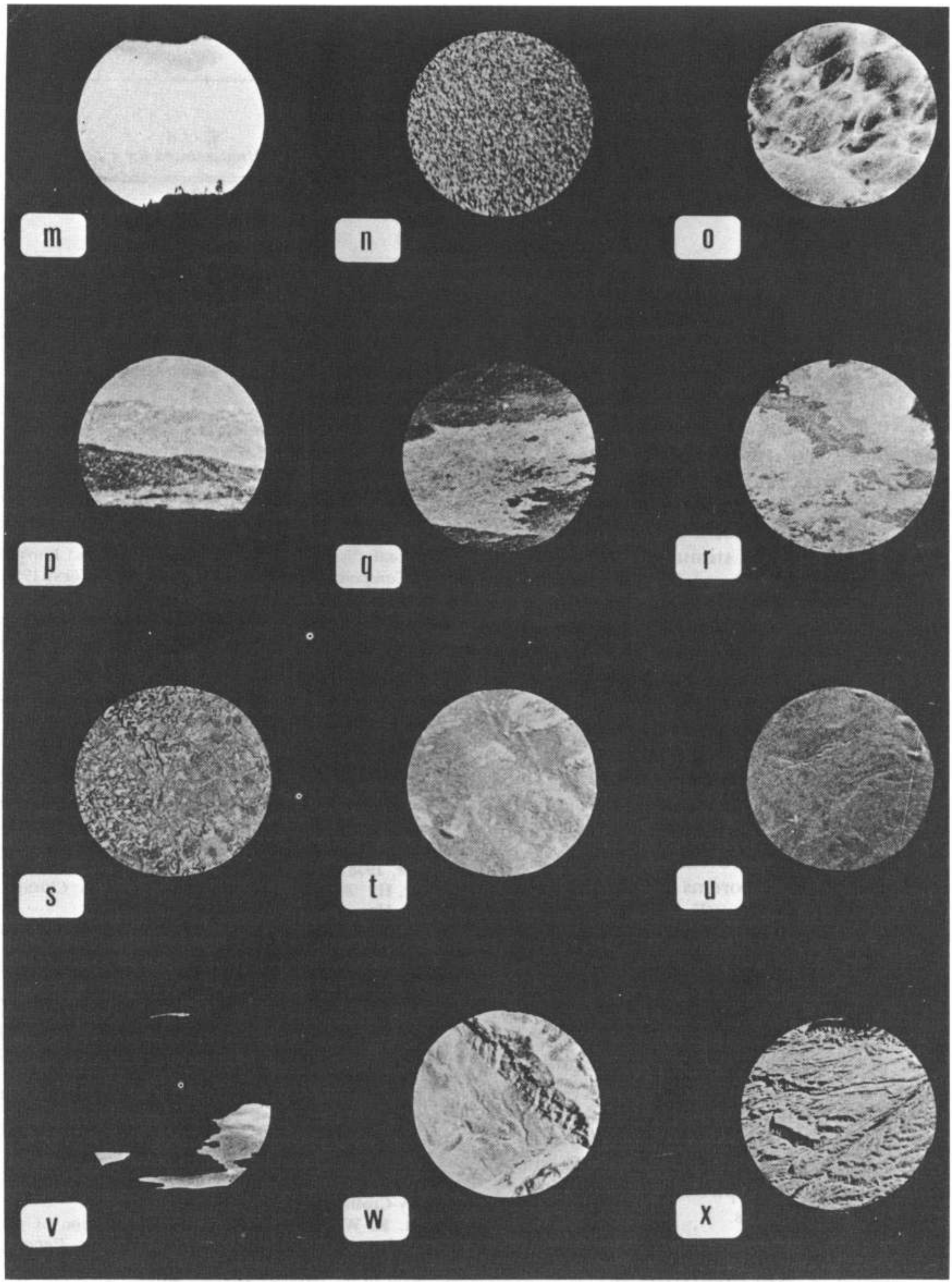

Fig. 5. A selection of slides with no man-made objects.

Table 1

Per cent of correspondence between each of six stimulus control hypotheses and responding for three subjects.

Subject	*A Number of Slides Responded to 70% or More*	*Per Cent of A Accounted for by Hypotheses*			*% of A Unaccounted for*
		I_p	II_p	III_p	
F	44	84	40	29	2
G	54	72	37	24	8
H	53	72	43	26	6
	Number of Slides Not Responded to 70% or More	I_a	II_a	III_a	*% of A Unaccounted for*
F	37	89	97	86	0
G	17	94	100	94	0
H	31	93	100	93	0

the other. The figures under column III_p, fairly low, indicate that although the presence of either I_p or II_p can control behavior, the presence of both is not a necessary condition.

An analysis of the stimulus conditions controlling not responding yields a somewhat similar picture. The major difference is that the absence of either the stimulus properties of I and II are highly correlated, and that either I_a or II_a is an excellent predictor for not responding.

More work is needed to refine the hypotheses still further into more exact physicalistic terms. The approach used in the present experiment may provide a method for determining invariant properties of complex stimuli. At the very least, it provides a method for generating existence theorems for the presence of such higher-order stimuli, and at best it may provide the data for inducing what these properties are. By studying the similarities and differences between slides that are consistently responded to incorrectly and those that are consistently responded to correctly, one can construct testable hypotheses concerning the invariant stimulus properties in the complex images. Although this proposed inductive method for studying invariant properties is conceptually simple, experience has shown that the rocks of empiricism require the perseverance of Sisyphus.

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