The substantia innominata and the lateral hypothalamus receive fiber connections from the mesencephalic reticular formation and paramedial limbic areas as well as from the amygdala (*3*). The HRP-positive neurons in the basal forebrain areas appear, therefore, to be located at the crossroads of limbic brainstem pathways. The activity of the limbic system has been shown to be related to motivational and emotional states. For example, stimulation of basal forebrain areas and hypothalamus may elicit sleep, food intake, and sexual activity (*6*), and the activity of neurons in the substantia innominata and the medullary laminae of the globus pallidus has been found in operant conditioning experiments to be related to the delivery of a fruit juice reward (*7*). In addition, lesions of the lateral hypothalamus have been shown to result in contralateral sensory inattention (*8*).

The present findings make it likely that the behavioral phenomena elicited by stimulation of limbic basal forebrain areas may be brought about not only by way of descending pathways to the brainstem as suggested by Nauta's classic anatomical findings (*3*) but also by way of the direct connections to the cerebral cortex demonstrated in the present study. Moreover, the latter connections may provide a channel by which the basal forebrain areas can influence directly the precentral motor cortex and cortical sensory areas in accordance with the motivational and emotional state of the organism.

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20 August 1974

Symbolic Matching by Pigeons: Rate of Learning Complex Discriminations Predicted from Simple Discriminations

Abstract. *Pigeons had no greater difficulty learning a complex discrimination involving arbitrary interrelations among stimuli (symbolic matching) than one involving interrelations based on stimulus similarity (matching-to-sample). The relative rates of acquisition of matching and symbolic matching may be accounted for by the discriminability between sample stimuli* **and** *between comparison stimuli, with the former playing the more important role.*

Cumming and Berryman (*1*) reported that pigeons readily learn to select, from among comparison colors, that hue which is identical to a sample color. Their procedure for establishing matching-to-sample performance is as follows. A naive pigeon, reduced to 80 percent of its normal weight, is placed in a chamber with three response keys on one wall. When a sample is presented on the center key, a single peck at this sample turns on the remaining keys. Now three stimuli are present, the sample and two comparison stimuli, one of which is identical to the sample. If the bird pecks at the comparison that matches the sample, it is given access to grain for 3 seconds. A peck at the odd key turns off all lights in the chamber for 3 seconds. Trials are separated by a 15-second interval.

Using a variant of this procedure, Eckerman trained pigeons in a symbolic matching task (*2*). The comparison stimuli were vertical or horizontal lines, but the sample stimuli were colors. When the sample was wavelength 506 nm, pigeons were rewarded with food for pecking the horizontal line, but when the sample was wavelength

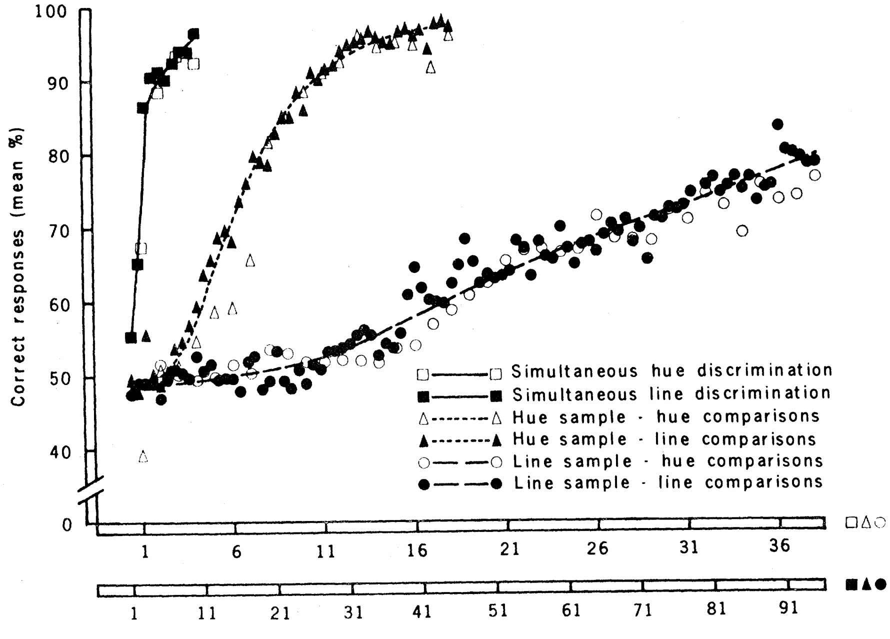

Fig. 1. Mean percentage of correct responses for each session for all four complex discrimination groups and for both simultaneous discrimination groups. The upper abscissa has been used for all discriminations involving colors on the side keys (comparison stimuli). The lower abscissa has been used for all procedures using lines on the side keys. One session on the upper abscissa is equal to 2.5 sessions on the lower abscissa.

583 nm, responses to the vertical line produced food. While acquisition of matching might indicate that a "similarity" rule is learned by pigeons, symbolic matching performance seems to demonstrate the acquisition of a set of "if . . . then . . ." rules. Inasmuch as Eckerman found acquisition of symbolic matching to be slower than that for color matching, it is possible that acquisition of a similarity concept is easier than acquisition of a set of rules (*3*).

However, evidence from experiments on the transfer of matching to novel stimuli suggests that a similarity rule may not be learned by pigeons. Rather, even matching appears to involve acquisition of a set of rules (*4*). But, as Farthing and Opuda (*5*) have argued, the failure to obtain transfer of matching to novel stimuli could also occur if pigeons avoid pecking at novel comparison stimuli simply because they are novel.

Our study makes a more direct comparison of matching and symbolic matching, with red and green lights and vertical and horizontal lines used as stimuli. The results demonstrate that symbolic matching is not necessarily learned more slowly than matching-to-sample. Instead, the relative rates of acquisition of complex discriminations of the type described above depend upon the choice of stimulus dimensions (here, color or line orientation) from which the samples and comparisons are selected by the experimenter. We conclude that the ease with which both matching and symbolic matching are learned is independent of the similarity between sample and comparison stimuli. It is the discriminability of one sample from another and of one comparison from another which controls the acquisition of complex discriminations.

The procedure was identical to that described above (*1*). Table 1 shows the experimental conditions. Using stimuli from not more than two dimensions (color and line orientation), four kinds of complex discriminations are possible: color matching, symbolic color matching, symbolic line matching, and line matching (Table 1). Twenty White Carneaux pigeons (five per group) served as subjects.

Two groups of four birds each were also trained on simultaneous discriminations with either colors or lines on the side keys. The center key was covered, and stimulus position varied randomly. Two more groups of four birds each were trained on successive discriminations, either with colors or lines on the center key. One center-key peck turned on the side keys, both illuminated by white lights. The center-key stimulus indicated which side was correct. All temporal variables, as well as food and blackout contingencies, were identical to those of the complex discrimination procedures.

Table 1. Experimental conditions.

Group	Sample stimuli (center key)	Comparison stimuli (side keys)	Number of 120-trial sessions
Color matching	Red, green	Red, green	45
Symbolic color matching	Red, green	Vertical, horizontal	45
Symbolic line matching	Vertical, horizontal	Red, green	95
Line matching	Vertical, horizontal	Vertical, horizontal	95
Color discrimination (simultaneous)	None	Red, green	10
Line discrimination (simultaneous)	None	Vertical, horizontal	20
Color discrimination (successive)	Red, green	Both keys white	10
Line discrimination (successive)	Vertical, horizontal	Both keys white	20

The data show no support for the hypothesis that matching-to-sample is easier than symbolic matching (*6*). Although color matching was learned most quickly, line matching was last to be acquired. This finding is consistent with the results of other studies which show that it is more difficult to maintain high accuracy during line matching than during color matching (*7*).

The relations among acquisition functions for the four complex discrimination tasks may be described as follows. (i) For either sample stimulus dimension, groups having color comparisons learn more quickly than groups having line comparisons. (ii) From either comparison stimulus dimension, groups with color samples learn more rapidly than groups with line samples.

Our complex discriminations consist of two kinds of simple discrimination tasks. First, a successive discrimination between samples on different trials is required. Second, a pigeon must make a simultaneous discrimination between comparison stimuli on each trial. By comparing the results for birds given complex discrimination training to data for pigeons trained on simple discrimi-

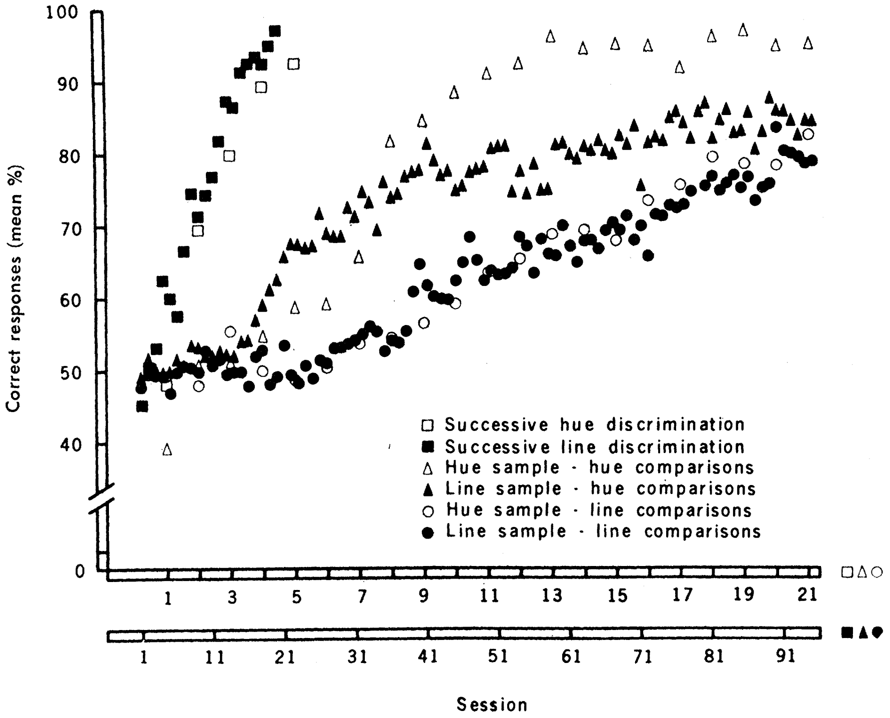

Fig. 2. Mean percentage of correct responses for each session for all four complex discrimination groups and for both successive discrimination groups. The upper abscissa has been used for all discriminations involving colors on the center key (sample stimuli). The lower abscissa has been used for all procedures using lines on the center key. One session on the upper abscissa is equal to 4.5 sessions on the lower abscissa.

nations, we can show how simple discriminations combine to determine the rate at which a given matching or symbolic matching discrimination will be learned.

Figure 1 shows the mean percentage of correct responses for each session for all complex discrimination groups and the two simultaneous discrimination groups. The upper abscissa has been used for all discriminations involving colors on the side keys. The lower abscissa has been used for all procedures using lines on the side keys. Because one session on the upper abscissa is equal to 2.5 sessions on the lower abscissa, two sets of data points will coincide if one involving line comparisons takes 2.5 times as long to learn as one involving color comparisons.

The relationship between abscissas was chosen empirically to test the following hypothesis: the relative difficulties of any pair of discriminations (simple or complex) bear the same quantitative relationship to one another if the discriminations of that pair differ from each other only in the sample stimulus dimension or only in the comparison stimulus dimension. For the curves in Fig. 1, one function of each pair was generated by using colors on the side keys. The other member of each pair was obtained by using lines on the side keys. The data support the hypothesis because the functions fall into three distinct pairs. The center-key stimulus determines the degree of separation among the pairs of curves.

The hypothesis stated above may also hold when pairs of discriminations differ only in the sample stimulus dimension. Figure 2 shows the mean percentage of correct responses for each session for all complex discriminations and for the simple successive discrimination procedures. The upper abscissa has been used for all discriminations involving colors on the center key. The lower abscissa has been used for all procedures using line samples. One session on the upper abscissa is equal to 4.5 sessions on the lower abscissa.

Four of the six functions support the hypothesis. Given a pair of discriminations which differ in no other way, the one having line samples takes 4.5 times as long to learn as the one having color samples. However, the curves for color matching and symbolic line matching do not coincide. Indeed, there is no linear transformation which will bring these curves together (*8*).

We have shown that the relative rates of learning for matching and symbolic matching may be accounted for by the discriminability between sample stimuli and between comparison stimuli, with the former playing the more important role. Identity between a sample and one of the comparison stimuli plays no role for pigeons. Put another way, matching-to-sample is just as symbolic as is the symbolic matching problem. In both paradigms, pigeons learn a set of a specific "if . . . then . . ." rules, with the sample stimulus serving an "instructional" function to indicate which of the comparison stimuli is the correct one.

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3. Another hypothesis is sometimes advanced to explain matching and symbolic matching behavior. It could be argued that the pigeon learns a specific response to each configuration of three stimuli. However, there were 4 configurations used in Eckerman's experiment (*2*) and 12 in the studies of Cumming and Berryman (*1*). Thus, if the configuration theory is correct, Eckerman should have found that symbolic matching is acquired more quickly than matching to sample. In addition, evidence favoring the rule interpretation is found by comparing studies of matching behavior with those involving oddity discriminations. The rate of learning in these experiments depends upon the number of rules to be learned rather than the number of stimulus configurations. For additional discussion, see (*9*).
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Sexual Selection in a Wild Population of the Butterfly Danaus chrysippus L.

Abstract. Danaus chrysippus *has two common forms,* chrysippus *and* dorippus, *in east Africa. Form* chrysippus *males have a mating advantage lasting 3 to 4 months, which is lost as their frequency increases. Female* dorippus *are normally superior to female* chrysippus *in sexual vigor. Sexual selection favoring different morphs in each sex contributes to the maintenance of the polymorphism.*

Darwin defined sexual selection as the advantage certain individuals had over others of the same sex and species solely in respect of reproduction. As defined, the phenomenon has been demonstrated frequently in laboratory conditions, for example, between mutants and karyotypes of *Drosophila* species (*1*) and different genotypes in mice (*2*), but its detection in wild populations has remained elusive. Here I present evidence for sexual selection involving both sexes of the polymorphic butterfly *Danaus chrysippus* (Danaidae) in the field.

Danaus chrysippus is ubiquitous in

Table 1. Mating success of male *Danaus chrysippus* forms *chrysippus* and *dorippus* between February 1972 and March 1974 at Dar es Salaam, Tanzania. Sample sizes are given in parentheses.

Period	Frequency of *chrysippus* in		Frequency of *dorippus* in	
	Population	Mating pairs	Population	Mating pairs
February–March 1972	0.38 (10)	0.29 (2)	0.62 (16)	0.71 (5)
April–July 1972	0.41 (96)	0.59* (19)	0.59 (138)	0.41* (13)
August 1972–March 1973	0.17 (78)	0.17 (13)	0.83 (385)	0.83 (65)
April–June 1973	0.29 (69)	0.43† (27)	0.71 (169)	0.57† (36)
July–August 1973	0.26 (102)	0.13* (7)	0.74 (294)	0.87* (47)
September 1973–March 1974	0.17 (91)	0.14 (17)	0.83 (458)	0.86 (103)

* $P < .05$ from χ^2 tests. † $P < .02$ from χ^2 tests.