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Symmetry: Can Pigeons Conceptualize It?[1,2]

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Pigeons were taught to distinguish a series of 30 bilaterally symmetric and asymmetric visual patterns with an operant simultaneous discrimination procedure for 140 training sessions. In 12 subsequent generalization tests under extinction conditions they classified with a high degree of accuracy six bilaterally symmetric and asymmetric visual patterns with which they had had no previous experience. The results indicate that pigeons can acquire the perceptual concept of symmetry, adding yet another to the list of concepts that these birds have been shown capable of mastering.

To survive in the wild, birds, as most other animals, must find food with the least expenditure of energy and time (Schoener, 1971). Many species are polyphagous and individuals will feed on a variety of foods within short periods of time. Most birds recognize their food visually. Is the recognition of different foods based on features [in the sense of Neisser (1967)], specific to each food variety, or is it based at least in part on generalized features characteristic of a given set of foodstuffs? Relating to certain insectivorous birds, Curio (1976) hypothesized that possession of the concept of bilateral symmetry might aid them in recognizing immobile camouflaged prey since such symmetry is a characteristic of insects. It is true that it is also typical of other organisms or parts of organisms, but as the first classificatory feature of a hierarchy of features it could be useful to dispose of many nonprey objects [Menne and Curio (in press), great tit *Parus major*; compare also Pietrowicz and Kamil (1977), blue jay *Cyanocitta cristata*; Lehr (1967), various primates; Julesz (1975), man *Homo sapiens*]. Insect-eating birds being inconvenient laboratory subjects, we have begun a study with pigeons (*Columba livia*). Of course, the pigeon is a seed-eater and the question is whether a symmetry concept

[1] This paper is dedicated to the memory of Otto Koehler, a pioneer on the subject of abstract concepts in animals and the senior author's respected teacher.

[2] We are grateful to Prof. E. Curio, Arbeitsgruppe Verhaltensforschung, Abteilung Biologie, Ruhr-Universität, Bochum, for initiating this study and for much advice. The research was supported by a grant from the Interdisciplinary Research Fund of the Ruhr-University.

would be useful to them. Many seeds are symmetrical or nearly symmetrical; few are asymmetrical, whereas nonseed objects are predominantly asymmetrical. Thus pigeons might also benefit from such a perceptual concept.

That birds can acquire complex perceptual concepts has been repeatedly demonstrated. Koehler and collaborators, in a series of studies [summarized in Koehler (1955); Thorpe (1963)], established that several bird species were able to acquire number concepts. Herrnstein and Loveland (1964) and, most convincingly, Siegel and Honig (1970) showed that pigeons can be trained to distinguish between scenes containing and not containing human figures and that they generalize this discrimination to sets of scenes they have not seen before [see also Malott and Siddal (1972), Lubow (1974)]. Poole and Lander (1971) demonstrated that pigeons can similarly acquire a concept of a pigeon as different from other animals, including other birds. The fact that they demonstrated possession of this concept very quickly suggests that the pigeons might have had it even before training began [see also Trillmich (1976), budgerigar *Melopsittacus undulatus*]. Morgan *et al*. (1976) taught pigeons the concept of a letter *A* and made it likely that the concept formed was not dependent on the coincidence of specific features but rather on the presence of a number of alternative feature combinations. Herrnstein *et al*. (1976) report work demonstrating the acquisition of several other perceptual concepts by pigeons.

Morgan *et al*. mention that they were not able to train pigeons on the concept of bilateral symmetry, leaving open the question of whether this was so because of imperfections in their early training techniques or because pigeons are inherently unable to acquire this concept. Zentall and Hogan (1975), however, using symmetric and asymmetric colored stimuli, obtained results suggesting that pigeons could learn the distinction symmetry–asymmetry, although their interpretation is in terms of the acquisition of an oddity concept. Similar results obtained with chickens *(Gallus gallus)* are reviewed by Rensch (1973). Thus, apart from the reasons given earlier, it seemed worthwhile to reinvestigate the issue.

The general design of the experiment was to train pigeons to discriminate a fairly large number of symmetric and asymmetric patterns with an operant simultaneous procedure and then to test in extinction trials whether they would generalize this distinction to a set of patterns with which they had no previous experience.

Six adult pigeons of local homing stock were used. Five of them completed the experiment, one becoming ill. They were maintained at 80% of their normal weight. A Skinner box with two keys was used. Twelve-channel miniature projectors were used to present the stimuli on the keys. Modular logic equipment controlled the sequence and duration of events. Counters recorded the responses. To begin with, the subjects were trained to peck the blank keys for food access during six daily sessions of 20 min each. Then they were taught to discriminate symmetric and asymmetric stimuli selected from the first 30 shown in Fig. 1. Projected on the keys, the patterns appeared as white figures on a dark background of a size just inscribable in a 1.3-cm-diameter imaginary circle.

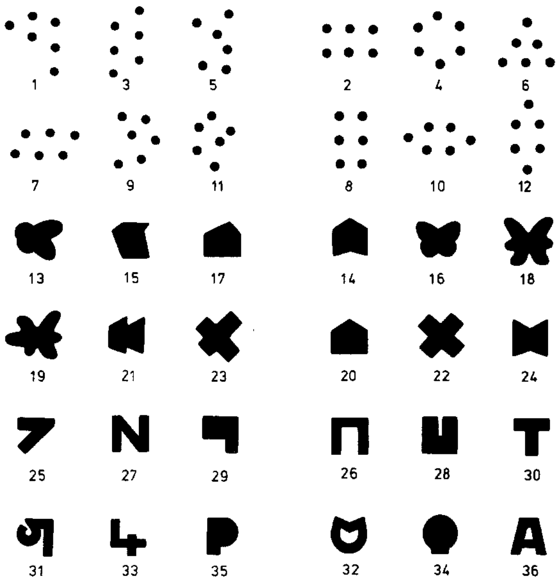

FIG. 1. Symmetric and asymmetric training and test stimuli. Patterns 1 to 30 served as training stimuli. Stimuli 31 to 36 served as test stimuli in the generalization trials.

Three pigeons (A_S, C_S, and E_S) were assigned the symmetric figures as positive and the asymmetric as negative. The remaining three (B_A, D_A, and F_A) were presented with the opposite task. A trial began with the stimuli appearing on the previously darkened keys. If the animal pecked the key bearing the positive stimulus, the stimuli went off and the feeder was activated for 6 sec. The next trial followed immediately, the position of the positive and negative stimulus on the right or left key being determined by a Gellermann (1933) sequence. If the subject pecked the key with the negative stimulus, the keys were darkened and the houselight went off for 15 sec (time-out period). The trials following an incorrect one retained the positive stimulus in the same position and the other key, normally bearing the negative stimulus, was kept unilluminated until the animal made a correct response, after which the Gellermann sequence came back into operation and both stimuli were again displayed. The correction trials were, of course, not recorded on the counters. A session consisted of 40 noncorrection trials; the sessions were daily. Sometimes a subject missed a session because of apparatus malfunction or other reasons.

The subjects learned to discriminate a pair of stimuli over the first 20 sessions. Then, until session 60, after every five sessions one of the stimuli was replaced by a new one. From session 61 to 90 both stimuli were replaced by different ones every five sessions, and between sessions 91 and 110 such an exchange took place before each session. During sessions 111 to 152, stimuli were repeatedly exchanged within a session. A variable-ratio schedule of reinforcement was gradually introduced from session 121 onward to obtain resistance against extinction. From session 136 onward the animals had to give a mean of 20 responses per trial to obtain reinforcement or time-out. Figure 2 shows in somewhat abbreviated form the performance of two typical subjects during this acquisition phase.

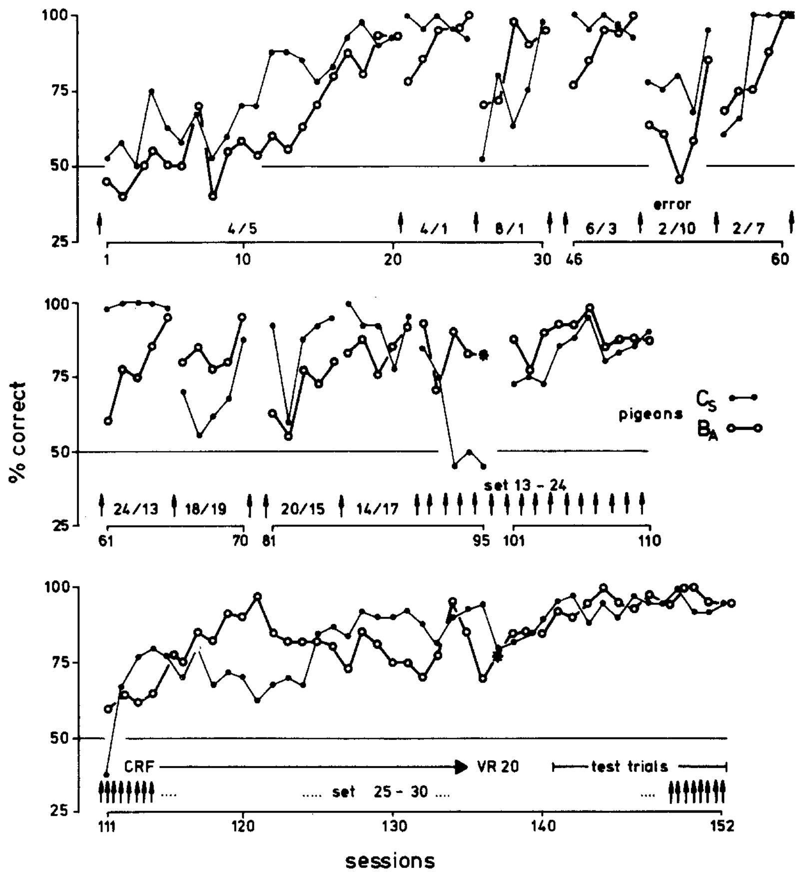

FIG. 2. Learning curves of subjects C_S (symmetric stimuli positive) and B_A (asymmetric stimuli positive). Asterisks indicate missing data, arrows indicate stimulus exchanges. Numbers refer to stimuli illustrated in Fig. 1. For space-saving reasons, several blocks of sessions have not been included. Results of generalization test trials inserted in sessions 141 to 152 are given in Fig. 3.

Sessions 141 to 152 incorporated the critical generalization test trials. Each session contained one such trial interjected between the normal trials 20 and 21. The symmetrical stimuli 32, 34, and 36, and the asymmetrical stimuli 31, 33, and 35, all totally new to the five subjects, were presented in 12 various pair combinations. On each of these test trials the subjects had to emit a total of 30 keypecks. The responses were recorded on two separate counters. None of these responses had any scheduled consequence, i.e., the subjects operated under extinction conditions.

The results of the 60 test trials are presented in Fig. 3. In 44 tests the subjects responded preferentially (more than 15 keypecks) to the correct generalization stimuli, that is, the symmetrical ones if during training the subject had been rewarded for responding to symmetrical stimuli, or the asymmetrical if it had been rewarded for responding to asymmetrical

Stimuli		Subjects					Mean
Right	Left	C_S	E_S	B_A	D_A	F_A	
S	A	25	26	29	29	25	27
A	S	28	30	23	2	*	21
S	A	30	11	30	30	15	23
A	S	4	30	20	29	17	20
S	A	26	27	27	30	29	28
A	S	26	2	*	30	*	19
S	A	13	11	28	29	30	22
A	S	30	25	30	27	0	22
S	A	12	0	30	15	30	17
A	S	23	18	30	30	30	26
S	A	0	28	30	30	28	23
A	S	30	30	19	0	28	21
Mean		20	20	27	23	23	23

FIG. 3. Symmetry concept generalization. Results of 60 test trials with five pigeons and six novel stimuli in 12 combinations. Asterisks indicate missing data. Numbers are responses to the correct transfer stimulus out of a total of 30. Small typeface marks trials yielding 15 or less correct. Symmetric stimuli were correct for subjects C_S and E_S, asymmetric for subjects B_A, D_A, and F_A. Right and left = right and left keys.

stimuli. They gave no evidence of preference on two occasions and pecked preferentially to the incorrect generalization stimulus in 11 tests. A binomial test [44 positive tests to 13 negative ones) yields $P < 0.001$ (Siegel, 1956)]. Three trials in which the subjects did not respond within 30 min have been excluded. Incidentally, the fact that the animals hesitated in responding to the test stimuli indicates that they did recognize them as new. Each pigeon responded predominantly to the correct stimuli in at least two of three of the test trials. On average, all of them directed more than 75% of their responses to the correct stimuli. All generalization stimulus pairs were classified such that, on average, the animals responded more to the correct stimulus than to the incorrect. In fact, except in the case of two pairs, the subjects gave on average at least two of three of their responses to the positive generalization stimulus of each pair.

These results suggest that, by learning to discriminate a series of 30 bilaterally symmetric and asymmetric visual patterns, pigeons acquire the capacity to generalize this discrimination to a set of symmetric and asymmetric stimuli with which they have had no previous experience. They thus seem capable of building up an abstract perceptual concept of symmetry. The results dispel the doubts of Morgan *et al.* (1976) about pigeons' capabilities to develop such a concept, and add yet another to the list of concepts that pigeons have already been shown capable of mastering. It remains to determine how general the concept is: Will subjects apply it to patterns with a symmetry axis other than vertical (Corballis and Beale, 1970), to patterns smaller and larger, to colored patterns? The somewhat ad hoc procedure used in the present study probably exaggerates the training needed to establish the perceptual concept. We intend to incorporate a more rapid introduction of a greater variety of symmetric and asymmetric stimuli, paired in a random fashion, and an accelerated inception of the variable-ratio schedule, allowing an earlier insertion of generalization tests.

Whether free-ranging pigeons already possess the concept of symmetry and may only have learned to use it in our experiment is also an open issue. One way to find out could consist of examining spontaneous, nonconditioned preferences of pigeons for symmetric and asymmetric patterns to see if they show consistent preferences for one or the other class of stimuli, as Rensch's (1958) jackdaws *(Corvus monedula)* seem to have done. Another method involves examining the discrimination learning performance of pigeons when the discriminanda are symmetric–symmetric, asymmetric–asymmetric, and symmetric–asymmetric pairs of patterns. If the latter stimulus combination would generally be learned faster than the two former combinations, it would again suggest previous possession of a symmetry concept. Further methodological issues need, however, to be solved before the question with which we introduced the study can be tackled: Do pigeons utilize a symmetry concept to recognize the seeds on which they feed?

REFERENCES

Corballis, M. C., and Beale, I. L. (1970). Bilateral symmetry and behavior. *Psychol. Rev.* **77,** 451–464.

Curio, E. (1976). "The Ethology of Predation." Berlin/New York: Springer-Verlag.

Gellermann, L. W. (1933). Chance orders of alternating stimuli in visual discrimination experiments. *J. Genet. Psychol.* **42,** 206–208.

Herrnstein, R. J., and Loveland, D. H. (1964). Complex visual concept in the pigeon. *Science* **146,** 549–551.

Herrnstein, R. J., Loveland, D. H., and Cable, C. (1976). Natural concept in pigeons. *J. Exp. Psychol. Anim. Behav. Process* **2,** 285–302.

Julesz, B. (1975). Experiments in the visual perception of texture. *Sci. Amer.* **232,** 34–43.

Koehler, O. (1955). "Zählende" Vögl und vergleichende Verhaltensforschung. *In* A. Portmann (Ed.), "Acta XI International Ornithological Congress, 1954." Basel: khäuser.

Lehr, E. (1967). Experimentelle Untersuchungen an Affen und Halbaffen über Generalisation von Insekten und Blütenabbildungen. *Z. Tierpsychol.* **24,** 208–244.

Lubow, R. E. (1974). High-order concept formation in the pigeon. *J. Exp. Anal. Behav.* **21,** 475–483.

Malott, R. W., and Siddal, J. W. (1972). Acquisition of the people concept in pigeons. *Psychol. Rep.* **31,** 3–13.

Menne, M., and Curio, E. (in press). Untersuchungen Zum Symmetriekonzept bei Kohlmeisen (*Parus major* L.). *Z. Tierpsychol.*

Morgan, M. J., Fitch, M. D., Holman, J. G., and Lea, S. E. G. (1976). Pigeons learn the concept of an "A". *Perception* **5,** 57–66.

Neisser, U. (1967). "Cognitive Psychology." New York: Appleton–Century–Crofts.

Pietrowicz, A. T., and Kamil, A. C. (1977). Visual detection of cryptic prey by blue jays *(Cyanocitta cristata). Science* **195,** 580–582.

Poole, J., and Lander, D. G. (1971). The pigeon's concept of a pigeon. *Psychonom. Sci.* **25,** 157–158.

Rensch, B. (1958). Die Wirksamkeit ästhetischer Faktoren bei Wirbeltieren. *Z. Tierpsychol.* **15,** 447–461.

Rensch, B. (1973). "Gedächtnis, Begriffsbildung und Planhandlung bei Tieren." Berlin: Parey.

Schoener, T. W. (1971). Theory of feeding strategies. *Annu. Rev. Ecol. Syst.* **2,** 369–404.

Siegel, R. K., and Honig, W. K. (1970). Pigeon concept formation: Successive and simultaneous acquisition. *J. Exp. Anal. Behav.* **13,** 385–390.

Siegel, S. (1956). "Nonparametric Statistics for the Behavioral Sciences." New York: McGraw–Hill.

Thorpe, W. H. (1963). "Learning and Instinct in Animals," 2nd ed. London: Methuen.

Trillmich, F. (1976). Learning experiments on individual recognition in budgerigars. *Z. Tierpsychol.* **41,** 372–395.

Zentall, T. R., and Hogan, D. E. (1975). Concept learning in the pigeon: Transfer to new matching and nonmatching stimuli. *Amer. J. Psychol.* **88,** 233–244.