Experimental control of beak shift during tests for interocular transfer of a lateral mirror-image discrimination*

I. L. BEALE, Dalhousie University, Halifax, N.S., Canada
and

R. J. WILLIAMS, University of Auckland, Auckland, New Zealand

Monocularly viewing pigeons were trained to peck a key when it displayed a 135-deg line, but not when it displayed a 45-deg line. During training, the key could be operated by pecks on the left side only. Tests for interocular transfer were given with either the left or right sides of the key operating. Changing the location of displaced pecking on the key between training and interocular transfer testing (beak shift) had a marked effect on the extent to which interocular mirror-image reversal occurred. However, some birds showed interocular reversal without a change in the direction of displaced pecking (i.e., without beak shift), indicating that beak shift is not crucial to interocular reversal.

Mello (1965, 1966) has reported experiments in which monocularly viewing pigeons were trained to peck a key when it displayed a line sloping at 45 deg (S+), but not when it displayed the lateral mirror image of S+, a line sloping at 135 deg (S-). (The lateral mirror image of an object is the reflection of that object in a vertical mirror, i.e., its left-right reversal.) During tests for interocular transfer, many birds, now viewing with the untrained eye, pecked more frequently during S- than during S+, demonstrating interocular mirror-image reversal. Beale & Corballis (1967) have shown that when monocularly viewing pigeons are pecking a key, their pecks are laterally displaced toward the side of the key facing the viewing eye. They proposed an explanation for interocular mirror-image reversal based on the likelihood that displaced pecking restricts the view of the stimulus to that part displayed on that side of the key (open side) facing the open eye. In an experiment where S+ was a 135-deg line and S- a 45-deg line displayed on the key, discriminative responding might be controlled by only that part of each line displayed on the open side of the key, so that for a bird viewing with the left eye the functional S+ might be a line in the upper left quadrant of the key and S- a line in the lower left quadrant. If the bird was then tested with only the untrained (right) eye open, and if stimuli on the right side of the key then controlled discriminative pecking, the functional S+ would then be provided by the nominal S-, the 45-deg line, and the functional S- by the 135-deg line.

Thus, if only the nominal discriminative stimuli were considered, veridical interocular transfer of a discrimination based on up-down cues appearing on the open side of the key would incorrectly be interpreted as interocular mirror-image reversal. Corballis & Beale (1970a) have shown that when monocularly viewing birds are trained to discriminate 135- and 45-deg lines on the key, discriminative responding is, in fact, based on up-down cues appearing on the open side of the key rather than on line orientation *per se*.

Beale & Corballis (1968) have reported a high correlation between the degree of interocular mirror-image reversal and the degree to which displaced pecking moves from the side of the key open during training, to the side open during interocular transfer testing. This shift in the direction of displaced pecking, termed beak shift, results from changing the viewing eye for the purpose of interocular transfer testing. Beak shift is clearly an important determinant of which part of the stimulus on the key controls pecking during interocular transfer testing. Beak shift is not the only factor influencing which part of the stimulus display controls pecking, however, since merely covering one eye restricts the view of the side of the key facing that eye. Changing the viewing eye in preparation for an interocular transfer test will change that side of the key of which the bird has a better view.

The extent to which interocular mirror-image reversal is dependent on beak shift was examined in the present experiment. The strategy employed was to use a key in which the left and right halves could be operated separately. Effective pecking could be restricted to either side of the key by making the other side immobile. This

permitted beak shift to be experimentally controlled. Following monocular discrimination training, birds were given four interocular transfer tests. In two of these tests beak shift was enforced, but in the other two it was prevented from occurring.

METHOD

Fourteen homing pigeons, maintained at 80% of free-feeding body weight, served as Ss.

A standard single-key pigeon chamber was used, in which a transparent Plexiglas key of 2.54 cm diam was located in one wall, 15 cm above the grain magazine aperture. The key was halved vertically and so constructed as to allow the whole key to be used as a single unit, both halves to be used independently, or either half to be made immobile. In any mode, the minimum force required to operate the key was approximately 15 g. Stimuli were presented by a digital display cell, which projected onto a screen 5 mm behind the key.

Following a session of magazine training, the birds were trained to peck the key, which operated as a single unit and was illuminated with white light. The reinforcer was 5 sec access to grain in the lighted magazine. The key light was off during reinforcement. One session of continuous reinforcement was followed by two sessions on a variable-interval schedule in which pecks were reinforced following intervals averaging 30 sec since the previous reinforcement (VI 30 sec). During this preliminary training, a 15-W white light provided general illumination of the chamber. Sessions were always terminated after 60 reinforcements. White noise was presented during all sessions to mask extraneous sounds.

General illumination of the chamber was then discontinued. This was done to reduce the likelihood that visual stimuli off the key could be used by the birds as part of a configurational discriminative stimulus. The birds were then given 10 sessions on VI 1 min. The birds were then fitted with plastic goggles that restricted vision to the anterior fields. A full description of these goggles is given elsewhere (Corballis & Beale, 1970a). A further session on VI 1 min was given, with only the left half of the key operative.

Discrimination training was then begun, using a multiple schedule in which S+, correlated with VI 1 min, was alternated with S-, correlated with extinction. S+ and S- were, respectively, 135- and 45-deg white lines with black background displayed centrally on the key. Two versions of each stimulus were used in mixed sequences to reduce the likelihood that aspects of the stimuli unrelated to

*Supported by a grant from the University Grants Committee, New Zealand. Reprints may be obtained from I. L. Beale, Department of Psychology, Dalhousie University, Halifax, N.S., Canada.

Fig. 1. Pecks made during S+ as a percentage of total pecks is averaged for the two transfer tests in each condition. Values for individual birds are shown. Condition A (no beak shift) is shown by white bars, and Condition B (beak shift) is shown by black bars.

the mirror-image elements might control discriminative responding. The lines were 2 mm wide and 2.5 cm long. S+ and S- were presented for 1-, 2-, or 3-min durations, according to a mixed sequence. Between stimulus presentations, the key was dark for 5 sec, and pecks were ineffective. During discrimination training sessions, the right eye of each bird was occluded by masking tape applied to the right goggle.

For each bird, the final session on discrimination training was the first in which 90% of pecks were to S+.

In the first session following the discrimination criterion being met, the birds were given the first of a series of four interocular transfer tests. In these tests, the birds viewed with the right (untrained) eye only. In two tests only the left side of the key was operative (Condition A), and in the other two tests only the right side of the key was operative (Condition B). For half the birds, the sequence of conditions in the four tests was ABBA, and for the other half, BAAB. In Condition A, beak shift produced ineffective pecks to the immobile side of the key, so that only pecks not displaying beak shift could operate the key. In Condition B, only pecks displaying beak shift could operate the key.

Each test session was begun with a short warm-up in which 10 reinforcements were given on VII min. The key was white during the warm-up. Following the warm-up, S+ and S- were presented for a total of 30 min. Duration and sequences of

stimuli were as for discrimination training sessions, but no reinforcements were given.

One session of discrimination training intervened between successive interocular transfer tests. In every case performance on these sessions met the 90% discrimination criterion.

RESULTS AND DISCUSSION

The percentage of pecks made during S+ by each bird was averaged for the two tests given in Condition A and Condition B. The values obtained are shown in Fig. 1. Figure 1 shows that for all but one bird (No. 8), a smaller proportion of pecks was emitted during S+ in Condition B than in Condition A. The average percentage of responses to S+ during tests in Condition A was 64.7%, and the average in Condition B was 34.3%. The difference between these mean percentages was significant ($t = 4.42$, $p < .001$).

The criterion used by Mello (1966) to define discrimination reversal was 40% or less of total pecks occurring during S+. The criterion for veridical transfer was 60% or more of total pecks occurring during S+. When these criteria are applied to the present results, there are 22 instances of reversal and 25 instances of veridical transfer. The remaining nine test results meet neither criterion. Of the 22 reversals, 16 occurred in Condition B, and of the 25 veridical transfers, 18 occurred in Condition A.

The data are summarized as showing that the enforced shift of effective pecking from the left to the right side

of the key in Condition B significantly affected the degree to which birds showed interocular mirror-image reversal. In only two birds, however, did enforced beak shift produce reversal and the nonshift condition produce veridical transfer (Fig. 1, Nos. 2, 4). Although three birds (Nos. 5, 8, 10) showed veridical transfer in both test conditions, in only one case (No. 8) did the test condition have no effect. It seems likely that this bird's discriminative responding was controlled by cues that were different from the other birds'. A learned asymmetrical observing response, such as pecking with the head tilted, could have produced discriminative stimuli that would lead to veridical interocular transfer, despite changes in the part of the stimulus being viewed. Birds readily learn such asymmetrical responses when required to discriminate lateral mirror-image stimuli (cf. Corballis & Beale, 1970b). The results are consistent with the high correlation between extent of interocular reversal and degree of beak shift reported by Beale & Corballis (1968), but they show that beak shift is not critical to reversal. The change of the viewing eye is apparently sufficient in some instances to produce the necessary change in which part of the stimulus controls discriminative responding.

Although the results show that asymmetrical pecking is not a crucial factor in interocular mirror-image reversal, it is nevertheless a strong contributing factor. Moreover, it is likely that it plays an important role in determining which aspects of the nominal discriminative stimuli control behavior during monocular discrimination training.

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