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# *APPARENT MOVEMENT DETECTION IN THE PIGEON*[1]

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Pigeons were trained to discriminate between the presence and absence of apparent movement in visual displays. Generalization gradients obtained on the dimension of speed indicated a broad range of movement detection. Extremely accurate discrimination performance on displays varying in direction of movement suggested formation of a "movement concept".

It is well known that pigeons can readily detect moving objects in their environment. Mello (1968) demonstrated that pigeons can learn to discriminate the direction of movement of striped patterns on a rotating drum. Such motion of a stimulus through a distance at a given rate has been termed real movement. Conversely, the perceived movement of a stimulus that is not in actual physical motion has been termed apparent movement. Examples of apparent movement include the phi phenomenon or lights moving on the marquee of a theater. Since Skinner's (1960) demonstration that pigeons can be trained to track "apparently" moving targets such as ships on a moving-picture film, apparent movement detection in the pigeon has been relatively ignored (*cf.* Aarons, 1964). While it has been suggested that this appearance of continuous movement may be produced by the successive stimulation of discrete retinal loci (Spigel, 1965) and that the pigeon has retinal movement detectors (Maturana and Frenk, 1963), a clear behavioral demonstration of apparent movement detection is needed.

## METHOD

### *Subjects*

Eight loft-reared homing pigeons were maintained at 70% of their free-feeding weights.

### *Apparatus*

All subjects were trained in an operant discrimination unit equipped with a 3 by 3 in. (7.62 by 7.62 cm) translucent response key positioned above a food magazine. Scheduling equipment was located in a separate room.

### *General Procedure*

Animals were trained to discriminate between the presence and absence of apparent movement in daily sessions of 20 successively presented slides. Slides were rear-projected on the response keys by means of a 35-mm projector. A polarized disc, located between the projector and the response key, was rotated at 120 rpm by means of a universal ac motor and this produced four changes of polarization per second (4 cps; See *Simulation of Motion* section below). In order to produce "no motion", the polarized disc was maintained in a stationary position (0 cps).

### *Stimuli*

The slides themselves were made of black and white strips of double refracting material placed on one sheet of plane polarized plastic. The slides were constructed from 13 basic types of double refracting material commercially available (Edmund Scientific Co., Barrington, New Jersey, stock numbers 70950-70963) so that horizontal, vertical, clockwise, counter-clockwise, and random directional motion could each be displayed. These materials were placed on 35-mm glass slides either singly or in randomly chosen pairs (*e.g.*, one half of the slide would show horizontal motion while

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the other half would show counter-clockwise motion). The resulting slide library contained a wide variety of displays (80 slides) moving in every conceivable direction.

*Simulation of Motion*

When a polarized disc was rotated between the projector and the response key, light was transmitted progressively and motion was simulated. At any given instant there are only two levels of illumination on the stimulus screen ("light" and "dark") and the display appears to move between these two levels. For example, consider a display in which horizontal motion is simulated. The display could consist of several strips of black and white material, alternating with one another. The strips are arranged in such a way that the display appears to be "vertically-striped"—that is, the strips appear perpendicular to the experimenter's eye. As the polarized disc is rotated, a white strip gradually darkens to a black strip. Concurrently, the horizontally adjacent black strip gradually lightens until it becomes white. This process is repeated across the display as the rotating disc successively polarizes adjacent strips. Thus, movement is induced from one strip to a horizontally adjacent one and this process repeats itself. This principle of rotary polarization is similar to that used to achieve motion in animation techniques. For example, it is similar to techniques employed by many television meteorologists to depict rain or snow "moving" on local areas of weather maps. It is also similar to motion produced by the flicker of neon lights, such as "arrows" directing customers to a particular commercial establishment.

*Training Procedure*

Birds 1 to 4 were trained on the following problem: responses to displays moving at 4 cps (S+) were reinforced on a variable-interval 30-sec (VI 30-sec) schedule. Responses to stationary displays at 0 cps (S−) were not reinforced (extinction). Birds 5 to 8 were trained on the opposite problem: responses to displays at 0 cps (S+) were reinforced on VI 30-sec while displays moving at 4 cps (S−) were presented while extinction was in effect. Each session consisted of 10 S+ and 10 S− trials, randomly alternated and 90 sec long. After seven sessions the trial length was increased to 3 min. Each trial was followed by a timeout interval of 10 sec. The slides presented during a session all differed from each other, and different sets of slides were presented during specific sessions. The slide library was sufficient to arrange four sessions without repetition. Since 20 training sessions were given in advance of the first test, each individual slide was repeated five times.

*Testing Procedure*

After 20 sessions, all animals were "emitting" between 88% and 97% of their total responses during S+ trials. Response rates were stable from Session 15 to Session 20 with less than a 10% daily change from Session 15. Two sessions of generalization testing were then given with five regular training sessions intervening between the two tests. All test trials lasted 30 sec. In Test 1, trials were presented in 10 blocks of five trials. Each block consisted of trials at five different speeds of movement: 0, 1, 2, 4, and 8 cps. The slide materials used in the test trials were selected from the library of training slides, but many of the test slides displayed these patterns in novel combinations not previously used in training. For example, one novel pattern displayed horizontal motion in one part, clockwise motion in another, and vertical motion in still another part of the display. As many as four different patterns of movement would be combined in these novel slides. The different patterns occupied various portions of and attitudes in the displays. The speed of the universal motor was adjusted during the 10-sec timeout employed between each trial. Reinforcements were not available during test trials. The second generalization test (Test 2) was essentially the same only trials were presented in 10 blocks of four trials. Each block consisted of trials at four speeds: 0, 4, 16, and 64 cps.

Animals were then given three regular training sessions followed by a third test (Test 3) in which fully new patterns, not previously used, were displayed. These new patterns included concentric movement (movement from the corners of the displays toward the center), explosive movement (movement from the center to the corners), and several others. Many of these patterns were in a variety of colors and some depicted "complex" scenes. For example, one "complex" scene displayed a picture of a record on a phonograph table. The record itself was covered with double refracting material representing clockwise motion. When the polarizing disc was rotated, the record appeared to be rotating (apparent movement) on the phonograph. Other such "complex" scenes displayed movement in a variety of objects such as electric motors, telephone receivers, *etc.* (all complex slides were developed for educational aids and are available from Edmund Scientific Company, stock no. 70893). Test 3 trials consisted of 10 S+ and 10 S– trials, randomly alternated, 30 sec long, with a 10-sec timeout between trials. Reinforcements were not available during Test 3.

## RESULTS AND DISCUSSION

In understanding the results of this experiment it would be helpful to note that human observers judged speeds of 0, 16, and 64 cps as fused and stationary, while speeds of 1 to 8 cps were judged as progressively increasing movement.

The results from the two generalization tests for Birds 1 to 4 and for Birds 5 to 8 are presented in Fig. 1 in terms of the mean response rates to each speed for each bird. In an intradimensional discrimination of this nature, it is always necessary to ask what the generalization gradients actually reflect. Generalization gradients measured across physical dimensions usually show gradual decreases in response rate as test stimuli depart more and more from training values. By contrast, there is a slight tendency for these gradients (Fig. 1) to approximate step-functions: animals responded at high rates or not at all. To the extent that this is true, a plausible but certainly speculative explanation is that animals were either detecting movement or detecting non-movement. For example, since response rates were similar for speeds of 0 cps and 1 cps in Test 1, whether the non-moving stimulus was S+ or S–, it is probable that birds were perceiving little difference between these values. Similarly, at speeds of 2, 4, and 8 cps, Birds 6 and 7 show nearly equivalent response rates, while only a very small decline in rate is observed for Birds 5 and 8. This suggests that movement was being perceived at these speeds. However, there are some exceptions to the step-function gradient where intermediate rates were observed. This is seen in some birds at 2 cps. Intermediate response rates are also seen at 16 cps for Bird I (Test 2). In Test 2, Birds 2, 3, and 4 all responded similarly to 0, 16, and 64 cps. While it is possible to argue that the values of 16 and 64 cps were so far removed from S+ that no responding would have occurred, these test values did bring responding back to maximum rates for Birds 5 to 8. Indeed, since speeds of 16 and 64 cps appear fused and stationary to human observers, a particularly attractive interpretation is that animals were not perceiving movement at these speeds. However, since the test stimuli were not closely enough spaced to generate conclusive step-functions, one must view this interpretation with caution.

The results of Test 3 are presented in Table 1 in terms of the discrimination ratios for each subject. Here, the discrimination ratio represents the proportion of the total responses in a session made to S+ trials. Pre-Test 3 ratios represent the means for the three training sessions before Test 3 and here all subjects show ratios between 0.88 and 0.98. In Test 3 itself, all birds maintained relatively high ratios with no significant changes from Pre-Test levels.

Extremely accurate performance during training indicates the presence of a discrimination based on speed of movement. Since the same slides were used for S+ and S– conditions, and only the speed of rotation of the polarized disc differed, this was the only cue available. Furthermore, the learning was not restricted to specific slides, as a wide variety of motion slides varying in direction and complexity were employed in training and testing.

**Table 1**

**Discrimination Ratios for Each Bird during Testing with New Patterns (Test 3)**

| | *Bird* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
| Pre-test 3 (mean of three sessions before Test 3) | 0.913 | 0.929 | 0.886 | 0.906 | 0.963 | 0.940 | 0.982 | 0.971 |
| Test 3 | 0.900 | 0.911 | 0.893 | 0.928 | 0.955 | 0.943 | 0.939 | 0.957 |

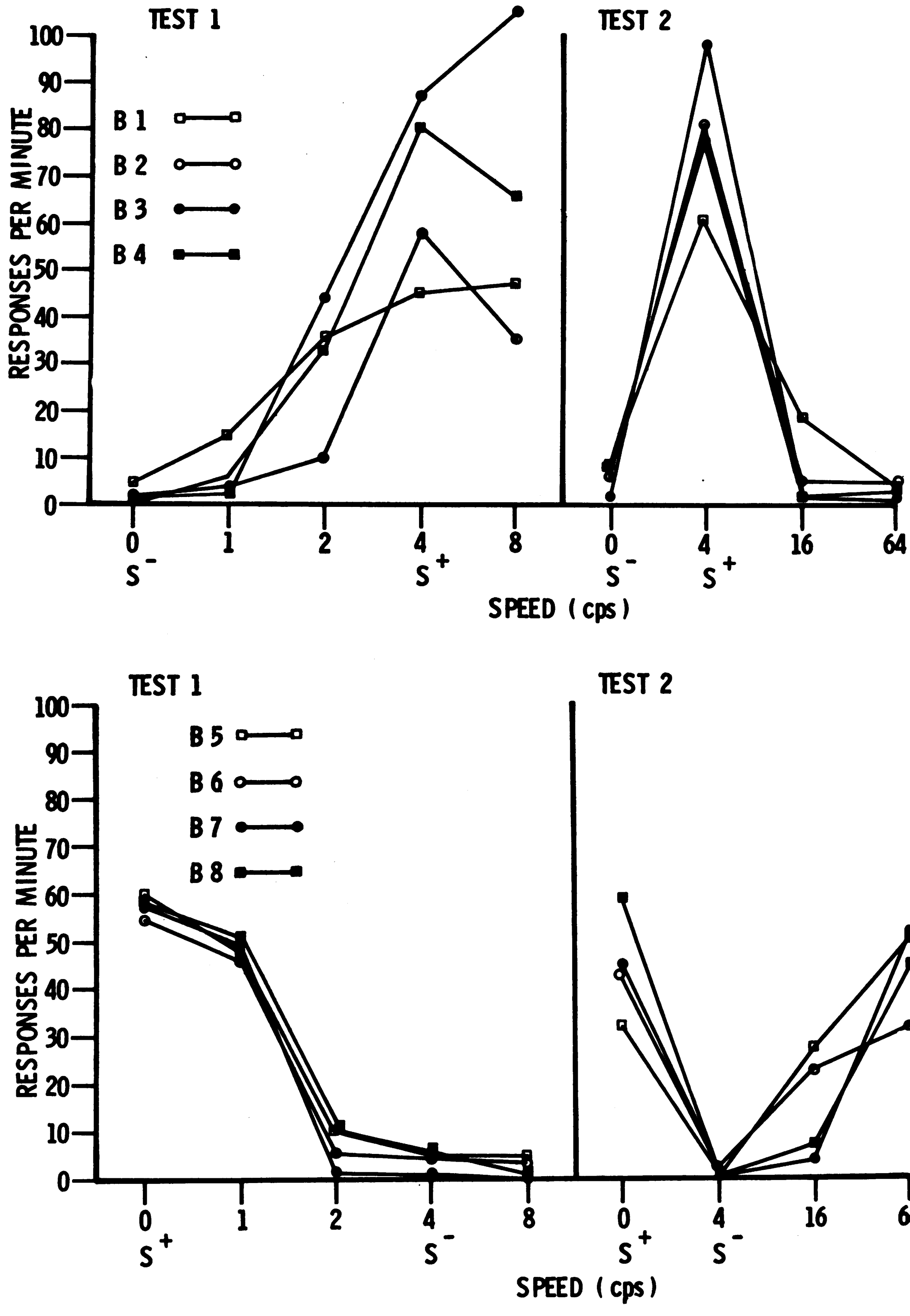


Fig. 1. Results from the generalization tests in terms of the mean response rates to each speed of rotation for each bird.

Indeed, accuracy of discrimination performance was maintained throughout testing with fully new patterns (Table 1). Some degree of "concept formation" of the movement problem is implied by this paradigm. The rapid acquisition and highly accurate nature of the final performance is consistent with previous suggestions (Herrnstein and Loveland, 1964; Siegel and Honig, 1970) that the pigeon can rapidly form a broad and complex concept when it is required. Because of the nature of the displays employed here, it remains possible that stimulus control was achieved by illumination change on a local area of the screen, rather than by the apparent movement of an entire pattern.

While precise psychophysical data must be obtained to explain these results fully, this work suggests a broad range of apparent movement detection in the pigeon. In addition, the use of the principle of rotary polarization to achieve apparent movement and the concept formation paradigm can be applied to new investigations of perceptual and cognitive processes in animals.

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