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Control of pigeons' choice behavior by the position and luminance of a spot of light

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Pigeons were trained to discriminate between a circular field containing a centrally located spot of light and an evenly illuminated circular field. During generalization tests done after training, the position and the luminance of the spot were varied. The results of the generalization tests are well described by a multiplicative "combination rule," which is derived from the assumption that the pigeons inspect only a small portion of the visual display, and that they base their choice of reponse on the presence or absence of a nonuniformity in the luminance of the area they inspect.

This paper describes an experiment in which pigeons were trained to discriminate between the presence and absence of a small spot of light that was projected on the center of a large, evenly illuminated disk. The position and the luminance of the spot were varied during generalization tests done after training. The principal purpose of this experiment was to examine the manner in which the effects of variations in luminance and position combine to determine performance during the generalization test.

METHOD

Subjects

The subjects were four White Carneaux pigeons, approximately 2 years old at the beginning of the experiment. They were kept at 80% of their free-feeding weight throughout the experiment.

Apparatus

The experiment was done in a modified three-key Lehigh Valley pigeon chamber with automatic control and recording equipment. The two side keys were 2.54 cm in diam. The center key, located midway between the side keys, was 7.62 cm in diam. The translucent surface of the center key was illuminated from behind by a Carousel slide projector. The slides inserted in this projector contained either a single Wratten neutral density filter, to produce a uniform illumination of 1.4 log fL (1 fL = 3.426 candela/m^2) on the center key, or they contained a combination of filters arranged to produce also a bright disk, 5 mm in diam, that appeared in the center of the center key. Whenever the 5-mm disk was presented, the remainder of the center key was evenly illuminated to a level of 1.4 log fL.

Procedure

Preliminary training. The center key was illuminated by red light and the pigeons were trained to peck on this key by the method of successive approximations. A single peck on the key caused the keylight to go off and a tray of mixed grain to be raised for 2.5 sec. After 15 reinforcements, an intertrial interval varying in duration from 5 to 35 sec was introduced. During the intertrial interval, the center key was not illuminated and keypecking was not reinforced. At the start of each trial, the center key light came on and remained on until the bird pecked the key. After 10 such trials on the center key, there were 45 trials during which one of the three keys, selected at random, was illuminated with red light and a response to the lighted key was the only one reinforced. During this and all subsequent phases of the experiment, the houselight was on during intertrial intervals and off during trials.

Discrimination. At the start of each trial, the center key was either evenly illuminated to a level of 1.4 log fL or the bright 5-mm-diam disk was projected on the center of the center key. The luminance of the disk was 1.8 log fL. During this and all subsequent phases of the experiment, the light reaching the center key was white.

For two of the birds, a peck on the center key (after the trial had begun) caused the two side key lights to come on. A subsequent peck on either side key ended the trial by causing the illumination on all three of the keys to go off. In addition, if the response was to the key defined as correct for the stimulus presented on the center key, it was followed by reinforcement.

The remaining two birds were not required to peck the center key in order to illuminate and enable the side keys. For these birds the three keys were illuminated simultaneously at the beginning of each trial, and pecks on the center key had no scheduled consequences.

The two visual stimuli (the blank field and the field containing the disk) were presented in random order, with the restriction that each appear 40 times within a session and no more than 3 times in succession. A trial that ended with a correct response was always followed by the next stimulus in the predetermined sequence, but, if an incorrect response was made, the stimulus presented during that trial was presented again on the next trial. A training session ended after 40 correct responses had been made to each stimulus.

The two birds that were required to peck the center key developed nearly perfect discriminations by Day 25 of training. For these birds the procedure of repeating stimuli that were incorrectly responded to was discontinued on Day 35, and between Days 44 and 52 the proportion of trials on which reinforcement was available for correct responses was gradually reduced from 1.0 to.5. The two birds that were not required to peck the center key had not developed any discrimination by Day 142 of training. On that day the repetition of stimuli that were incorrectly responded to was discontinued for these birds also, and between Days 147 and 152 the proportion of trials on which reinforcement was available for correct responses was reduced from 1.0 to .5, in preparation for the generalization tests.

Generalization tests. During the generalization tests, the small disk was presented in five different locations on the center key: in the center, where it had been during training, and on the periphery of the key at azimuth values of 0, 90, 180, and 270 deg

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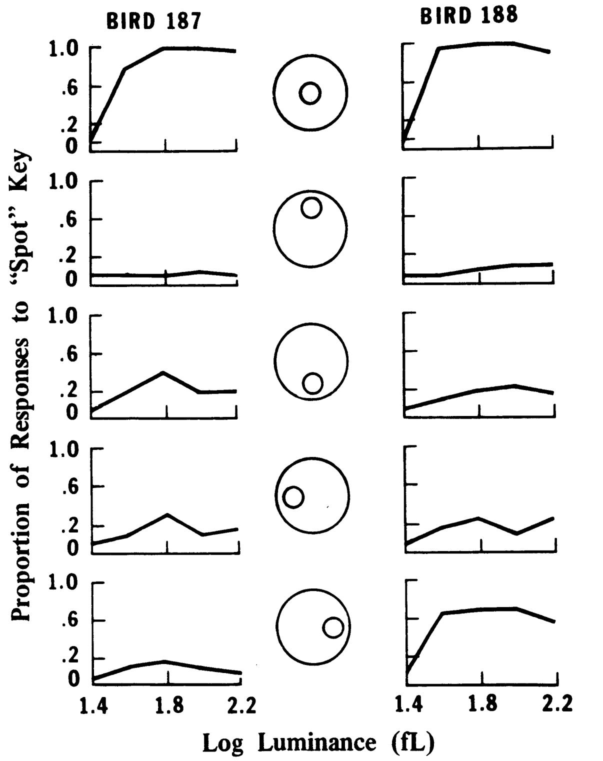

Figure 1. Choice curves obtained after training to discriminate between a circular field containing a centrally located spot of light and an evenly illuminated field. The central figure in each row shows the position of the spot, but the relative sizes of the spot and background field are not drawn to scale.

(see Figure 1). The luminance of the disk assumed each of the following values: 1.6, 1.8, 2.0, and 2.2 log fL. The five positions and four levels of luminance were presented in all combinations, and the blank field was also presented, making a total of 21 stimuli. The two training stimuli, the blank field, and the centered disk at a luminance of 1.8 log fL were each presented on 43 trials during a single test session, and all correct responses to these stimuli were reinforced. Each of the test stimuli was presented four times during a session, and responding in the presence of these stimuli was never reinforced. Five generalization tests were done on 5 successive days.

RESULTS

The two birds that were not required to peck the center key did not learn the discrimination during 152 days of training. The results of the generalization tests (not shown) also failed to reveal any evidence of stimulus control; whatever the position or luminance of the disk, the birds chose each key on roughly 50% of the trials.

The results of the generalization tests for the two birds that were required to peck the center key are shown in Figure 1. Each row of panels represents the results obtained when the spot had the position shown in the illustration. Consider first the top row, which shows the results obtained with the spot in the center, where it was during training. At 1.4 log fL the luminance of the disk is equal to the luminance of the surround, so that level represents the blank field. It can be seen that, as the luminance of the spot was raised above that level, the proportion of trials on which the birds chose the "spot" key increased and attained a final value near 1.0 when the disk luminance exceeded the surround luminance by from .2 to .4 log units, depending on the bird.

The results presented in the remaining panels show that the degree to which the choice of key was influenced by the luminance of the disk depended strongly on the position of the disk. No matter how bright the disk was, when it was located at the top of the field (row 2), both birds behaved almost as though it was not there at all. When the disk was to the right of center (bottom row), its luminance did have a substantial effect on the behavior of Bird 188, but virtually no effect on the behavior of Bird 187. When the disk was in other positions, both birds chose the "spot" key on a few trials, but not nearly as often as they did when the disk was in the center.

DISCUSSION

One way to account for the results of this experiment is to assume that the pigeons look only at a limited area of the visual display and base their choice of response upon the presence or absence of a nonuniformity in the luminance of the area they inspect. Interpreted in this way, the results indicate that Bird 188 was examining primarily an area that extended from the center to the right-hand border of the field, and Bird 187 was examining primarily a more restricted area near the center of the field.

The sort of rigid staring at a limited area of the display that is implied by our interpretation probably should not be thought of as behavior typical of pigeons, but as behavior that results from the circumstance that the feature that distinguishes to two displays always occupies the same position during training. Jenkins and Sainsbury (1969) have shown that, when such a feature is moved about from trial to trial during training, pigeons learn to search for it.

It may be useful to restate our interpretation in more precise terms. We shall call the area of the display in which the small disk is presented on any particular trial the "target area," and identify each of the target areas investigated by a number $i{:}i = 1, 2, \ldots, 5$. The symbol j will be used to denote a particular luminance level of the disk. Assume that when the pigeon detects the presence of the small disk, it always makes one of the responses, R_s, and when it does not, it makes the other response, R_b. Assume further that, for those trials on which the pigeon inspects the target area, the proportion of trials on which response R_s occurs depends only on the luminance of the disk, and reaches a value near 1.0 when this luminance exceeds that of the immediate background by about .4 log units. This proportion will be called $p^*(R_s|j)$. All failures to detect the presence of the disk at luminance levels for which $P^*(R_s|j) = 1.0$ are assumed to result from failure to inspect the target area.

On these assumptions, the proportion of trials on which the pigeon inspects a particular target area, to be called $p(E_i)$, is equal to the difference between the proportion of trials on which R_s occurs to disks of luminance greater than 1.8 log fL and the proportion of trials on which R_s occurs to the blank field. In the present experiment, the latter proportion is equal to zero, for all practical purposes. The probability with which response R_s occurs when a disk of luminance j is presented in a particular target i is then,

$$p(R_s|i,j) = p(E_i) \cdot p^*(R_s|j). \quad (1)$$

Equation (1) can be used to obtain the relation between any two luminance gradients. Consider a disk of luminance j that is presented in each of two target areas, say i = 1 and i = 2. Then

$$\frac{p(R_s|1,j)}{p(E_1)} = \frac{p(R_s|2,j)}{p(E_2)} = p^*(R_s|j)$$

and

$$p(R_s|1,j) = \frac{p(E_1)}{p(E_2)} \cdot p(R_s|2,j) \quad (2)$$

Thus, the two luminance gradients are multiples of each other. The combination rule given in Equation 2 describes the results of the present experiment quite well. Specifically, when the proportion shown in each of the panels of Figure 1 are multiplied by the appropriate ratio of p(Ei) values, the gradients that result do not appear to differ from each other in any systematic way.

Butter (1963) has reported that a multiplicative combination rule accounts quite well for the generalization gradients obtained in an experiment in which pigeons were trained to peck at a key that was illuminated by a narrow vertical strip of monochromatic light and were given a generalization test in which the wavelength of the light and the angular orientation of the strip were varied. It is possible that Butter's result reflects a process similar to that discussed above, i.e., the birds in Butter's experiment may have been inspecting only a limited area of the visual display, such as that occupied at the top end of the line that was presented in training.

A detailed discussion of the relation of the multiplicative combination rule to various theories of generalization may be found in Cross (1965). According to Cross, the multiplicative rule is not compatible with the theories of Pavlov and Hull but is compatible with the view of generalization proposed by Lashley and Wade (1946).

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