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FURTHER EVIDENCE OF A SENSORY-TONIC INTERACTION IN PIGEONS[1]

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The five pigeons in Group 1 were given successive intradimensional discrimination training in which responses to a line of 49° were reinforced on a variable-interval schedule and responses to a line of 33° were not reinforced. Subsequent generalization testing with other line orientations revealed a peak shift from the positive stimulus in the direction away from the negative stimulus in all subjects. The four pigeons in Group 2 received successive discrimination training with the 49° value on the key during both stimuli. During the negative stimulus, however, the floor was tilted 16° counterclockwise. When tested (with the floor flat) these subjects showed peak shifts similar to those observed with Group 1. A third group of three pigeons, given successive interdimensional discrimination training with the 49° line as the positive stimulus and the absence of the line as the negative, showed no peak shift in a subsequent generalization test. It was concluded that tilting the floor on which the pigeon stood systematically distorted the bird's visual perception of the orientation of the line in a manner consistent with the results of other studies in this laboratory.

Successive discrimination training involving two values closely spaced along the same continuum (*e.g.*, wavelength) typically results in a postdiscrimination generalization gradient with modal responding displaced from the positive stimulus (S^D) in the direction opposite the negative stimulus (S^Δ). This "peak shift" occurs whether responding to the S^Δ value is extinguished in training (*cf.* Hanson, 1959; Honig, Thomas, and Guttman, 1959; Thomas, 1962) or is reinforced less often (*cf.* Guttman, 1959; Terrace, 1966) or with less duration (*cf.* Mariner, 1967) than responding to the S^D. Furthermore, the effect is neither specific to the pigeon nor to the wavelength dimension. Pierrel and Sherman (1960, 1962) demonstrated a postdiscrimination peak shift in rats after discrimination training along the auditory dimension of loudness. Bloomfield (1967) demonstrated (with pigeons) a postdiscrimination peak shift along the visual dimension of angular orientation of a line ("angularity"), a finding of particular significance for the present study.

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Thomas and his associates (Lyons and Thomas, 1967; Thomas and Lyons, 1966; Thomas, Lyons, and Freeman, 1966) obtained data which they interpreted as evidence of a "sensory-tonic" interaction between the inclination of the floor on which the pigeon stands during testing and its perception of the visual vertical. It is presumed that visual perception is affected by concurrent sensory input from other modalities, including the kinesthetic one. Thus, the muscular imbalance created by tilting the floor on which the pigeon stands results in systematic "errors" in perception. In a typical study (Lyons and Thomas, 1967), pigeons were trained in a darkened Skinner box, with the floor in a normal horizontal (0°) position, to peck a key on which a white vertical (90°) line was projected. In subsequent generalization testing, the floor of the box was tilted laterally (by differing degrees in different groups) and the subjects tended to respond maximally to a line tilted from vertical in the same direction (*e.g.*, counterclockwise) and by the same extent that the floor was tilted. Thus, when the floor is tilted 30° counterclockwise, a line inclined at an angle of 120° (30° counterclockwise rotation from vertical) becomes functionally equivalent to vertical. Presumably then, a true vertical line, under that floor-tilt condition, is "equivalent to" one rotated 30° clockwise under the normal floor condition. According to this analysis, manipulating the angle of the floor alters the "apparent" inclination of the line on the key, and the subject then responds accordingly.

If it is true that a tilt of the floor changes the apparent inclination of the line on the key, then discrimination training involving two floor inclinations (with the key-line constant) should be perceived by the subject as involving two different angles of the line on the key. With the key-line inclined, say, 49° from horizontal during the S^D (horizontal floor) condition, the key angle should be perceived veridically, *i.e.*, as 49°. If the floor were tilted 16° counterclockwise under the S^Δ condition, the (49°) key-line should appear to be inclined 33°. Bloomfield's (1967)[2] results suggest that if the S^Δ were actually (*i.e.*, with respect to gravity) 33°, the result would be a peak of responding displaced to an angle greater than 49°. If the above analysis is correct, the 16° floor-tilt manipulation should produce exactly the same result. The present experiment sought to test this hypothesis.

Two groups of subjects were used. For each, a line of 49° served as the positive stimulus (S^D) in discrimination training. For Group 1, the negative stimulus (S^Δ) was a line inclined 33°; for Group 2 the key stimulus was unchanged but the floor was tilted 16° counterclockwise during S^Δ periods, presumably making the 49° angle "equivalent to" one of 33°. After the discrimination problems had been mastered, both groups received identical generalization tests in which the floor was horizontal and the line on the key varied from 0° to 90°. To distinguish between specific effects of intradimensional discrimination training (presumably occurring with both of these groups) and general effects which would have been obtained even if S^Δ were not on the same dimension as S^D, (*cf.* Friedman and Guttman, 1965; Switalski, Lyons, and Thomas, 1966) a third group was tested after training with 49° as S^D and a white blank key as S^Δ. No peak shift was anticipated for this third group.

The training stimulus of 49° was chosen to avoid the possible complications which could result from a mirror-image transfer effect. Thomas, Klipec, and Lyons (1966) have shown that pigeons trained to peck an oblique line (*e.g.*, 60° counterclockwise rotation from horizontal) often yield bimodal angularity generalization gradients with peaks of responding at both the conditioned stimulus and at its mirror-image (in this case 120°). It was reasoned that a peak shift from a vertical S^D might also be accompanied by a mirror-image which would make interpretation of the results difficult. To avoid this possibility, a 49° S^D was used and testing was restricted to stimuli from 0° to 90°.[2]

METHOD

Subjects

Twelve experimentally naive homing pigeons, maintained at approximately 75% of free-feeding weight, completed the experiment.

Apparatus

Two operant conditioning chambers, described in detail by Hiss and Thomas (1963), were used. In one, a gear mechanism permitted the lateral (sidewise) inclination of the floor up to 30° in either direction from horizontal (0°). With one exception, noted later, the key stimuli to both boxes were supplied by Industrial Electronics Engineers in-line display cells, and consisted of a black line ⅛-in. wide by ⅞-in. high on a white background. The line could be inclined from 0° to 90° (vertical) in 8.18° steps.

Procedure

After magazine and key-peck training with a 49° stimulus, all subjects received two daily 30-min sessions in which responses were reinforced on the average of every 30 sec (VI 30-sec). These were followed by two daily 30-min sessions of VI-1 min training. During this training, stimulus-on periods of 50 sec were alternated with timeout periods of 10 sec, during which the chambers were in complete darkness. On the next day, discrimination training was begun for all subjects. The S^D was the 49° training stimulus. For Group 1 (n = 5), the S^Δ was a line of 33°. For Group 2 (n = 4), the S^Δ was a 16° counterclockwise

[2]Bloomfield (1967) used a 90° S^D and found no mirror-image effect. We found one in several pilot subjects (for which a 90° S^D value was used) before this experiment was initiated. The reason (or reasons) for this discrepancy remain to be specified, but one procedural difference which may be significant is Bloomfield's use of a house light. In our studies the key stimulus has been the only source of illumination in the chamber.

floor tilt with the key stimulus unchanged. For Group 3 (n = 3), S^{Δ} was a homogeneous white key (illuminated by an appropriately placed desk lamp).

During discrimination training, S^D and S^{Δ} periods of 50-sec duration were randomly alternated with 10-sec timeout periods intervening. The VI-1 min reinforcement schedule was in effect during all S^D periods; responses in the presence of S^{Δ} and during timeout periods were not reinforced. Discrimination training was continued until each subject achieved a discrimination ratio of 10 responses to S^D for each response to S^{Δ} during a given 30-min training session. On the next day, after 5 min of warm-up training, each subject was tested for generalization in extinction with 12 stimuli ranging from 0° to 90° in 8.18° steps. These stimuli were randomized within a series and five different random series were presented to each subject. Stimulus presentations were for 50 sec with 10-sec timeout periods intervening.

RESULTS AND DISCUSSION

Group 1. The discrimination between lines of 49° and 33° proved to be exceedingly difficult for most subjects in this group. Bird B6 achieved criterion after 36 sessions, P3 required 72, P1 took 87, P5 needed 103 sessions, and P2 took 137. Four other birds initially assigned to this group failed to approach criterion after 137 sessions and were discarded without being tested for generalization. The generalization gradients of the five subjects in Group 1 which completed the experiment are presented in Fig. 1. Two attributes of these gradients are immediately apparent.

First, a peak shift was obtained in every case, with modal responding displaced from S^D 16° in two cases and 25° in the other three.

Secondly, the gradients are much more variable (*i.e.*, they show many more inversions) than is typical of postdiscrimination generalization gradients along the wavelength dimension. There appears to be no relationship between the extent of the peak shift and the variability of the gradient, and neither seems related to the number of training sessions required to achieve criterion.

Group 2. These subjects also found their discrimination difficult; S1 required 27 sessions to meet criterion, S4 needed 54, B13 took 76, and S3 needed 105 sessions.

Figure 2 presents the generalization gradi-

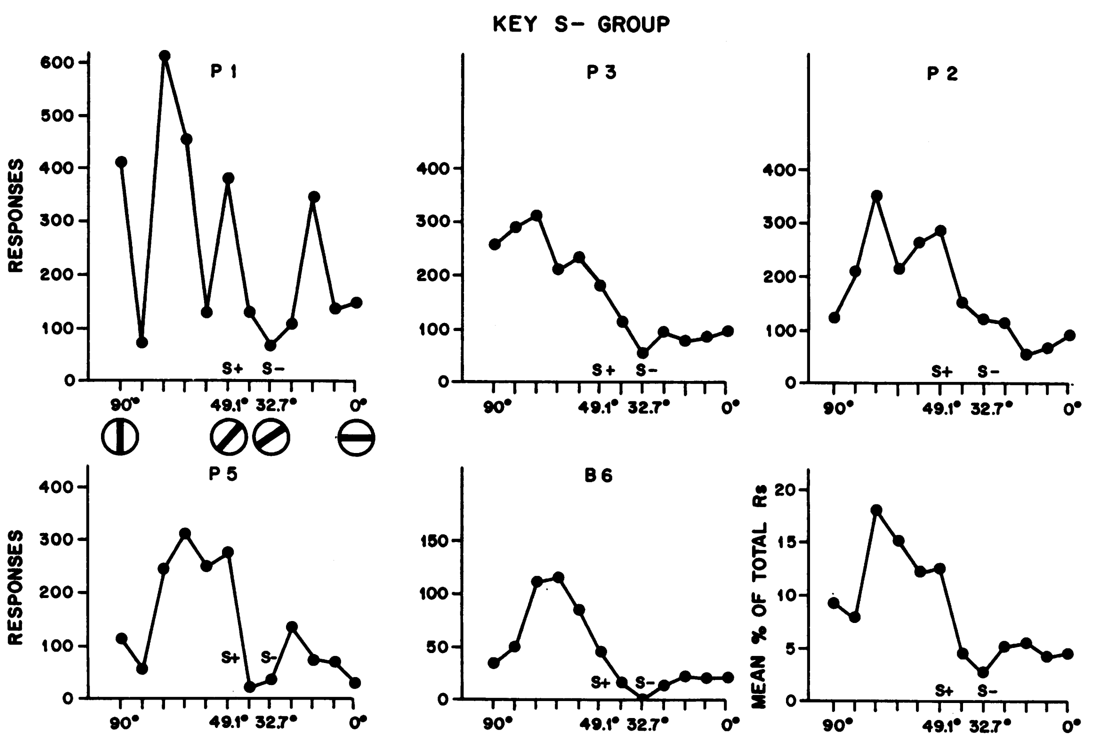

Fig. 1. Postdiscrimination generalization gradients for the birds in Group 1.

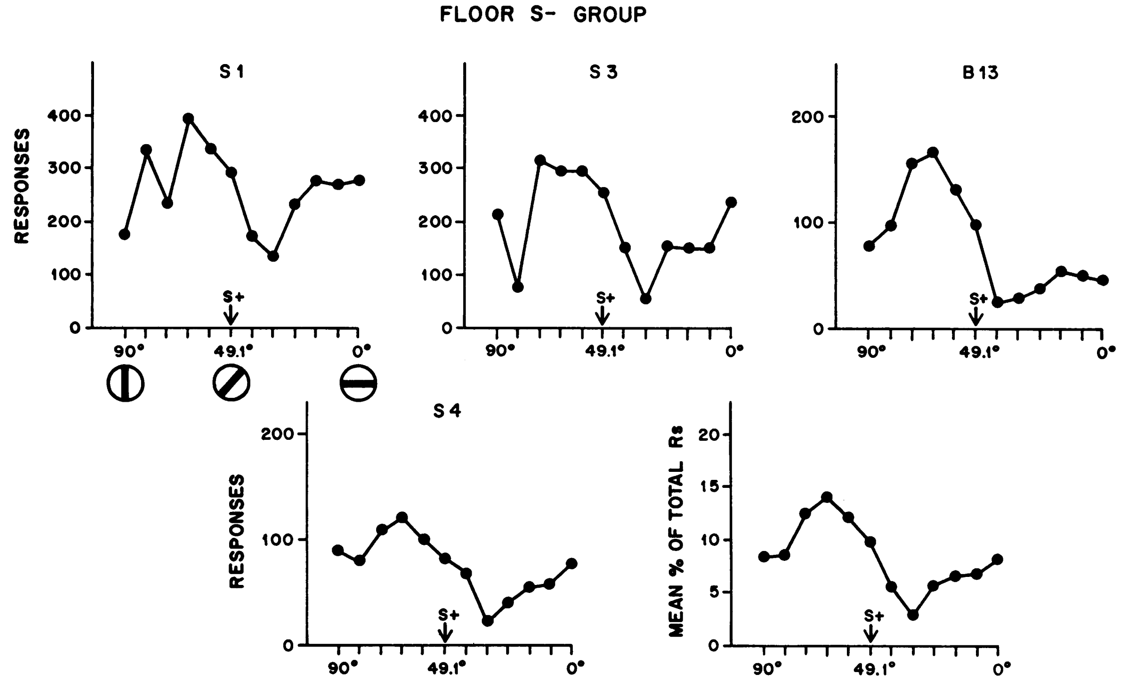

Fig. 2. Postdiscrimination generalization gradients for the birds in Group 2.

ents of the four subjects in Group 2 for which data are available. Each gradient shows the predicted peak shift; the displacement of the mode from S^D is 16° in two cases and 25° in the other two. These gradients are comparable to those obtained with Group 1. The trough in each gradient is clearly in the vicinity of 33°. This fact, in combination with the peak shift from 49° in the direction opposite 33°, provides seemingly incontrovertible evidence that when the floor is inclined 16° counterclockwise the 49° key line "appears to be" (*i.e.*, the subject responds as if it were) inclined 33°.

One possible alternative interpretation remains to be precluded; that training with a line of 49° would yield a gradient with a displaced peak even in the absence of intradimensional discrimination training.

To test this possibility, Group 3 was given interdimensional discrimination training in which S^{Δ} was simply the absence of the 49° line which characterized S^D.

Group 3. The discrimination between the 49° line and the homogeneous white key was a very easy one. Pigeon G3 achieved criterion in just three sessions, G1 and G5 required six.

Interdimensional discrimination training established some control over response rate by the angularity dimension. The subjects in Group 3 yielded extremely variable decremental generalization gradients with peak responding to the training stimulus value. Despite the variability of these gradients, it may be concluded from them that the peak shift observed with Groups 1 and 2 was attributable to the use of another inclination of line (real or apparent) as the S^{Δ}. Again, as in Groups 1 and 2, there was no relationship between sessions to achieve criterion and the nature of the generalization gradient.

In conclusion, successive intradimensional discrimination training with a 49° line as S^D and a 33° line as S^{Δ} results in a peak shift in the postdiscrimination generalization gradient. Successive discrimination training with the 49° line always on the key, and the floor tilted 16° counterclockwise during S^{Δ} periods, yielded generalization gradients comparable to those produced with an actual 33° S^{Δ} and no floor-tilt manipulation. This supports the contention that this floor-tilt manipulation renders the 49° stimulus equivalent to one of 33°, indicating that (as predicted) the visual perception of vertical is systematically distorted by the muscular imbalance created by the floor-tilt manipulation. This study thus contributes to a growing body of literature which demonstrates that operant conditioning

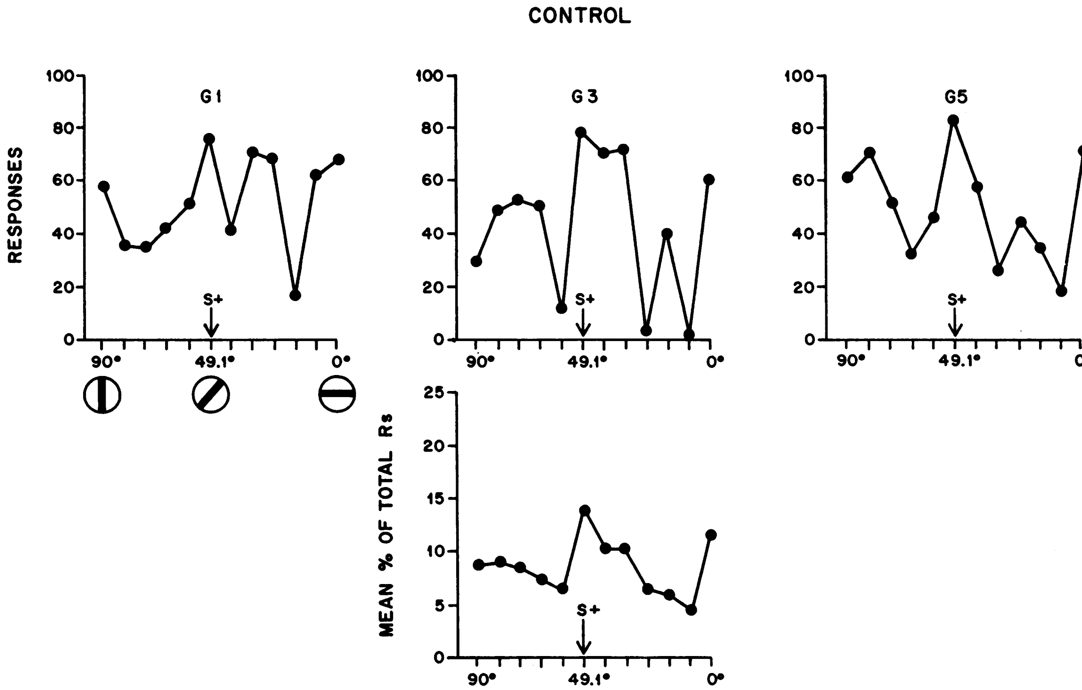

Fig. 3. Postdiscrimination generalization gradients for the birds in Group 3.

procedures can be used to investigate complex perceptual phenomena previously inaccessible to scientific investigation in non-verbal organisms.

REFERENCES

Bloomfield, T. M. A peak shift on a line-tilt continuum. *J. exp. Anal. Behav.*, 1967, **10**, 361-366.

Friedman, H. and Guttman, N. Further analysis of the various effects of discrimination training on stimulus generalization gradients. In D. I. Mostofsky (Ed.), *Stimulus generalization*. Stanford, Calif.: Stanford University Press, 1965. Pp. 255-267.

Guttman, N. Generalization gradients around stimuli associated with different reinforcement schedules. *J. exp. Psychol.*, 1959, **58**, 335-340.

Hanson, H. M. Effects of discrimination training on stimulus generalization. *J. exp. Psychol.*, 1959, **58**, 321-334.

Hiss, R. H. and Thomas, D. R. Stimulus generalization as a function of testing procedures and response measure. *J. exp. Psychol.*, 1963, **65**, 587-592.

Honig, W. K., Thomas, D. R., and Guttman, N. Differential effects of continuous extinction and discrimination training on the generalization gradient. *J. exp. Psychol.*, 1959, **58**, 145-152.

Lyons, J. and Thomas, D. R. The influence of postural distortion on the perception of visual vertical in pigeons. *J. exp. Psychol.*, 1968, **76**, 120-124.

Mariner, R. W. Reward duration, behavioral contrast, and postdiscrimination generalization gradients. MA thesis. Kent State University, 1967.

Pierrel, R. and Sherman, J. G. Generalization of auditory intensity following discrimination training. *J. exp. Anal. Behav.*, 1960, **3**, 313-322.

Pierrel, R. and Sherman, J. G. Generalization and discrimination as a function of the S^D—S^Δ intensity difference. *J. exp. Anal. Behav.*, 1962, **5**, 67-71.

Switalski, R. W., Lyons, J., and Thomas, D. R. Effects of interdimensional training on stimulus generalization. *J. exp. Psychol.*, 1966, **72**, 661-666.

Terrace, H. S. Stimulus control. In W. K. Honig (Ed.), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 271-344.

Thomas, D. R. The effects of drive and discrimination training on stimulus generalization. *J. exp. Psychol.*, 1962, **64**, 24-28.

Thomas, D. R., Klipec, W., and Lyons, J. Investigations of a mirror-image reversal effect in pigeons. *J. exp. Anal. Behav.*, 1966, **9**, 567-571.

Thomas, D. R. and Lyons, J. The interaction between sensory and tonic factors in the perception of the vertical in pigeons. *Percept. and Psychophys.*, 1966, **1**, 93-95.

Thomas, D. R., Lyons, J., and Freeman, F. The interaction between sensory and tonic factors in the perception of the vertical in pigeons: II. A replication via an alternative procedure. *Psychon Sci.*, 1966, **4**, 495-496.

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