JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1972, 17, 107-111 NUMBER 1 (JANUARY)

EFFECTS OF MONOCHROMATIC REARING ON SPECTRAL DISCRIMINATION LEARNING AND THE PEAK SHIFT IN CHICKS[1]

ROBERT L. RUDOLPH AND WERNER K. HONIG

DALHOUSIE UNIVERSITY

Chicks were hatched and raised in white or monochromatic sodium (589 nm) light. They were trained on a 590 (+) *vs.* 580 (−) nm successive discrimination. The combined results of two experiments indicated that rearing illumination did not affect discrimination acquisition. All subjects given generalization tests after discrimination training exhibited peak shifts that were equivalent for the two rearing conditions. The peak shifts exhibited by the monochromatically reared subjects represent maximum responding to stimuli they had not previously seen. This result further confirms the notion that behavioral control by the spectral dimension in birds is organized independently of differential early experience on that dimension.

Rudolph, Honig, and Gerry (1969) reported a series of experiments in which birds were raised under various restricted conditions of spectral stimulation, and then tested for generalization on the spectral continuum after acquisition training with one monochromatic value. In contrast to results previously reported by Peterson (1962), steep decremental gradients were obtained following restricted rearing, and these gradients did not differ from those obtained from control subjects raised in white light. Similar findings have been reported by Malott (1968) and Mountjoy and Malott (1968). Tracy (1970) also obtained decremental gradients from monochromatically reared ducklings. The results of these studies are consistent with Hull's (1943) assertion that the occurrence of a reinforced response in the presence of a stimulus is sufficient for the development of stimulus control. Furthermore, they contradict the Lashley and Wade (1946) claim that differential reinforcement on a dimension must occur before stimulus control on that dimension can be observed.

The present experiment represents an extension of this research to the situation in which subjects are given a generalization test after spectral discrimination training, rather than after simple acquisition. This is of particular interest because of the peak or area shift commonly produced by such a training procedure (Guttman, 1959; Hanson, 1959; Honig, 1962; Terrace, 1966*a*, 1966*b*, 1968). With monochromatically reared subjects, such a shift would represent maximum responding to a value that they had not previously seen, and would confirm the notion that behavioral control on the spectral dimension in birds occurs independently of differential early experience on that dimension.

The current study involved raising chicks in sodium light (589 nm). The positive training value of 590 nm was almost the same as the rearing value, while the negative stimulus was 580 nm. This difference of 10 nm is likely to produce many errors in discrimination training, and a marked post-discrimination peak shift (Hanson, 1959).

EXPERIMENT 1

METHOD

Subjects

Thirteen Hubbard Golden Comet chicks (a cross-breed of female White Comet x male New Hampshire Red), 10 days old at the start of training, were fed freely for the first nine days, and then deprived of food for 24 hr before the first training session. During the initial training sessions, they were fed 10 g a day in addition to the food that they obtained

[1]This research was supported by Grant No. APA-102 to W. K. Honig and by Grant No. APA-297 to R. L. Rudolph from the National Research Council of Canada. A portion of this research was reported at the American Psychological Association meetings in San Francisco, September 1968. Reprints may be obtained from R. L. Rudolph, Dept. of Psychology, Dalhousie University, Halifax, Nova Scotia.

from the magazine. During discrimination training, this supplement was raised to 14 g a day because the number of reinforcements during training was reduced.

Rearing Conditions

Eight subjects were hatched and raised in light produced by a sodium vapor lamp; the other five were hatched and raised in light produced by a Westinghouse Daylight fluorescent bulb covered with Wratten neutral density 0.30 filters. The light source in each room was arranged so that subjects could view it directly from their home cages. The luminance of the sodium source was 440 ft lamberts; that of the white source was 500 ft lamberts. These two sources provided equal levels of illuminance at the front of the home cages, since the area of the sodium source was somewhat greater than that of the white source. The levels of illuminance at the front of both sodium and white cages ranged from 2 to 4 ft candles depending on the distance of the cage from the source.

Apparatus

A two-key operant behavior chamber was used, but only one key, located roughly in the middle of the front panel, was operative. The food magazine was located below and to the right of this key. Spectral values on the response key were produced by interposing Bausch and Lomb second-order monochromatic interference filters (half width = 10 nm) in the path of a beam of light produced by a Carousel projector. The optical system was arranged so that light entered the interference filter at an angle that varied from the perpendicular by no more than 2°. A Wratten K-2 (yellow) filter was used to eliminate third-order spectral values transmited by the filters. A similar arrangement was used to illuminate the food magazine during reinforcement with the positive spectral training value (590 nm). The animal's chamber was on one side of a light-proof partition, while the projectors and scheduling equipment were on the other.

Procedure

The subjects were trained to peck the key illuminated by 590 nm, which approximated the rearing value of 589 nm. Thirty reinforcements (involving 4.5 sec operations of the feeder) were permitted during each of five sessions of pretraining. During these sessions, the reinforcement schedules were as follows: one day of continuous reinforcement (every peck reinforced); one day of variable ratio 7 (every seventh response reinforced on the average); one day of variable interval 30-sec (irregular reinforcement for pecks with an average interval of 30 sec between reinforcements), and one day of variable interval 1-min (irregular reinforcement at an average interval of 1 min). When the variable-interval schedules were in effect, the training sessions were divided into stimulus-on periods of 1 min each separated by 10-sec blackouts.

After pretraining, all of the white-reared subjects (the "White" group) and five of the sodium-reared subjects (the "Sodium" group) were given 10 days of discrimination training. Thirty 1-min stimulus-on periods separated by 10-sec blackouts comprised a training session. During 15 of these periods, the 590-nm value was displayed on the key and reinforcement was available on the variable interval 1-min schedule. During the other 15 periods, the key was illuminated by 580 nm, reinforcement never occurred, and the reinforcement schedule did not operate. The luminance levels of the key during the 580- and 590-nm stimuli were 23 and 28 ft lamberts respectively. Positive and negative periods alternated randomly, with the restriction that not more than two periods of the same kind were presented in a row.

The remaining three sodium-reared chicks were trained like the discrimination groups, except that they received extended blackout periods during those trials when the discrimination groups were presented with 580 nm (the negative value). This training procedure is similar to the simple acquisition of responding to 590 nm carried out in previous work, except for the extended timeouts. This group was included to determine whether any "spontaneous" peak or area shift in the generalization gradient would follow a training procedure identical to discrimination except for the omission of the negative spectral value.

On the day after the last training session, all subjects were given a generalization test in extinction on 570, 580, 590, 600, and 610 nm. The luminances of these stimuli were 27, 23, 28, 21, and 20 ft lamberts respectively. (Note that a discrimination between 580 nm (23 ft lam) and 590 nm (28 ft lam) based on luminance would not produce a peak shift to either 600 or 610 nm.) These stimuli were presented in randomized order over 10 blocks of five trials each. As in training, test trials lasted 1 min and were separated by 10 sec of blackout.

RESULTS AND DISCUSSION

Table 1 presents the generalization gradient for each subject with responses to each test value expressed as a percentage of the total responses emitted during the generalization test. The three sodium-reared control birds, which were given single stimulus training on 590 nm, exhibited gradients with the peak in each case at the training value. The gradients were orderly for each animal with the exception of small inversions for Subjects 11 and 13 between 600 and 610 nm. These data confirm the results of previous research with sodium-reared chicks, and because the mean gradient is quite symmetrical, there is no indication of any "spontaneous" peak shift.

All subjects in the two discrimination groups demonstrated peak shifts toward the longer wavelengths. For each subject, the percentage of responses to 600 and to 610 nm was greater than to the training value of 590 nm. The mean percentage gradient from the White group indicates a somewhat smaller peak shift, but this difference is entirely due to the gradients of Subjects 3 and 9. Their gradients differ from those of the other three White subjects, while the gradients of the latter are almost identical to those obtained from the Sodium group (*cf*. the mean of White Subjects 1, 6, and 12 in Table 1). The relatively smaller peak shifts of Subjects 3 and 9 are attributable to their poor discrimination performance on the last day of training. Although the percentage of correct responses for these subjects was above 70% on the fourth day of training, these percentages decreased towards the end of training and were only 50.8% and 53.3% for Subjects 3 and 9 respectively on the last day of training. The remaining three White subjects emitted a mean of 74.1% correct responses, while the Sodium group attained a level of 79.8% on the last day. The poor discrimination between the training values achieved by Subjects 3 and 9 is also reflected by the test data: they respectively emitted 14.8% and 20.5% of their responses to 580 nm, the nonreinforcement training stimulus, while the remaining subjects gave only about 4% of their responses to the same value.

The level of discrimination attained during training appears to be the primary determinant of the amount of peak shift. As seen, the shape of the gradient and the amount of peak

Table 1

Percentage of responses emitted to 590 nm on the last day of training and to each test value.

Group	*Subject*	*Last Day of Training*	*Test Stimulus in nm* 570	580	590	600	610	*Total Test Responses*
	11	–	18.1	18.9	25.4	18.1	19.4	386
Sodium-Reared	13	–	8.7	16.8	25.7	23.7	25.1	346
Control	14	–	15.3	26.6	28.0	18.2	11.8	346
	Mean	–	14.0	20.8	26.4	20.0	18.8	359
	5	92.0	0.6	0.0	9.9	44.0	45.5	332
	6	67.7	1.6	9.3	22.4	34.3	32.2	428
Sodium-Reared	8	86.9	0.4	2.1	21.3	38.8	37.3	726
Discrimination	10	84.5	0.4	1.1	26.7	29.5	42.3	281
	16	68.1	3.5	7.8	19.8	31.3	37.6	434
	Mean	79.8	1.3	4.1	20.0	35.6	39.0	440
	1	77.6	0.3	3.5	25.4	32.4	38.4	599
	3	50.8	13.5	14.8	22.2	25.2	24.3	1089
White-Reared	6	65.6	1.1	5.5	26.9	31.0	35.4	802
Discrimination	9	53.3	11.3	20.5	19.8	22.6	25.8	771
	12	79.1	2.9	3.1	16.2	34.1	43.8	977
	Mean	65.2	5.8	9.5	22.1	29.1	33.5	848
Mean for Birds 1, 6, & 12		74.1	1.4	4.0	22.8	32.5	39.2	793

shift were very similar for those subjects that reached comparable levels of discrimination performance. A rank-order correlation between per cent correct responses on the last day of training and the combined percentage of responses to 600 and 610 nm on the test provides further evidence in favor of this relationship. The value of r_s is 0.95 when all 10 discrimination birds are included in the correlation, and 0.93 if the two White birds that discriminated poorly are excluded from the sample. Both of these rank-order values are well beyond the 1% level of confidence.

The rather aberrant performance of two of the White subjects suggests that rearing illumination may affect discrimination acquisition. The mean percentage correct responses over days of acquisition for the White and Sodium groups is plotted in Figure 1. It appears that the Sodium group (1) acquired the discrimination more slowly and (2) exhibited a higher level of terminal performance. However, these differences were not replicated in Experiment 2.

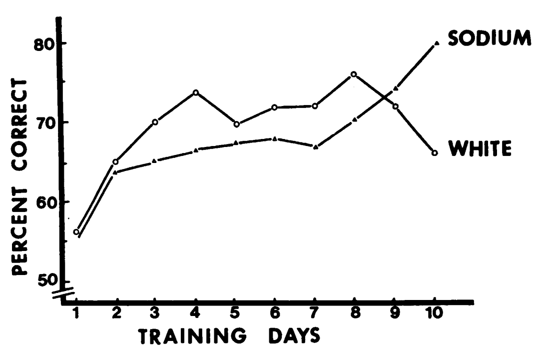

Fig. 1. Mean percentage correct responses for each training day in Experiment 1 for the sodium-reared and the white-reared groups.

EXPERIMENT 2

Method

This experiment, which utilized four sodium-reared and five white-reared subjects, was essentially a replication of the first experiment. The differences between experiments, and the reasons for them are listed below.

1. Two days of variable interval 1-min training, instead of one day, were given before the initiation of discrimination training. This change was made because responding by some of the subjects in the first experiment was partially extinguished on the first day of discrimination training and required either additional or free reinforcement to maintain responding.

2. Fourteen days of discrimination training, instead of 10, were given to provide sufficient time for the appearance of any possible differences between groups.

3. No post-discrimination generalization tests were given because the generalization results of Experiment 1 were quite clear. Instead, the rearing illumination of the subjects was reversed. When a subject was taken out of the experimental chamber on the fourteenth day of training, it was not returned to its home cage, but was placed in a cage in the other rearing room: *i.e.,* White subjects were placed in the sodium room, and Sodium subjects were placed in the white room. Normal discrimination training was given on the next day. This was carried out to determine whether such a change in rearing conditions would disrupt the acquired discrimination.

RESULTS AND DISCUSSION

The mean percentage correct responses over the 14 days of discrimination training and on the test day are presented in Figure 2. A comparison of these results with those presented in Figure 1 indicates the following.

1. The somewhat faster acquisition of the discrimination by the White group in Experiment 1 (Days 3 and 4) was not replicated in Experiment 2. The performances of the Sodium and White groups in Experiment 2 were almost indistinguishable for the first eight days of training.

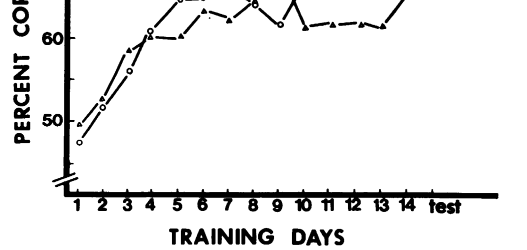

Fig. 2. Mean percentage correct responses over training days and on a test day in Experiment 2 for the sodium-reared and white-reared groups.

2. In Experiment 1 the terminal performance of the sodium-reared group was superior. In Experiment 2 this difference disappeared and, if anything, was reversed.

3. In Experiment 1 the performance of two of the White subjects was seriously disrupted during training. Although it is not obvious from Figure 2, no White subject in Experiment 2 exhibited a deterioration of performance that was comparable to that which occurred in Experiment 1. However, one Sodium subject in Experiment 2 did exhibit a comparable deterioration. The percentages of correct responses for this subject on Days 11, 12, and 13 were 67.2, 50.5, and 36.9% respectively.

Thus, the apparent differences in discrimination acquisition obtained in Experiment 1 either disappeared or were reversed in Experiment 2. Furthermore, the change in rearing illumination in Experiment 2 had no discernible effect. Though the average improvement in discrimination performance was superior for the White group shifted into the sodium room, the largest increase in performance—16.5%—occurred in a Sodium subject shifted into the White room. Hence, the combined results of Experiments 1 and 2 indicate that there are no reliable differences between sodium-reared and white-reared birds in the acquisition of a spectral discrimination.

Assuming that there is no difference in discrimination performance, it appears that there should be no difference between sodium- and white-reared subjects in the extent of the peak shift, since the correlation between discrimination performance and magnitude of the peak shift observed in Experiment 1 was almost perfect. Although it is not possible to prove the null hypothesis, the evidence to date indicates that rearing illumination does not affect (1) the acquisition of spectral stimulus control (Malott, 1968; Mountjoy and Malott, 1968; Rudolph, Honig, and Gerry, 1969; but see Tracy, 1970, for some possibly contradictory data), (2) the acquisition of a spectral discrimination, and (3) the magnitude of the peak shift. This evidence is consistent with the position that the organization of the spectral dimension is independent of differential spectral stimulation during early rearing.

REFERENCES

Guttman, N. Generalization gradients around stimuli associated with different reinforcement schedules. *Journal of Experimental Psychology*, 1959, **58**, 335-340.

Hanson, H. M. The effects of discrimination training on stimulus generalization. *Journal of Experimental Psychology*, 1959, **58**, 321-334.

Honig, W. K. Prediction of preference, transposition, and transposition-reversal from the generalization gradient. *Journal of Experimental Psychology*, 1962, **64**, 239-248.

Hull, C. L. *Principles of behavior*. New York: Appleton-Century-Crofts, 1943.

Lashley, K. S. and Wade, M. The Pavlovian theory of generalization. *Psychological Review*, 1946, **53**, 72-87.

Malott, M. K. Stimulus control in stimulus deprived chickens. *Journal of Comparative and Physiological Psychology*, 1968, **66**, 276-282.

Mountjoy, P. and Malott, M. K. Wavelength generalization curves for chickens reared in restricted portions of the spectrum. *Psychological Record*, 1968, **18**, 575-583.

Peterson, N. Effect of monochromatic rearing on the control of responding by wavelength. *Science*, 1962, **136**, 774-775.

Rudolph, R. L., Honig, W. K., and Gerry, J. E. Effects of monochromatic rearing on the acquisition of stimulus control. *Journal of Comparative and Physiological Psychology*, 1969, **67**, 50-57.

Terrace, H. S. Behavioral contrast and the peak shift: effects of extended discrimination training. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 613-617. (*a*)

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. (*b*)

Terrace, H. S. Discrimination learning, the peak shift, and behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 727-741.

Tracy, W. K. Wavelength generalization and preference in monochromatically reared ducklings. *Journal of the Experimental Analysis of Behavior*, 1970, **13**, 163-178.

Received 25 January 1971.
(Final Acceptance 23 August 1971.)