*THE FAILURE OF STIMULUS CONTROL
AFTER PRESENCE-ABSENCE DISCRIMINATION
OF CLICK-RATE¹*

BEN A. WILLIAMS

THE COLORADO COLLEGE

Pigeons were trained to discriminate a slow click-rate from its absence, or to discriminate it from a faster click-rate. Subsequent click-rate generalization tests produced the usual steepened gradients after the intradimensional discrimination but produced flat gradients after presence/absence discrimination. The occurrence of stimulus control only after intradimensional discrimination, combined with previous results showing stimulus control sometimes after nondifferential reinforcement and sometimes after presence/absence discrimination, argues for a reformulation of the problem of stimulus control. A theoretical framework, relying upon blocking effects inherent in the different discrimination procedures, was presented to account for the diversity of results.

The training conditions necessary to produce stimulus control have remained an unresolved issue. Previous attempts to define the necessary conditions have usually fallen between two extremes: the Hull-Spence view (Spence, 1936; Hull, 1947) that simple reinforcement in the presence of the training stimulus is sufficient (nondifferential reinforcement), *versus* the Lashley-Wade (1946) position that discrimination between two points on the same continuum is necessary (intradimensional discrimination). Although the Hull-Spence view gained considerable support from the classic findings of Guttman and Kalish (1956) that steepened generalization gradients occurred after nondifferential reinforcement in the presence of a single color, neither of the two extreme positions is currently as popular as an intermediate position that holds that some type of discrimination is necessary, but that the discrimination need not be intradimensional. This intermediate position was fostered by the well-known experiment of Jenkins and Harrison (1960), who found no stimulus control for tone frequency after pigeons

were simply rewarded for responding in the presence of a 1000-cps tone, but found sharp control when the pigeons learned to discriminate the 1000-cps tone from its absence.

Although the theoretical position inspired by Jenkins and Harrison has gained wide acceptance (*cf.* Terrace, 1966), demonstrations of stimulus control after nondifferential reinforcement still offer exception to its generality. Such demonstrations have not been accepted uncritically, however, as several investigators have suggested that extraneous sources of discrimination have been present in the experimental procedures (*e.g.*, pecking the key *versus* pecking the box surrounding the key). Although such extraneous discrimination sources have been established for some situations (Heinemann and Rudolph, 1963), the appeal to such sources as an explanation for all demonstrations of stimulus control after nondifferential reinforcement remains largely *post hoc*, and for some experiments at least (Hearst, 1960, 1962), of questionable applicability. The role of discrimination training in establishing stimulus control, therefore, remains open to question.

The present experiment questions a second aspect of the generality of the Jenkins and Harrison position. Their experiment showed clearly that presence/absence discrimination does produce stimulus control by tone frequency with pigeons, but it is unclear whether such discrimination training will produce stimulus control to other stimulus dimensions.

¹This experiment was conducted when the author was a National Science Foundation Predoctoral Fellow and was supported by research grants NIMH 15494 and NIH-GM-15258 to Harvard University. The author thanks C. L. Roberts and D. W. Shearn for their criticisms of an earlier draft of this paper. Reprints may be obtained from the author, Department of Psychology, University of California, San Diego; La Jolla, Calif. 92037.

The present experiment trained pigeons using a different stimulus dimension, click-rate, to determine if presence/absence discrimination is a generally sufficient condition to produce stimulus control.

METHOD

Subjects

Four White Carneaux pigeons were maintained at 80% of their free-feeding body weights. All subjects had extensive experience on a variety of reinforcement schedules, but had no experience with auditory discrimination.

Apparatus

The test chamber consisted of a 30.5-cm (12-in.) wire-mesh cube enclosed within a larger chamber to dampen outside noise. The outer chamber, constructed of 2-cm (0.75 in.) acoustical tile measured 73 by 68 by 48 cm (29 by 27 by 9 in.). Seven cm (2.75 in.) below the top of the front panel of the inner chamber were two Gerbrands' pigeon keys, 1.9 cm (0.6 in.) in diameter, and 7 cm (2.75 in.) apart, center to center. Only the left key was used (the right key was darkened and inoperative), and it required a force of at least 15 g (0.15 N) for operation. Between and 7.5 cm (3 in.) below the keys located a 5.0 by 4.5 cm (2 by 1.75 in.) aperture through which the birds were fed when a grain hopper was activated.

The stimuli were different frequency click-rates emitted from a 4.0-in. (10 cm) speaker located 1.3 cm (0.5 in.) above the top of the inside chamber, approximately 10 to 12 cm above the pigeon's head while pecking. The different click-rates were produced by running 28 V dc through the ABA terminals of a Grason-Stadler Electronic Timer (Model E5350A) in series with the speaker.

The frequencies of the 10 generalization stimuli were 1.35, 1.95, 2.45, 3.50, 5.50, 7.70, 9.20, 11.45, 13.10, and 15.25 cps. The loudness values of the training stimulus, measured by the fast setting of a General Radio sound level meter, model 1551-C, placed at the approximate position of the pigeon's head, was 84 dB SPL. The loudness values of the faster click-rates measured 1-2 dB louder. The ambient noise level, measured when no click-rate was present, was 64 dB SPL.

Procedure

Discrimination training. The subjects were divided into two groups of two each. For both groups a click-rate of 2.45 clicks per second was positive (S+). For Group I, the negative stimulus (S-) was silence; for Group II, the negative stimulus was a click-rate of 11.45 clicks/sec. The positive and negative stimulus trials were randomly alternated, separated by 5-sec periods of darkness in which all lights were extinguished. The duration of the trials was 15 sec for Sessions 1 to 10 and 20 sec for all subsequent sessions. The reinforcement schedule during S+ trials was continuous reinforcement for Sessions 1 to 10, a variable-interval 20 sec for Sessions 11 to 20 (VI 20-sec), and a VI 30-sec for all subsequent sessions (21 to 60 for Subjects 7, 8, and 462, and 21 to 72 for Subject 467). Responses during S- trials had no scheduled consequences throughout the experiment. Each session was terminated after 120 trials, except for Sessions 1 to 10, which terminated after 50 reinforcements had been obtained.

Generalization testing. Generalization sessions began with a warm-up period of 10 min in which the discrimination contingencies were in effect, followed by the generalization test conducted during extinction. The generalization click-rates were presented in 10 blocks of 10 stimuli each. Each stimulus trial continued for 20 sec, followed by a 5-sec blackout. The order of the stimuli within blocks was random, with each block having a different order. Group II subjects received a single generalization test; Group I subjects received two tests. For the latter, 10 sessions of discrimination training were given between the two tests. The tests differed in that test 1 presented only click-rates, whereas test 2 presented click-rates interspersed with periods of silence (five presentations of each of the 10 click-rates and 50 periods of silence).

RESULTS

Discrimination Acquisition

Subjects 8, 462, and 7 received a total of 60 discrimination sessions; Subject 467 received 72 sessions. The additional training for 467 was given because its discrimination performance was still improving after 60 sessions. Its generalization test was given after no improvement in discrimination had occurred for 10 ses-

sions. The percentage correct for all responses in the last two sessions before generalization testing was 92.2 and 89.7 for Subjects 8 and 462, which were trained on the presence/absence discrimination, and 91.0 and 82.2 for Subjects 7 and 467, which were trained on the discrimination between two click-rates.

Generalization

The results for all subjects are shown in Figure 1. Subjects in the upper panel were trained to discriminate a slow click-rate from periods

of silence; those in the lower panel were trained to discriminate the same slow click-rate from a faster click-rate. The latter subjects produced the steepened gradients typically found after intradimensional discrimination, but the former subjects gave no evidence of a gradient steepened around S+. It should be noted that these subjects were discriminating accurately both before and after the generalization test (around 90% correct).

A possible interpretation of the failure of a steepened gradient to occur after presence/

Fig. 1. Generalization responses to different click-rates. Subjects in the upper panel were trained to discriminate a slow click-rate from its absence; subjects in the lower panel were trained to discriminate slow *versus* fast click-rates. The click-rates used (ordinal values 1 to 10) were 1.35, 1.95, 2.45 (S+), 3.50, 5.50, 7.70, 9.20, 11.45 (S-), 13.10, and 15.25 cps

absence discrimination is the change that occurred between discrimination and generalization testing. Whereas 50% of all stimulus periods during discrimination training were periods of silence, all stimulus periods during the first generalization test were different click-rates. This change in the distribution of stimulus periods perhaps disrupted the discrimination. To test this possibility, a second generalization test was given, using the same click-rates as in test 1, but now with interspersed periods of silence. The results are shown in Figure 1 as test 2. Except for the elimination of a response bias during the faster rates for Subject 462, the introduction of the silence periods did not change the gradients in any significant respect. In addition, clear stimulus control continued throughout the generalization test in that virtually no responding occurred during the periods of silence.

DISCUSSION

The major finding in the present experiment was the failure of presence/absence discrimination training to produce a steepened generalization gradient to click-rate. In contrast, a discrimination between two click-rates produced the steepened gradients typically found after discrimination training. The present results contrast sharply with the results of Jenkins and Harrison (1960), who found steepened gradients to tone frequency with pigeons after presence/absence discrimination involving a 1000-cps tone. Although procedural differences should not be discounted completely, the experiments appear generally similar except for the difference in stimulus dimension. An apparent conclusion, therefore, is that different stimulus dimensions require different discrimination conditions for stimulus control to occur.

One approach to understanding the relations between stimulus dimension and the conditions necessary for stimulus control is the recent learning model of Rescorla and Wagner (1972), which was inspired by earlier work on the blocking effect (Kamin, 1968, 1969). Simply described, their model states that the amount learned about a stimulus on an exposure to reinforcement contingencies is a function of the difference between the asymptotic strength possible and the *sum* of the existing response

strengths to *all* of the stimuli in the situation. To the extent one stimulus has acquired a response strength equal to the asymptotic strength, other stimuli will not gain response strength, regardless of their number of pairings with reinforcement.

The relevance of the Rescorla-Wagner model to the general problem of stimulus control can be seen by considering its treatment of presence/absence discrimination in establishing stimulus control. The model predicts that such discrimination training will be necessary for some stimulus dimensions but that nondifferential reinforcement will be sufficient for other dimensions. The crucial difference is the rate of conditioning for the relevant cue varied by the experimenter *relative to* the rates of conditioning to situational cues. Since by definition all cues in a nondifferential reinforcement situation are equally paired with reinforcement, if any situational cues are conditioned significantly faster than the relevant cut, control by the relevant cut should be blocked.

The failure of Jenkins and Harrison (1960) to produce stimulus control by tone frequency with nondifferential reinforcement provides a good illustration. One of the situational cues present in their procedure was the keylight at which the pigeons pecked. Since brightness is almost certainly conditioned faster than tone frequency, response strength to brightness should quickly approach the asymptotic strength possible, and thus block the occurrence of control by tone frequency. Van Houten and Rudolph (1972) produced strong evidence that such blocking did indeed occur. The apparent reason, therefore, that Jenkins and Harrison found stimulus control after presence/absence discrimination, but not after nondifferential reinforcement, was that discrimination training neutralized the situational cue of "bright keylight", which otherwise blocked stimulus control by tone frequency.

To account for the present results where even presence/absence discrimination failed to produce control by click-rate, an additional source for blocking must be considered. Not only are there situational cues in addition to the relevant cue varied by the experimenter, but also there are cues that are necessarily correlated with the relevant cue. For example, the 1000-cps tone used by Jenkins and Harrison necessarily possessed loudness as well as pitch.

Since both cues were equally associated with reinforcement, both should tend to gain response strength. Further, to the extent that one of the cues was conditioned significantly faster than the other, blocking of stimulus control by the second cue should occur. Since Jenkins and Harrison found stimulus control to tone frequency, it must be assumed that little if any blocking due to loudness occurred. For the present experiment, however, where no control by click-rate occurred after presence/absence discrimination, such blocking is a plausible explanation. Presumably, the click-rate used as S+ had at least one attribute other than frequency (probably loudness) that was conditioned significantly faster than frequency, thus causing control by frequency to be blocked. The reason that stimulus control resulted from a discrimination between two different click-rates was that this correlated attribute was neutralized because it was present during periods of nonreinforcement, just as general situational cues are neutralized during presence/absence discrimination.

The fact that different stimulus dimensions require different discrimination conditions for stimulus control can of course be handled by models other than Rescorla and Wagner's. An alternative model, for example, is Sutherland and Macintosh's (1971) selective attention theory. Regardless of the relative merits of particular models, however, one fundamental issue should be emphasized. To understand the training conditions that will produce stimulus control, it is necessary to consider not only which stimulus is designated S+, but also what irrelevant stimuli are present that may compete for control. Only by comparing the *relative* salencies of the possible controlling stimuli will any general account of the principles of stimulus control be possible.

REFERENCES

- Guttman, N. and Kalish, H. I. Discriminability and stimulus generalization. *Journal of Experimental Psychology*, 1956, **51**, 79-88.
- Hearst, E. Simultaneous generalization gradients for appetitive and aversive behavior. *Science*, 1960, **132**, 1769-1770.
- Hearst, E. Concurrent generalization gradients for food-controlled and shock-controlled behavior. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 19-31.
- Heinemann, E. G. and Rudolph, R. L. The effect of discriminative training on the gradient of stimulus generalization. *American Journal of Psychology*, 1963, **76**, 653-658.
- Hull, C. L. The problem of primary stimulus generalization. *Psychological Review*, 1947, **54**, 120-134.
- Jenkins, H. and Harrison, R. H. Effect of discrimination training on auditory generalization. *Journal of Experimental Psychology*, 1960, **59**, 246-253.
- Kamin, L. J. "Attention-like" processes in classical conditioning. In M. R. Jones (Ed.), *Miami symposium on the prediction of behavior: aversive stimulation*. Miami: University of Miami Press, 1968. Pp. 9-31.
- Kamin, L. J. Predictability, surprise, attention and conditioning. In R. Church and B. Campbell (Eds.), *Punishment and aversive behavior*. New York: Appleton-Century-Crofts, 1969. Pp. 279-296.
- Lashley, K. S. and Wade, M. The Pavlovian theory of generalization. *Psychological Review*, 1946, **53**, 72-87.
- Rescorla, R. A. and Wagner, A. R. A theory of Pavlovian conditioning: variations in the effectiveness of reinforcement and nonreinforcement. In A. Black and W. F. Prokasy (Eds.), *Classical conditioning II*. New York: Appleton-Century-Crofts, 1972. Pp. 64-99.
- Spence, K. W. The nature of discrimination learning in animals. *Psychological Review*, 1936, **43**, 427-449.
- Sutherland, N. S. and Mackintosh, N. J. *Mechanisms of animal discrimination learning*. New York: Academic Press, 1971.
- 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.
- Van Houton, R. and Rudolph, R. The development of stimulus control with and without a lighted key. *Journal of the Experimental Analysis of Behavior*, 1972, **18**, 217-222.

Received 9 November 1972.

(Final Acceptance 28 February 1973.)