ACQUISITION AND MAINTENANCE OF AUTOSHAPED KEY PECKING AS A FUNCTION OF FOOD STIMULUS AND KEY STIMULUS SIMILARITY

G. D. STEINHAUER

CALIFORNIA STATE UNIVERSITY, FRESNO

The results of a number of recent studies suggest that acquisition of autoshaped key pecking in pigeons is affected by the similarity of the grain-hopper stimulus and response-key stimulus. In Experiment 1 this hypothesis was tested by training independent groups of pigeons to key peck under six different hopper-stimulus and key-stimulus similarity conditions, and three procedures containing either immediate reinforcement, variable delay of reinforcement, or omission of reinforcement for key pecking. Number of trials to acquisition was found to be related to the similarity variable. Maintained responding was affected by the response-reinforcer contingency. This effect was found both within and between subjects. Under two of the contingencies (automaintenance and omission), maintained responding continued to be affected by the similarity of the hopper stimulus and key stimulus. In Experiment 2 pigeons were given omission training with a hopper light on or off. Both acquisition and maintenance of key pecking were facilitated by the presence of the hopper light. The present findings suggest that much of the responding reported in various automatic shaping and training procedures may reflect the effects of key stimulus/food stimulus similarity.

Key words: autoshaping, transfer, generalization, acquisition, key pecking, pigeons

Acquisition of the autoshaped key-peck response in pigeons can be facilitated or retarded by the specific conditions of training to eat from the grain hopper. Downing and Neuringer (1976), and Steinhauer, Davol, and Lee (1976) have reported that as the amount of grain-hopper training increases, acquisition of autoshaped responding is facilitated. This relationship obtains only up to some optimal amount of grain-hopper training, with subsequent training retarding acquisition (Downing & Neuringer, 1976). The similarity of stimuli that occur concurrently with grain-hopper presentation and the stimulus that is presented on the key prior to grain presentation (which is also the stimulus to which autoshaped responding is directed) also affects response acquisition. Experiments by Ettinger, Finch, and McSweeney (1978, Experiment 2), and by Sperling, Perkins, and Duncan (1977, Experiment 4) found that initial key pecks were directed towards a key stimulus similar in hue to the grain stimulus rather than to a stimulus dissimilar in hue but a better predictor of

food. Davol, Steinhauer, and Lee (1977, Experiment 4), and Fisher and Catania (1977) reported that when the grain-hopper light is green, for example, and autoshaping consists of concurrent presentation of red and green key, followed by grain, the initial responses will occur on the green key. Davol et al. (1977, Experiment 1, Condition 1) and Ettinger et al. (1978, Experiment 1) have reported that acquisition is retarded, or does not occur at all, when the grain hopper is not illuminated. Although these recent data suggest that grain-hopper stimuli contribute to acquisition of autoshaped key pecking, three reviews of the literature (Hearst & Jenkins, 1974; Lajoie & Bindra, 1976; and Schwartz & Gamzu, 1977) conclude that the autoshaped pigeon key-peck response is acquired as a result of the key stimulus-grain contingency.

There are at least two ways that key stimulus and grain stimulus similarity may facilitate response acquisition in autoshaping. Rescorla and Furrow (1977) and Rescorla and Gillan (1980) have demonstrated that CS1 and CS2 similarity facilitates acquisition of second-order key pecking in pigeons. If we think of the key stimulus as CS2, the grain-hopper stimulus as CS1, and the grain as the US in a typical autoshaping preparation, then acquisition of

This paper is based, in part, on a dissertation submitted by the author to the Graduate Faculty of the University of Montana. Send requests for reprints to G. D. Steinhauer at Department of Psychology, California State University, Fresno, California 93740.

key pecking would be facilitated by CS1-CS2 similarity. In such an analysis grain-hopper training would be important because it involves respondent conditioning of pecking to the hopper stimulus. Alternatively, Logan (1971) has suggested a response transfer via generalization account of autoshaping. According to this account "generalization from pecking into the lighted hopper could induce pecking at a lighted key which then, being followed by a reward, continues as a kind of superstition" (Logan, 1971, p. 51). The following experiments were conducted to test predictions from this transfer via generalization and operant reinforcement account of various autoshaping phenomena.

EXPERIMENT 1

In this experiment pigeons were studied in 18 conditions defined by six levels of hopper-stimulus and key-stimulus similarity factorially combined with three response-reinforcer contingencies. The procedure was similar to that reported by Steinhauer, Davol, and Lee (1977) using auditory stimuli. Five groups of pigeons were trained with a 1000 Hz grain-hopper tone and key tones of either 450 Hz, 650 Hz, 1000 Hz, 1500 Hz, or 2200 Hz. A sixth group was trained with no grain-hopper tone and a 1000-Hz key tone. Within each of these six conditions, pigeons were trained with one of three response-reinforcer contingencies. Following magazine training all subjects were placed in training sessions containing 8-sec key-stimulus presentations immediately followed by grain. For one third of the subjects key pecks to the key stimulus resulted in offset of the stimulus, followed by grain (response-contingent condition). For a second third, key pecks had no consequence (automaintenance condition). For the remaining third of the pigeons, key pecks during the key stimulus resulted in offset of the stimulus and omission of the next scheduled grain delivery (omission). It was predicted that the number of key stimulus-grain pairings prior to the initial key peck would be related to the hopper stimulus/key stimulus similarity variable. The response-contingent reinforcement group was predicted to yield the highest rate of maintained responding, followed by the automaintenance and omission groups, in that order.

METHOD

Subjects

Fifty-four experimentally naive, male, adult Columba pigeons, obtained from Mogul-Ed, Oshkosh, Wisconsin, were used in this study. All of the pigeons were housed in individual cages, with water and grit freely available throughout the experiment. Each subject was weighed daily, reduced in weight by limiting the grain intake, and then maintained at 78% to 85% of its free-feeding weight throughout the experiment.

Apparatus

The experimental sessions were conducted in a modified operant conditioning chamber. The interior measurements were similar to a Lehigh Valley Electronics Model 1519C operant conditioning chamber (30.4 cm in width, 34.4 cm in length, and 33.8 cm in height). One wall of the chamber contained two rectangular openings 62.5 mm in length and 46.8 mm in height. These two openings were centered on an imaginary line bisecting the intelligence panel into a left and right side. The lower aperture was 75 mm above the floor and allowed the pigeon access to grain when the grain hopper was in the raised position. A 37.5 mm-diameter speaker was mounted inside the grain hopper and no grain-hopper light was present. The second aperture was centered 75 mm from the ceiling of the chamber. A perforated key was mounted on a microswitch behind this opening. A second 37.5 mm speaker was mounted in a sound-attenuating enclosure behind the key. The speaker enclosure was open on the side adjoining the response key so that a key tone could be propagated into the chamber through the key. All tone stimuli were adjusted to a volume of 80 db re 20 μ N, measured at 2.5 cm from the intelligence panel openings. The houselight was on continuously throughout the experiment. Control and recording equipment were located in a nearby room.

Procedure

The first 18 pigeons were trained in the response-contingent procedure, the second in the automaintenance procedure, and the third 18 were given omission training. Within each of these three procedures the pigeons were ran-

domly assigned to one of six hopper-stimulus and key-stimulus similarity conditions. After each bird's weight had been stable for three days at the 80% level, it was given three daily sessions of training to eat from the grain hopper. A daily session consisted of 40 grain-hopper presentations. For 45 pigeons onset and offset of the 1000 Hz, 80-db grain-hopper tone was programmed to occur coincident with presentation and retraction of the grain hopper. For the remaining nine pigeons (those in the no-hopper-tone-1000-Hz key-tone conditions), the hopper tone was not present either during hopper training or the subsequent training procedures. A hopper-training trial consisted of presentation of the grain hopper and holding it in the raised position until the pigeon had been observed by the experimenter to eat for four seconds. The hopper-training trials were scheduled to occur with an average inter-trial interval of 30 seconds (VT 30-sec).

On the day following hopper training, pigeons were placed in either response contingent, automaintenance, or omission training. For the nine birds that received hopper training without the hopper tone, experimental sessions occurred without the hopper tone. For the other 45 pigeons experimental sessions occurred with the onset and offset of the 1000 Hz, 80-db hopper tone coincident with presentation and retraction of the grain hopper. For all birds, the experimental sessions began with presentations of the 8-sec key tone followed by 4-sec presentation of the grain hopper. These trials were programmed to occur on a VT 60-sec schedule. In the response-contingent procedure, key pecks occurring during the 8-sec

key-tone period resulted in immediate offset of the key tone and presentation of the grain hopper. Key pecks in the automaintenance condition did not affect the course of the key tone-hopper presentations. Under the omission training procedure, key pecks during the key-tone period resulted in omission of the next grain-access period. Under all procedures key pecks that occurred during the interval from grain offset to key-stimulus onset were recorded but did not have any programmed consequence. All birds received 10, 60-trial, daily sessions in their respective autotraining procedure.

Two birds initially trained on the 1000-Hz key tone, 1000-Hz hopper tone response-contingent procedure (subjects number S-215 and S-230) were subsequently exposed to the other two procedures. Subject S-215 was given the following sequence: 10 sessions response contingent, five sessions omission training, five sessions response contingent, five sessions automaintenance, and five additional sessions of the response-contingent procedure. Subject S-230 was given a somewhat different sequence as follows: 10 sessions response contingent, five sessions automaintenance, five sessions response contingent, five sessions omission training, and five sessions of the response-contingent procedure.

RESULTS

Initial Responses

The number of key stimulus-grain hopper pairings (trials) prior to the first key peck, and prior to the fifth key peck, for each pigeon, is given in Table 1. A three by six analysis of

Table 1
Trial of the First Key Peck—Trial of the Fifth Key Peck for all Pigeons in Experiment 1

<i>Hopper Tone Key Tone</i>	<i>1000 Hz 450 Hz</i>	<i>1000 Hz 650 Hz</i>	<i>1000 Hz 1000 Hz</i>	<i>1000 Hz 1500 Hz</i>	<i>1000 Hz 2200 Hz</i>	<i>0 1000 Hz</i>	<i>Mean</i>
Response- Contingent	5-8	7-14	6-8	1-2	11-22	82-117	40.89-
	65-72	2-6	2-9	17-23	63-69	61-64	
	1-3	86-89	2-5	62-84	17-31	246-281	50.39
Automaintenance	111-117	40-46	6-21	97-102	159-168	304-326	66.11-
	62-72	2-7	24-29	3-16	21-26	5-34	
	176-179	5-13	4-8	2-11	86-98	83-89	75.61
Omission	38-46	75-83	3-5	5-19	23-39	251-348	75.83-
	84-89	58-62	11-16	68-73	19-22	294-418	
	104-111	62-73	17-18	26-34	156-207	71-92	97.50
Mean 1st peck	71.78	37.44	8.33	31.22	61.67	155.22	
Mean 5th peck	77.33	43.67	13.22	40.44	75.78	196.56

Fig. 1. Mean trial of the first key peck, as a function of key-tone and hopper-tone similarity for all pigeons in Experiment 1.

variance (three levels of autoshaping procedure by six levels of key stimulus-grain stimulus similarity) yielded the following results for trial of the first key peck: The main effect of similarity was statistically significant, $F(5,36) = 5.82, p < .001$; the main effect of procedure was not significant, $F(2,36) = 1.43, p > .25$, and the obtained F for the interaction was less than one. Analysis of the measure trials to the fifth peck led to the same conclusions. Since the three procedures are identical until responding occurs, and the three procedures did not reliably affect the acquisition data, subsequent analysis of key-peck acquisition was done by collapsing over the three autoshaping procedures.

Mean trial of the first key peck for each of

the six similarity groups is shown in Figure 1. Subjects given training with a 1000-Hz key tone and no hopper tone constitute a control group in which there is only minimal similarity of hopper and key stimuli. Comparing each of the five experimental groups with the control group confirmed that trial of the first key peck occurred following fewer trials in each of the five experimental groups (Dunnett's Test, $\alpha = .05$). According to the response transfer via generalization account of autoshaping (or the second-order conditioning via similarity account) when the groups are ordered as they are on the abscissa in Figure 1, the relationship between trial of the first key peck and the similarity variable should be a U-shaped function. Figure 1 shows a U-shaped function. An analysis of trend using the method of orthogonal polynomials (Keppel, 1973) was conducted on trial of the first key peck. Only the quadratic component was statistically significant, $F(1,40) = 11.66, p < .01$. This analysis confirms the shape of the functional relationship.

Maintained Responding

Total key pecks (fewer than 10% of all pecks were ITI pecks) in the tenth 60-trial session are shown as a function of key-tone and hopper-tone similarity for birds in each of the three procedures in Figure 2. Data for individual subjects and group means are given in Table 2. One of the striking features of these data is the substantially lower rates of respond-

Table 2
Total Responses in Session 10 for all Pigeons in Experiment 1

Hopper Tone	1000 Hz	1000 Hz	1000 Hz	1000 Hz	1000 Hz	0	
Key Tone	450 Hz	650 Hz	1000 Hz	1500 Hz	2200 Hz	1000 Hz	Means
Response-Contingent	61	57	68	63	56	49	
	58	61	84	54	63	(859)	
	62	46	92	42	86	52	61.36
Means	60.33	54.67	81.33	53.00	68.33	50.50	
Automaintenance	4	12	23	4	7	21	
	20	47	117	47	3	4	
	6	11	22	14	0	0	20.11
Means	10.00	23.33	54.00	21.67	3.33	8.33	
Omission	4	46	42	21	7	0	
	1	18	47	11	6	2	
	3	16	41	31	0	2	16.56
Means	2.67	26.67	43.33	21.00	4.33	1.33

Fig. 2. Mean total key-peck responses in the tenth 60-trial session, as a function of key-tone and hopper-tone similarity, for all pigeons in Experiment 1. The top portion shows total key pecks for birds given omission training, the middle portion birds given automaintenance training, and the bottom portion birds given autoshaping (response-contingent reinforcement).

ing than are obtained using lighted grain hoppers and lighted keys. No information on why auditory stimuli would engender fewer responses than visual stimuli is presently available. All analyses of maintained response rate omit Subject S-229 in the 1000-Hz key tone and no hopper tone, response-contingent condi-

tion. That pigeon made 859 key pecks in Session 10. That value was 7.42 standard deviations above the mean number of key pecks in Session 10 for all 54 birds. That subject was not included in any of the data analyses for responses in Session 10 because it was found to be an outlier (Edwards, 1960).

An overall analysis of variance on the dependent measure total responses in Session 10 yielded a significant main effect of response-reinforcer contingency, $F(2,35) = 37.18$, $p < .001$, and a significant main effect of key-tone and hopper-tone similarity, $F(5,35) = 6.10$, $p < .001$. The interaction was not statistically significant. Further analysis of the main effect of the differences between the three response-reinforcer procedures was by Scheffe's tests for comparisons among means. Both the automaintenance and omission procedures produced significantly lower rates of responding than the response-contingent procedures ($\alpha = .05$), but they did not differ from one another. Analysis of the main effect of key-tone and hopper-tone similarity was by tests of significance on trend components within each of the three response-reinforcer contingency procedures. To the extent that the similarity variable continues to affect response rate, the analysis of trend should show a significant quadratic component when the levels of that variable are ordered as they are on the abscissa of Figure 2. Both the automaintenance and omission procedures showed a significant quadratic component, $F(1,3) = 6.74$, $p < .05$, and $F(1,3) = 8.59$, $p < .001$. No other trend components approached significance either in those two procedures or in the response contingent procedure. This result suggests that the similarity of the key stimulus and hopper stimulus affects not only acquisition, but also response rates after 10 sessions of automaintenance and omission training.

Data for Subjects S-215 and S-230 appear in Figures 3 and 4 respectively. For both of these pigeons, responding under the omission procedure declined to near zero within three sessions. Responding during automaintenance sessions occurred at a rate intermediate to response rates in the response-contingent and omission procedures. Although it is apparent that the stability of response rates established in just five sessions can be questioned, it does appear that these within-subjects data are in agreement with those for the independent

Fig. 3. Total responses per session for Pigeon S-215. Sessions 6 to 10 were response-contingent reinforcement, 11 to 15 omission training, 16 to 20 response-contingent reinforcement, 21 to 25 automaintenance, and Sessions 26 to 30 response-contingent reinforcement.

groups of pigeons trained under the three different reinforcement contingencies.

EXPERIMENT 2

In Experiment 1 pigeons in the no-hopper tone, 1000-Hz key-tone condition began pecking the key in an average of 155.22 trials. In this condition the similarity of the hopper and key stimuli is minimal. These findings can be contrasted with a similar study by Davol, Steinhauer, and Lee (1977, Experiment I, Condition I) in which there was no hopper stimulus and the key stimulus was a light. In this condition only one of five pigeons pecked the key in 200 trials. Ettinger et al. (1978) reported similar results. The discrepancy between the results of

Experiment 1 and the results of these previous studies could reflect some difference due to the use of auditory or visual cues, the different amounts of preliminary grain-hopper training used in the two studies, or simply that the pigeons in the previous studies were not given sufficient training. The following experiment examined further whether or not key pecking would be acquired when the similarity variable is at a minimum. It also examined the contribution of the similarity variable to maintained response rates in an omission procedure.

METHOD

Subjects

Six experimentally naive, adult, male *Columba* pigeons, obtained from Mogul-Ed, were housed and maintained as in Experiment 1.

Apparatus

This experiment was conducted in a standard, three-key, operant conditioning chamber, manufactured by Lehigh Valley Electronics (Model #1519C). Only the center key was used. White noise in the experimental room and the ventilation fan in the experimental chamber masked extraneous sounds. The control and recording equipment was in an adjoining room. The houselight in the chamber was on at all times during the experiment.

Procedure

On Day 1, a pigeon was placed in the chamber with the grain hopper raised. After the pigeon had eaten for 20 sec, the hopper was lowered. For the remainder of Session 1, the hopper was presented 39 times on a VT 30-sec schedule. Each time the hopper was raised, it remained in the raised position until the pigeon had been observed to eat for four seconds. On Day 2 the pigeons were placed in the chamber with an autoshaping plus omission contingency in effect. Presentations of the eight-second keylight illumination, followed by four seconds of grain access, occurred on a VT 60-sec schedule. Until the pigeon pecked the illuminated key, this procedure is a conventional autoshaping procedure. When the pigeon pecked the illuminated key the delivery of reinforcement was precluded. Throughout this experiment the hopper light was never on for three of the pigeons (SG-10, SG-11, and SG-12). For Pigeons SG-7, SG-8, and SG-9, during magazine training, and the first 15 training ses-

Fig. 4. Total responses per session for Pigeon S-230. Sessions 6 to 10 were response-contingent reinforcement, 11 to 15 automaintenance, 16 to 20 response-contingent reinforcement, 21 to 25 omission training, and Sessions 26 to 30 response-contingent reinforcement.

sions, the hopper light was on when the grain hopper was in the raised position. Sixty presentations of the keylight and grain were scheduled each day for 15 days. Subject SG-8 was shifted from hopper light on to hopper light off for five additional sessions. This procedure allows a comparison of both number of trials prior to the first key peck and maintained rates of responding during an omission procedure, when the similarity of the hopper and key stimuli is large and small.

RESULTS

Trial of the first key peck and total responses per session (including intertrial interval responses) are given for each pigeon in Table 3. The mean trial of the first key peck was 24.67 for the three pigeons in the lighted-hopper condition and 241.67 for the three pigeons in the unlighted-hopper condition. This difference is statistically significant, $t(4) = 2.90$, $p < .05$. Pigeons in the hopper-light-on condition made an average of 29.22 responses per session, whereas pigeons in the no-hopper-light condition made an average of 3.51 responses per session. Figure 5 shows total responses per session as a function of consecutive 60-trial sessions for Pigeons SG-8. From Sessions 8 to 15, all with the hopper light on, this pigeon made over 60 key pecks per session.

Table 3

Trial of the first key peck and total responses per session for pigeons in Experiment 2.

	<i>Hopper light ON</i>			<i>Hopper light OFF</i>		
	<i>SG 7</i>	<i>SG 8</i>	<i>SG 9</i>	<i>SG 10</i>	<i>SG 11</i>	<i>SG 12</i>
<i>Trial of first peck</i>	14	15	45	97	286	342
<i>Session Number</i>	<i>Total Responses Per Session</i>					
1	30	30	6	0	0	0
2	20	42	17	21	0	0
3	16	24	0	24	0	0
4	23	28	0	4	0	0
5	40	57	0	8	2	0
6	33	62	0	3	0	1
7	18	74	0	1	0	19
8	22	113	1	0	0	10
9	10	116	2	0	0	4
10	1	71	3	6	0	22
11	4	98	0	4	0	1
12	7	61	0	3	0	10
13	5	89	1	4	0	6
14	3	76	0	3	0	0
15	4	106	2	0	0	2

Fig. 5. Total key-peck responses per session for Pigeon SG 8 in Experiment 2. Sessions 1 to 15 were conducted with the hopper light on and Sessions 16 to 20 with the hopper light off.

When shifted to the unlighted hopper on the 16th session, responding began to decline and this pigeon made only 15 key pecks in Session 17, one key peck in Session 18, six in Session 19, and zero key pecks in Session 20.

GENERAL DISCUSSION

Response Acquisition

The results of Experiments 1 and 2 indicate that the more similar the grain-hopper stimulus and key stimulus the fewer presentations of the key stimulus and grain that are required before key pecking is engendered. The shape of the function relating the similarity variable to the trial of the first key peck is of the same form that would be predicted from previous studies of auditory generalization in pigeons. The data obtained in Experiment I provide more direct evidence for the role of stimulus similarity in facilitating key-peck acquisition than previous studies. Although these data provide substantial additional support for the transfer via generalization account of auto-shaping, they do very little to refute alternative accounts.

Existing theoretical accounts of autoshaping (Hearst & Jenkins, 1974; Lajoie & Bindra, 1976; Schwartz & Gamzu, 1977) emphasize the temporal relationship between key stimulus and grain as the variable that is responsible for key-peck acquisition. A large amount of data shows that key-peck acquisition is facilitated when the key stimulus is a good predictor of food (Bilbrey & Winokur, 1973; Gamzu & Williams, 1971, 1973; Wasserman, Franklin, & Heart, 1974). The present data are consistent

with these respondent conditioning accounts if they incorporate Rescorla and Furrow's (1977) suggestion that CS2 and CS1 similarity is an important determiner of response acquisition in a second-order conditioning analysis of autoshaping. Experiments reported by Ettinger et al. (1978) and Sperling et al. (1977), however, indicate that key pecking is more likely to be directed at a key stimulus that is similar to a hopper stimulus than to a key stimulus that is a better predictor of food. These findings suggest that the similarity variable may indicate a different mechanism than simple facilitation of respondent conditioning.

The present data show that although pigeons do acquire the key-peck response when the conditions of similarity are minimized, the speed of acquisition is substantially retarded relative to conditions that maximize similarity. These findings are interpretable in a number of different ways. First of all, they may represent the facilitating effect of CS2-CS1 similarity in a second-order conditioning process. Secondly, even in these conditions there is some similarity of the key stimuli and hopper stimuli. The key and hopper are both recessed with respect to the chamber wall. They both share the property of sudden and irregular onset and their offset is a stimulus change. Perhaps one of these shared characteristics provides sufficient similarity of the hopper and key to facilitate transfer via generalization. A third possibility concerns the effects of periodic grain presentation on the behavior of a hungry pigeon. Periodic grain presentation is an intrinsic part of the autoshaping procedure. Killeen (1975) presented and reviewed data showing that a hungry pigeon has an increased probability of emitting behavior appropriate to food (addressing the beak at environmental objects is clearly appropriate to food for hungry pigeons) when receiving grain on a temporal schedule. Staddon and Simmelhag (1971) found that pigeons placed on a variable-interval schedule of response-independent grain presentation showed a dramatic increase in frequency of orienting toward the wall on which the key and hopper are mounted and directing beak movements toward that same wall. The relevant suggestion from these studies is that grain presentation alone may function to increase the probability of pecking and the key stimulus only serves in some unknown way to direct

or localize that behavior. All three of these possibilities need to be examined.

Maintained Responding

Experiment 1 found that the response-contingent grain procedure produced overall response rates that were higher than those produced by automaintenance, which were in turn higher than those produced by the omission procedure. The response rates of the two pigeons who were successively placed under the three response-reinforcer contingencies (S-215 and S-230) also show that key pecking is sensitive to the different response-reinforcer contingencies present in each of the three procedures. These findings are in essential agreement with the conclusions of Schwartz and Gamzu (1977): "The maintenance of responding in autoshaping procedures is partly determined by operant response-reinforcer contingencies" (p. 91).

The low rates of responding in the negative response-reinforcer contingency group (omission) and the variable-delay-of-reinforcement group (automaintenance) continue to reflect the similarity of the hopper stimulus and the key stimulus: The more similar the two stimuli, the higher the response rates. The data from Experiment 2 suggest that hopper stimulus and key stimulus similarity might be the only variable that maintains responding in the omission procedure. After 15 sessions of Experiment 2, pigeons in the lighted-hopper condition continued to peck at approximately the same level they had responded early in training, whereas pigeons in the unlighted-hopper condition pecked only very rarely. When Pigeon SG-8 was shifted from a hopper-light-on procedure to a hopper-light-off condition in omission training, the response rate dropped to near zero and remained there.

Data from omission procedures are, of course, a major source of support for the respondent account of autoshaping. Careful examination of the literature reporting responding in omission procedures reveals that the effect is not as strong as might be expected from a respondent analysis. Williams and Williams' (1969) initial study of pigeon key-peck responding in an omission procedure reported high rates of responding for pigeons which had considerable prior key-peck training, with a lighted grain-hopper presentation as the reinforcer. One, of only two naive pigeons used in

their study, responded on only a few trials per session after two 50-trial sessions. Griffin and Rashotte (1973) reported very low rates of key pecking for pigeons placed in an omission procedure when the chamber was well illuminated. Powell and Kelly (1976) shaped pigeons to key peck using contingent reinforcement and then placed them in an omission procedure. Responding in the omission procedure declined quite rapidly. Even when the key stimulus and grain stimulus are similar, it appears that the negative operant contingency present in the omission procedure acts to suppress responding.

The effect of the grain stimulus/key stimulus similarity variable on maintained response rate is a new finding. Whether this result represents an effect of stimulus similarity in higher order conditioning (via a continual operant-respondent interaction), a simple response transfer via generalization process, or some other as yet unknown process is in need of further research. Since we typically use a lighted grain hopper and a lighted key in the study of maintained key pecking in a wide variety of procedures (interval schedules, ratio schedules, chained schedules, multiple schedules, etc.), the contribution of the similarity variable to maintained response rate is in need of careful study.

REFERENCES

- Bilbrey, J., & Winokur, S. Controls for and constraints on auto-shaping. *Journal of the Experimental Analysis of Behavior*, 1973, **20**, 323-332.
- Davol, G. H., Steinhauer, G. D., & Lee, A. The role of preliminary magazine training in acquisition of the autoshaped key peck. *Journal of the Experimental Analysis of Behavior*, 1977, **28**, 99-106.
- Downing, K., & Neuringer, A. Autoshaping as a function of prior food presentations. *Journal of the Experimental Analysis of Behavior*, 1976, **26**, 463-469.
- Edwards, A. L. *Experimental design in psychological research* (Rev. ed.). New York: Holt, Rinehart, and Winston, 1960.
- Ettinger, R. H., Finch, M. D., & McSweeney, F. K. The role of generalization in the acquisition of auto-shaped keypecking in pigeons. *Bulletin of the Psychonomic Society*, 1978, **12**, 235-238.
- Fisher, M. A., & Catania, A. C. Autoshaping: Relation of feeder color to choice of key color. *Bulletin of the Psychonomic Society*, 1977, **9**, 439-442.
- Gamzu, E., & Williams, D. R. Classical conditioning of a complex skeletal response. *Science*, 1971, **171**, 923-925.
- Gamzu, E. R., & Williams, D. R. Associative factors underlying the pigeon's key pecking in auto-shaping procedures. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 225-232.
- Griffin, R. W., & Rashotte, M. E. A note on the negative automaintenance procedure. *Bulletin of the Psychonomic Society*, 1973, **2**, 402-404.
- Hearst, E., & Jenkins, H. M. *Sign-tracking: The stimulus-reinforcer relation and directed action*. Austin, Tex.: The Psychonomic Society, 1974.
- Keppel, G. *Design and analysis: A researcher's handbook*. Englewood Cliffs, N. J., Prentice-Hall, 1973.
- Killeen, P. On the temporal control of behavior. *Psychological Review*, 1975, **82**, 89-115.
- Lajoie, J., & Bindra, D. An interpretation of autoshaping and related phenomena in terms of stimulus-incentive contingencies alone. *Canadian Journal of Psychology*, 1976, **30**, 157-173.
- Logan, F. A. Incentive theory, reinforcement and education. In R. Glaser (Ed.), *The nature of reinforcement*. New York: Academic Press, 1971.
- Powell, R. W., & Kelly, W. Responding under positive and negative response contingencies in pigeons and crows. *Journal of the Experimental Analysis of Behavior*, 1976, **25**, 219-225.
- Rescorla, R. A., & Furrow, D. R. Stimulus similarity as a determinant of Pavlovian conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, 1977, **3**, 203-215.
- Rescorla, R. A., & Gillan, D. J. An analysis of the facilitative effect of similarity on second-order conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, 1980, **6**, 339-351.
- Schwartz, B., & Gamzu, E. Pavlovian control of operant behavior. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N. J.: Prentice-Hall, 1977.
- Sperling, S. E., Perkins, M. E., & Duncan, H. J. Stimulus generalization from feeder to response key in the acquisition of autoshaped pecking. *Journal of the Experimental Analysis of Behavior*, 1977, **27**, 469-478.
- Staddon, J. E. R., & Simmelhag, V. L. The "superstition" experiment: A reexamination of its implications for the principles of adaptive behavior. *Psychological Review*, 1971, **78**, 3-43.
- Steinhauer, G. D., Davol, G. H., & Lee, A. Acquisition of the autoshaped key peck as a function of amount of preliminary magazine training. *Journal of the Experimental Analysis of Behavior*, 1976, **25**, 355-359.
- Steinhauer, G. D., Davol, G. H., & Lee, A. A procedure for autoshaping the pigeon's key peck to an auditory stimulus. *Journal of the Experimental Analysis of Behavior*, 1977, **28**, 97-98.
- Wasserman, E. A., Franklin, S. R., & Hearst, E. Pavlovian appetitive contingencies and approach versus withdrawal to conditioned stimuli in pigeons. *Journal of Comparative and Physiological Psychology*, 1974, **86**, 616-627.
- Williams, D. R., & Williams, H. Auto-maintenance in the pigeon: Sustained pecking despite contingent non-reinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 511-520.

Received October 13, 1981

Final acceptance June 24, 1982