*STIMULUS GENERALIZATION FROM FEEDER TO
RESPONSE KEY IN THE ACQUISITION
OF AUTOSHAPED PECKING*

SALLY E. SPERLING¹, MARK E. PERKINS, AND HEATHER J. DUNCAN

UNIVERSITY OF CALIFORNIA, RIVERSIDE

During autoshaping, a 6-second presentation of one stimulus and a variable time 30-second presentation of a second stimulus alternated in appearance on a pigeon key. Grain always was delivered for 3 seconds at the end of the first stimulus interval. In the first experiment, autoshaped pecking of the stimulus preceding grain delivery began much sooner when that stimulus was a black vertical line on a white background and the other stimulus was green than when the opposite stimulus arrangement was used. Because these two stimuli differed in form, hue, brightness, and similarity in hue and brightness to the illumination of the raised feeder, three subsequent experiments examined whether the differential speed of autoshaping in the two groups was due to a feature-positive, feature-negative effect, a preference for brighter over darker stimuli, a simple preference for white over green, or stimulus generalization from the brightness or hue of the illuminated, raised feeder to the stimulus on the key preceding grain delivery. The data from these experiments showed that the first autoshaped key peck was most likely to be made to the stimulus of the same hue as that illuminating the feeder, regardless of whether that stimulus was positively or negatively associated with grain delivery. At least under some conditions, therefore, stimulus-generalization mediated response transfer of pecking grain in the presence of the hue illuminating the feeder to pecking the key illuminated by a similar hue appears to account for the occurrence of autoshaped key pecking.

Key words: autoshaping, stimulus generalization, response transfer, key peck, pigeons

Brown and Jenkins' (1968) seminal autoshaping experiment used several different pairs of stimuli alternating in appearance on the response key. No difference in the speed of autoshaping was observed when the key was transilluminated with white light preceding grain delivery and was either dark or red-lighted during the intervening interval. Each of these conditions, however, led to faster autoshaping than when the key was dark before grain delivery and white-lighted otherwise.

Although most subsequent autoshaping studies have not been directly concerned with the stimuli presented on the key, there is some evidence that the speed of autoshaping can be affected by the specific stimuli used. Sperling, Perkins, Duncan, and Lewis (1974), *e.g.*, found that autoshaping was about 25 times faster

when a black vertical line on a white background preceded grain delivery and a green light was present, than when the opposite arrangement was used. The stimulus dimension or dimensions associated with this difference could not be identified from this experiment, however, since their two stimuli confounded form (presence *versus* absence of the black vertical line), hue (green *versus* white; for convenience, white, a nonspectral hue, will be referred to here simply as a hue), and brightness (the white stimulus was observably brighter than the green). In addition, although Brown and Jenkins (1968) found no difference in the speed of autoshaping related to the similarity between the stimulus preceding grain delivery and the illumination of the raised feeder, the feeder illumination in Sperling *et al.* (1974) was more similar to the white key stimulus than to the green in both hue and brightness.

Other studies provide some data on the relationship between variations in some of these stimulus dimensions and the speed of autoshaping, but their results are not entirely consistent with each other. Wasserman (1973), *e.g.*,

¹We are grateful to Lewis Harvey, University of Colorado, for the brightness reversal technique used in Experiment III. The experimental work was supported by a University of California intramural grant to the first author. Reprints may be obtained from Sally E. Sperling, Department of Psychology, University of California, Riverside; Riverside, California 92502.

found no evidence for a form-related feature-positive (FP), feature-negative (FN) effect analogous to that observed in response-contingent training (e.g., Jenkins and Sainsbury, 1969, 1970). Wasserman and Anderson (1974) and Wolff and Hearst (1975), on the other hand, observed a FP-FN effect in autoshaping with hues; Ricci (1973) and Perkins, Beavers, Hancock, Hemmendinger, Hemmendinger, and Ricci (1975) did not report any hue-related differences in the speed of autoshaping.

The present experiments systematically examined whether the Sperling *et al.* (1974) data (presented here as Experiment I) can be accounted for by a FP-FN effect, hue or brightness preferences, or generalization of hue or brightness from the illuminated feeder to the stimulus preceding grain delivery. All experiments were conducted in an overlapping series to ensure comparability of the data. They differed only in the stimuli displayed on the key, the brightness of those stimuli, and the hue and brightness of the feeder bulb.

GENERAL PROCEDURE

Subjects

Experimentally naive, Roller pigeons between 3 and 8 yr of age were obtained from a local supplier and maintained at 80% of their free-feeding weights. Water was freely available in individual home cages, and mixed grain was used for all home cage and experimental chamber feedings. Birds received scheduled training only when their weight did not exceed their 80% weight and was no more than 5% below it. The mean free-feeding weights of the birds was 294.03 g, with a standard deviation of 32.71 g.

Apparatus

Two Foringer two-key pigeon chambers with a feeder centered between the two keys were used. Each transparent key was 2.3 cm in diameter, with its center 22 cm above the floor of the chamber. The bottom of the feeder opening was 5.4 cm above the floor of the chamber, and the opening was 4.4 cm high by 5.8 cm wide. The feeder bulb was mounted just above and behind the top of the opening. The perpendicular distance from the top of the feeder to the center of either key was 16.5 cm. Either key could be transilluminated from

Industrial Electronics Engineers (IEE) cells mounted behind the key. The houselight, a 7-W shielded fluorescent bulb, was mounted on the wall opposite the response panel, 32 cm from the floor of the chamber.

Pecks on either key resulted in an auditory click, a ventilating fan provided masking noise, and the electromechanical control and recording equipment were in an adjoining room.

Procedure

Both keys were covered with masking tape during magazine training. Each pigeon was placed in an experimental chamber with the houselight on and the grain hopper filled, raised and lighted. The feeder was lowered after the bird had eaten for approximately 10 sec; 60 feeder operations on a variable-time (VT) 30-sec schedule, with the experimenter controlling the duration of each, then were used progressively to decrease the availability of grain to 3 sec. A few birds that were not approaching the feeder and eating within 3 to 4 sec during the last 20 grain deliveries were given additional training until they met that criterion.

Autoshaping training, with the houselight on, began with the next session. One key was randomly chosen as the response key for each bird, and it was unmasked. The stimulus not followed by grain (S-) and the stimulus followed by grain (S+) alternated in appearance on the key; S- duration was determined by a VT 30-sec tape, and S+ duration was 6 sec. The feeder was raised for 3 sec immediately after each S+ interval. Each autoshaping session was 80 trials long, beginning with an S- interval and ending after the grain delivery that followed the eightieth S+ interval. Training sessions ordinarily occurred every other day.

Stimuli

The response key could be transilluminated from an IEE cell mounted behind it. The stimuli back-projected onto the key in each of the four experiments represented two different points from each of three dimensions: hue, brightness, and the presence or absence of a bisecting vertical black line. Only six of the resulting eight stimuli possibilities, were used. They were a brighter white stimulus with and without a bisecting vertical black line, VW(B) and W(B); a darker white stimulus without a

vertical black line, W(D); a darker green stimulus with and without a vertical black line, VG(D) and G(D), and a brighter green stimulus without the black vertical line, G(B). The W stimulus was an illuminated blank position of the IEE cell; the G stimulus was obtained by illuminating a position of the IEE cell after putting Oxford Filing Supply Co., Inc., Stock No. 22 CW clear green plastic over that position on the IEE stimulus mask.

The hue of the raised grain feeder was white (W) in the first three experiments and made green (G) in the fourth by placing the same clear green plastic as that used for the key stimuli between the bottom of the feeder bulb and the top of the feeder opening. The brightness of the feeder bulb changed with the hue.

The dominant wavelengths of the G(D) and G(B) key stimuli and the G-illuminated feeder are shown in Table 1, along with the luminous flux of all six key stimuli and both feeder hues. Wavelength measurements were made with an Instrumental Specialties Co., Inc. (ISCO) model SR Spectroradiometer. The differences between the dominant wavelengths of the two G-key stimuli and the G-illuminated feeder were within the range of the error of measurement of the instrument (bandwidth of reading = 15 nm; dial reading error = 7 to 10%). The bandwidth of the G stimuli was approximately 475 to 610 nm and was a smooth curve on each side of the dominant wavelength.

The brightnesses of all three stimuli were below the spectroradiometer's range of accurate intensity measurement. These measurements, therefore, were taken with an SEI Photometer through the porthole on the top of the experimental chamber by reflecting the appropriate stimulus onto a mirror placed in the chamber.

The response-key wall, measured perpendicular to the feeder at the level of the key was 68.4 candela per square meter (cd/m^2). The house-light was on during all wavelength and brightness measurements.

The specific stimuli for each experiment are described in the appropriate section below. Unless otherwise indicated, GE No. 1820 bulbs were used in both the IEE cell and the grain feeder.

EXPERIMENT I

The original purpose of this experiment was to examine gradients of excitation around S+ and inhibition around S- after either response-independent or response-contingent training. Those data have been reported elsewhere (Sperling *et al.*, 1974). Only the acquisition data for the autoshaped birds are presented here.

METHOD

Subjects

Nine Rollers were used in this experiment.

Apparatus and Procedure

These were as described above.

Stimuli

Four pigeons were randomly assigned to be autoshaped with VW(B) as S+ and G(D) as S-. The reverse arrangement was used for the other five pigeons. The dominant wavelength of the G(D) stimulus and the luminous flux of both key stimuli and the feeder are given in Table 1. The grain-feeder illumination was W during the 3 sec that it was raised after each S+ presentation and dark otherwise.

Table 1

Dominant wavelengths of the spectral hue stimuli and luminous flux in candela per square meter (cd/m^2) of all stimuli transilluminating the response key and the stimulus used to illuminate the feeder during grain delivery in each experiment. W = white, G = green, V before W or G indicates a superimposed black vertical line, (B) = brighter, (D) = darker.

Experiment	Stimuli Transilluminating the Response Key						Stimulus Used in the Feeder		
	VW(B) cd/m^2	W(B) cd/m^2	W(D) cd/m^2	G(B) cd/m^2	G(D) cd/m^2	VG(D) cd/m^2	W cd/m^2	G cd/m^2	
I	86.1				13.6 550		68.4		
II	86.1	86.1			13.6 550	13.6 550	68.4		
III		86.1	12.2	76.7 560	13.6 550		68.4		
IV		86.1	12.2	76.7 560	13.6 550			16.4	555

RESULTS

As shown in Table 2, median trials to the first autoshaped peck to S+ in the VW(B)+, G(D)- condition was 4.5, compared to a median of 113 trials for the birds in the G(D)+, VW(B)- condition. Since there was no overlap between the two distributions, the difference between the two groups in the speed of autoshaping can be assumed to be reliable.

Table 2 also shows the trial on which the first peck was made to the S- stimulus in each condition. None of the VW(B)+, G(D)- birds pecked S- before their first peck to S+; in the reverse condition, two birds pecked S- once before the first peck was made to S+.

DISCUSSION

A reliable and large difference in trials to the first autoshaped key peck was observed as a function of which of the two stimuli appeared as S+ and which as S- during training. Since these data did not permit identification of the aspect or aspects of the stimuli that accounted for this difference, the experiments reported below explored the extent to which differences between the two stimuli in form, hue, brightness, and similarity to the hue and brightness of the feeder affected the differential speed of autoshaping observed here.

EXPERIMENT II

Control over responding by S+ in response-contingent discrimination training is acquired more rapidly if the S+ stimulus contains both common elements and a distinctive feature and the S- stimulus contains only common elements than if the reverse arrangement is used (e.g., Jenkins and Sainsbury, 1969). Wasserman's (1973) previously cited data suggest that the speed of autoshaping is not affected by whether a distinctive feature appears with S+ or with S-. The only two birds in Experiment I that pecked S- before pecking S+, however, were in the condition where the black vertical line appeared with S-, and this suggests that a distinctive feature may be responded to during autoshaping. Experiment II, therefore, directly tested whether the presence of a black vertical line with S+ or with S- affected the speed of autoshaping.

METHOD

Subjects

Twenty-one Rollers were used. One was discarded from the VG(D)+, G(D)- condition for failure to autoshape in 1000 trials.

Apparatus and Procedure

These were described above.

Stimuli

Three different pairs of stimuli, with their positive and negative values counterbalanced within each pair, were used in autoshaping six groups of pigeons. One pair consisted of the same W(B) and G(D) stimuli used in Experiment I with the black vertical line omitted. The two stimuli in each of the other two pairs were of the same hue and brightness, but one of them contained the black vertical line. The dominant wavelengths of the G stimuli and the brightnesses of all of the stimuli are shown in Table 1.

Eight birds were autoshaped with W(B), G(D) stimuli; three with W(B)+ and G(D)-, and five with the reverse arrangement. Six birds were autoshaped with VW(B), W(B) stimuli; three in each of the two stimulus conditions. Six birds were autoshaped with a VG(D), G(D) stimulus pair, three with VG(D)+ and G(D)-, and three with the reverse arrangement. The grain-feeder illumination was W for all groups during each 3-sec food-delivery period.

RESULTS

The trial number of the first peck to S+ and to S- is shown in Table 2 for each of the birds in each of the six groups. The W(B), G(D) stimulus pair in this experiment differed from the VW(B), G(D) stimulus pair in Experiment I only in the omission of the black vertical line from the W(B) stimulus. This difference did not appear to affect the autoshaping data. As in Experiment I, all birds with W(B) as S+ and G(D) as S- autoshaped before any birds in the opposite condition, and median trials to the first autoshaped peck to S+ was similar for the comparable groups in the two experiments (5.0 and 4.5, respectively, for the W(B)+, G(D)- group in this experiment and the VW(B)+, G(D)- group in Experiment I, and 83 and 113, respectively, $U = 9$; $p = 0.27$, for the G(D)+, W(B)- group used in this experiment and the

Table 2
Trial number of first peck to S+ and to S- for individual birds in each training condition and median number of trials for each condition. W = white, G = green, V before W or G indicates a superimposed black vertical line, (B) = brighter, (D) = darker.

Trial Number of First Autoshapec Peck											
Stimulus Pair	W Feeder Illumination						G Feeder Illumination				
	W+, G-			G+, W-			W+, G-			G+, W-	
	Pigeon	S+	S-	Pigeon	S+	S-	Pigeon	S+	S-	Pigeon	S+
VW(B), G(D)	19S	3	20	122	88	141					
	22V	3	26	124	99	51					
	14N	6	220	123	113	113					
	18R	15	20	120	113	124					
	Median	4.5	23(1) ¹	121	204	316					
				113	124(1)						
W(B), G(D)	13M	2	6	S19	54	47	11K	1	1	111	3
	23W	5	7	115	60	4	105	15	11	108	21
	140	12	21	20T	83	97	102	42	47	114	22
				113C	129	112	V22	72	77	103	365
	Median	5	7(2)	J10	493	4		28.5	29(4)	21.5	25.5(4)
					83	47(2)					
W(D), G(B)	109	3	11	21U	38	52	M13	4	1	90I	1
	70F	6	78	12L	92	155	N14	41	29	015	2
	80H	11	36	70G	107	127	105	58	6	P16	28
				101	111	9	112	64	1		32
							L12	180	1		
							17Q	249	305		
	Median	6	36(3)		99.5	89.5(3)		61	3.5(4)	2	19(4)
W(B)+, VW(B)-	190	5	6	200	2	2	VW(B)+, W(B)-				
	202	23	96	026	2	4					
	160	111	117	260	32	7					
	Median	23	96(2)		2	4(2)					
				030	166	166	G(D)+, VG(D)-	VG(D)+, G(D)-		090	183
				050	264	266				240	283
				070	325	337				500	182
					264	266(2)				Median	645
										221	283(2)

¹Indicates experiment number in which group was run.

G(D)+, VW(B)- group used in Experiment I).

The presence of the black vertical line with S+ or with S- also did not have any observable effect on the speed of autoshaping within either of the other two stimulus pairs. Median trials to the first peck to S+ was 2.0 for the VW(B)+, W(B)- group and 23.0 for the W(B)+, VW(B)- group, $U = 2$; $p > 0.20$. For the VG(D), G(D) stimulus pair, median trials to the first peck to S+ was 221 for the VG(D)+, G(D)- group and 264 for the G(D)+, VG(D)- group, $U = 4$; $p > 0.50$. Since all birds in the two VW(B), W(B) groups autoshaped before any birds in the two VG(D), G(D) groups, the difference in the speed of autoshaping between these two conditions can be assumed to be reliable.

DISCUSSION

If faster autoshaping with the VW(B)+, G(D)- stimulus pair than with the G(D)+, V(W)B- stimulus pair in Experiment I was due to a FP-FN effect related to whether the black vertical line appeared with S+ or with S-, then omitting the black line in this experiment should have eliminated the difference in the speed of autoshaping between the W(B)+, G(D)- and the G(D)+, W(B)- groups. Neither the range of trials to the first peck to S+ nor the median number of trials preceding the first peck to S+, however, were affected by the absence of the black vertical line. The data from these two groups, therefore, are not consistent with a FP-FN explanation of the results of Experiment I.

The data from the other two stimulus conditions in this experiment also are not consistent with a FP-FN interpretation of Experiment I, since the presence of the black line with S+ or with S- did not differentially affect the speed of occurrence of autoshaped pecking when the black line was the only aspect of the key stimuli that differentiated S+ from S-. The results from these two conditions, then, replicate and extend Wasserman's (1973) findings.

All three conditions in this experiment, therefore, yielded results that appear to rule out a FP-FN explanation of the data from Experiment I. They do not rule out any of the other possible explanations. Autoshaping was faster with W(B) as S+ and G(D) as S- than with the opposite arrangement, and autoshap-

ing was faster when both S+ and S- were W(B) than when they both were G(D). An absolute preference for W over G or for brighter over darker could account for these data. Generalization from the illumination of the feeder to the illumination of the key also remains a plausible account, since the W feeder illumination was more similar to the W(B) stimulus than to the G(D) stimulus in both hue and brightness. These possibilities were examined in the next two experiments.

EXPERIMENT III

As indicated in Table 1, the W stimulus in the two previous experiments was brighter than the G stimulus. Hue and brightness, therefore, have been completely confounded. In this experiment, the brightness of the two hues was reversed to permit an independent assessment of the effect of hue and of brightness on the speed of autoshaping.

METHOD

Subjects

Seven Rollers were used.

Apparatus and Procedure

These were as described.

Stimuli

Neutral density filters were placed in the IEE cell to reduce the brightness of a second W stimulus from 86.1 cd/m², W(B), to 12.2 cd/m², W(D). The latter brightness approximated that of the G(D) stimulus, 13.6 cd/m², used in the previous two experiments. The brightness of the G stimulus was increased by placing a GE No. 1891 bulb in the IEE cell behind a second G stimulus and running this 12-V bulb at 28 V dc by means of a resistor connected to the line controlling the illumination of the bulb. (Since this could be expected to shorten the life of the GE No. 1891 bulbs, the used bulb was checked at the end of each session to ensure that it had not burned out during the session, and then was discarded. No burned-out bulbs were found.) This procedure changed the brightness of the G stimulus from 13.64 cd/m², G(D) to 76.7 cd/m², G(B) but did not significantly alter the dominant wavelength of the G stimulus. The brightness of the G(B) stimulus approximated that of the W(B) stimulus, 86.1 cd/m², in the previous two experi-

ments. The magazine illumination was W during the 3 sec of grain delivery and dark otherwise.

Three birds were randomly assigned to the W(D)+, G(B)- condition and four to the reverse condition.

RESULTS

Trials to the first autoshaped peck to S+ and to S- are shown in Table 2 for each of the birds in the two groups. The range of trials did not overlap, indicating that autoshaping was reliably faster in the W(D)+, G(B)- condition (Mdn = 6) than in the G(B)+, W(D)- condition (Mdn = 99.5).

Neither the individual data nor the group median for the W(D)+, G(B)- group were different from the data for the VW(B)+, G(D)- group in Experiment I or the data for the W(B)+, G(D)- group in Experiment II. The data for the G(B)+, W(D)- group in this experiment likewise did not differ from those of the G(D)+, VW(B)- group in Experiment I or the G(D)+, W(B)- group in Experiment II.

DISCUSSION

Reversing the brightness of the W and the G stimuli in this experiment also made the brightness of the G stimulus similar to that of the W illuminated feeder and decreased the similarity between the brightness of the W stimulus and the illuminated feeder. If either a preference for brighter stimuli over darker or generalization along a brightness dimension from the illuminated feeder to the S+ stimulus were tenable accounts of the data from Experiments I and II, reversing the brightness of the W and G stimuli ought also to have reversed the direction of the differences in the speed of autoshaping observed in those experiments. No such effect was found. On the contrary, both direction and magnitude of the previous differences in the speed of autoshaping with W+, G- and with G+, W- were replicated in the present experiment.

These data, then, suggest that a preference for brighter over darker stimuli or generalization of brightness from the illuminated feeder to the S+ stimulus are not factors affecting the observed faster autoshaping with W+ and G- than with G+ and W- in Experiment I. The remaining two possibilities—a preference for W over G and generalization from the hue illuminating the feeder to the hue of the S+

stimulus—were examined in the next experiment.

EXPERIMENT IV

In the three previous experiments, the feeder was illuminated by a W bulb during the 3-sec grain delivery at the end of each S+ interval, and was dark otherwise. The relationship between the brightness of the illuminated feeder and the brightness of the S+ and S- stimuli was examined in Experiment III. This experiment studied the relationship between the hue of the illuminated feeder and the hue of the S+ and S- stimuli.

METHOD

Subjects

Seventeen Rollers served.

Apparatus and Procedure

These were as described.

Stimuli

A piece of the same clear green plastic used to make the G stimulus in the IEE cells was taped inside the compartment housing the feeder bulb so that it covered the bottom of the compartment and rested just below the bulb. The green plastic was not visible from the front of the response panel, except when looking up at the feeder bulb compartment from inside the feeder opening. The green plastic changed the light illuminating the feeder from W to G and reduced the brightness of the light from 68.4 cd/m² to 16.4 cd/m². As indicated in Table 1, the dominant hue of the G-illuminated feeder was 555 nm and its brightness was most similar to key stimuli G(D) and W(D).

Four groups of pigeons received magazine training and autoshaping sessions with the feeder illuminated by G during each grain delivery and dark otherwise. The S+ and S- stimuli for each group were one of the four possible combinations of W and G with B and D. Four pigeons were trained with W(B)+, G(D)-, four with G(D)+, W(B)-, six with W(D)+, G(B)-, and three with G(B)+, W(D)-.

RESULTS

The data on trials to the first autoshaped peck to S+ and to S- are shown in Table 2 for the birds in each group. Overall, the G(B)+,

W(D)– group began to peck S+ fastest ($Mdn = 2$), followed in order by the G(D)+, W(B)– group ($Mdn = 21.5$), the W(B)+, G(D)– group ($Mdn = 28.5$), and the W(D)+, G(B)– group ($Mdn = 61.0$). One of the seven birds in the two G+, W– groups pecked S– before making the first peck to S+, compared to seven of the 10 birds in the two W+, G– groups.

The group trained with G(B)+, W(D)– autoshaped reliably faster than the group trained with the opposite arrangement of W(D)+, G(B)–, $U = 1$; $p = 0.02$. There was no apparent difference in the speed of autoshaping between the G(D)+, W(B)– group and the W(B)+, G(D)– group, $U = 5$; $p = 0.24$.

DISCUSSION

In Experiment III, where the feeder illumination was W, the group trained with W(D)+, G(B)– autoshaped faster than the group trained with G(B)+, W(D)–. Changing the feeder illuminated from W to G in this experiment reversed the direction of the difference in the speed of autoshaping for this stimulus pair. A simple preference for W over G, therefore, does not appear to provide an adequate account of the data from the previous three experiments.

For the other stimulus pair used in this experiment—W(B), G(D)—changing the feeder illumination from W to G apparently only eliminated, but did not reverse, the direction of the difference in the speed of autoshaping observed in Experiment II. Even with the difficulties inherent in interpreting the absence of a reliable difference, especially with small group *ns* and large within-group variability, these data are consistent with the above conclusion that a simple preference for W over G does not provide an adequate account of the results of the previous experiments.

The data from this experiment, like those of Experiment III, do not support the hypothesis that similarity between the brightness of the feeder illumination and the brightness of the S+ stimulus is a critical factor in the occurrence of the first autoshaped key peck. As Table 1 shows, the brightness of the G feeder was more similar to W(D) and to G(D) than to W(B) and G(B). Autoshaping, however, was faster when G(B) was S+ and W(D) was S– than when the opposite arrangement was used, and there was not any observable difference in the speed of autoshaping between the

G(D)+, W(B)– group and the W(B)+, G(D)– group.

GENERAL DISCUSSION

The data from these experiments are not consistent with the position, perhaps most clearly stated by Hearst and Jenkins (1974), that the first autoshaped key peck will be made to the S+ stimulus because its presence on the key reliably predicts or signals grain delivery. Instead, several comparisons among the experiments in this series suggest that the similarity between the hue illuminating the feeder and the hue of one of the two stimuli appearing on the response key is a more important determiner of the stimulus to which the first peck will be made than which stimulus appears in the S+ position preceding grain delivery and which appears in the S– position. (The data from Experiment I are not included in these comparisons because the stimuli used on the response key in that experiment confounded the single variables, whose effects were examined in the other three experiments.)

First, each of the four groups in Experiment IV had a counterpart in either Experiment II or Experiment III that was trained with the same S+ and S–, but with the feeder illuminated by W instead of G. As Table 2 shows, all four comparisons of groups from Experiment IV with their counterparts from the other two experiments show that the median number of trials to the first autoshaped peck to S+ was smaller when S+ and the feeder were illuminated by the same hue than when they were illuminated by different hues. Within each comparison, furthermore, at most one bird from a faster condition autoshaped slowly enough to fall within the range of trials to the first peck to S+ in the slower condition.

Second, whether the first peck to the key was made during a S+ or a S– interval was reliably influenced by whether S+ or S– was the same hue as that illuminating the raised feeder. Combining the two groups within each experiment that were trained with different brightnesses of the same S+ and S– hues, pecking S– before pecking S+ was more likely in Experiment IV in the W+, G– condition, where both S– and the feeder illumination were the same hue, than in the G+, W– condition, where S– was W and the feeder was G ($p = 0.70$ and 0.14 , respectively; $t(15) = 2.26$; $p <$

0.05). Similarly, in Experiments II and III, pecking S- before pecking S+ was more likely in the G+, W- condition, where S- and the feeder both were illuminated with W, than in the W+, G- condition, where S- was G and the feeder was W ($p = 0.66$ and 0 , respectively; $t(13) = 2.54$; $p < 0.05$). These data, then, are different from the typical report in the literature (e.g., Brown and Jenkins, 1968) that little if any responding occurs to S- before the first response to S+. The difference probably is related to the low probability of pecking the darkened key used as S- in most autoshaping experiments.

Additional, but indirect, evidence for the present hypothesis is provided by the data from the WV, W, and GV, G conditions in Experiment II. With the raised feeder illuminated by W light, median trials to the first autoshaped peck within each of these conditions was not affected by which stimulus was S+ and which S-. The birds in both groups in the WV, W condition, where the feeder and the response key were illuminated by the same hue, however, pecked the response key before the birds in either of the GV, G groups, where the feeder and key hues were different. In addition, autoshaping training in all of these experiments always began with an S- interval, followed by an S+ interval, followed by grain delivery. Four birds pecked the key before the first grain delivery—Birds 11K, M13, 112, and L12 during the first S- interval, and Bird 901 during the first S+ interval. In all five of these instances, where pecks were made before the first grain delivery was scheduled, the stimulus to which the peck was made and the feeder were the same hue. Direct response transfer from the feeder to the key mediated by hue similarity seems to be a more parsimonious account of these data than conditioning, since these pecks were made before the complete conditioning procedure had been experienced for the first time.

The data from these experiments, therefore, suggest that at least under some conditions, the first peck to the response key occurs because primary stimulus generalization of hue from the illuminated feeder to the response key mediates direct response transfer from pecking the feeder in the presence of a given hue to pecking the key in the presence of that same hue. Following Logan (1971), Steinhauer, Davol, and Lee (1976) proposed a similar, gen-

eral account of autoshaping that also depends on stimulus generalization.

Because of procedural differences that themselves are or may be parameters in the speed of acquisition of autoshaped pecking, e.g., duration of the S- interval (Terrace, Gibbon, Farrell, and Baldock, 1975), it is difficult to test the tenability of the above account in the published literature. Brown and Jenkins (1968), however, did use a lighted key as S+ and a dark key as S- (Experiment I) and the reverse arrangement (Experiment III). In both cases, the feeder was illuminated while it was raised and dark otherwise. The first recorded key peck occurred to S+ in both conditions. Mean trials to the first peck was 45 in the first condition and 181.5 in the second for the four birds of six that autoshaped within the maximum allowable 320 trials. These data, therefore, are consistent with the stimulus generalization hypothesis. Also, Fisher and Catania (*in press*) have used a two-key autoshaping procedure with simultaneous presentation of two S+ stimuli. With red and green S+ key-lights, the first peck to either key was made to red when the feeder bulb was red and to green when the feeder bulb was green. These data, therefore, also are consistent with the hypothesis that, at least under some conditions, autoshaped key pecking occurs because primary stimulus generalization of hue from the feeder to the key mediates the transfer of the response of pecking from the feeder to the key.

REFERENCES

- Brown, P. L. and Jenkins, H. M. Auto-shaping the pigeon's key peck. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 1-8.
- Fisher, M. A. and Catania, A. C. Autoshaping: relation of feeder color to choice of key color. *Bulletin of the Psychonomic Society*, (*in press*).
- Hearst, E. and Jenkins, H. M. *Sign tracking: The stimulus-reinforcer relation and directed action*. Austin, Texas: Psychonomic Society, 1974.
- Jenkins, H. M. and Sainsbury, R. S. The development of stimulus control through differential reinforcement. In N. J. Mackintosh and W. K. Honig (Eds), *Fundamental issues in associative learning*, Halifax: Dalhousie University Press, 1969. Pp. 123-161.
- Jenkins, J. M. and Sainsbury, R. S. Discrimination learning with the distinctive feature on positive or negative trials. In D. Mostofsky (Ed), *Attention: contemporary theory and analysis*, New York: Appleton-Century-Crofts, 1970. Pp. 239-273.

- Logan, F. A. Incentive theory, reinforcement and education. In R. Glaser (Ed), *The nature of reinforcement*, New York: Academic Press, 1971. Pp. 45-61.
- Perkins, C. J., Jr., Beavers, W. O., Hancock, R. A., Jr., Hemmendinger, P. C., Hemmendinger, D., and Ricci, J. A. Some variables affecting rate of key pecking during response-independent procedures (autoshaping). *Journal of the Experimental Analysis of Behavior*, 1975, 24, 59-72.
- Ricci, J. A. Key pecking under response-independent food presentation after long simple and compound stimuli. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 509-516.
- Sperling, S. E., Perkins, M. E., Duncan, H. J., and Lewis, J. *Excitatory and inhibitory stimulus control after autoshaping*. Paper presented at the fifteenth annual meeting of the Psychonomic Society, Boston, 1974.
- Steinhauer, G. D., Davol, G. H., and 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.
- Terrace, H. S., Gibbon, J., Farrell, L., and Baldock, M. D. Temporal factors influencing the acquisition and maintenance of an autoshaped key peck. *Animal Learning and Behavior*, 1975, 3, 53-62.
- Wasserman, E. A. The effect of redundant contextual stimuli on autoshaping the pigeon's key peck. *Animal Learning and Behavior*, 1973, 1, 198-206.
- Wasserman, E. A. and Anderson, P. A. Differential autoshaping to common and distinctive elements of positive and negative discriminative stimuli. *Journal of the Experimental Analysis of Behavior*, 1974, 22, 491-496.
- Wolff, W. and Hearst, E. *A feature-positive superiority in discriminations involving a temporally prior feature*. Paper presented at the sixteenth annual meeting of the Psychonomic Society, Denver, 1975.

Received 24 June 1976.

(Final Acceptance 17 December 1976.)