THE ASSOCIATIVE RELATION UNDERLYING AUTOSHAPING IN THE PIGEON¹

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Fifteen pigeons were exposed to either response-independent or response-dependent schedules of water reinforcement, whereby water was injected directly into the unrestrained pigeons' mandibles. Key-contact responses were released by a lighted key correlated with water, but not by a lighted key uncorrelated with water. A negative response-reinforcer contingency suppressed autoshaped key-contact responses, resulting in responding directed away from the lighted key. In all pigeons, water injected directly into the mandibles elicited a consummatory fixed-action pattern of "mumbling" and swallowing. The lighted key correlated with water released a broader set of both appetitive and consummatory responses: approach to the lighted key, "bowing", "rooting", "mumbling", and swallowing. Key-contact responses were "rooting" and "mumbling" motions of the beak on the surface of the key. Views of autoshaping based on stimulus substitution or stimulus surrogation do not fully explain the origin of autoshaped responses not previously elicited by the reinforcer. The present findings are consonant with views of conditioning that emphasize the large degree of biological pre-organization in conditioned response patterns, and the importance of associative factors in the control of such patterns.

Key words: autoshaping, respondent conditioning, stimulus substitution, stimulus surrogation, "learned release", water reinforcer, species-specific behavior, key peck, pigeon

The phenomenon of autoshaping entails conditioning the pigeon's key peck with a respondent conditioning procedure. Correlation of a lighted key with grain presentations generally produces key pecking (Brown and Jenkins, 1968; Gamzu and Williams, 1971). The stimulus (lighted key)—reinforcer (grain) relationship exerts powerful control over the development of key pecking when reinforcers are independent of responding (Gamzu and Schwartz, 1973; Gamzu and Williams, 1973), or dependent on not responding (Barrera, 1974; Griffin and Rashotte, 1973; Schwartz, 1972; Williams and Williams, 1969). The nature of the stimulus-reinforcer relation in autoshaping was the concern of the present study.

One view of autoshaping attributes the ori-

gin of key pecking to stimulus substitution (Jenkins and Moore, 1973; Moore, 1971; Staddon and Simmelhag, 1971). According to a stimulus substitution principle, stimulus control of some type of response is transferred from an unconditioned stimulus (US) to a conditioned stimulus (CS). In autoshaping, the particular conditioned response generally resembles the response exhibited during reinforcement. This correspondence between conditioned and unconditioned responding holds across several species (pigeons, chickens, quail, fish, rats, dogs), responses, and reinforcers used in autoshaping situations (Hearst and Jenkins, 1974; Moore, 1973; Schwartz and Gamzu, *in press*).

An experiment by Jenkins and Moore (1973) is the clearest support for a stimulus substitution account of autoshaped key pecking with pigeons. During autoshaping with grain reinforcement, pigeons directed pecks to the grain (US) in the food magazine and toward a lighted key (CS) paired with grain. Likewise, during autoshaping with water reinforcement pigeons directed drinking responses to the water (US) in the magazine and toward a lighted key (CS) paired with water. Jenkins

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and Moore interpreted these results in terms of stimulus substitution, suggesting that the CS gained control of the type of response (peck or drink) found to be elicited by the grain or water US. These authors offered the term "stimulus surrogation" as an even better description of the results. Their pigeons responded to the CS as though it were the US, *i.e.*, the lighted key became a surrogate for either grain or water in the magazine.

Stimulus substitution or surrogation suggests that approach and contact responses to the CS develop because the reinforcer elicits such responses. However, approach and contact responses are also inherent requirements for acquisition of the reinforcer in the conventional procedure of delivering grain or water in a magazine or dipper. These responses are typically well established during "magazine training" before conditioning sessions are initiated. Is the occurrence of these responses necessary for the development of autoshaped approach and contact responses to the lighted key, as substitution or surrogation principles would suggest?

Williams' (*cf.* Schwartz and Gamzu, *in press*) "learned release" account of autoshaped key pecking suggests not. In this view, the associative relation underlying autoshaping involves the visual stimulus of the lighted key and the interoceptive oral stimuli arising from grain or water in the mandibles. Approach and contact responses to the sight of grain, or water, or the lighted key paired with either grain or water, are controlled by the correlation between each visual stimulus and an oral reinforcing stimulus. Normally, approach and pecking or drinking responses arrange and maintain a correlation between visual and oral stimuli during feeding in the home cage as well as during reinforcement in the conditioning apparatus. However, any other "artificial" way of arranging a correlation between visual and oral stimuli should also produce and maintain approach and contact responses to the visual stimulus. By this view, autoshaping with grain or water introduced directly into the mandibles, bypassing approach and contact responses to the reinforcer, should be just as effective as autoshaping with grain or water presented in a magazine. Since the lighted key acquires its releasing properties solely from its correlation with oral reinforcing stimuli, the associative relation established

by the autoshaping procedure may be said to instigate, rather than transfer, control of responding to the lighted key.

The following questions about this issue over the nature of the role of the stimulus-reinforcer relationship in autoshaping were addressed by the present experiment. (1) Can water introduced directly into the mandibles of a pigeon be a reinforcer in the autoshaping procedure? (2) If so, what responses are elicited by the oral stimulus of water, and by the lighted key with which it is paired? (3) If autoshaped responding occurs, may its development be described as stimulus substitution? That is, does the visual stimulus gain control of responses previously controlled by the oral stimulus? May the results be described as stimulus surrogation? Does the pigeon respond to the visual stimulus as though it were the oral stimulus?

Autoshaping, omission training, and random control procedures were investigated with a new method of delivering water to pigeons. Water was injected through a cannula directly into the mandibles of water-deprived pigeons. The data of primary interest were the effects of this method of correlating visual and oral stimuli on the development of conditioned responding to the visual stimulus.

METHOD

Subjects

Eleven White King and four White Carneaux adult pigeons, experimentally naive at the start of the experiment, were maintained at 80% of their free-feeding body weights by restriction of daily water rations. Grain and grit were always available in the home cages.

Apparatus

A modified Lehigh Valley operant conditioning chamber (31 by 35 by 33 cm) for pigeons was used. Two 2.4-cm diameter response keys, 7.5 cm apart and 25.5 cm above the floor, protruded 2 mm into the chamber from the stimulus panel. A 7-W red Westinghouse Christmas Bulb (D 18-7½) transilluminated the right-hand key, the only one used. The response key required 15 g force (0.15 N) to operate a photocell attached to the back of the stimulus panel and record a key-contact response. Horizontal key displacement during

responses was recorded by a Hewlett-Packard displacement transducer (Model number 24-DCDT-250) connected to the back of the key. Pen tracings of key displacement were made by connecting the output of the transducer to one channel of an eight-channel Beckman Dynograph (Type 506RA; Serial number 17251).

For purposes of photography, the standard houselight was replaced by an overhead 60-W light and the door was replaced by a clear Plexiglas screen. The houselight was always on during sessions. To eliminate reflections from the houselight and the lighted key, white cheesecloth covered the inside of the Plexiglas door and light brown paper covered the aluminum walls, floor, and stimulus panel. Holes were cut in the paper covering the stimulus panel to expose the keys.

A water pump next to the chamber delivered water during reinforcement. The pump consisted of two solenoids, two microswitches, a syringe, and a reservoir. One solenoid operated the syringe plunger and injected the contents of the syringe; the second solenoid returned the syringe plunger and the first solenoid to their resting positions. Each injection lasted 6 sec and delivered 0.4 to 0.5 cc of water. The syringe automatically refilled with water from the reservoir as it returned to its resting position. The solenoids produced a moderate sound during operation.

Water was injected from the syringe through a large polyethylene tube. The tube coiled around a wooden dowel crossbar on top of the chamber and ran through a hole in the ceiling of the chamber. A light jacket worn by each pigeon during experimental sessions provided a place for anchoring and attaching the large tube to a thin cannula implanted in the bird's beak. A metal weight at one end of the crossbar counterbalanced the weight of the jacket, tube, and cannula, and left the pigeon relatively unrestrained.

Procedure

A small cannula was implanted in each pigeon's beak. A 1-mm diameter hole was drilled through the upper mandible of each pigeon during anesthesia, induced with either 2.0 cc/kg Equithesin or a combination of 20 mg/kg Nembutal and 32 mg/kg Ketalar injected intraperitoneally. The hole was placed

approximately 1 cm from the tip of the mandible on the midline. The cannula was a piece of PE 50 polyethylene tubing (o.d. = 0.97 mm; i.d. = 0.38 mm) 4 cm in length. The end of the cannula inside the bird's beak was flared and protruded no more than 1 mm. The tube was bent to a 90-degree angle where it emerged from the top of the upper mandible, to prevent dislodgement. However, several subjects received a replacement cannula during the experiment because their tubing was torn during home-cage activity.

At least three days were allowed for recovery from the operation, after which no subject showed impairment of feeding or drinking. Each bird then wore the jacket, with the large tube and cannula attached, for at least 1 hr before its first experimental session to allow adaptation to the jacket.

The 15 pigeons were assigned to one of the four groups described below.

(1) *Autoshaping*: four pigeons (P1, P2, P3, and P4) were exposed to four sessions of an autoshaping procedure (Jenkins and Moore, 1973), followed by a number of extinction sessions. Extinction sessions were continued for each bird until a criterion of two consecutive sessions without a response occurred. Two birds (P1 and P2) were finally returned to the autoshaping procedure for four sessions.

In the autoshaping and extinction procedures, daily sessions consisted of 50 CS presentations. CSs were separated by interstimulus intervals (ISI) averaging 60 sec, with a range from 36 to 84 sec. In the autoshaping procedure, a CS was followed immediately by an unconditioned stimulus (US) presentation. In the extinction procedure, the US was omitted. In all cases, the CS was a 6-sec fixed-duration illumination of the right-hand key. The US was a 6-sec fixed-duration injection of 0.4 to 0.5 cc of water into the mandibles. The response key was darkened during reinforcement (US) and throughout the ISI. Key-contact responses had no scheduled consequences.

(2) *Autoshaping with stimulus overlap*: four pigeons (P9, P10, P11, and P12) were exposed to a second autoshaping procedure. The purpose was to examine one aspect of the results for the first group of birds. For clarity, the second procedure is described here and the purpose for the procedure follows presentation of the results for the first autoshaping group.

In the stimulus-overlap procedure, the oc-

currence of a darkened key during water injections was eliminated by illuminating the key during US presentations. The procedure was otherwise identical to that for the first autoshaping group. Thus, each illumination of the key lasted 12 sec and overlapped the reinforcer (Schwartz, 1972 used a similar autoshaping procedure). Two birds (P9 and P11) received 10 sessions; the other two (P10 and P12) received five sessions of the stimulus-overlap procedure, followed by five sessions of the first autoshaping procedure.

(3) *Omission training*: three pigeons (P13, P14, and P15) were exposed to 20 or 25 sessions of an omission-training procedure (Schwartz, 1972). The procedure was the same as that for the first group, except for the addition of a negative response-reinforcer contingency. A response during illumination of the key omitted the US scheduled to occur at the end of that CS. Key-contact responses had no other scheduled consequences.

(4) *Associative control*: four pigeons (P5, P6, P7, P8) were exposed to 10 sessions of an associative-control procedure (Gamzu and Williams, 1971) in which illumination of the key and reinforcement (US) were uncorrelated. Key illumination occurred according to the same temporal schedule as that described for the first autoshaping group, but reinforcers occurred randomly throughout sessions. Water injections were delivered by the output of a probability generator set at $p = 0.09$ and sampled once every 6 sec. About 50 reinforcers were delivered each session. Lighted key and reinforcer could, and did, occasionally occur together.

Each pigeon in all four groups was observed by the first author during each of the first two or three sessions, to observe what responses were elicited by water in the mandibles.

RESULTS

Autoshaping Group

Figure 1 shows the proportion of CSs in which there was a key-contact response during each acquisition, extinction, and reacquisition session for each bird in the first group. Key-contact responses were autoshaped in all four birds. Mean number of CSs to the first response was 39 (range: 15 to 75) and each bird's first response occurred during a key illumina-

tion. Responding steadily increased to more than 0.8 of the CSs by the third or fourth session. Responses per minute in Session 4 during the CS and the ISI were, respectively: P1 (31.0, 41.9), P2(92.2, 11.7), P3(70.6, 11.3), and P4(131.0, 34.9).

Extinction began with Session 5, and responding decreased quickly and ceased within eight extinction sessions for three birds (*cf.* Figure 1). P4 continued to respond during several CSs per session for many sessions, but eventually met the extinction criterion after 25 sessions.

Responding was quickly regained in P3 and P4 during reacquisition, but in P3 remained at only a moderate level of 0.5 of the CSs by the fourth reacquisition session (*cf.* Figure 1).

Rates of response during the ISI were unusually high for autoshaping in the first group of birds. Indeed, for P1, responding was greater during the ISI than during the CS. Observation of the birds showed an unanticipated outcome of the present technique of reinforcer delivery, and provided a clue to the source of the high ISI response rates. Key-contact responses first occurred during key illuminations, but soon began to occur during injections of water. If responding was initiated during a CS, it tended to persist after the light was extinguished while water was injected into the mandibles. By the fourth session, each pigeon consistently consumed reinforcers while operating the darkened key. This behavior was not anticipated by the experimenters, and responses were unfortunately partitioned into only two categories by the recording equipment, those occurring during the illuminated key (CS) and those occurring during the darkened key (ISI). Possibly, high rates of response in the ISI were an artifact produced by including responses during the US in calculating ISI response rates.

However, the occurrence of responding to the dark key during water injections only partially accounts for the present findings. Each bird also tended to respond throughout the ISI by Session 4. Perhaps consumption of water while responding to the darkened key increased the tendency to respond to the dark key at all times. The second autoshaping procedure was designed to test this hypothesis. The occurrence of a dark key and consumption of water was eliminated by illuminating the key during water injections.

Fig. 1. Proportion of CS presentations with at least one key-contact response during autoshaping for each bird in the first group. Solid lines indicate acquisition, or reacquisition sessions (P3 and P4). Dotted lines indicate extinction sessions.

Autoshaping with Stimulus-Overlap Group

Figure 2 shows the proportion of CSs in which there was a key-contact response for each bird in the second group. Key-contact responses were autoshaped in all four birds. Mean number of CSs to the first response was 43 (range: 8 to 75) and the first response occurred during a key illumination for each bird. Responding steadily increased to a high level for three birds, but showed a more gradual increase for P12.

Key-contact responses were partitioned into three categories for this group of birds: those occurring during the first 6 sec of key illumination (the CS), those occurring during injection of water while the key remained illuminated, and those occurring during the ISI while the key was dark. Responses per minute for each of the birds during Session 4 in

each of these three categories were, respectively: P9(38.0, 20.4, 1.1), P10(83.6, 72.6, 14.1), P11(216.7, 282.9, 0.8), and P12(89.6, 123.5, 0.9).

By Session 4, with birds in both the autoshaping and the stimulus-overlap groups having each experienced the same number of CS and US presentations, rates of response in the CS showed no marked difference between groups. In contrast, responding during the ISI was much less in the stimulus-overlap group. Only P10 showed substantial responding during the ISI in the second group. Figure 3 presents examples of cumulative records for one bird in each group and allows comparison of the patterns of response generated by the two autoshaping procedures. The pattern of responding found with the first autoshaping procedure was irregular. Bursts of responding occurred throughout the ISI as well as the CS.

Fig. 2. Proportion of CS presentations with at least one key-contact response during autoshaping for each bird in the stimulus-overlap group. Solid lines indicate sessions in which the illumination of the key overlapped injections of water. Dotted lines for P10 and P12 indicate a switch to the first autoshaping procedure, in which illumination of the key terminated as water was injected.

The pattern found with the second procedure was marked by the regularity of the pattern. Responding was confined to periods of key illumination.

Since responses were not partitioned in the same manner for both groups, a comparable measure of ISI responding for both groups was sought. Pen tracings of key-contact responses made with the dynograph were used

to tabulate bursts of responding on the key. Bursts of responding during the dark key, but not during the illuminated key or during water injection, were counted. A burst was defined as a period of continuous contact with the key, preceded by at least 2 sec without contact. This measure reflects the number of initiations of bouts of responding to the dark key. The measure excludes responding initiated

Fig. 3. Cumulative records of two pigeons' autoshaped contact responses to the lighted key. The lower event marker indicates CS presentations. The upper event marker located on the cumulative record itself indicates US presentations. The record on the left shows a portion of Session 4 for P3 in the first autoshaping group. The overall pattern of responding is irregular, with many responses occurring during the ISI as well as during the CS and US. The record on the right shows a portion of Session 4 for P11 in the stimulus-overlap group. The pattern of responding was very regular, with virtually all responses occurring during the CS and US.

during illumination of the key and persisting afterward during the dark key at the beginning of the ISI. Figure 4 shows the number of bursts during the dark key for each bird in the first and second groups. Birds in the first autoshaping group showed high levels of responding, which tended to increase over sessions. Birds in the stimulus-overlap group showed low levels of responding, which tended to decrease over sessions. By Session 4, there was no overlap between groups in levels of responding. All four pigeons in the first group far exceeded the highest levels of responding in the second group. Furthermore, P10 and P12 did not develop substantial responding during the dark key when switched from the stimulus-overlap to the first autoshaping procedure. Responding during the dark key found in the first group was apparently specific to the first autoshaping procedure during initial acquisition of key-contact responding. Thus, the high levels of ISI responding in the first group may be attributable to an increased tendency to respond to the dark key, produced by consuming reinforcers during contact with the dark key.

Omission-Training Group

Figure 5 shows the proportion of CSs in which there was a key-contact response for each pigeon in the omission-training procedure. Key-contact responses were autoshaped in all three birds. Mean number of trials to the first response was 71 (range: 69 to 73). The steady increase in responding found with the first two autoshaping groups was not evidenced by this group. Responding gradually increased to moderate or low levels, and then declined to very low levels in all birds. After prolonged exposure to the negative response-reinforcer contingency, the three birds seldom operated the key. Rather, these pigeons exhibited responses directed away from the illuminated key to adjacent areas of the stimulus panel, Plexiglas door, or floor. P15 adopted a response that did not operate the key, by making contact responses to the 2-mm wide edge of the key. Beginning with Session 14, the key was recessed for this bird and Figure 5 shows the immediate increase in recorded responding. Subsequently, responding declined to low

Fig. 4. Number of bursts of responding on the key during the ISI for birds in the first and second autoshaping procedures plotted across sessions. On the left are the data for the birds in the first group. On the right are the data for the stimulus-overlap group. Solid bars indicate sessions under the first autoshaping procedure. Hatched bars on the right indicate sessions under the stimulus-overlap procedure. Notice that P10 and P12 were switched to the first procedure after Session 5, shown at the far right of the figure.

levels as responses were directed away from the key, as was the case for P13 and P14.

In contrast to previous reports of omission training with grain (Williams and Williams, 1969), key-contact responses autoshaped with the present water reinforcement technique showed a marked sensitivity to the negative response-reinforcer contingency.

Associative-Control Group

Key-contact responding was not generated by the associative-control procedure. One of the birds (P5) struck the key during an ISI once. By the end of 10 sessions, two birds consumed reinforcers while rooting on the floor of the chamber, and the other two birds remained relatively inactive and merely swallowed each reinforcer.

Topography of Water-Associated Responses

Observation of all 15 birds showed that swallowing and "mumbling" (Moore, 1971) responses were always elicited by water in the mandibles. Peristaltic movements of the throat (swallowing) were accompanied by rapid, rhythmic (four to seven per second) opening and closing movements of the beak (mumbling). This pattern is the pigeon's species-specific consummatory response for water (Craig, 1912; Lorenz, 1937).

In all 11 birds in the first three groups, responses released by the illuminated key included mumbling and swallowing, but consisted of a broader set of water-associated responses. The complete species-specific drinking pattern in pigeons includes "bowing",

Fig. 5. Proportion of CS presentations with at least one key-contact response for each bird in the omission-training group. Solid lines indicate sessions with the standard key protruding 2 mm from the stimulus panel; the dotted line indicates sessions for P15 in which the key was recessed 2 mm behind the stimulus panel.

“rooting”, “mumbling”, and swallowing (Craig, 1912). Bowing is lowering the head to the ground in a quick and smooth manner. Rooting is a vigorous head and neck movement with the beak pressed to a surface. The beak is moved back and forth across a surface by the rooting response. All four component topographies occurred to some extent during key illuminations. However, key-contact responses included only a portion of this set of

behaviors. Rooting and mumbling motions of the beak operated the key; swallowing motions of the throat and bowing responses to the floor did not.

Rooting and mumbling were the predominant key-contact responses recorded by the displacement transducer attached to the key in the present experiment, and presumably also in the study by Jenkins and Moore (1973). Figure 6 shows examples of key-contact re-

Fig. 6. Examples of response records from the dynograph connected to a displacement transducer on the response key. Contact with the key produced vertical excursions of the pen proportional to the horizontal displacement of the key. Illuminations of the key (CS) and injections of water (US) are indicated by upward deflections of the event pen. Notice that the time base for individual records is different: each event lasted 6 sec, however. Record A shows responding for P1 during Session 4 of autoshaping. The event pen shows two paired presentations of the CS and US. This bird struck the key predominantly with a peck topography, resulting in discrete deflections of the pen. Record B shows responding for P4 during Session 4. This bird showed a pattern more typical of responding autoshaped with water. Contact with the key was maintained for long periods of time, during which rooting and mumbling movements produced sharp deflections and slower changes in the horizontal displacement of the key. Pressure maintained on the key produced an envelope pattern of key displacement. Record C shows responding for P13 during Session 3 of omission training. The second CS presentation contains responses that omitted the US. Record D shows two CS presentations containing responses for P14 during Session 18 of omission training. Both P13 and P14 showed rapid movements of the beak in contact with the key; only P13 maintained pressure on the key, producing small envelopes of key displacement. Record E shows responding for P12 during Session 4 of the stimulus-overlap procedure. The key was illuminated during both the CS and the US. Record F shows responding for P9 during Session 3 of the same procedure. Responding consisted exclusively of rooting and mumbling during maintained contact with the key. Note that there was very little responding during the ISI compared to that shown in Records A and B for birds in the first autoshaping procedure.

sponse topography found with the present procedures. Topography was similar to that illustrated in Jenkins and Moore's (1973) Figure 4 (p. 177). Nine of the 11 birds showed only rooting and mumbling topographies; two birds (P1 in the first group and P11 in the second group) struck the key forcefully with a ballistic-peck topography. Only the rapid mumbling motions that occasionally appeared on the pen tracings distinguished these birds' topography from that of food pecks (Jenkins and Moore, 1973).

The four birds in the associative-control group also occasionally showed rooting and bowing responses, but in each case they were directed to the floor of the chamber. These responses were observed infrequently in the first few sessions, and did not occur consistently during or immediately after water injections. They were not elicited by water in the mandibles, but rather appeared to develop in the present situation over several sessions.

DISCUSSION

A major finding of the present experiment is that water introduced directly into the mandibles of pigeons was an effective reinforcer for autoshaping contact responses to a lighted key correlated with water. Three general characteristics of autoshaping were evident in the present data. (1) Responding emerged after a typical number of pairings of the lighted key and water (mean = 49 pairings; range = 8 to 76 pairings) for the 11 birds in the two autoshaping groups and the omission training group. (2) Once responding emerged, substantial rates of responding quickly developed for birds in the two autoshaping groups. (3) Responding did not develop in the control group with uncorrelated presentations of the lighted key and water.

Two aspects of the present results differed markedly from previous reports of autoshaping and omission training. First, in the omission-training group, the negative response-reinforcer contingency suppressed autoshaped contact responses to the key. Bowing and rooting responses were directed toward the floor and parts of the stimulus panel near the key as responding directed toward the lighted key diminished. This finding is at odds with some studies of omission training with grain reinforcement, which showed substantial re-

sponding to the key in spite of the negative contingency (Schwartz, 1972; Williams and Williams, 1969). However, Barrera (1974) found that a substantial amount of responding may be directed away from the key during omission training with grain reinforcement. In our laboratory, we often find that bowing and rooting responses in the water magazine tend to replace autoshaped contact responses to the key during extended exposure to omission training with water. A second difference was the unusually high level of ISI responding generated by the first autoshaping procedure. Previous studies of autoshaping (Brown and Jenkins, 1968; Gamzu and Williams, 1971; Jenkins and Moore, 1973) have typically found very little responding during the ISI, although there are instances of substantial responding during the ISI in the literature (Gamzu and Schwartz, 1973; Perkins, Beaver, Hancock, Hemmendinger, Hemmendinger, and Ricci, 1975). In the present experiment, this effect is attributable to the occurrence of responding on the dark key during reinforcement in the first procedure, and not to the water reinforcement technique, *per se*. The second procedure (stimulus overlap) eliminated the occurrence of responding to the dark key during reinforcement, and effectively eliminated ISI responding. Thus, neither the suppression of responding by the negative response-reinforcer contingency, nor the generation of significant levels of ISI responding, alter the conclusion that water introduced directly into the mandibles is an effective reinforcer for autoshaping.

A further finding of importance concerns the particular responses controlled by the lighted key and reinforcer in the present procedures. The oral stimulus of water in the mandibles reliably elicited mumbling and swallowing consummatory responses. The lighted key paired with water controlled a more complex set of conditioned behaviors comprising the pigeon's complete species-specific drinking pattern. Approach to the lighted key, bowing in a downward direction, rooting on the surface of the key, mumbling motions of the mandibles, and swallowing motions of the throat were observed during the CS. Contact responses autoshaped to the lighted key consisted of a subset of the complete pattern: rooting and mumbling motions. Notably, both the complete set of conditioned responses, as well as the subset consisting of

contact responses to the key, included responses not elicited by the oral reinforcing stimulus.

The origin of autoshaped approach, bowing, and rooting responses is not accounted for in terms of stimulus substitution or surrogation principles. The lighted key did not merely gain control of mumbling and swallowing responses elicited by water (substitution), nor did the pigeons behave toward the lighted key as though it were the oral stimulus of water (surrogation). Likewise, stimulus or response generalization from reinforcer to lighted key do not account for the emergence of those responses not initially controlled by the reinforcer. It is important to note here that substitution, surrogation, and generalization principles may apply in the conventional autoshaping procedure with reinforcers presented in a magazine. The lighted key might substitute for, or become a surrogate for the sight of water in the magazine (Jenkins and Moore, 1973), and stimulus or response generalization from events in the magazine to the key might also play some role in the emergence of autoshaped responding. Our experiment merely shows that autoshaping does not depend on the operation of these factors. The present reinforcement technique restricted the stimulation provided by the water reinforcer to oral stimuli, and thereby restricted unconditioned responding to consummatory responses of mumbling and swallowing. Nevertheless, the complete set of conditioned behaviors typical of autoshaping with water emerged.

The emergence of approach, bowing, and rooting in the present situation fits well with a "learned-release" view of autoshaping. This principle asserts that biologically pre-organized appetitive behavior patterns are released by signals for impending reinforcing stimuli. These patterns normally result in contact with the reinforcer and the release of a different pattern of consummatory fixed-action patterns. Consistent with this view is the observation that approach, bowing, and rooting are the appetitive responses observed in water-deprived pigeons exposed to the sight of water in a magazine, or to pools of water in the wild (Craig, 1912). They result in contact with the oral stimulus of water, which releases consummatory mumbling and swallowing. Also consistent with "learned release" is the observation that approach, bowing, and rooting were

reliably initiated in the present situation by associative factors. These responses were released by a stimulus correlated with water (in the autoshaping and omission-training procedures) but were observed only sporadically, or not at all, when the stimulus was uncorrelated with water (in the associative-control procedure). The positive correlation between the lighted key and water in the mandibles, rather than the prior occurrence of approach and contact responses to the reinforcer, accounts for the emergence of these responses to the lighted key.

The present results join a host of others which show that conditioned responses often do not resemble unconditioned responses. In traditional classical conditioning studies, for example, conditioned breathing and heart-rate changes (Hilgard, 1936), details of the conditioned eyeblink (Martin and Levey, 1971), and responses accompanying conditioned salivation (Zener, 1937) do not resemble unconditioned responses. In autoshaping, as well, pecking and snuggling responses autoshaped with heat-light reinforcement in young chicks (Wasserman, 1973) do not resemble unconditioned responses to the reinforcer. These examples do not find an explanation in terms of traditional principles that identify the origin of the conditioned response with the development of an anticipatory unconditioned response (Moore, 1971). However, these examples do share a common feature, which is perhaps most striking in autoshaping situations: the conditioned response is "preparatory" (Rescorla and Solomon, 1967) for receipt of the reinforcer. "Learned release" suggests that "preparatory" is an apt description for autoshaped responses, because they are often (1) *pre-organized* (neuromuscularly, phylogenetically) to achieve effective contact with the reinforcer (*e.g.*, pecking at grain, or bowing and rooting for water in pigeons), and (2) they are initially released by stimuli that *precede* receipt of the reinforcer, rather than by the reinforcing stimulus itself. The pre-organized nature of autoshaped responses is especially clear in experiments in which the species-specific autoshaped response persists even when the situation (Wasserman, 1973), or the response-reinforcer contingency (Williams & Williams, 1969), is so arranged as to thwart the normal course of approach and contact with the reinforcer. The initial release of these pre-

organized responses by stimuli that precede reinforcement, rather than by the reinforcer itself, is made clear by experiments such as Wasserman's (1973) and the present one. "Learned release" suggests that the origin of autoshaped "preparatory" responses lies in the selection and instigation of components of the organism's species-specific behavior repertoire by associative learning factors.

REFERENCES

- Barrera, F. J. Centrifugal selection of signal-directed pecking. *Journal of the Experimental Analysis of Behavior*, 1974, **22**, 341-355.
- Brown, P. L. and Jenkins, H. M. Auto-shaping of the pigeon's keypeck. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 1-8.
- Craig, W. Observation on doves learning to drink. *Journal of Animal Behavior*, 1912, **3**, 273-279.
- Gamzu, E. and Schwartz, B. The maintenance of key pecking by stimulus-contingent and response-independent food presentation. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 65-72.
- Gamzu, E. and Williams, D. R. Classical conditioning of a complex skeletal response. *Science*, 1971, **171**, 923-925.
- Gamzu, E. and Williams, D. R. Associative factors underlying the pigeon's key pecking in autoshaping procedures. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 225-232.
- Griffin, R. W. and Rashotte, M. E. A note on the negative automaintenance procedure. *Bulletin of the Psychonomic Society*, 1973, **2**, 402-404.
- Hearst, E. and Jenkins, H. M. *Sign tracking: the stimulus-reinforcer relation and directed action*. Psychonomic Society Monograph, 1974.
- Hilgard, E. R. The nature of the conditioned response: I. The case for and against stimulus substitution. *Psychological Review*, 1936, **43**, 366-385.
- Jenkins, H. M. and Moore, B. R. The form of the auto-shaped response with food or water reinforcer. *Journal of the Experimental Analysis of Behavior*, 1973, **20**, 163-181.
- Lorenz, K. Über den Begriff der Instinkthandlung. *Folia Biotheoretica*, 1937, **2**, 18-50.
- Martin, I. and Levey, A. B. *The genesis of the classical conditioned response*, Oxford: Pergamon Press, 1971.
- Moore, B. R. *On directed respondents*. Unpublished doctoral dissertation, Stanford University, 1971.
- Moore, B. R. The role of directed Pavlovian reactions in simple instrumental learning in the pigeon. In R. A. Hinde and J. Stevenson-Hinde (Eds.), *Constraints on learning*. New York: Academic Press, 1973. Pp. 159-186.
- Perkins, C. C. Jr., Beaver, W. O., Hancock, R. A. Jr., Hemmendinger, P. C., Hemmendinger, D., and Ricci, J. Some variables affecting rate of key pecking during response-independent procedures (auto-shaping). *Journal of the Experimental Analysis of Behavior*, 1975, **24**, 59-72.
- Rescorla, R. A. and Solomon, R. L. Two-process learning theory: relationships between Pavlovian conditioning and instrumental learning. *Psychological Review*, 1967, **74**, 151-182.
- Schwartz, B. The role of positive conditioned reinforcement in the maintenance of key-pecking which prevents delivery of a primary reinforcement. *Psychonomic Science*, 1972, **28**, 277-278.
- Schwartz, B. and Gamzu, E. Pavlovian control of operant behavior: an analysis of autoshaping and its implications for operant conditioning. In W. K. Honig and J. E. R. Staddon (Eds.), *Handbook of operant behavior*. New York: Prentice Hall, (in press).
- Staddon, J. E. R. and Simmelhag, V. L. The "superstition" experiment: a re-examination of its implications for the principles of adaptive behavior. *Psychological Review*, 1971, **78**, 3-43.
- Wasserman, E. A. Pavlovian conditioning with heat reinforcement produces stimulus-directed pecking in chicks. *Science*, 1973, **181**, 1875-1877.
- Williams, D. R. and Williams, H. Automaintenance in the pigeon: Sustained pecking despite contingent nonreinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 511-520.
- Zener, K. The significance of behavior accompanying conditioned salivary secretion for theories of the conditioned response. *American Journal of Psychology*, 1937, **50**, 384-403.

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