Minimizing Stimulus-Reinforcer Contributions to Operant Latency

Mario Miguel Delgado Zambrano
Western Michigan University

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MINIMIZING STIMULUS-REINFORCER CONTRIBUTIONS TO OPERANT LATENCY

by

Mario Miguel Delgado Zambrano

A Thesis Submitted to the Faculty of The Graduate College in partial fulfillment of the requirements for the Degree of Master of Arts Department of Psychology

Western Michigan University Kalamazoo, Michigan August 1987
MINIMIZING STIMULUS-REINFORCER CONTRIBUTIONS TO OPERANT LATENCY

Mario Miguel Delgado Zambrano, M.A.
Western Michigan University, 1987

The present study involved two experiments using an unlighted food hopper. The first provided magazine training with the darkened hopper, followed by a test for autoshaping potential. The second, using birds that showed very little autoshaped behavior in the first experiment, and continuing to use the unlighted hopper, measured operant latencies in a Hesse (1984) discrete-trial multiple schedule using a two-key procedure for separating stimulus-reinforcer and response-reinforcer contributions. The objective here was to demonstrate latency differences between favorable and unfavorable schedule components, while limiting the possible confound of stimulus-reinforcer contributions as measured by initial stimulus-key responding.

Despite being unable to completely eliminate the potential for autoshaping during the magazine training of Experiment 1, the use of an unlighted hopper succeeded in reducing initial stimulus-key pecks in the latency study. This supports the basic contention that pairing grain with a hopper light may contribute to the general efficacy of the autoshaping paradigm. It also suggests an improved technique for obtaining latency measures unconfounded by stimulus-reinforcer contributions.
ACKNOWLEDGEMENTS

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I would like to thank Dr. Jack Michael for his contribution to both my intellectual development and the present project. I thank him for being my advisor and for teaching me about behavior analysis.

I would also like to thank Dr. Kay Malott for use of the experimental equipment. Special thanks go to Tom Bell for his technical help and contribution to this thesis.

Most of all, I would like to thank and dedicate this thesis to my family, Cecilia, Luis, Juan, Jorge, and Ana for their constant emotional and financial support, and for their continued faith in me.

Mario Miguel Delgado Zambrano
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Minimizing stimulus-reinforcer contributions to operant latency

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INTRODUCTION

The time between the onset of a stimulus and the occurrence of the response evoked by that stimulus is referred to as the stimulus-response latency, or just the latency. In respondent conditioning latency is one of the principal dependent variables, along with response magnitude, and the proportion of stimulus trials on which responding occurred. Latency also refers to the time between the occurrence of a discriminative stimulus and the first resulting response in a relation of operant stimulus control, but this measure has not been used much in the study of such relationships. Rate of response has been the primary operant dependent variable. Even when operant stimulus control is studied by alternating different stimulus conditions, the customary practice is to compare rates in each condition. Typically such rates contain the latency, but the stimulus condition remains in effect long enough that the rate is determined largely by subsequent interresponse times.

The relative unpopularity of latency as a measure of operant stimulus control may be partly due to Skinner's strongly worded criticism of this measure on theoretical grounds, and his data showing that latency did not vary systematically with satiation and extinction (1950, pp. 196-198). It would appear, however, that latency has been a useful dependent variable in a small number of studies (for example, Hienz & Eckerman, 1974; Schuster, 1959; Stebbins, 1962; Stebbins & Lanson, 1961, 1962). More recently at Western Michigan University there has been a series of studies concerned with the effects on latency of ratio requirement, duration of reinforcement,
and probability of reinforcement (Hesse, 1984; Hesse, Michael, Whitley, Nuzzo, & Sundberg, 1984; Neal, 1985; Nuzzo, 1984; Schlinger, 1985; and several others in progress). The present study was an effort to overcome a methodological limitation in this latter sequence of studies as described below.

In the first of the W. M. U. studies, reported by Hesse et al. (1984), a two-component, multiple fixed-ratio procedure was used in which the components were separated by an intertrial interval (ITI) of 5 seconds. Pigeons pecked a single key when it was transilluminated either red or green, and completion of the required response ratio caused the key to become dark and reinforcement (operation of a grain hopper) to be delivered. An ITI always followed reinforcement, and each key peck during the ITI reset the 5-sec timer. Simultaneous with the timing out of the 5-sec ITI timer the key was again transilluminated either red or green (with probability of red = probability of green = .50).

The main dependent variable was the latency of the first peck to the key after the ITI ended and the key was illuminated. The independent variable was the condition with respect to reinforcement that was associated with the two key colors. Thus for some birds one key color would be associated with a small ratio requirement and the other with a larger ratio requirement (for example, FR 3 vs. FR15), but the probability of reinforcement (e.g., 0.9) and the duration of reinforcement (e.g., 4 sec) would be the same for both colors. Other birds had the same ratio requirement in each color (e.g., FR 5) and the same probability of reinforcement (e.g., 0.9), but would receive 6 sec of grain exposure in one color and only 2 sec in the other. Still other birds would have equal ratio requirements and equal
durations of reinforcement in the two colors, but different probabilities of reinforcement (e.g., 0.9 in one color and 0.3 in the other).

In each type of experimental condition there was a more favorable and a less favorable component, and in general the latencies to the more favorable component stimulus, irrespective of the reason for its being more favorable, were shorter than the latencies to the less favorable stimulus. Typically, after the median latencies appeared stable the conditions would be switched so that the more favorable component stimulus became the less favorable, and the latencies would also change in the appropriate direction. There were several complications that were not explained (for example, when the ITI was changed to 20 sec the latency differences would typically vanish), and sometimes the effect would not be seen or would disappear for no apparent reason.

There was a more serious problem with this procedure, however. After most of this first group of studies had been completed it was realized that what were being considered operant latencies might be in part the result of another type of behavioral control, namely autoshaped responding. Brown and Jenkins (1968) showed that pigeons pecked a key whose illumination was correlated with free food delivery. This "autoshaping" procedure, as they termed it, resembles classical conditioning because, after a few pairings, the lighted key (CS) which had preceded food (US) presentation elicits the key peck response (CR) which is somewhat like the pecking response to food (UR). Many other experiments have since been concerned with the study of autoshaped responding, which can be easily demonstrated in the pigeon (Gamzu & Schwartz, 1973; Gamzu & Williams, 1971, 1973; Jenkins & Moore, 1973; Moore, 1973; Ricci, 1973; Schwartz, 1973; Schwartz &
Williams, 1972a; Schwartz & Williams, 1972b), and is sufficiently strong behavior that it will continue even if the response prevents the delivery of food (Williams & Williams, 1969).

In the auto shaping paradigm the pigeon pecks a localized visual stimulus if its onset is associated with some type of improvement. In the typical experiment this consists in a key being illuminated for a few seconds before food is delivered. In the latency procedure used by Hesse et al. (1984), this condition might well be in effect. No food is available during the ITI, but as soon as the key is lit (with either color) food is only a few seconds away (if the bird pecks the key). Thus the first peck to both colors might be an auto shaped peck. This would mean that the latencies to both colors might be confounded with what could be a respondent latency, which might be shorter than the operant latency ostensibly being measured.

More frequent autoshaped responses to the favorable color would constitute an alternative explanation of the reduced latencies to the more favorable color that were typically obtained. In any case, the possibility of an autoshaped first response in the one-key procedure used by Hesse et al. (1984) renders the interpretation of results with that procedure unclear.

Modifying a two-key procedure developed by Keller (1974), Hesse (1984) continued to study latencies and was able to distinguish autoshaped from operant responses. He used the same two-component multiple schedule of the earlier studies, but projected the colors on a different key from the one that had to be pecked to obtain food. Pecking the stimulus key in this two-key procedure had no effect on food delivery, but as in the earlier studies, different ratio requirements were in effect on the food key depending upon the color now projected on the stimulus key. The food key was lighted
with a yellow color throughout the procedure, including the ITI, and was thus referred to as the "constant" key which is the terminology that will be used hereafter. When the ITI ended the stimulus key was illuminated either red or green, and then completing a ratio requirement on the constant key turned out the stimulus-key lights and operated the food hopper, after which the ITI began, and so on. Responses on the stimulus key were recorded but had no effect on the programmed contingencies.

With this two-key procedure Hesse (1984) was indeed able to identify autoshaped responses, and found that the first response after the ITI ended was often a very quick peck to the stimulus key, with the ratio requirement being completed on the constant key. Furthermore, when the ratio requirements on the constant key associated with the two colors (red and green) were equal, stimulus-key pecking occurred infrequently or equally to the two stimulus-key colors. When ratio requirements were unequal, however, stimulus-key pecking occurred more frequently to the favorable color. This is exactly the behavior which would produce shorter latencies to the favorable color in the earlier one-key procedure, not as a result of shorter operant latencies, but rather as a result of a greater proportion of first pecks to the favorable color being the quick autoshaped and possibly respondent pecks.

With the two-key procedure involving separate stimulus and constant keys, the recorded latency on the constant key would include the time it took the bird to peck the stimulus key and then peck the constant key. This meant that constant-key pecks in the presence of the favorable color were often lengthened because of the stimulus-key peck, whereas constant-key latencies in the presence of the unfavorable color were not so lengthened. This resulted in the constant-key latencies in favorable and unfavorable
conditions being more like one another with the two-key than with the one-key procedure. In spite of this spurious lengthening of the constant-key latencies in the presence of the favorable color, however, latencies to the favorable color were generally shorter than in the presence of the unfavorable color.

In summary, the Hesse (1984) two-key procedure made it possible to identify autoshaped responding; showed that there was a good deal of such responding in the favorable component; but also showed that it was not possible to obtain "pure" operant latencies with the procedure as it was used in that research. Hesse had confined his latency comparisons to conditions differing with respect to the ratio requirement. The earlier one-key work had also shown latency differences produced by differential probabilities of reinforcement and differential durations of reinforcement. Schlinger (1985) extended the two-key findings to latency differences produced by differential reinforcement probabilities and durations. His results were quite similar to those of Hesse, with clear evidence of autoshaped responding to the favorable stimulus, which confounded any measurement of the effects on operant latency of the probability and duration variables.

A possible way out of this difficulty is suggested by the results of work by Steinhauer, Davol, and Lee (1976). They proposed that the hopper light may acquire stimulus control over pecking at the grain hopper during initial magazine training. Pecks at the lighted hopper are reinforced because the pigeon obtains food, whereas pecks at the unlighted hopper are unsuccessful in producing food. Thus pigeons may peck at the lighted key during the autoshaping procedure as a result of generalization from the lighted hopper during magazine training. A number of other studies have shown
that acquisition of autoshaped key pecking in pigeons is affected by the similarity between the grain hopper and the key as stimuli (Davol, Steinhauer, & Lee, 1977, Experiment 4; Ettinger, Finch, & McSweeney, 1978, Experiment 2; Fisher & Catania, 1977; Herrnstein & Loveland, 1972; Hursh, Navarick & Fantino, 1974; Sperling, Perkins, & Duncan, 1977, Experiment 4; Steinhauer, 1982).

Most relevant to the present purpose, Davol et al. (1977, Experiment 2, Condition 1) and Ettinger et al. (1978, Experiment 1) reported that the acquisition of autoshaped key pecking is retarded or does not occur at all when the food magazine is not illuminated. In the Davol et al. study pigeons were randomly assigned to three conditions (unlighted grain-hopper, lighted grain-hopper, and keylight-only) and were then given initial magazine-training trials (10, 10, and 25, respectively). Following this training, pigeons were given autoshaping trials during which an 8-sec white keylight was followed by 4-sec grain hopper elevation for birds in conditions 1 and 2, (the grain hopper was not elevated for birds in condition 3). Pecks on the key terminated the keylight and operated the grain hopper. Results showed that 4 of 5 pigeons in the unlighted hopper condition never pecked the key during the 200 autoshaping trials. However, all pigeons in the lighted hopper condition initiated and maintained responding to the stimulus key.

The above line of research suggests that if an unlighted food hopper were used one might be able to measure unconfounded operant latencies using the two-key procedure of Hesse (1984) and Schlinger (1985). This was the main purpose of the present study. But first it was necessary to replicate the Davol et al. (1977) procedure in the W. M. U. laboratory, and if the replication was successful, to use birds that showed no or very little
autoshaped responding in the two-key latency study. Experiment 1 was the Davol et al. replication and Experiment 2 was a replication of the Hesse research but using an unlighted hopper.
EXPERIMENT 1

This experiment was a study of autoshaping in pigeons using a continuously lighted chamber and an unlighted food magazine. The procedure was similar to that of Davol et al. (1977, Experiment 2). Pigeons were first hopper trained using an unlighted food magazine. Key pecking was not expected to occur if pairing the hopper light with grain delivery is a condition necessary for the occurrence of autoshaping.

Method

Subjects

Eleven experimentally naive barren hen White Carneaux pigeons were used as subjects. Pre-session body weights were maintained between 78 and 83 percent of each subject's free-feeding weight through both parts of the experiment. Subjects were not run on days when their weight exceeded this range prior to session start. Supplementary post-session feeding compensated for insufficient food intake during sessions.

Apparatus

The subjects' behavior was studied in three Lehigh Valley sound-attenuated pigeon chambers (31 cm in length, 37 cm in height, and 30 cm in width), each equipped with a three-key intelligence panel. The 2.5 cm diameter keys, spaced 3.7 cm apart edge-to-edge, were horizontally positioned 24.5 cm above the chamber floor. Each key could be transilluminated by an
Industrial Electronics, Inc. stimulus projector mounted from behind. The intelligence panels also included a 5 x 6 cm aperture located in the middle of the panel, 10.5 cm above the chamber floor. This opening permitted access to mixed grain when it was delivered by the food hopper. A 7.5 w houselight, medially positioned 3 cm from the top of the panel, provided indirect illumination of the entire chamber. White noise was presented through a 7.5 cm diameter array of holes in the lower right-hand side of the panel behind which a speaker was mounted. The right-hand wall of the chamber, which also served as its door, was equipped with a one-way mirror (19 cm in height, and 23 cm in width). This was covered by black cardboard containing a one cm diameter hole for the purpose of observing subjects. Pecks to a key with a force greater than .2N closed a microswitch which automatically caused the response to be recorded by a Digital Equipment Corporation PDP-8A computer equipped with SuperSKED software and State Systems, Inc. interfacing. All stimulus presentations and interval times were recorded in this same manner.

Procedure

The houselight remained on and the grain hopper light remained off during both the training and test phases of this experiment.

Magazine Training

Due to early problems in adapting pigeons to the experimental chambers, a more gradual technique was adopted for magazine training than in the procedure employed by Davol et al. (1977). All subjects proceeded through a series of magazine training phases wherein hopper presentations
became increasingly frequent and shorter in duration. Table 1 provides the relevant features for each of these programs.

For the first trial of each session, a pigeon was placed in the chamber with the grain hopper elevated. After the subject had been observed to eat for ten seconds, the hopper was lowered and the first ITI was started (phases 3-8). Ensuing trials consisted in the cycling of this ITI/hopper-presentation schedule.

The experimenter observed each subject through its entire daily session. Pigeons were moved to the next condition when for each trial of the current phase they consistently approached the food hopper and took grain.

Table 1

<table>
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<td>2</td>
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<td>8</td>
<td>18</td>
<td>VT 30-sec</td>
<td>4-sec</td>
</tr>
</tbody>
</table>
Unlike Davol et al. (1977), who provided a fixed number of training trials for each bird, this criterion ensured that subjects were under adequate stimulus control of the hopper delivery-mechanism before proceeding to the next phase.

The final condition was identical to the magazine-training procedure used by Davol et al. (1977), except that a variable-time 30 sec schedule (10 sec to 50 sec, by 5 sec) was substituted for their fixed-time 30 sec schedule. The number of trials provided for each subject during this last phase is presented with the results in Table 2 (p. 15).

**Autoshaping Test**

After subjects were reliably eating from the unlighted hopper, an autoshaping test was conducted for either a maximum of five days or until evidence for autoshaping had been obtained. During this phase an automaintenance procedure was employed, the general features of which are diagrammed in Figure 1. This represents a further departure from Davol et al. (1977), who used an autoshaping procedure where key pecks were followed immediately by key-light offset and delivery of food reinforcement. But since the critical dependent variable was occurrence of the first key peck, rather than the number of pecks occurring in later trials, a maintenance procedure was used to preclude any operant reinforcement which could result from a shaping paradigm. This was done in consideration of the subject selection for Experiment 2, for which the automaintenance history was more appropriate.

Only the center key was functional during this phase. Following its illumination by white light for an 8 sec period, grain was delivered for 4 sec.
Figure 1. State Diagram for the Autoshaping Test of Experiment 1.

A variable-timed 60-sec ITI (30 sec to 90 sec, by 5-sec intervals) separated each of the 50 presentations per session. Pecks at any time during the test had no effects on the programmed schedule. This phase was terminated if the birds began to show reliable pecking to the lighted stimulus key.

Results and Discussion

All pigeons were feeding readily from the unlighted grain hopper by the end of magazine training. For most birds the progression through training phases required only one or two days per condition, but exceptions were noted. There was some difficulty getting two of the subjects to eat from the hopper during early training: P-1923 spent twelve days in Phase 1 (10 min free access) and six days in Phase 3 (introduction of the ITIs); P-3176 required ten days in Phase 1.

These early problems led to the adoption of a gradual program for the remainder of magazine training, and ultimately determined the large number of individual trials provided for each subject. This was in marked contrast to the ten trials given subjects in the Davol et al. (1977) study. By the time training was finished in the present experiment, 1:9 was the least number of trials given to any bird (P-1739 & P-1919), while one subject (P-1923) had as
many as 324 trials in Phase 8 alone.

Number of magazine training trials was related to the effectiveness of autoshaping in an earlier study by Steinhauer, Davol, and Lee (1976). They found an inverse relation between the number of autoshaping trials preceding the first key peck and the degree of hopper training when subjects were provided 0, 3, 10, or 25 magazine trials. With a larger number of training trials (1, 10, 100, or 1000), Downing and Neuringer (1976) found that a U-shaped curve best fit the relation between the first autoshaped response and degree of magazine training. The same relation found by Steinhauer et al. held for subjects with up to 100 training trials, but a steep decline was seen in autoshaping efficacy after 1000 trials. Neither of these studies used a darkened food-hopper, which according to Davol et al. (1977) would have lessened the possibility for autoshaping.

Table 2 presents the summary data for this experiment. Subjects with approximately 100 Phase 8 trials (P-1739 & P-1919) required an average of 44.5 autoshaping trials, many more than was needed for the Downing and Neuringer birds with comparable histories. Eight subjects showed a wide range of autoshaping trials preceding the first peck when given approximately 200 training trials (P-1946: trial 1 after 252 training trials vs. P-3176: trial 102 after 198 training trials). The average was near the same 45-trial range as with the 100-trial birds. P-1923 (324 training trials) was the only bird not to peck during the autoshaping test. It was observed to be under the strong control of stimuli arising from the hopper delivery mechanism, and was later discontinued from further research due to problems in accomplishing key peck shaping.

Five subjects (P-1919, P-1929, P-1946, P-6400, & P-6840) required
fewer than five sessions to provide evidence for autoshaping. P-4973 and P-3277 also provided early evidence, but completed the full 250 trials regardless. These seven birds all demonstrated consistent responding to the stimulus key after the initial key peck. Pigeons 1739, 3176, and 4953 did not peck the stimulus key consistently, although they all produced an initial key peck, two of which were in the first session.

The results of Experiment 1 suggest that autoshaped key pecking is

Table 2
Results of Experiment 1
(See Text for a Description of the Autoshaping Test)

<table>
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<tr>
<th>Pigeon</th>
<th>Phase 8 Trials</th>
<th>Trial of 1st Peck</th>
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<th>% Trials w/Rsp. after 1st Peck</th>
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<td>250</td>
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<td>43</td>
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</table>

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not simply a matter of hopper-light presence alone. This supports the findings of Downing and Neuringer (1976) in that autoshaping success appeared to be partially determined by the degree of magazine training. Only subjects with little training have shown poor autoshaping when a hopper light was not used (Davol et al., 1977; Steinhauer, 1982; Steinhauer et al., 1976). When magazine training has been more thorough, autoshaping is likely both with (Downing & Neuringer, 1976) and without the hopper light (present study, all but P-1739, P-1923, P-3176, & P-4953). Extreme degrees of magazine training appear to conflict with effective autoshaping (Downing & Neuringer, 1976; present study, P-1923). A reasonable conclusion might be that hopper-light presence improves the chances for successful autoshaping when relatively weak magazine training has occurred, but its effects are attenuated as hopper training is made more complete. This interpretation is not inconsistent with a stimulus-similarity interpretation of initial autoshaped key pecking, but rather extends it by noting the relevance of a second variable, namely, degree of magazine training.
EXPERIMENT 2

Three birds that failed to show consistent key pecking during Experiment 1's autoshaping test were used as subjects in the second experiment. After being hand-shaped to peck the center key for grain delivery from the unlighted food hopper, these pigeons were exposed to a discrimination training regimen which gradually adapted them to the two-key discrete-trial multiple schedule used by Hesse (1984). The remainder of Experiment 2 duplicated Hesse's manipulations with fixed-ratio schedules, while continuing to assess stimulus-reinforcer contributions via initial latency trial responses to the stimulus key. The hopper light remained off through all phases of this experiment. Of principal interest was the extent of stimulus-key responding under such conditions. If there was relatively little stimulus-key responding, then how were the latencies to the constant key affected by the different ratio sizes, and how did such effects differ from those obtained by Hesse?

Method

Subjects and Apparatus

Three pigeons that failed to respond consistently during the autoshaping test of Experiment 1 (P-1739, P-3176, and P-4953) were maintained as previously described. The apparatus used was identical to that of the former experiment.
Procedure

As with Experiment 1 the hopper light remained off during the three phases of this experiment. The houselight, however, was turned off during occasional periods of nonreinforcement in the multiple schedule, as described below.

Hand Shaping

Only the center key, constantly illuminated by white light, was functional during this phase. For each response approximation to pecking this key, 4-sec reinforcement was delivered by the experimenter using a remote control switch. Reinforcement was delivered automatically when key pecks were produced by the subject with a force greater than .2N. Subjects were moved to the discrimination training procedure when they were consistently pecking the lighted key.

Discrimination Training

Table 3 shows the conditions to which pigeons were exposed during this training, which involved a gradual transition from the hand-shaping program up to the discrete-trial multiple fixed-ratio baseline. Phase 1 added trials to the preceding free-operant shaping schedule. Each trial was separated by a 10 sec ITI, during which responses had no effects on the programmed contingencies. The center key was not illuminated until after the ITI had timed-out. The ratio requirement remained at one (CRF), and a 5-sec limited hold was included. Duration of reinforcement was reduced to 3 sec. If the subject did not respond during the limited hold, the key light
Table 3  
Discrimination Training  
(See Text for a Description of the Conditions)

<table>
<thead>
<tr>
<th>Phase</th>
<th>#Trials</th>
<th>ITI</th>
<th>C-Key&lt;sup&gt;a&lt;/sup&gt;</th>
<th>S-Key&lt;sup&gt;b&lt;/sup&gt;</th>
<th>DRO</th>
<th>FR</th>
<th>LH</th>
<th>S&lt;sup&gt;R&lt;/sup&gt;(Dur)</th>
<th>P(S&lt;sup&gt;R&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>72</td>
<td>10&quot;</td>
<td>Off</td>
<td>On</td>
<td>No</td>
<td>1</td>
<td>5&quot;</td>
<td>3&quot;</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>72</td>
<td>10&quot;</td>
<td>Off</td>
<td>On</td>
<td>No</td>
<td>1</td>
<td>5&quot;</td>
<td>3&quot;</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>72</td>
<td>5&quot;</td>
<td>Off</td>
<td>On</td>
<td>Yes</td>
<td>3</td>
<td>10&quot;</td>
<td>2&quot;</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>5&quot;</td>
<td>On&lt;sup&gt;c&lt;/sup&gt;</td>
<td>On&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Yes</td>
<td>3</td>
<td>30&quot;</td>
<td>3&quot;</td>
<td>100</td>
</tr>
</tbody>
</table>

<sup>a</sup>Constant key  
<sup>b</sup>Stimulus key  
<sup>c</sup>White  
<sup>d</sup>Red or green, according to trial onset

was turned off and a new ITI was started. These sessions were terminated after the delivery of 72 reinforcements.

Phase 2 modifications increased the response requirement to three (FR 3), and stretched the limited hold period to 10 sec. In Phase 3, the ITI was reduced to 5 sec and a DRO contingency was established for key pecks during this period (i.e., the ITI timer was restarted if a response occurred during the 5 sec). This meant that key light onset was delayed until 5 sec had elapsed without a response, a contingency which remained in effect through the duration of the experiment. Reinforcement was reduced to 2 sec during this phase.
Phase 4 involved adding a second key, according to the two-key procedure used by Hesse (1984). The center key was now constantly illuminated by white light, and served as the response key (constant key) for meeting the ratio requirement. Trial onset was marked by onset of a second key (stimulus key) located to the left of the constant key. On a random basis, either a red or green stimulus transilluminated this key after the ITI timed-out. This stimulus was terminated upon delivery of reinforcement, now increased to 3 sec duration. The limited hold was increased to 30 sec, where it remained for the duration of the experiment. Phase 4 terminated after 50 reinforcements.

Sessions averaged 25 minutes in length. Subjects were changed to the next phase when they consistently pecked the appropriate key, and their performance was judged to be adequate by the experimenter. All pigeons were exposed to Phase 4 until median response latencies across sessions stabilized.

Multiple Schedules of Fixed-Ratio Reinforcement

This part of Experiment 2 contained two phases during which the ratio requirement for each of the multiple schedule components was manipulated. The general procedure followed that used in Phase 4 discrimination training and is diagrammed below in Figure 2. Two changes included raising the number of trials to include 72 latency responses, and changing the probability of reinforcement to 0.9. During the 10 percent of trials when delivery of reinforcement was not scheduled to occur, all lights in the experimental chamber were darkened for a period of 0.5 sec. Another change involved reducing the reinforcement duration to 2 sec.
Figure 2. State Diagram for the Discrete-Trial Multiple Schedule of Experiment 2.
Phase 1 involved between-session differences in fixed-ratio size, with equivalent ratios being used for the two schedule components. Ratio requirements were gradually increased by three responses each time the median latencies appeared to be stable for a period of five sessions. This arrangement duplicated the histories of Hesse's (1984) subjects, half of which followed a similar plan in order to assess stimulus- and constant-key pecking as ratio requirements were progressively raised for both components simultaneously.

Phase 2 involved within-session differences in fixed-ratio size, with different ratios being used for each of the schedule components. This manipulation involved contrasting the two components by dropping one of the ratio requirements, either red or green, to FR 3 (the "favorable" component) while maintaining the other component at a higher ratio (the "unfavorable" component). The purpose here was to observe variations in the relative frequency of initial stimulus-key pecks as latency separations were obtained on the constant key. The proportion of stimulus-key pecks that occurred prior to response-key pecks, and the latencies to the constant key were the primary dependent variables for this experiment.

Results

Hand shaping and discrimination training proceeded rapidly for each of the three subjects. Only P-4953 (4 sessions) required more than one day of shaping. Discrimination training required one or two sessions for each of the first three phases. Subjects spent an average of 5 days in Phase 4.

Each subject progressed to a different level of equivalent ratio requirements in the first phase of the discrete-trial procedure. Pigeon-4953 stopped
increasing after reaching Mult FR 12, FR 12 (82 sessions), P-1739 was raised to Mult FR 15, FR 15 (114 sessions), and P-3176 reached Mult FR 9, FR 9 (121 sessions). As with the studies of Hesse (1984) and Schlinger (1985) there was almost no stimulus-key pecking during this baseline training. After this point each schedule was altered to give two different multiple schedule components, one favorable and the other unfavorable. Ratios were reversed for the components after latency separations were obtained.

Figure 3 displays median constant-key latencies and the relative frequency of initial stimulus-key responding for pigeon 4953. When the red ratio was lowered from 12 to 3 after baseline, median latencies shortened in both components (a relation of positive contrast). After nine sessions, latencies in the favorable component continued to shorten, while latencies in the unfavorable component began to increase. Latencies in this component were highly variable throughout, perhaps contributing to the convergence of median latencies during the middle portion of this condition (session 37).

When ratio requirements were reversed, both median latencies again declined, but there was no consistent relation to the ratio requirements until that for the unfavorable component was further decreased to a value of 18. Median latencies in the favorable component then followed a relatively stable decline while unfavorable component latencies increased and showed high variability. A brief convergence of latencies also occurred midway through this phase before latencies again separated.

The bottom portion of Figure 3 depicts the relative frequency of initial stimulus-key responding. In sharp contrast to the Hesse (1984) results, this value never exceeded 20%. More typically, values less than 5% were noted. When differences were observed, proportions were only slightly higher for
Figure 3. Median Constant-Key Latencies and Proportion of Initial Stimulus-Key Responding for P-4953.
the favorable ratio component.

Figure 4 displays similar results for pigeon 1739. Latencies for the FR 3 components were always longer than those for the FR 15 baseline. Obtaining good latency separations was also difficult with this bird. The unfavorable ratio requirement had to be raised twice in order to achieve the desired result. When the ratio was first lowered from 15 to 3 in the red component, latency values were not appreciably affected. After 9 sessions the expected latency relations were seen, but only for a period of ten days. Median latencies in the unfavorable component then declined rapidly, while those in the favorable component increased. This trend continued until latencies were separated in a direction opposite to that expected.

Increasing the unfavorable component to FR 18 at first increased the latencies for this component, without affecting favorable-component latencies. But a return to levels of the previous condition was noted after only six sessions. A further increase to FR 24 boosted the unfavorable latencies above those for the FR 3 component for a period of 11 days. Again, effects were not found in the favorable component. Throughout these changes to the green schedule component, a high degree of latency variability was noted.

When ratio requirements were reversed between the two colors, latency separations switched after 9 sessions. Median latencies to the unfavorable component increased to their highest levels, while exhibiting the same high variability seen in other less favorable components. Meanwhile latencies in the FR 3 component declined to a lower point than found in the favorable component of the prior condition. This separation was maintained for a period of 11 days.
Figure 4. Median Constant-Key Latencies and Proportion of Initial Stimulus-Key Responding for P-1739.
As with P-4953, relative frequency of initial stimulus-key pecking always remained below 20% for this subject. During periods of latency separations in the expected direction, slightly more stimulus-key responding was seen overall. This responding was typically greater for the relatively better schedule component.

Similar difficulty in achieving latency separations and reversals was found with P-3176. Figure 5 displays the relevant data. When the FR 3 ratio change was initially made for the green component, median latencies declined for both schedules (positive contrast). These became more variable as this condition progressed, and opposite kinds of latency relations were ultimately seen. When the unfavorable ratio requirement was increased to FR 15, latencies for the favorable component remained unchanged, while unfavorable component latencies increased both in duration and in variability. This separation was quickly obtained, and lasted for a period of 12 days.

Reversal of these ratio requirements initially produced declines in the median latencies for both components. After three sessions these began to rise and then stabilize. For the favorable component, latencies were nearly the same as with the prior FR 3 component. Latencies for the unfavorable component, however, maintained their shorter position relative to the previously favorable color. This relation was reversed when the unfavorable component was further increased to FR 21. Favorable component latencies maintained their relatively stable values, while those for the unfavorable component quickly increased in duration and variability. This separation held for 10 days.

Figure 5 also depicts the proportion of trials for which the first response
Figure 5. Median Constant-Key Latencies and Proportion of Initial Stimulus-Key Responding for P-3176.
of the trial was to the stimulus key. This was again minimal (less than 30%), but higher for the favorable component during conditions of separation. In fact, as reported by Schlinger (1985), initial stimulus-key pecking was obtained when clear latency separations were lacking.

Discussion

Constant-Key Pecking

The results showed median response latency on the constant key to be sensitive to operant control. Response latency varied directly with ratio size: latencies shortened for small ratios, and lengthened for high ratios. Although the short latencies were similar to those reported in other studies using the two-key procedure (Hesse, 1984; Schlinger, 1985), they were longer than those reported with a one-key procedure (Hesse et al., 1984; Nuzzo, 1984).

One could presume that the present study's minimizing of stimulus-reinforcer contributions would further improve median latencies in the favorable component. This might seem reasonable considering that Hesse's subjects required more time to peck the constant-key due to their abundant stimulus-key pecking in the favorable component. But it is possible that latency values similar to those found with single-key procedures may never be seen with a two-key procedure. Placement of the component stimulus in a location other than that for pecking requires a separate observing response and changeover, especially when a DRO contingency is specified during the ITI. In effect this places several contingencies on the subject, which renders difficult any comparison of absolute speed of responding between these two
quite different procedures.

Direct observation of subjects indicated that other variables may as well be contributing to the relatively slow favorable-component latencies. When using a darkened food magazine, pigeons were found to engage in significant observing behavior with respect to the grain hopper. This became more pronounced as reinforcement delivery approached. When the ratio was small, this observing behavior may have interfered with the speed of responding to the constant key. In fact subjects responding during the favorable component were observed to make several motions between the hopper and constant key throughout the trial. Competition with constant-key pecking, especially if it occurred at trial onset, might well have confounded the latency measure. This raises the possibility for improving discriminative stimuli during the reinforcement period in any later application of the darkened hopper methodology.

Such interference was not the case for the longer latencies of the unfavorable components. Subjects in these instances, after making an observing response to the stimulus key, were often observed to engage in interim behavior. This included turning away from the intelligence panel, pacing through the chamber, pecking the walls, grooming, and wing-flapping. At times this adjunctive behavior lasted long enough to interfere with completion of the ratio before the 30-sec limited-hold contingency timed-out. In such cases reinforcement was ultimately withheld, making it likely that weaker behavior (and longer latencies) should be the expected result. Thus, longer median latencies in the unfavorable components were probably a complex function of several variables, rather than a direct indication of simple operant response strength.
The observing behavior described above is consistent with some statements formulated by Brown and Jenkins (1968), Hesse (1984), and Williams and Heyneman (1981). Furthermore, the interim behavior that was observed when high ratios were in effect is consistent with the pre-ratio pause findings as they relate to the response requirement in fixed-ratio schedules; i.e., the pre-ratio pause increases as the number of responses to complete the ratio is increased (cf. Crossman, Heaps, Nunes, & Alferink, 1974; Felton & Lyon, 1966; Ferster & Skinner, 1957; Powell, 1968).

**Stimulus-Key Pecking**

The results of the present experiment showed that stimulus-key pecking could be significantly reduced by selecting pigeons that were not likely to autoshape, and by eliminating the pairing of stimuli similar to the manipulandum (constant key) and to the reinforcement (grain hopper). The data are consistent with those of previous studies which also found low rates of stimulus-key pecking (Schwartz, Hamilton, & Silberberg, 1975; White & Braunstein, 1979; Williams & Heyneman, 1981).

The data showed that stimulus-key responding was somewhat more likely to occur to the stimulus correlated with the more favorable component, although not to any great extent. Perhaps as has been previously suggested (Hesse, 1984; Schlinger, 1985), this represents the contribution of operant conditioned reinforcement for stimulus-key pecking. In the case of the favorable component, any initial pecks to the stimulus-key would be rather quickly followed by stimuli arising from pecks to the constant key and then by ensuing reinforcement. Initial stimulus-key pecks in the unfavorable component are not likely to be followed by these sources of conditioned reinforcement,
as demonstrated by the interim behavior and/or pausing which seems to dominate the early portions of such trials.

An alternative explanation is that the darkened hopper procedure was not completely effective in eliminating stimulus-reinforcer effects. The failure to replicate Davol's et al. (1977) findings in Experiment 1 contribute to the validity of this explanation. However, that initial stimulus-key responding was reduced as much as it was gives sufficient evidence to recommend the further use of this technique. It may be possible to refine the procedure in such a way as to further eliminate the contribution of stimulus-reinforcer effects.
CONCLUSION

Experiment 1 was a systematic replication of the study of Davol et al., (1977), but with a behavioral criterion for terminating magazine training, an automaintenance rather than an autoshaping procedure, and a somewhat larger number of stimulus-reinforcer pairings. Under these conditions only one bird failed to peck the key during the autoshaping test, and seven of the birds showed fairly consistent key pecking. Three of the birds pecked but only a few times. It can be concluded, therefore, that a lighted hopper is not as essential for the development of autoshaped pecking as Davol et al. claimed. However, the present findings would seem to confirm the fact that a lighted hopper facilitates the occurrence of autoshaped responding, since, as with the Davol et al. study, there was considerably less such responding than is usually seen when a lighted hopper is used.

Experiment 2 replicated the Hesse (1984) two-key latency procedure but using three subjects of Experiment 1 that had shown very little key pecking during the autoshaping test. The main findings were that (1) they did not develop much more stimulus-key pecking during the extensive training of the latency experiment, and (2) latency separations related to the different ratio requirements were obtained as in the Hesse study. Thus working with a darkened hopper seems to make it possible to study operant latencies without the confound of autoshaped responses to the stimulus key. However, the birds showed a good deal of observing behavior directed at the unlighted hopper, especially during the favorable stimulus condition. This represents still another type of confound in efforts to measure

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operant latencies.
BIBLIOGRAPHY


