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Response Acquisition with Delayed Reinforcement in the Presence of an Irrelevant Operandum

DISSERTATION

Submitted to the Eberly College of Arts and Sciences

of

West Virginia University
In Partial Fulfillment of the Requirements for
the Degree of Doctor of Philosophy in Psychology

by
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1996

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Response acquisition with delayed reinforcement in the presence of an irrelevant operandum

The focus of behavior analysis is the evaluation of behavior-environment interactions. Primary among the events in the environment that affect behavior are those labelled by Thorndike (1911) as satisfiers and annoyers. Although the original labels have been replaced by ones more appropriate to a functional analysis of behavior, the Law of Effect remains central in behavior analytic interpretations of learning. Experimenters since Thorndike have found that not only is behavior controlled generally by the reinforcing or punishing aspects of environmental consequences, but more precisely by consequence characteristics such as their frequency, duration, intensity, and their relation to the response.

Studies of the relation between consequences and responses include those that measure the effects of changes in the temporal contiguity between responses and reinforcers. Hull (1932) proposed that responses are conditioned most strongly to stimuli present at the time of the response, and the more removed the stimuli are in time or space from the response the weaker the conditioning. Response rates generally decrease as a function of increases in the delay to reinforcement (Zeiler, 1977), demonstrating the value of maintaining a close temporal relation between responses and reinforcers. Although lower response rates usually occur in the presence of delayed reinforcement than when reinforcers are delivered immediately, responding generally is maintained by both procedures. This may be due to the maintenance of the contingent relation, or positive correlation, between responses and reinforcers.

Another explanation for the maintenance of responding observed in the presence of delayed reinforcement is that often these experiments were conducted without the actual presence of a degraded temporal relation between behavior and its consequences. For example, in many early studies of responding under delayed reinforcement, an exteroceptive stimulus that occurred simultaneously with the delay was dependent on the response that started the delay period. Although primary reinforcement was delayed in this situation, it was suggested that stimulus changes preceding reinforcer delivery maintained responding through their reliable and immediate pairing with reinforcement. Thus, such stimulus changes acquired reinforcing properties. These stimuli were termed secondary or conditioned reinforcers. Spence (1947) and Grice (1948) concluded that conditioned reinforcers make learning possible in delayed reinforcement procedures, implying that maintenance of temporal contiguity between a response and its (in the present case, secondary or conditioned) consequences is needed to ensure responding.

Even in the absence of an explicit stimulus change that serves as a conditioned reinforcer, other more subtle stimuli may be present or there may be other variables in the experimental situation that maintain responding in delayed reinforcement experiments aside from the contingency. In experiments involving delayed reinforcement, responding typically is trained with immediate reinforcement before delays are introduced (Lattal & Gleeson, 1990). The effects of delayed reinforcement then may be confounded with the effects of a history of immediate reinforcement. Another way to study the effects on responding of delayed reinforcement is to study such effects on response acquisition. Then, the influence of prior experience with immediate reinforcement can be eliminated because responses are acquired as well as maintained with delayed reinforcement.

Delays between responses and reinforcers traditionally have been found to retard the acquisition of responding (Renner, 1964), but many of the early experiments on this problem involved complications similar to the ones described previously. For example, Harker (1956), Logan (1952), and Seward and Weldon (1953) purportedly demonstrated response acquisition using delayed reinforcement in the absence of an explicit stimulus signalling the delay. However, each of these experiments involved a brief immediate stimulus change following a response that was perfectly correlated with reinforcement or a procedure that otherwise elicited responding or provided immediate reinforcement. The notion that conditioned reinforcers are necessary for behavior in the presence of delayed reinforcement was not ruled out in these experiments, so the premise that the delayed reinforcement contingency primarily accounted for acquisition was not supported.

Contrary to these early findings concerning delayed reinforcement and Spence's and Grice's conclusions, several recent experiments (e.g., Critchfield & Lattal, 1993; Lattal & Gleeson, 1990; Lattal & Metzger, 1994; Lattal & Williams, 1996; Wilkenfield, Nickel, Blakely, & Poling, 1992) have shown that responding can be established with delays to reinforcement in the absence of stimulus changes that function as conditioned reinforcers. Such results suggest that immediate consequences for responding are not necessary for the acquisition of new behavior. These and similar studies of response acquisition with delayed reinforcement have minimized the influence of conditioned reinforcers while prohibiting the exposure of subjects to procedures involving immediate reinforcement before reinforcer delays were introduced. Such experimental procedures permit us to address more specifically the limitations of the control of responding by delayed reinforcement, as well as the possibility that immediate response-reinforcer contiguity is not essential for conditioning. However, other variables operating when delayed reinforcement contingencies are effected continue to be analyzed.

In the conventional experimental situation, one operandum is available and responding on that operandum is reinforced according to the schedule in effect. A problem with this procedure is that, with only one response being measured, it may be difficult to isolate multiple determinants of responding. For example, responding may be determined not only by the delayed reinforcement contingency but also may be elicited by the food delivery per se, and when only one operandum is available the recorded responses may be erroneously attributed to one or the other of these potential controlling variables. Changing the procedure to include two operanda may allow a clearer separation of responses controlled by the delayed consequences from those elicited or induced by food delivery.

The present experiments extended the analysis of response acquisition with delayed reinforcement using a two-operandum procedure. In each condition, one of the two operanda was irrelevant and responding on the other produced each reinforcer only after an unsignalled, resetting delay. In the following literature review some of the prior findings concerning response acquisition with delayed reinforcement are examined. Then, other possible sources of control of responses observed in the presence of delayed reinforcement are addressed.

Literature Review

Early investigations led to conclusions that delayed reinforcement increased time, errors, and the number of trials required to learn a task relative to immediate reinforcement. Furthermore, responses that were immediately reinforced were "chosen" over responses that led to delayed reinforcement (Chung, 1965; Renner, 1964). Now it is recognized that close temporal contiguity between responses and reinforcers enhances response rates but is not necessary for response acquisition and maintenance. There is substantial evidence that responding can be maintained under conditions involving unsignalled delays to reinforcement and acquired using these procedures without specific response shaping (e.g., Critchfield & Lattal, 1993; Lattal & Gleeson, 1990; Wilkenfield et al., 1992), even when magazine training is omitted (Lattal & Williams, 1996). Such findings with delayed reinforcement bear directly on theoretical accounts of reinforcement regarding the roles of response-reinforcer temporal contiguity and response-reinforcer contingency in operant response acquisition and serve as the starting point for the present analysis.

Acquisition of Responding with Delayed Reinforcement

Skinner (1953) observed that "the reinforcement which develops skill must be *immediate*. Otherwise the precision of the differential effect is lost" (p. 96, emphasis his). Several recent experiments suggest that Skinner's observation must be qualified. For example, Lattal and Gleeson (1990) demonstrated response acquisition by rats and pigeons in the presence of delayed reinforcement. Subjects first were trained to eat from the food magazine and then were exposed to response-dependent, but delayed, reinforcement. Under a variety of conditions, subjects exposed to delayed reinforcement schedules acquired the operant response without explicit training and in the absence of any immediate consequences that served to signal or otherwise mediate the delay intervals, that ranged from 5 to 30 s in separate experiments.

In Lattal and Gleeson's experiments, procedural and environmental variables that could have accounted for responding apart from the delayed reinforcement contingency were ruled out through various control procedures. One possibility, that responding was adventitiously reinforced, was precluded because a resetting delay ensured that there always was a minimum amount of time separating a response and the subsequent reinforcer. Lattal and Gleeson ruled out the possibility that response acquisition was due to the simple passage of time when an operandum was provided in the absence of reinforcement and very little responding occurred. In addition, using rats, two different response topographies were measured and found not to differentially affect acquisition. Response acquisition with delayed reinforcement was found not to be species-specific because rats and pigeons both responded in the situations under investigation. Finally, induction effects were comprehensively examined and their role in the acquisition of responding was discounted. The specific steps that Lattal and Gleeson took to identify and measure the occurrence of induced responses will be described in a section devoted to the role of such responses in delayed reinforcement experiments.

Wilkenfield et al. (1992) replicated and extended Lattal and Gleeson's findings on response acquisition by comparing the effects of resetting and non-resetting delayed reinforcement procedures with those of a stacked-delay procedure. Wilkenfield et al. trained rats to consume pellets delivered into a food magazine and then exposed them to one of the following schedules: tandem fixed-ratio (FR) 1 fixed-time (FT) t-s (non-resetting delay condition), tandem FR 1 differential-reinforcement-of-other behavior (DRO) t-s (resetting delay), or tandem FR 1 FT t-s (stacked delay). The delay intervals measured were 0, 4, 8, and 16 s. The effects of a 32-s delay interval were measured using subjects in the resetting delay group. The behavior of subjects in each condition was compared to the behavior of subjects that were exposed to extinction or immediate reinforcement in two control conditions. In all conditions except extinction, responses on one of two bars were reinforced, with responses on the second bar having no consequence.

The only difference between the schedules that reinforced the behavior of subjects in the different groups in Wilkenfield et al.'s experiment was the consequence for responding during the delays. The resetting delay procedure ensured that there always was a period of time separating a response and the reinforcer it produced. Responses that occurred during the delay simply reset the delay timer. This was the same type of schedule used by Lattal and Gleeson (1990) in their experiments. In the non-resetting delay procedure, responses that occurred during the delay had no effect on subsequent reinforcer delivery. Theoretically, such responses could occur closely in time to reinforcer delivery, thus maintaining the temporal relation between responses and reinforcers (Lattal & Gleeson, 1990). In the stacked delay procedure used by Wilkenfield et al., each response initiated a delay interval that always resulted in reinforcer delivery after a specified time. This procedure ensured that each response was directly correlated with reinforcement, which was not the case in the other procedures where often there were several responses during the delay that never actually produced reinforcement.

Wilkenfield et al. measured the effects of the different delay procedures on responding to determine if maintaining a perfect correlation between responses and reinforcers by using the stacked delay procedure permitted better control of responding by the delayed reinforcement contingency, as measured by speed of acquisition, than in the other procedures. They found that response rates and the speed of acquisition (that is, the time it took for responding to occur at higher rates than were produced by subjects undergoing extinction) under the stacked delay procedure were comparable to the results obtained with the non-resetting delay procedure. However, reinforcement rates in the stacked delay group were slightly higher than those of subjects responding under the other procedures.

Wilkenfield et al. observed that responses were acquired and maintained by all subjects (except those undergoing extinction), but the response rates and the speed of acquisition for some subjects in the resetting delay group were lower than in the non-resetting or stacked delay groups. This latter result may be because obtained delays were shorter than the programmed delays and thus closer temporal contiguity between responses and reinforcers occurred for the other groups than for the group exposed to the resetting delay procedure. In addition, pausing likely was being reinforced due to the nature of the resetting delay procedure, and this may have led to slower response acquisition by some of the subjects in the resetting delay group. Overall, the speed of acquisition under the delay conditions for the subjects in all groups except for the resetting delay group at the longest delay values (i.e., 16 and 32 s) did not differ significantly from those of the control group subjects whose responding was immediately reinforced.

Although reinforcers always were delayed in their experiments, the procedures used by Lattal and Gleeson and Wilkenfield et al. involved the use of operanda that resulted in the click of a microswitch when a response occurred. The noise that was paired with each instance of responding was correlated with reinforcement and thus may have served as a conditioned reinforcer that helped maintain responding, in addition to the delayed reinforcement contingency. Critchfield and Lattal (1993) measured the effects of an audible conditioned reinforcer while examining response acquisition with delayed reinforcement when the response consisted of breaking a photocell beam near the rear wall of a rat chamber. A resetting delay procedure similar to that used by Lattal and Gleeson (1990) was in effect, meaning responses were not trained and reinforcers always were preceded by a delay. In the first experiment, subjects in one group experienced a tone following responses that initiated delays to reinforcement. Subjects in a second group were provided with no audible feedback for responding. Subjects in both groups acquired the photocell beam-breaking response, although response acquisition was facilitated in the presence of the audible stimulus. Specifically, subjects that experienced the audible feedback following responses exhibited faster response acquisition and required fewer sessions until responding was stable, while experiencing a greater rate of reinforcement than subjects responding in the absence of the tone.

In a second experiment, Critchfield and Lattal examined the possibility that responding was a function of the passage of time and experience with the chamber as well as the possibility that the tone had elicited responding in the previous experiment. The tone was presented as in the first experiment, but no food was delivered at the end of the delay intervals. The results from this condition were compared with those from the following condition, where the tone again was presented after responses that initiated resetting delays and food was delivered at the conclusion of the delay intervals. Responding seldom occurred in the first condition, when the tone was present but food was not delivered, yet subjects reliably responded when the delayed reinforcement schedule was in effect in the second condition. The results of these two experiments demonstrated that neither the presence of a mechanically defined response operandum nor an immediate external stimulus change was sufficient to explain response conditioning, suggesting that the delayed reinforcement schedule predominately accounted for responding.

Critchfield and Lattal (1993) measured and controlled for two factors that could possibly account for responding in delayed reinforcement experiments: the elicitation of responses by an operandum and the conditioned reinforcement of responding by a stimulus correlated with operandum operation and therefore food delivery. Although they found that neither of these variables appeared to supplant control of responding by the delayed reinforcement contingency, the possibility still remains that the delivery of reinforcers induces responses and partially contributes to the responding observed under schedules where relatively long delays to reinforcement are imposed. Lattal and Gleeson (1990) measured the occurrence of induced responses, by measuring responding during response-independent reinforcer delivery and extinction, but their analysis may have been restricted by the availability of a single operandum. In other words, induced responses may have occurred on the available operandum but were indiscriminable from operant responses. The possibility remains that induction may affect responding in delayed reinforcement experiments, therefore its role in such experiments must be considered.

Food-Induced Responding and Delayed Reinforcement

The role of responses induced by the delivery of food in delayed reinforcement procedures is of interest because the fundamental question in any reinforcement procedure, including delayed reinforcement, is to what degree responding is controlled by the dependent relation between the response and reinforcer and to what degree responding occurs for other reasons, such as the presentation of food (Segal, 1972). The fact that response rates in delayed reinforcement procedures are low begs the question of to what extent responses are due to such an induction process rather than being controlled directly by the response-reinforcer relation.

One of the aspects of the delayed reinforcement procedure that Lattal and Gleeson (1990) addressed was the role of food-induced responding in response acquisition with delayed reinforcement. Lattal and Gleeson used several techniques and arguments to isolate induction effects from those of delayed reinforcement contingencies in maintaining responding. In one procedure, a variable-time (VT) schedule of reinforcement for one group of subjects was yoked to the delayed reinforcement schedule controlling responding of another group of subjects. The rate of reinforcement was equated between the groups, but responding was not maintained in the VT condition. The maintenance of responding only in the group of subjects for whom reinforcers were delivered dependent on responding made the potential inductive effects of reinforcement unlikely as a sole explanation for responding under the delayed reinforcement schedule.

A second procedure used by Lattal and Gleeson (1990) that was designed to minimize induction effects involved moving the response bar away from the food tray, so that responses were less likely to be induced by reinforcer delivery. As before, induction was assumed to have little effect on responding when responses occurred irrespective of the proximity of the operandum to the food magazine. Also, elicitation due to the presence of the operandum was believed to have little effect on responding because subjects exposed to an extinction condition responded on the available operandum only rarely. Finally, the role of induction was minimized in Lattal and Gleeson's experiments simply because the first response occurred from several minutes to many hours following food presentations during magazine training. If induction brought on by food delivery had played a role in response acquisition, Lattal and Gleeson reasoned, the first response in each experiment should have occurred closer in time to the reinforcer presentations during food magazine training.

On the basis of the aforementioned evidence, Lattal and Gleeson concluded that induction was not a significant variable relative to the contingency in establishing behavior with delayed reinforcement. Despite their arguments, however, a case still might be made for food-induced responding in the presence of delayed reinforcement. In Lattal and Gleeson's experiments, only a single operandum was available. Therefore, all responses that were measured in the presence of response-dependent reinforcer delivery, whether they were induced or operant, occurred in the same form and location. In this situation, any responses that were induced by reinforcer delivery could not have been identified as such. As a result, all responses were considered to be operant responses. It also is possible that, while it prevented the adventitious reinforcement of responding, the resetting delay contingency caused induced responses that occurred during delays to reinforcement to be punished (along with operant responses) by resetting the delay intervals and thus lowering the overall reinforcement rate. Therefore, it may be that the lack of an irrelevant operandum affected the detection as well as the occurrence of induced responses in Lattal and Gleeson's experiments.

Due to these potential problems with the measurement of induced responses in the presence of a single operandum, a second operandum might be useful in distinguishing food-induced from operant responses during response acquisition with delayed reinforcement. In the experiments by Wilkenfield et al. (1992) and Critchfield and Lattal (1993), an operandum uncorrelated with the reinforcement schedule was available. In the resetting delay condition of the experiment by Wilkenfield et al., responding on the irrelevant operandum often equalled or exceeded reinforced responding. The irrelevant operandum responses in Wilkenfield et al.'s experiment may have been induced or adventitiously reinforced. Induction may have occurred as a result of food delivery, while adventitious reinforcement may have controlled irrelevant operandum responses since there was no resetting delay contingency for responding on that operandum. Thus, there was no way to preclude close temporal contiguity between irrelevant operandum responses and the delivery of reinforcers occurring at the end of delay intervals that were initiated by responses on the relevant operandum.

In contrast to the results of Wilkenfield et al. (1992), Critchfield and Lattal (1993) found that responses on the irrelevant operandum occurred rarely or not at all, even though their's also was a resetting delay procedure. The responses on the relevant operandum in the Wilkenfield et al. experiment presumably were operant responses that were controlled by the delayed reinforcement schedule, but responses on the irrelevant operandum may have been either adventitiously reinforced or induced as a result of food delivery. Critchfield and Lattal observed few responses on the irrelevant operandum, but subjects engaged in responses that were similar in appearance to the reinforced photocell beam-breaking response in different areas of the chamber. Although these latter responses only were anecdotally reported, they also may have been food-induced or adventitiously reinforced. Due to the relative lack of information about the variables responsible for responding on irrelevant operanda and the different situations under which this type of responding occurs, it seems useful to consider results from experiments using irrelevant operanda in the presence of schedules of immediate reinforcement.

Irrelevant Operandum Responses and Delayed Reinforcement

The presence of an irrelevant operandum has been shown to affect responding under schedules of immediate reinforcement that require subjects to engage in low-rate or pausing behavior. Schwartz and Williams (1971) examined the influence of an irrelevant operandum (a response key) on differential-reinforcement-of-low rate (DRL) schedule responding in pigeons. The subjects first were trained on a DRL 6-s schedule using a discrete trials procedure. During the first condition of the experiment, if no response occurred for 6 s following the trial onset, the first response after this interval was reinforced. If a response occurred before the 6-s interval elapsed, the keylight extinguished and the trial terminated without reinforcement. In a second condition, an irrelevant key was illuminated concurrently with the DRL key and responses on this second key were without consequence during the trial. In the first condition the subjects obtained only 4% of the available reinforcers. When the irrelevant key was added, responding on the irrelevant key increased as did the number of reinforcers obtained. Eventually the subjects obtained 70% of the available reinforcers in this second condition.

Schwartz and Williams (1971) concluded that responding on the irrelevant operandum was maintained because such responses, unlike those on the relevant operandum, did not have the adverse effect of postponing reinforcement. Other experimenters have observed the same type of behavior as did Schwartz and Williams. Bruner and Revusky (1961) found that when responding of humans on one key on a keyboard was reinforced under a DRL schedule, many responses also occurred on other, irrelevant keys. Nevin and Berryman (1963) observed responding during the delay period in a 2-key DRL procedure where a response was required on one operandum to initiate the delay interval and a response on the second operandum was reinforced at the conclusion of the delay. In this situation, irrelevant responses on the first operandum during delay intervals developed. Similarly, Laties, Weiss, Clark, and Reynolds (1965) observed tail-biting in the presence of a DRL schedule. While this behavior was not directed toward a mechanically-defined operandum, it appeared to be similar in function to that of irrelevant operandum responding in the other experiments because tail-biting reliably occurred during the delay intervals required by the schedule of reinforcement. The results from these experiments indicate that irrelevant responses, which are not directly controlled by the reinforcement schedule and may originate through induction, possibly are maintained because they allow for more efficient responding under some schedules of reinforcement, although adventitious reinforcement of irrelevant operandum responses could explain some of these results.

Based on the results concerning the use of irrelevant operanda in DRL schedules of reinforcement, it seems reasonable to conclude that irrelevant operandum responding can make reinforced responding more efficient in schedules involving the DRO contingency as well. Wilkenfield et al. (1992) suggested that the responses on the irrelevant operandum that were observed during the resetting delay condition in their experiment may have been maintained because such responding prevented the subjects from performing the reinforced response and thereby resetting the delay period. Critchfield and Lattal (1993) observed almost no responding on the irrelevant operandum in their experiments. However, the subjects performed responses similar to the reinforced response that were not controlled by the reinforcement schedule. Perhaps if the beam-breaking type responses in the different areas of the chamber had been recorded, these responses would have been found to occur to the same extent as those on the irrelevant operandum in the Wilkenfield et al. experiment.

Irrelevant operandum responding may be induced by food delivery in schedules that require pausing, such as DRO and DRL schedules. Also, induced responding may be reinforced indirectly in the presence of these schedules of reinforcement by making the reinforced response more efficient, or less likely to occur when the consequence of responding on the relevant operandum would be to decrease the rate of reinforcement. The present experiments examined response acquisition with delayed reinforcement in the presence of an irrelevant operandum. The controlling variables of responding on the relevant and irrelevant operanda were manipulated and their effects were measured to determine the situations under which food-induced and contingency-controlled responses occurred.

Statement of the Problem

Studies of response acquisition in the presence of delayed reinforcement are important for understanding the control of responding by the delayed reinforcement contingency. Several experiments involving unsignalled, resetting delay procedures have shown that responses can be acquired and maintained in the absence of temporal contiguity between responding and primary or conditioned reinforcement. However, two questions remain to be answered about the control of responding by delayed reinforcement: 1. How reliable is this control? In other words, how sensitive is behavior to the delayed reinforcement contingency? and 2. How much responding that is attributed to delayed reinforcement actually occurs for other reasons? The addition of an irrelevant operandum to the delay of reinforcement procedures described previously allows these questions about how delayed reinforcement affects responding to be answered.

First, the sensitivity of responding to delayed consequences may be revealed to the extent that responding favors the relevant operandum. Presumably, such an outcome would reflect the control of behavior by the reinforcement contingency. Higher response rates on the relevant operandum than on the irrelevant one would support the conclusions from single-operandum experiments that the delayed reinforcement contingency is sufficient to control responding. Prior experiments by Wilkenfield et al. (1992) and Critchfield and Lattal (1993) using delayed reinforcement produced different results regarding the amount of responding on the irrelevant operandum. These findings may be reconciled through new procedural variations. For instance, the development of the control of behavior by the relevant and irrelevant operanda can be measured by varying the operandum associated with the delayed reinforcement contingency. Subsequent responding can be examined to determine whether behavior changes or remains the same as the operandum correlated with the delayed reinforcement schedule changes. Higher responses rates on the operandum correlated with the delayed reinforcement schedule (i.e., the relevant operandum) regardless of its location would indicate the sensitivity of responding to the reinforcement contingencies, an aspect of the response-reinforcer relation that was not explicitly measured in the earlier experiments with two operanda.

The second question to be addressed by the inclusion of an irrelevant operandum during a delay of reinforcement preparation is that of how much responding occurs for reasons other than the delayed reinforcement schedule. One possibility is that responding is adventitiously reinforced. The adventitious reinforcement of irrelevant operandum responding can be controlled for by adding to the delayed reinforcement procedure a resetting contingency for irrelevant operandum responses that occur during delays. This would make it less likely that such responses would be adventitiously reinforced, a possible effect on responding that was not controlled for in the experiments by Critchfield and Lattal (1993) and Wilkenfield et al. (1992).

On the other hand, responding in delayed reinforcement experiments may be primarily food-induced rather than contingency-controlled. The usual account of responding maintained by delayed reinforcement on a single operandum is that responding results from the dependency between the response and reinforcer delivery. However, it may be that the single operandum masks variables controlling the behavior other than the reinforcement contingency, such as the response-inducing effects of food delivery. Lattal and Gleeson's (1990) experiments suggested that a minimal number of responses are food-induced as opposed to contingency-controlled, but a second operandum may allow induced responses to be separated from operant responses even more precisely. When one operandum is present, it is not possible to separate food-induced from operant responses. However, when two operanda are present during the acquisition of a new response with delayed reinforcement, food-induced responses should occur equally on both operanda. In addition, responses controlled by the contingency should occur exclusively on the operandum correlated with the delayed reinforcement schedule. Therefore, if both food-induced and operant responses are occurring, response rates should be higher on the operandum correlated with delayed reinforcement but responses should be observed to occur on the irrelevant operandum as well.

The question of how much responding is due to factors other than the contingency also can be addressed by examining the possibility that responses on the irrelevant operandum make reinforced responding more efficient. That is, irrelevant operandum responses may be maintained because such responding precludes the postponement of reinforcer delivery. Schwartz and Williams (1971) and others hypothesized that irrelevant operandum responses in their experiments helped maintain DRL responding by increasing the reinforcement rate over that obtained in the presence of a single operandum. Wilkenfield et al. (1992) suggested that irrelevant responses were serving this mediating function in their experiment as well, thereby preventing the postponement of reinforcer delivery during delays. Adventitious reinforcement of irrelevant operandum responses could be avoided in this situation, unlike in previous experiments, through the use of a short resetting delay. Responses on the irrelevant operandum would initiate delay intervals when reinforcer delivery was imminent only for the purpose of avoiding immediate temporal contiguity between the irrelevant operandum response and the reinforcer produced by the most recent relevant operandum response.

The present experiments examined responding in the presence of two operanda during response acquisition and maintenance with delayed reinforcement. One operandum was correlated with the reinforcement schedule, and the control of responding by the delayed reinforcement contingency was measured by varying the operandum correlated with reinforcement and observing the resulting effects on responding.

Experiment 1

The first experiment examined the contingency control of responding when there were two operanda available but responding on only one was reinforced. The location of the relevant and irrelevant operanda (correlated with reinforcement or the absence of reinforcement) was determined by the behavior of the subjects in each individual session. The effects of different delay intervals on responding also were investigated. Because the location of the relevant and irrelevant operanda could vary between sessions, the distinctions between the relevant and irrelevant operanda were expected to be diminished. Therefore, higher response rates on the relevant operandum were to serve as evidence of the control of behavior by the delayed reinforcement schedule.

Method

Subjects. Each of four experimentally naive female Wistar rats was maintained at 70% (± 2%) of its ad libitum weight. The subjects were 120 days old at the beginning of the experiment.

Apparatus. A Ralph Gerbrands Company Model G7010 rat chamber was enclosed in a sound-attenuating, ventilated enclosure. The chamber was 20.5 cm wide by 19.5 cm high by 23.5 cm long. The work panel contained two rat bars (Gerbrands Model G6312), each requiring 0.25 N to operate. The bars were equidistant from each other and 8.0 cm from the floor. A recessed feeder tray and a houselight were located on the same wall. The houselight was illuminated continuously throughout each session. Reinforcers were single 45-mg standard Noyes pellets, delivered from a Gerbrands Model G5100 feeder. Electromechanical equipment and a Tandy 286EX computer programmed using Med-PC© software was used to control the experiment from an adjacent room.

Procedure. At the beginning of the first session, each rat was placed in the illuminated chamber and a VT 30-s schedule was initiated. The time between the delivery of each food pellet and its consumption was measured. This continued until the subject consumed 20 consecutive food pellets within 2 s of delivery. The session then was terminated. In the next session the same procedure was in effect until 10 consecutive pellets were consumed within 2 s of delivery. Immediately after this criterion was met, the first session of the experiment proper began. No explicit shaping or other training of the bar-press response occurred.

In each subsequent session of the experiment, responding on the bar correlated with reinforcement (hereafter described as the relevant operandum) was correlated with a tandem VI 30-s DRO t-s scheduleinitiated an unsignalled delay according to a VI 30-s schedule. The values comprising the VI schedule were determined according to the progression described by Fleshler and Hoffman (1962). Responses on the same bar (the relevant one) during the delay reset the delay for a period that varied depending on the condition in effect. Responding on the bar that did not produce reinforcement (i.e., the irrelevant bar) had no consequence, except when responses occurred on the same bar during a delay to reinforcement. If a response occurred on this irrelevant operandum within 10 s of a scheduled reinforcer delivery (5 s in the fourth condition), the reinforcer was postponed by an additional 10 s (or 5 s as noted). As a result, responses on only one bar produced reinforcement, and responses on neither bar were contiguous with reinforcer delivery.

The length of the delay interval and the determination of the location of the relevant and irrelevant operanda were varied across conditions. In the first condition (DRO 30-s), the first bar pressed in each session was the relevant operandum for that session and the delay interval was 30 s. The other bar was the irrelevant operandum. In the second condition (also DRO 30-s), the delay interval remained 30 s but the irrelevant operandum in each session was the first bar pressed and the remaining bar was the relevant one. The same procedure determined the relevant and irrelevant operanda in the remaining three conditions of the experiment (DRO 10-s, DRO 5-s, and DRO 30-s), but the delays were, as noted, 10, 5, and 30 s respectively. Each condition was in effect for 30 consecutive sessions. Sessions were conducted daily as long as the body weights of the subjects remained in the targeted range and ended after three hours or after 60 reinforcers were delivered, whichever occurred first.

Results

The average session lengths for the individual subjects in each condition are shown in Table 1. The average lengths of the sessions decreased during the conditions where the delay values were decreased (DRO 10-s and DRO 5-s). Table 2 shows the location of the relevant operandum for the individual subjects during every session of each condition. In the first DRO 30-s condition, the relevant operandum was the first one pressed during each session and it most frequently was located on the

Table 1

Average Session Lengths (in Minutes) for Individual Subjects in Each Condition of Experiment 1.

	Conditions				
Subject	DRO 30-s	DRO 30-s	DRO 10-s	DRO 5-s	DRO 30-s
Rat 1	140	142	69	49	135
Rat 2	167	126	75	56	119
Rat 3	128	126	75	50	123
Rat 4	122	155	76	58	136

Table .

Location of the Relevant Operandum for Each Subject in Individual Sessions of Experiment 1.

Subject	Condition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	% of Sessions where L Operandum was Pressed 1st
	DRO 30-s	L	L	-	-	-	-	-	-	-	R	R	L	L	L	L	L	L	L	L	L	L	L	L	-	L	R	L	L	L	L	86%
	DRO 30-s	R	R	R	R	L	R	R	R	-	L	R	R	R	R	R	L	R	R	R	R	R	R	R	L	L	R	R	R	R	R	83%
Rat 1	DRO 10-s	L	R	R	L	R	R	L	L	L	L	R	R	L	R	L	L	R	R	R	L	L	R	R	R	L	R	R	R	R	L	57%
	DRO 5-s	L	R	R	R	R	L	L	R	L	R	R	L	R	L	L	L	R	R	R	R	L	L	R	L	R	R	L	R	L	L	53%
	DRO 30-s	L	L	L	L	R	L	R	L	L	L	L	L	R	R	R	R	L	L	R	L	R	R	L	L	L	L	R	R	R	L	40%
	DRO 30-s	R	R	L	-	-	-	-	-	-	-	R	R	R	R	R	R	L	L	R	L	R	L	L	R	L	L	R	R	R	R	35%
	DRO 30-s	L	R	R	L	L	R	R	R	R	L	L	R	R	L	R	L	R	R	R	R	R	L	R	R	R	R	R	R	R	R	73%
Rat 2	DRO 10-s	R	R	-	R	R	R	L	L	L	L	L	L	L	R	R	L	L	R	R	R	R	R	R	R	L	L	R	R	L	R	59%
	DRO 5-s	R	R	L	L	L	R	R	R	L	L	L	L	L	R	R	R	R	R	L	L	R	R	R	R	L	R	L	R	R	R	60%
	DRO 30-s	R	R	R	R	L	R	L	L	L	L	L	L	L	L	R	R	L	R	R	L	R	L	L	R	L	L	R	L	L	R	43%
	DRO 30-s	L	L	-	-	-	-	-	-	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	R	L	L	L	L	L	R	92%
	DRO 30-s	R	L	L	R	R	R	R	L	L	R	R	R	L	R	R	R	R	R	R	R	L	R	R	R	R	R	L	L	L	R	70%
Rat 3	DRO 10-s	L	R	L	L	L	R	L	R	R	R	L	L	L	L	R	R	L	L	R	R	L	L	L	L	R	L	R	R	L	R	43%
	DRO 5-s	L	R	L	L	R	R	R	R	L	L	R	L	L	L	L	R	R	R	R	R	R	L	R	L	L	R	L	R	L	R	53%
	DRO 30-s	R	R	L	R	R	R	R	R	R	R	R	L	R	R	R	R	R	R	R	R	R	R	R	L	L	L	R	R	R	R	83%
	DRO 30-s	L	L	R	L	-	-	-	-	-	-	R	L	L	L	L	L	L	-	L	L	L	L	L	L	L	L	L	L	L	L	91%
	DRO 30-s	R	R	-	-	R	L	R	R	R	R	R	R	R	R	R	L	R	R	R	R	R	R	R	R	R	R	R	R	R	R	93%
Rat 4	DRO 10-s	R	R	R	R	R	R	L	L	R	R	L	R	R	R	R	R	R	L	R	R	L	R	L	R	R	R	R	R	R	L	77%
	DRO 5-s	R	R	L	L	L	R	R	R	L	R	R	L	R	R	L	R	R	R	L	L	L	L	R	L	R	L	R	R	L	R	57%
	DRO 30-s	I	R	R	R	L	R	L	L	R	R	R	R	R	R	L	R	R	L	L	L	R	L	R	R	R	R	R	R	L	R	67%

Note. Dashes indicate missing data. L Left operandum, R Right operandum.

left side for all subjects except Rat 2, who responded first on the operandum on the right side of the chamber in most sessions. In the second DRO 30-s condition and in the remaining conditions, the relevant operandum was the second one pressed in each session. The fact that the relevant bar most frequently was on the right side in the second DRO 30-s condition reflects a change in the procedure of determining the relevant operandum but no change in the subjects' behavior. That is, Rats 1, 3, and 4 still were pressing the left bar first in most sessions and responding primarily on this bar (as indicated in the following figures), even though the right bar was the relevant operandum. Throughout the DRO 10-s and DRO 5-s conditions, the location of the relevant operandum varied more frequently across sessions, reflecting the variation in the bar that was pressed first during these conditions. In the final DRO 30-s condition, the relevant operandum varied less frequently between sessions than in the previous two conditions for Rats 1 and 3.

Figure 1 shows the rate of responding on each operandum for the individual subjects in each session of Experiment 1. Responding was acquired by all subjects during the first session. Response rates on the relevant operandum were calculated using responses measured when both the VI and DRO schedules were in effect. Differences in the response rates on the relevant and irrelevant operanda emerged by the end of the first DRO 30-s condition for Rats 1, 3, and 4, while response rates were more

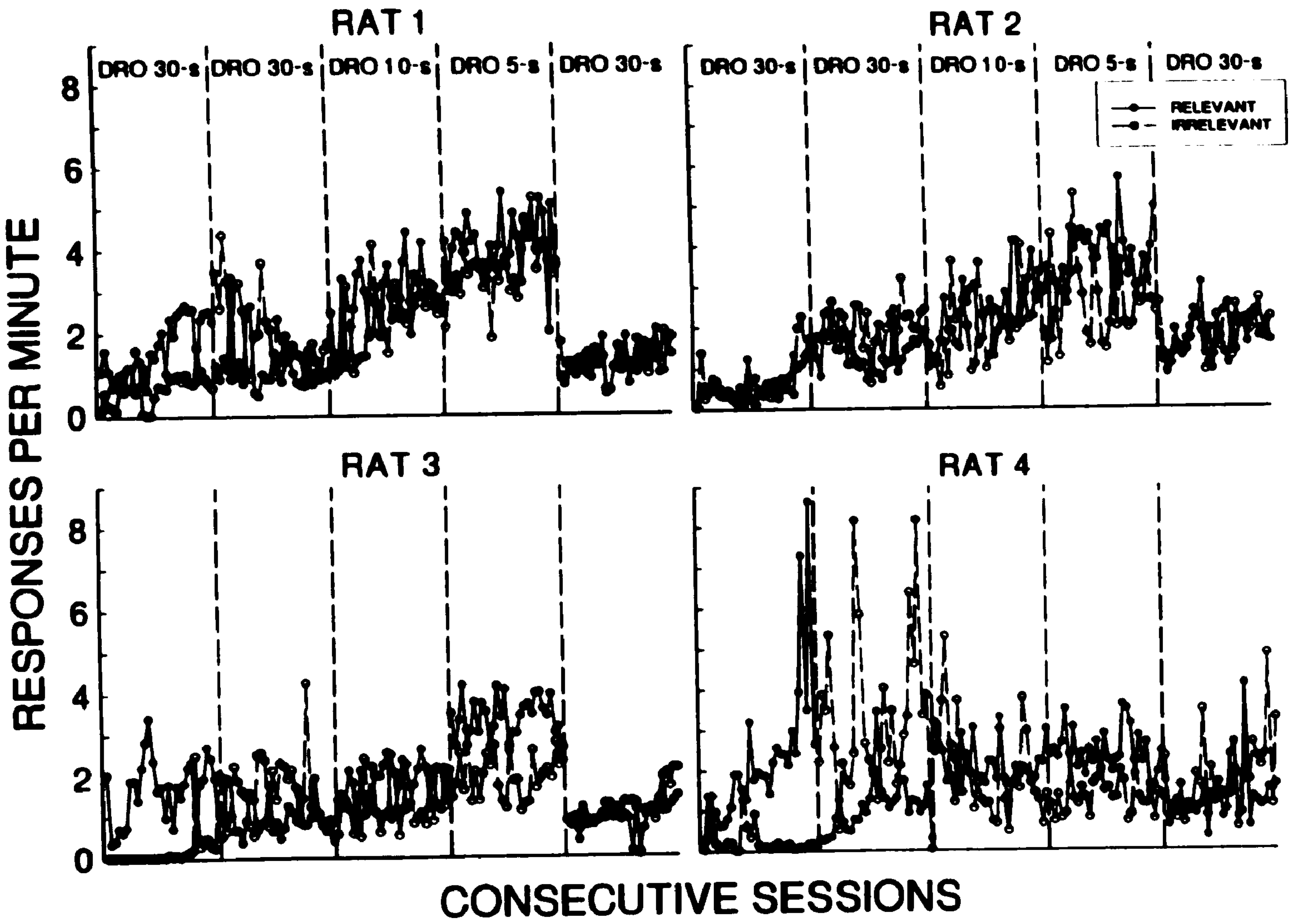

Figure 1. Response rates (responses per minute) on the relevant and irrelevant operanda for each session in Experiment 1 during conditions where the delay intervals were 30, 10, or 5 s. The first operandum pressed in each session was relevant in the first condition and irrelevant in the remaining four conditions.

equally distributed between the operanda for Rat 2. Differences in the response rates on each operandum are less clear in most of the remaining conditions for the individual subjects. These data correspond with those presented in Figure 2, which shows the average discrimination ratios obtained for the sessions in each condition. Discrimination ratios were calculated by dividing the number of responses on the relevant operandum in a session by the number of responses on both operanda in that session. This provides an index of how well each subject's responding was controlled by the relevant operandum and therefore by the delayed reinforcement contingency.

The discrimination ratios indicate that, on the average, each subject responded more on the relevant operandum than on the irrelevant one in sessions during the first DRO 30-s condition, but they responded at lower rates on the relevant operandum than on the irrelevant one in sessions during the second DRO 30-s condition. That is, the subjects continued to respond primarily on the first bar pressed in each session throughout the first two conditions, although in the second condition the first bar pressed was the irrelevant one. The discrimination ratios increased slightly in the DRO 10-s and DRO 5-s conditions and decreased in the final DRO 30-s condition, indicating an increased control of responding by the relevant operandum during the shorter delay periods that decreased with the reintroduction of the 30-s delay intervals.

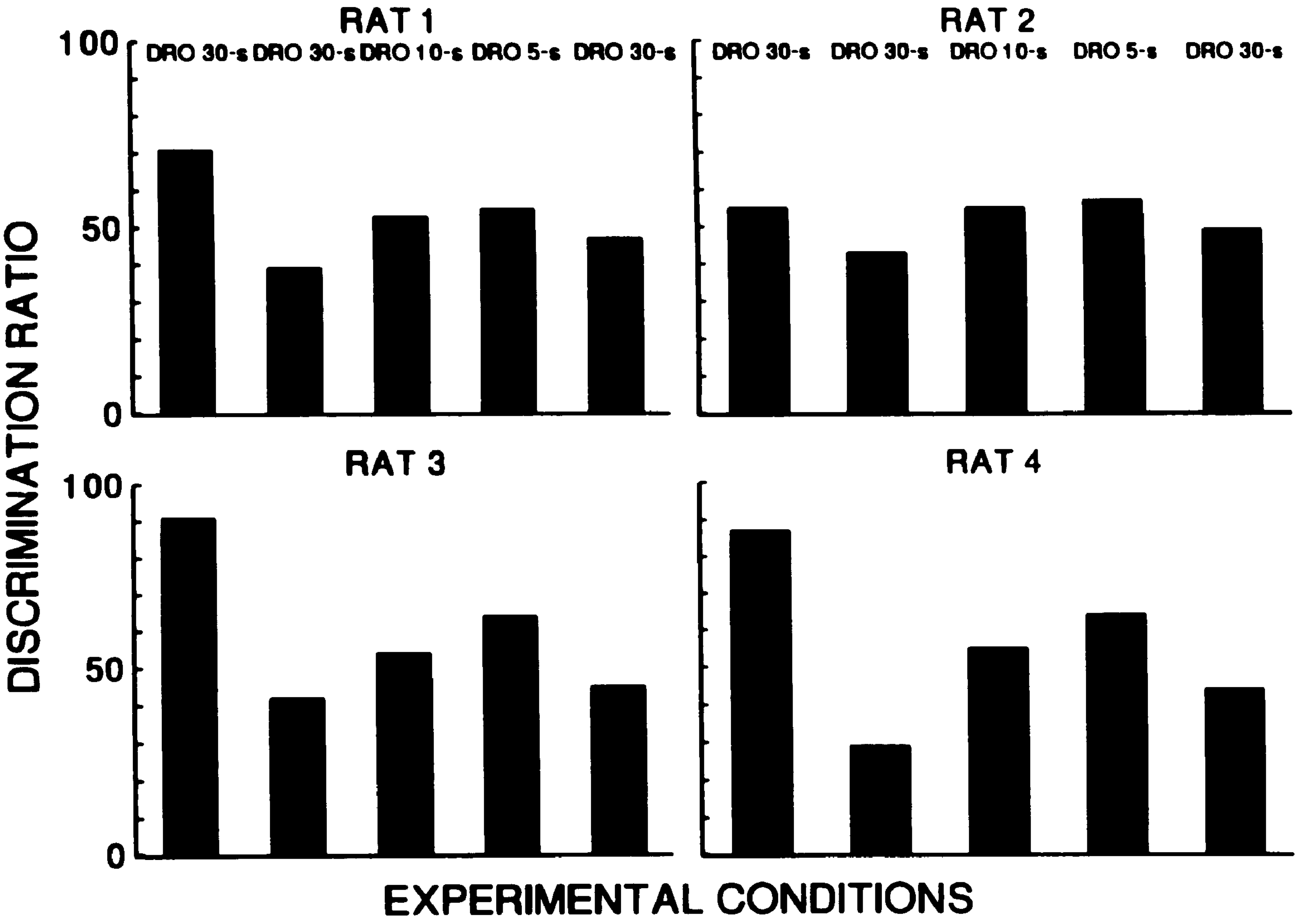

Figure 2. Average discrimination ratios of responding on the relevant operandum during each of the five conditions of Experiment 1.

The differences in responding across the different conditions presented in Figure 2 are made even more clear in the next figure. In Figure 3, the percentage of sessions in each condition where response rates on the relevant operandum were higher than those on the irrelevant operandum is given for each subject. Both Figures 2 and 3 indicate that the majority of responses during the first DRO 30-s condition took place on the relevant operandum for Rats 1, 3, and 4. When the second DRO 30-s condition was effected, the contingency control of responding was disrupted in that more responding occurred on the irrelevant operandum than on the relevant one. Therefore, there were more sessions during this condition where the response rate was higher on the irrelevant operandum than in the first condition. In the third condition (DRO 10-s), where the first bar pressed still was irrelevant but the delay intervals were shortened, there were a greater number of sessions than in the previous condition where the relevant operandum response rate was higher than the irrelevant operandum response rate. When the delay intervals were shortened further in the fourth condition (DRO 5-s), response rates on the relevant operandum were greater than irrelevant operandum response rates in most sessions for each subject. Finally, in the fifth condition, a return to the 30-s delays yielded more sessions where the irrelevant operandum response rate was higher than the rate on the relevant operandum than was the case in the conditions where the shorter delays were

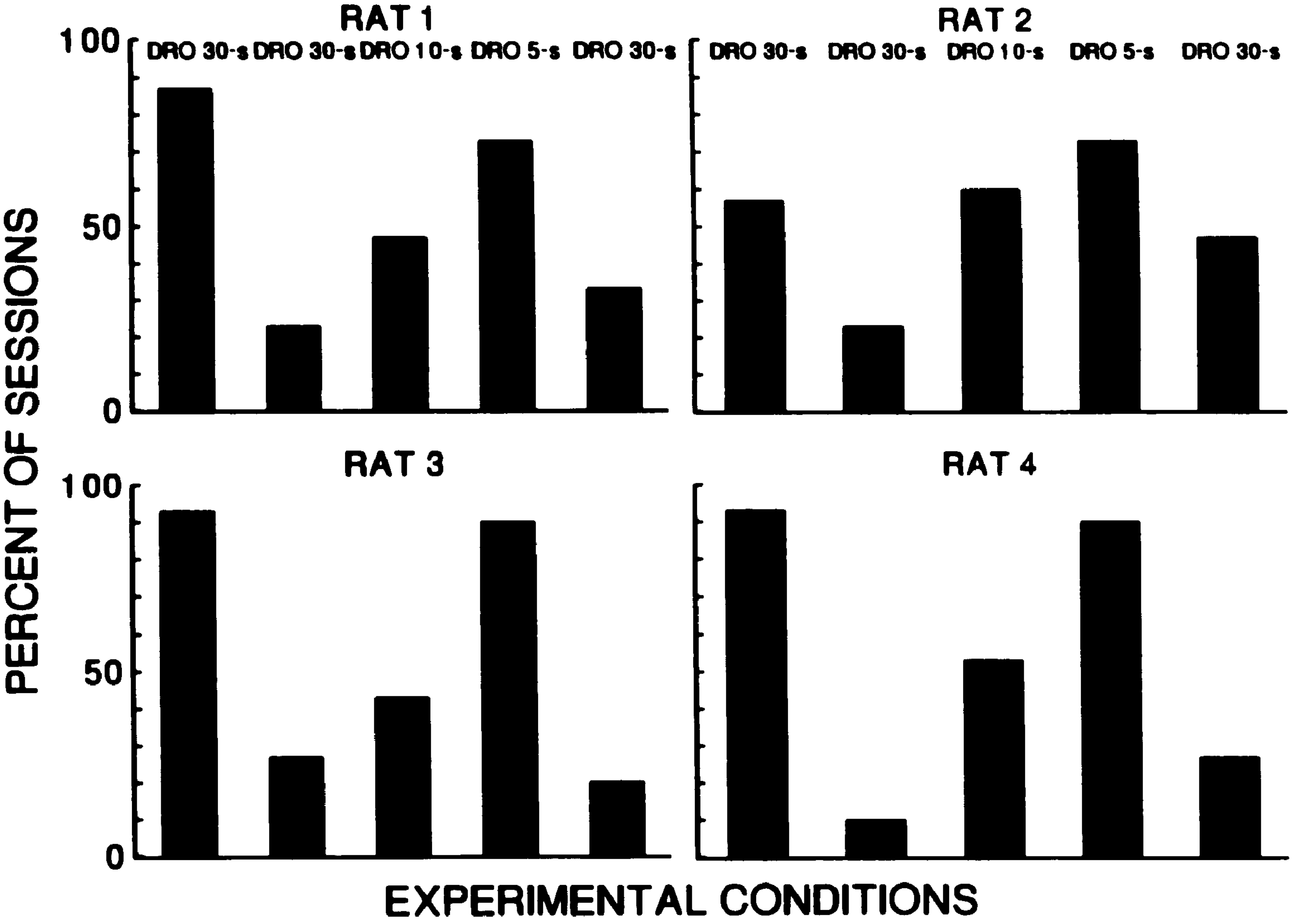

Figure 3. Percentage of sessions in each condition of Experiment 1 where response rates on the relevant operandum were higher than response rates on the irrelevant operandum.

effected.

Sample cumulative records of responding for Rat 1 are presented in Figure 4. The records, taken from a representative session in each condition (Sessions 19, 40, 63, 119, and 146 respectively), show that responding was steady throughout the sessions and that responses occurred on each operandum regardless of the schedule correlated with that operandum.

In summary, subjects in Experiment 1 acquired the operant response without explicit response training, but the data do not show clear contingency control of responding by the delayed reinforcement schedule. A problem with this experiment was that responding changed as the conditions changed, but it was difficult to determine what specific factors had an effect on responding. For example, it is possible that the delay intervals were too long to permit the control of responding by the delayed reinforcement contingency or that the procedures used to determine the relevant operandum in each session reduced the sensitivity of the subjects' behavior to the delayed reinforcement contingency. It is not likely that the large amounts of responding observed on the irrelevant operandum in the final four conditions occurred solely because such responses prevented the postponement of reinforcement, as observed in the experiment by Schwartz and Williams (1971), but mediating behavior cannot be ruled out on the basis of this experiment

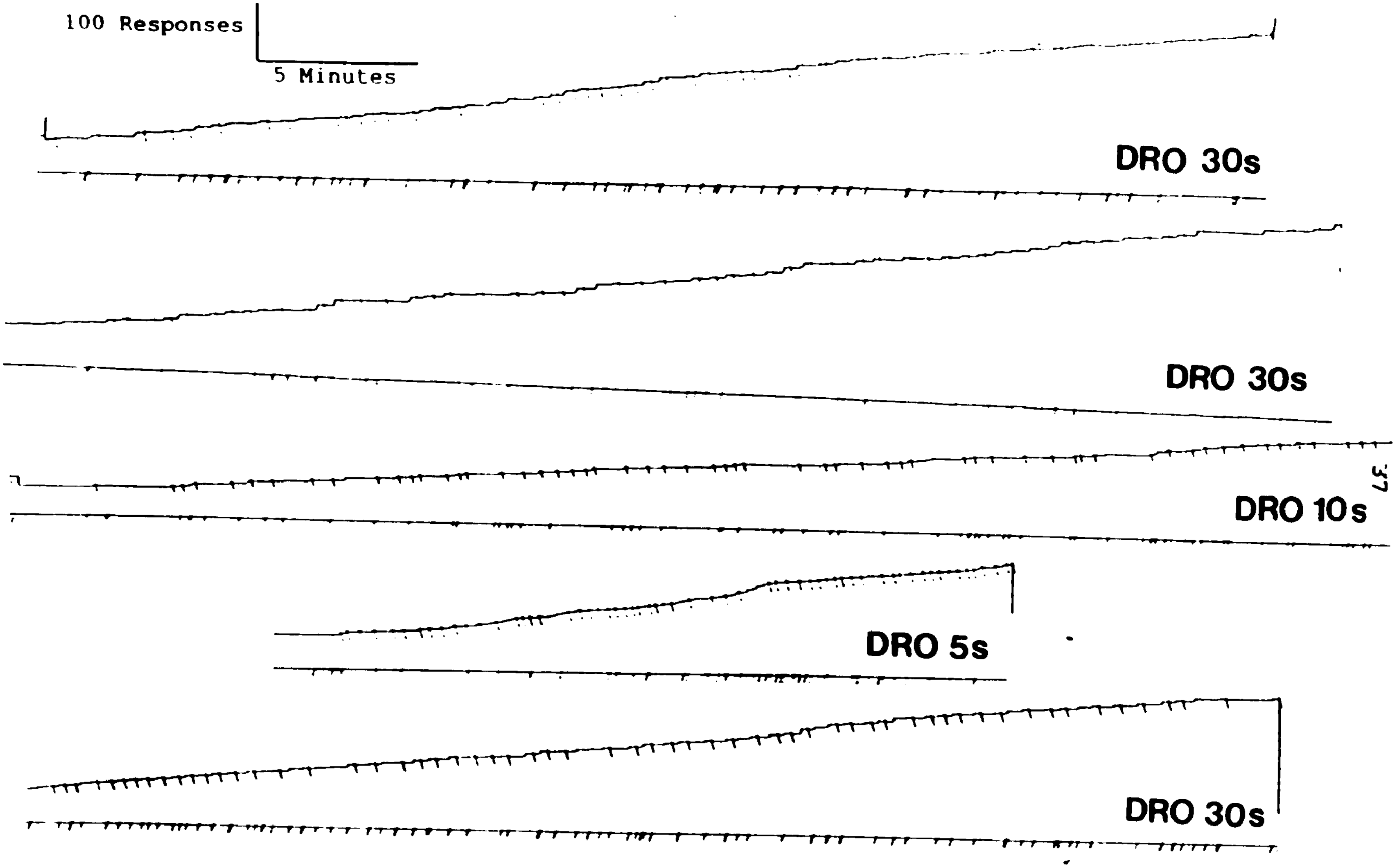

Figure 4. Sample cumulative records of responding for Rat 1 in each condition of Experiment 1. Increments of the top pen indicate relevant operandum responses, deflections represent reinforcer deliveries, and event pen deflections denote irrelevant operandum responses.

alone. Similarly, if responding on both operanda simply was induced by food delivery, response rates on the irrelevant operandum would have been more equal to those on the relevant operandum during the first DRO 30-s condition as was the case for many of the sessions in the remaining conditions. Again, however, the other variables do not allow conclusions to be drawn about the reasons for the lack of contingency control.

Experiment 2

In the first experiment, either operandum could be the relevant one in a given session. This was because the relevant operandum differed from one session to the next, depending on the subject's first response in each session. The changing location of the relevant operandum may have made the subjects' behavior less sensitive to the delayed reinforcement contingency because the operandum correlated with reinforcement presumably was less detectable than if it always had been in the same location. In Experiment 2, the relevant operandum in each session was selected by the experimenter and remained the same in every session within each condition, to determine if the consistent location facilitated the control of responding by the delayed reinforcement schedule. The new procedure allowed for the determination of whether the lack of control of behavior by the delayed reinforcement schedule during most of the sessions in the previous experiment resulted from the poor temporal contiguity between responses and reinforcers, an explanation supported by the increase in relevant operandum response rates relative to irrelevant operandum response rates when the delay intervals were shortened, or if the lack of control of responding by the contingency was affected by the procedure used to determine the relevant operandum.

Method

Subjects. Three experimentally naive female Wistar rats were maintained at 70% (± 2%) of their individual ad libitum body weights. The subjects were 120 days old at the beginning of the experiment.

Apparatus. The apparatus was identical to that described in Experiment 1.

Procedure. Each rat was magazine-trained according to the procedure described in Experiment 1. Following magazine training, a concurrent [tandem VI 30-s DRO 30-s] [EXT] schedule of reinforcement was effected. The values comprising the VI schedule were determined according to the progression described by Fleshler and Hoffman (1962). The relevant and irrelevant operanda were selected arbitrarily by the experimenter and remained the same within each condition. Responding on the relevant operandum was reinforced according to a tandem VI 30-s DRO 30-s schedule. As in the first experiment, responses on the relevant operandum during the delay interval reset the delay interval to 30 s. Responding on the irrelevant operandum never was reinforced.

For Rat 6, the right bar was the relevant one in the first and third conditions, and the left bar was the relevant one in the second condition. Responding on the irrelevant operandum reset the delay timer to 30 s if responses occurred during the delay for the first 45 sessions. In subsequent sessions, responses on the irrelevant operandum had no consequence unless they occurred within the last 10 s preceding reinforcer delivery. Then, irrelevant operandum responses that occurred within 10 s before a scheduled reinforcer delivery reset the delay interval to 10 s. This procedural change after the first 45 sessions was to make the resetting contingency identical to that used in Experiment 1 so that the results of the two experiments would be more comparable. For Rats 7 and 8, the left bar was the relevant one in the first and third conditions, and the right bar was relevant in the second condition. For these subjects, responses on the irrelevant operandum were without consequence for the first 45 sessions of the experiment. In subsequent sessions, responses on the irrelevant operandum that occurred in the last 10 s preceding reinforcer delivery reset the delay interval 10 s.

For all subjects, the relevant operandum was the same for each of the first 55 sessions (on the right side for Rat 6 and the left side for Rats 7 and 8). The length of the first condition was increased over that of the conditions in the previous experiment to account for the slower rate of response acquisition of the subjects under the different procedure for determining the relevant operandum. The relevant and irrelevant operanda then were reversed for each subject for the next 21 sessions (left for Rat 6 and right for Rats 7 and 8). Finally, the relevant and irrelevant operanda again were reversed for the final 21 sessions (right for Rat 6 and left for Rats 7 and 8). The last two conditions were shorter than the first because the subjects already had acquired the operant response. Sessions were conducted daily as long as the body weights of the subjects remained in the targeted range. Each session lasted for three hours or until 60 reinforcers were delivered.

Results

The average session lengths for the individual subjects in each condition are shown in Table 3. The average lengths of the sessions decreased for all subjects across conditions as the experiment progressed. Figure 5 shows the response rates of each subject on both operanda in the individual sessions of the experiment. Relevant operandum rates were calculated using responses that occurred when the VI and DRO schedules were in effect. Rat 6, exposed first to the procedure whereby irrelevant operandum responding during any part of the delay to reinforcement postponed reinforcer delivery for 30 s, responded initially on the irrelevant operandum infrequently. This also was the case for Rats 7 and 8, which were not exposed initially to the food-postponement contingency on the irrelevant operandum.

When the food-postponement contingency was changed to 10 s

Table 3

Average Session Lengths (in Minutes) for Individual Subjects in Each Condition of Experiment 2.

Subject	Condition		
Rat 6	155 (R)	143 (L)	138 (R)
Rat 7	155 (L)	153 (R)	138 (L)
Rat 8	144 (L)	132 (R)	116 (L)

Note. R = Right lever; L = Left lever.

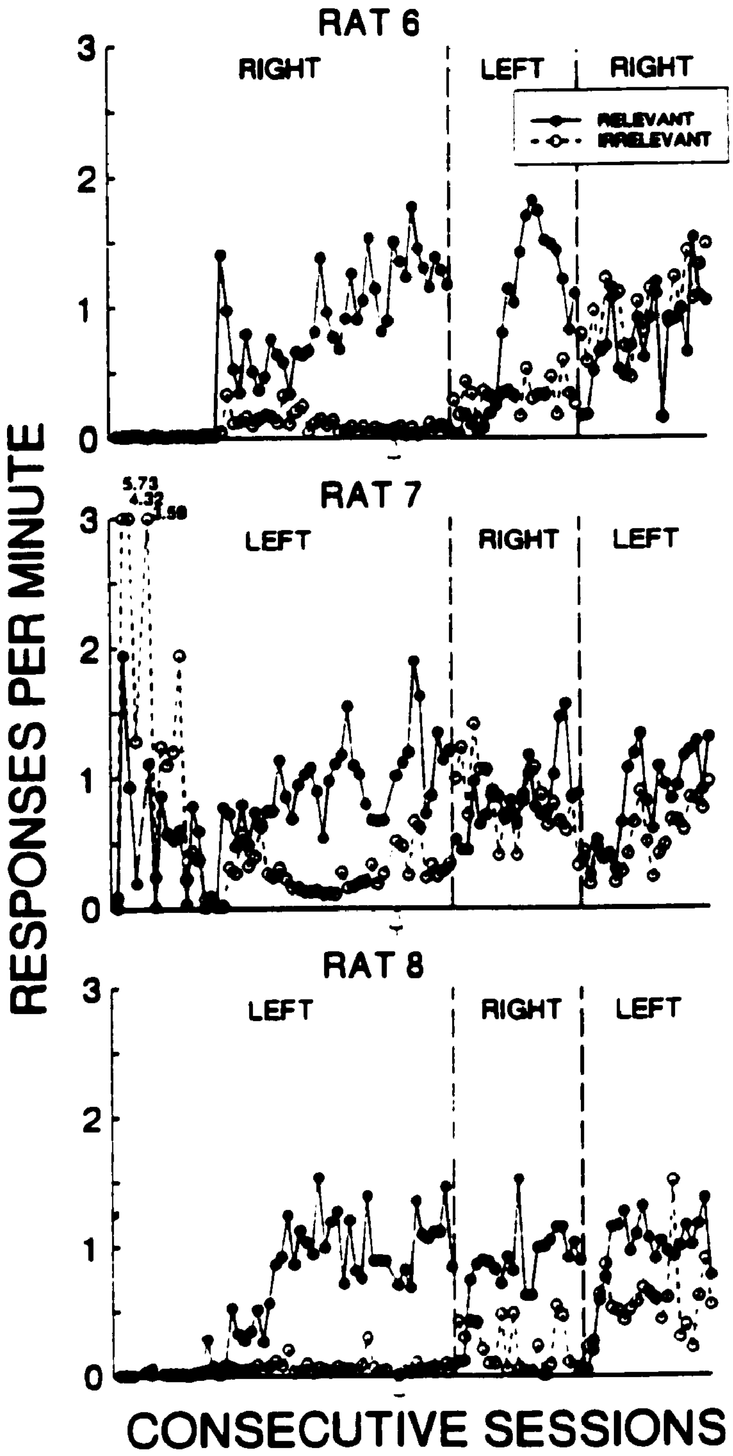

Figure 5. Response rates (responses per minute) on the relevant and irrelevant operandum in individual sessions of Experiment 2 during conditions where the right or left operandum was relevant. Arrows indicate a change in the resetting delay contingency for irrelevant operandum responses (see text).

for irrelevant operandum responses in the last 10 s of a reinforcement delay, identified by an arrow at the bottom of each graph in Figure 5, a slight increase in irrelevant operandum responding was observed for Rat 7. No changes in behavior occurred for the other two subjects when the food-postponement contingency for responding on the irrelevant operandum during delays changed. Rat 7 initially responded at higher rates on the irrelevant operandum in the first condition, but irrelevant operandum responding then decreased as relevant operandum response rates increased. There was some disruption of responding when the relevant operandum changed locations in the second and third conditions of the experiment, meaning response rates on the irrelevant operandum initially were higher than rates on the relevant operandum after the conditions changed. However, relevant operandum response rates recovered and were higher than irrelevant operandum response rates by the end of each condition (with the exception of the third condition for Rat 6, who responded on the irrelevant operandum at higher rates throughout most of the sessions in that condition, and the second condition for Rat 7, who responded at approximately equivalent rates on both operanda).

The average discrimination ratios for each subject in all three conditions are presented in Figure 6. The discrimination ratios were calculated as described in Experiment 1. These data indicate that, on the average, a higher percentage of the total

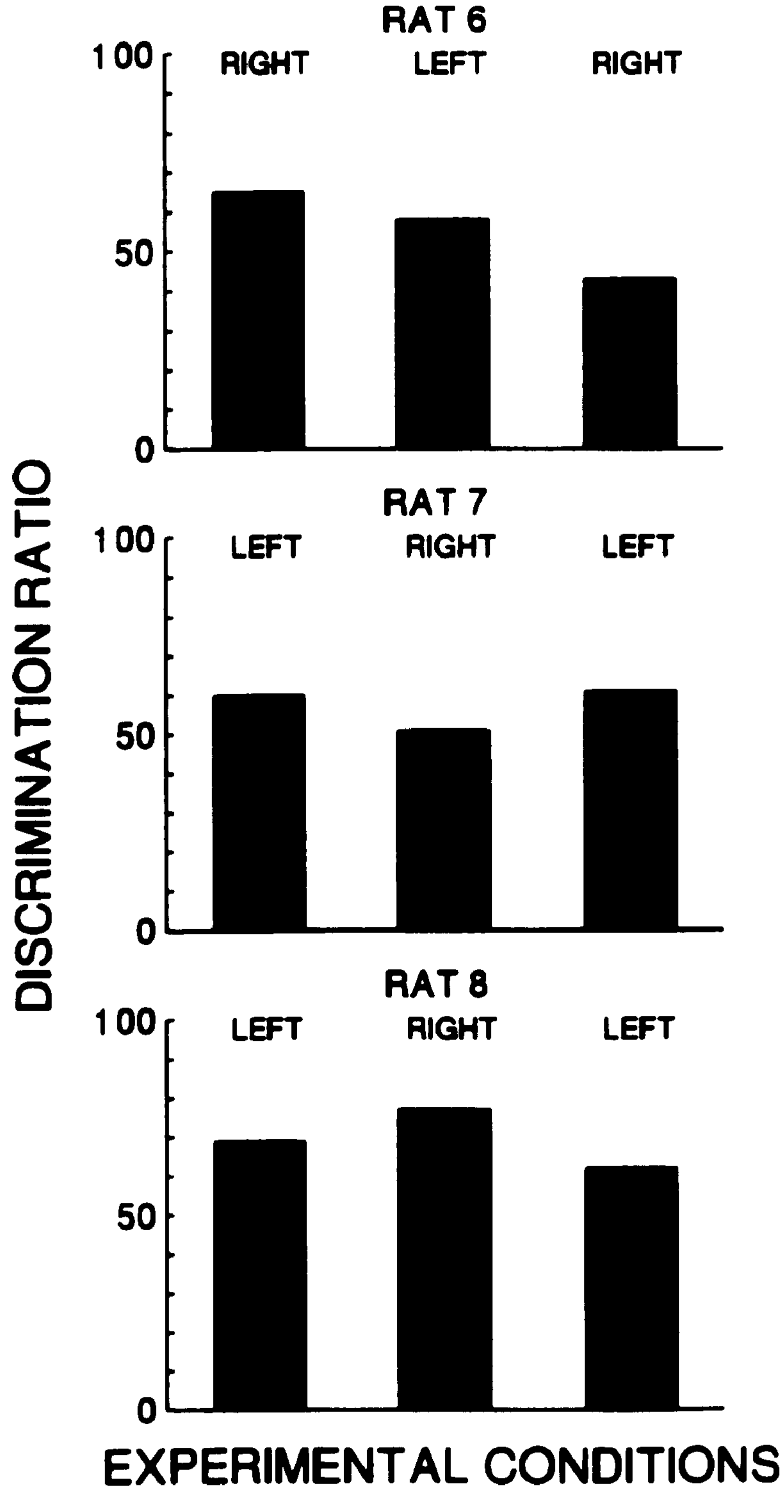

Figure 6. Average discrimination ratios for responding in Experiment 2 during conditions where the right or left lever was relevant.

responding within each session occurred on the relevant operandum than on the irrelevant one. For the most part, higher rates were exhibited on the relevant operandum whether it was on the right or left side. Figure 7 shows the percentage of sessions in each condition where response rates for the individual subjects on the relevant operandum were higher than response rates on the irrelevant operandum. Rat 6 responded at a higher rate on the relevant operandum in most of the sessions in the first two conditions, while Rat 7 responded at higher rates on the relevant operandum throughout most of the first and last conditions. Rat 8 responded at a higher rate on the relevant operandum in almost every session of each condition.

Sample cumulative records of responding, taken from Sessions 53, 73, and 95 for Rat 7, are presented in Figure 8. These records show that behavior changed according to the changes in conditions. In the first condition, Rat 7 exhibited little responding on the irrelevant operandum, and this also was the case for the other subjects (see Figure 5). As the conditions changed, more responding occurred on the irrelevant operandum, although the response rates on that operandum still were lower than rates on the relevant operandum in the third condition for two of the three subjects.

Greater control of responding by the delayed reinforcement contingency was exhibited in the present experiment than in Experiment 1. However, the degree of contingency control of

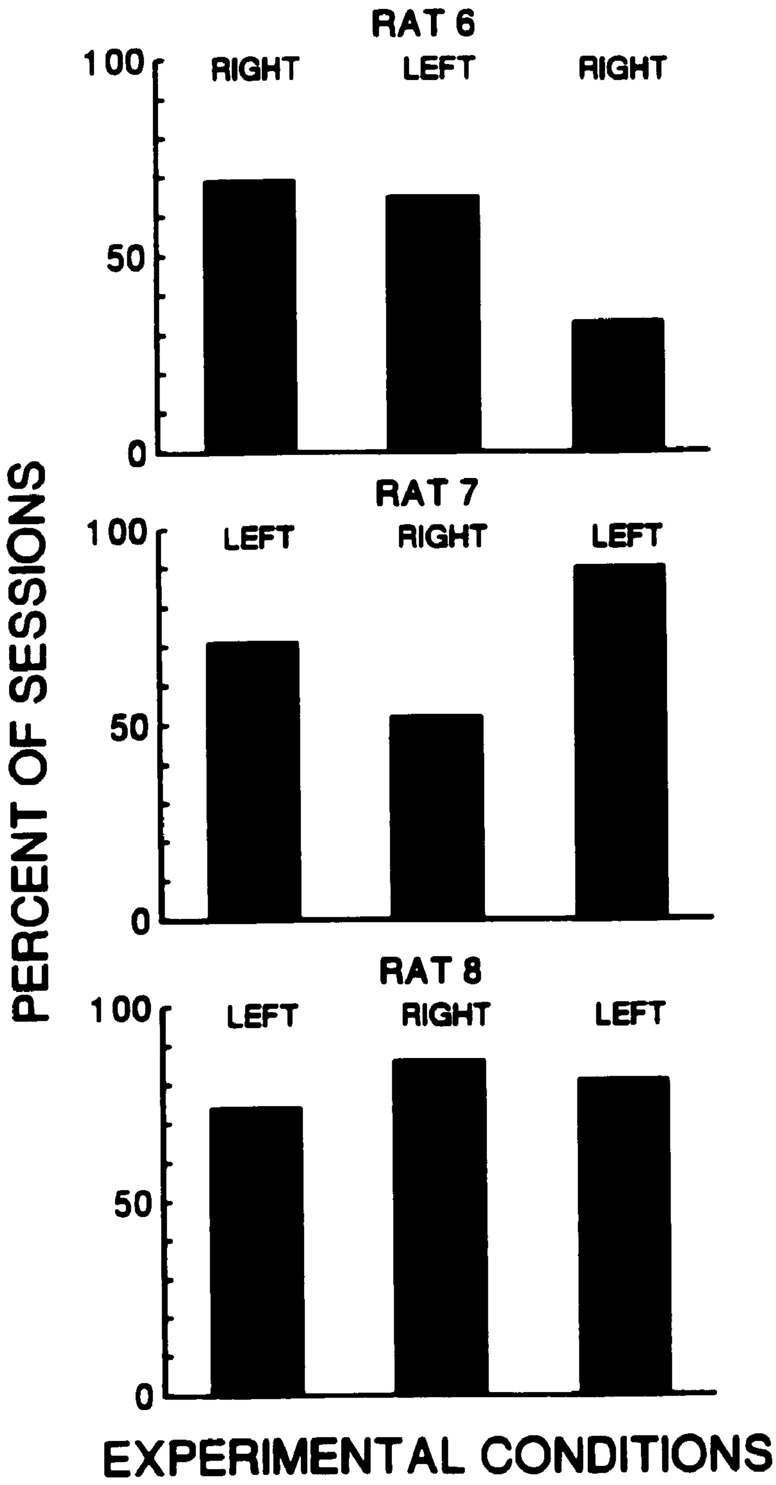

Figure 7. Percentage of sessions in each condition of Experiment 2 where response rates on the relevant operandum were higher than response rates on the irrelevant operandum.

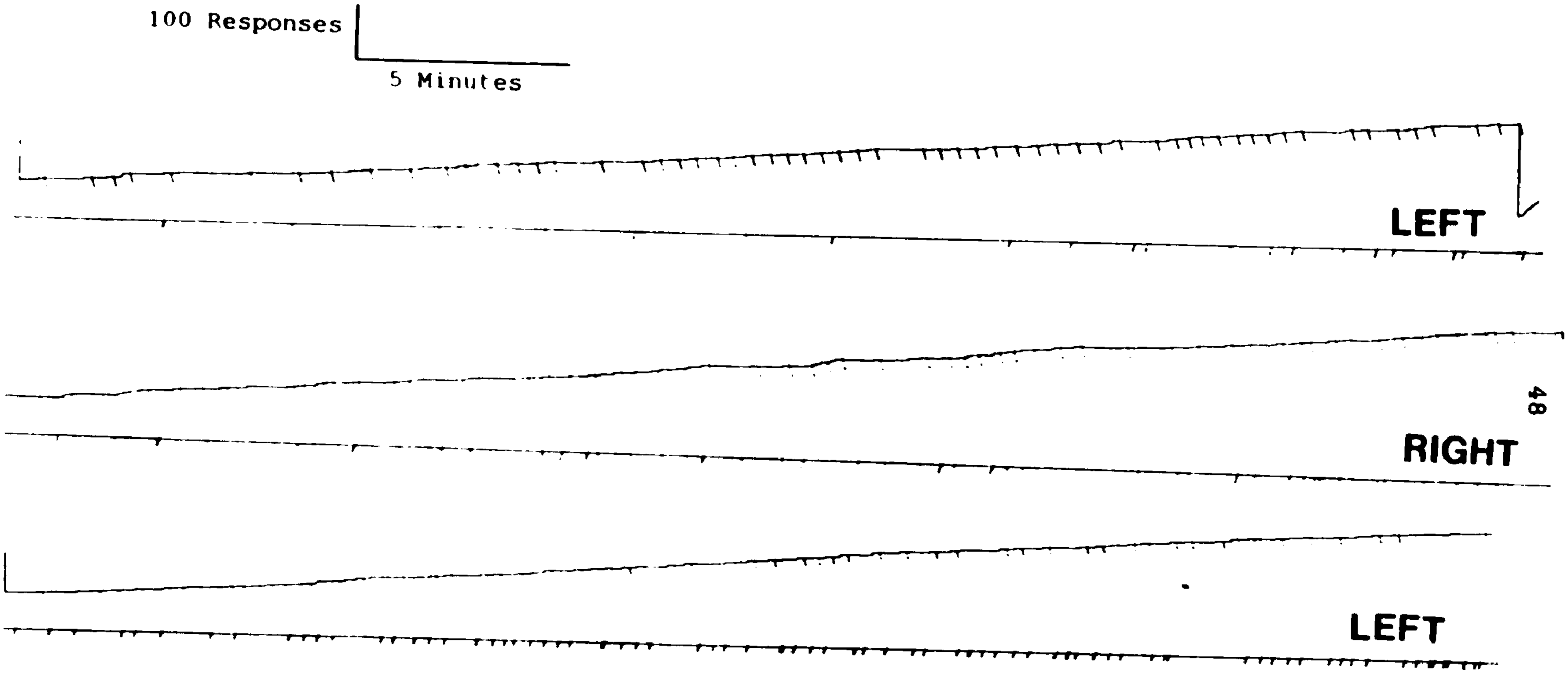

Figure 8. Sample cumulative records of responding for Rat 7 in each condition of Experiment 2. Increments of the top pen indicate relevant operandum responses, deflections represent reinforcer deliveries, and event pen deflections denote irrelevant operandum responses.

responding often changed with changes in the location of the relevant operandum across conditions. The results of this experiment, unlike those of Experiment 1, indicate that the delayed reinforcement contingency does control behavior in the presence of an irrelevant operandum, although this control can be adversely affected when the location of the relevant operandum changes. To further examine the effects of the changing location of the relevant operandum on the contingency control of responding, Experiment 3 was conducted. The final experiment involved more frequent changes in the location of the relevant and irrelevant operanda, as was the case in Experiment 1, although the relevant operandum was determined by the experimenter as in Experiment 2.

Experiment 3

The results of most of Experiment 2 and the first condition of Experiment 1 show that responding was controlled by contingent response-reinforcer relations when reinforcer delivery was delayed from responses. These results indicate that the control of responding by the delayed reinforcement contingency would have been exhibited in the remaining conditions of the first two experiments in the absence of certain procedural manipulations. Specifically, unsignalled changes in the operandum that was relevant, in addition to the subjects' history of responding on a different relevant operandum, may have prohibited the development of control of responding by the delayed reinforcement contingency in the remaining sessions of the first two experiments. The final experiment examined the effects of a procedure that was a combination of the two from the previous experiments with regard to the determination of the relevant operandum. In the third experiment, the relevant operandum was pre-determined by the experimenter and varied semi-randomly. The procedure used allowed for the measurement of changes in behavior as each session progressed as well as for comparing changes in behavior across different sessions. In addition, pigeons rather than rats were used as subjects in the third experiment to test the generality of the control of responding by delayed reinforcement contingencies across species.

Method

Subjects. Four adult male, White Carneau pigeons, each with a prior experimental history of responding on VI reinforcement schedules, were maintained at 70% (± 2%) of their ad libitum weights.

Apparatus. A standard experimental chamber, 33.5 x 30 x 31.5 cm, was used. The walls were wooden except for a metal work panel. The 4.5 x 6-cm hopper aperture was located in the middle of the work panel, 7.5 cm from the floor. The reinforcer consisted of 4-s availability of mixed grain. The hopper was raised and illuminated by a white light during grain presentations. Two response keys were 24 cm from the floor and 5 cm from the right and left walls of the chamber. They were transilluminated by white, green, or yellow bulbs, according to the condition in effect. The force required to operate each key was 0.15 N. A Tandy 286EX computer, programmed with Med-PC© software, and electromechanical equipment were in an adjoining room for the control of the experiment and the recording of data.

Procedure. Although the subjects had a prior history of responding under various reinforcement schedules, magazine training and response shaping was undertaken to ensure consistent responding. During magazine training, the individual subjects were placed in the chamber with one of the keys illuminated (a white keylight on the right or a green keylight on the left). The hopper was raised according to a VT 15-s schedule until the subject began to consume the grain immediately after it was presented, which took an average of three sessions. In the next session after each subject was eating reliably from the raised hopper, the keypeck response was shaped through the differential reinforcement of successive approximations. In each of the training sessions, a single key was illuminated and alternated daily between the two side keys.

After responding was acquired, which occurred during the first session following magazine training for each of the subjects, the keys continued to alternate daily and each was correlated with a tandem FR 1 DRO 10-s schedule of reinforcement. This procedure was, in effect, an unsignaled delay of reinforcement where each response initiated a 10-s delay interval. Reinforcers were delivered 10 s following a response unless another response occurred during the delay. Responses that occurred during the delay reset the delay interval to 10 s. This schedule was in effect for approximately 12 sessions. Next the schedule of reinforcement was changed to tandem VI 15-s DRO 10-s. The values of the VI schedule were chosen according to Fleshler and Hoffman (1962). This schedule was in effect for six sessions, thus concluding pre-training.

In the remaining sessions of the experiment, both keys were transilluminated yellow and a concurrent [tandem VI 15-s DRO 10-s] [EXT] schedule of reinforcement was effected. The response key correlated with the EXT schedule had no consequence except to reset the delay timer to 10 s if a response on this key occurred when a delay to reinforcement was in effect for responding on the other key. The keys to be correlated with each schedule were determined at the beginning of each session according to a semi-random sequence. The location of the relevant operandum in each session is presented in Table 4.

The operanda were varied so that the same one was relevant for no more than three consecutive sessions. Exceptions were the first few sessions of the experiment for Birds 2405 and 2228, who experienced five and six sessions respectively of responding on the same relevant operandum due to a programming error. Otherwise, the relevant operandum locations were counterbalanced so that each subject responded on each key with one, two, or

Table 4

Location of the Relevant Operandum for Individual Subjects in Each Session of Experiment 3.

	Subject			
Session	Bird 2408	Bird 2485	Bird 2405	Bird 2228
1	R	L	L	R
2	L	R	L	R
3	R	R	L	R
4	R	L	L	R
5	L	R	L	R
6	L	L	R	R
7	L	L	R	L
8	R	L	L	R
9	R	R	R	R
10	R	R	L	L
11	L	R	L	L
12	L	L	L	L
13	R	L	R	R
14	L	R	R	R
15	R	L	R	R
16	L	R	L	L
17	L	R	L	L
18	L	R	R	R
19	R	L	L	L
20	R	L	R	R
21	L	R	R	L
22	L	R	R	L
23	R	L	L	L
24	R	L	L	R
25	R	L	R	R
26	L	R	R	L
27	R	L	L	L
28	L	R	L	R
29	R	R	L	R
30	R	L	R	R
31	L	R	L	L
32	L	L	R	L
33	L	L	R	R
34	R	L	L	L
35	R	R	R	L
36	R	R	L	R
37	L	R	L	R
38	L	L	L	R
39	R	L	R	L
40	L	R	R	L
41			R	L
42			L	R
43			L	L
44			R	

three sessions of prior responding in which the relevant operandum was the other key in an irregular sequence. There were 40 sessions total for Birds 2408 and 2485, 44 sessions for Bird 2405, and 43 sessions for Bird 2228. The total number of sessions in the experiment differed for Birds 2405 and 2228 to compensate for the programming error described previously. Individual sessions ended after 90 reinforcer deliveries and were conducted daily while the subjects' body weights remained in the targeted range.

Results

To better understand the distribution of responses on the relevant and irrelevant operanda across sessions, responding was analyzed separately in each session according to the order in which the sessions occurred as well as whether each was the first, second, or third consecutive session with the same relevant operandum. The average session lengths for each subject when responding in the first, second, or third consecutive session with a given relevant operandum are presented in Table 5. Sessions where the relevant operandum was different than in a previous session or sessions lasted longer than sessions where the relevant operandum was the same.

The response rates for each subject during each consecutive session is shown in Figure 9. In most of the sessions the response rate on the relevant operandum (calculated using

Table 5

Average Session Lengths (in Minutes) for Individual Subjects on the First, Second, or Third Consecutive Session of Responding with the Same Relevant Operandum in Experiment 3.

Subjects	1 Day (21 Sessions)	2 Days (13 Sessions)	3 Days (6 Sessions)
Bird 2408	127	95	94
Bird 2485	192	118	105
Bird 2405	147	116	115
Bird 2228	126	93	94*

*The number of sessions used to calculate the average session length for Bird 2228 with 3 consecutive sessions of responding with the same relevant operandum was 7.

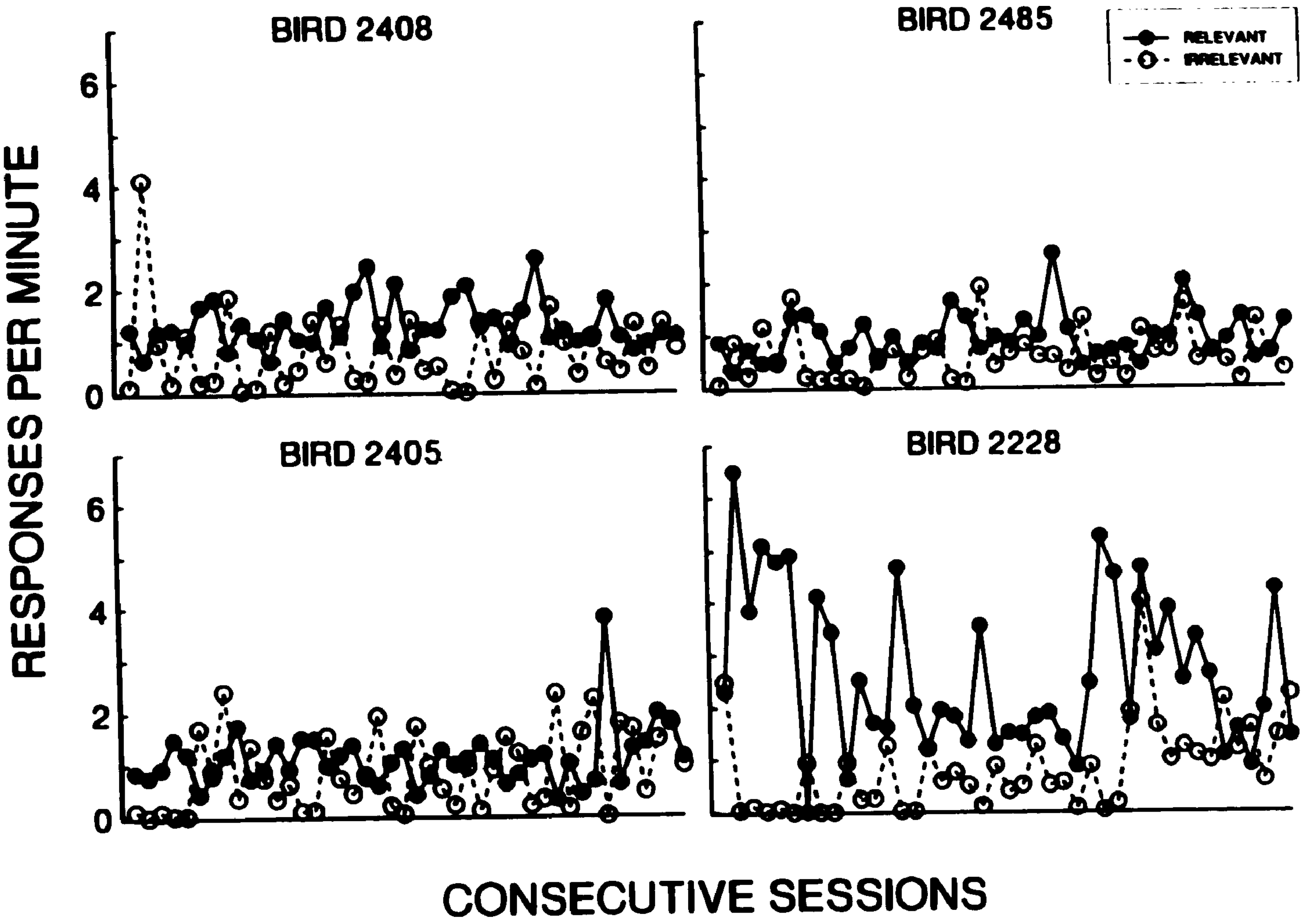

Figure 9. Response rates (responses per minute) on the relevant and irrelevant operanda for each subject in each session of Experiment 3.

responses when the tandem VI DRO schedule was in effect) was higher than the rate of responding on the irrelevant operandum. The differences between the response rates on the relevant and irrelevant operanda are most clear for Bird 2228, while Bird 2405 responded at a higher rate on the relevant operandum less consistently. There was variability in response rates across sessions, but there were no systematic trends in responding across the experiment. Figure 10 shows the average percentage of responses on the relevant or irrelevant operanda relative to the average number of total responses made on both operanda, recorded in consecutive 10-min intervals within each session. In general, as each session progressed, responding on the relevant operandum increased slightly while responding on the irrelevant operandum decreased somewhat more sharply. However, these results do little to explain the variability in responding observed across sessions that is apparent in Figure 9.

As noted previously, responding also was analyzed according to the number of consecutive sessions with the same relevant operandum, and the results of this analysis are shown in Figure 11. The average percentage of responses on each operandum differed depending on the location of the relevant operandum in the previous session(s). The leftmost column of Figure 11 shows the distribution of responses on the operanda by each subject in the first session of responding when a given operandum was

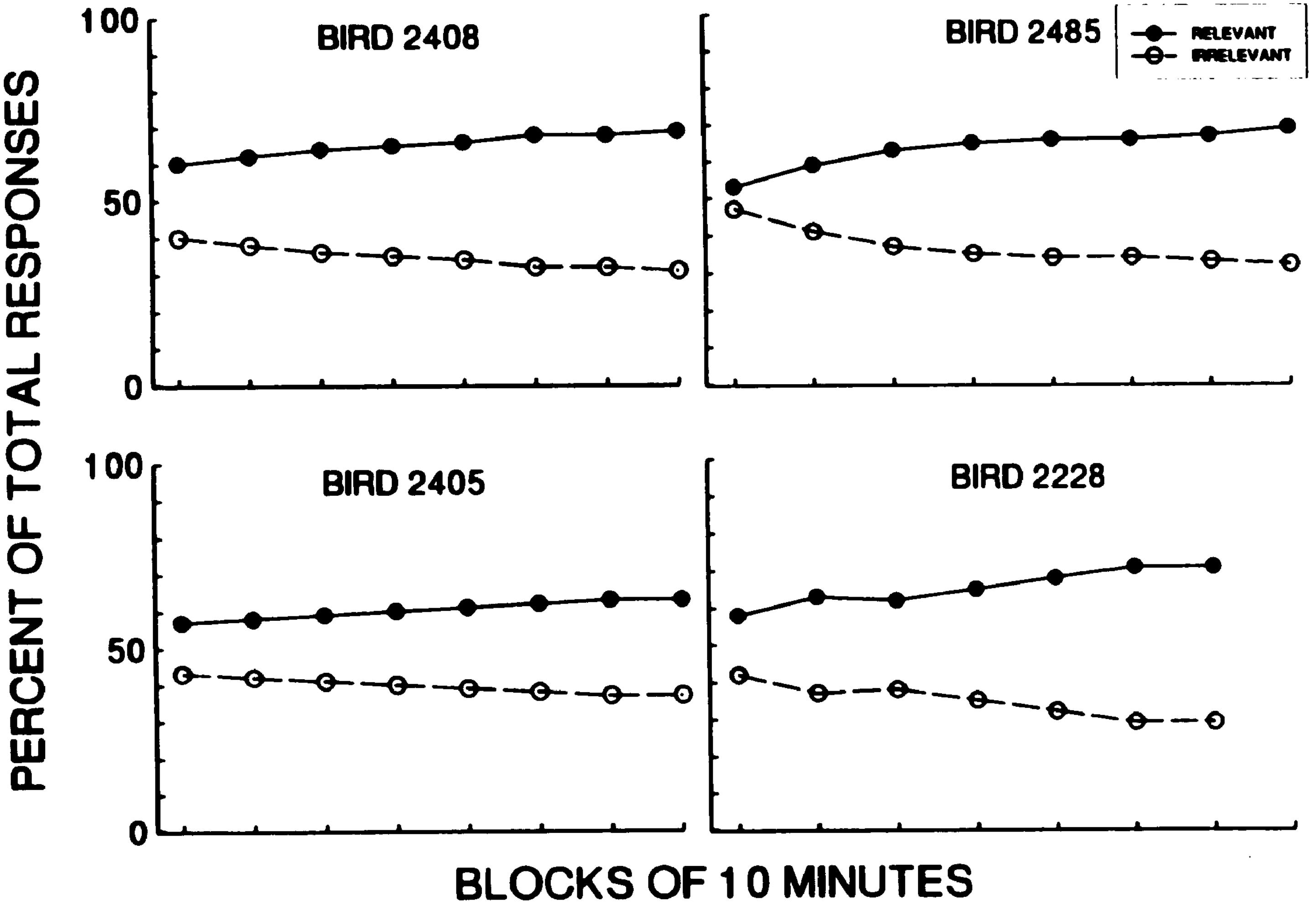

Figure 10. Average percentage of total responses distributed on the relevant and irrelevant operanda at consecutive 10 min intervals in each session of Experiment 3.

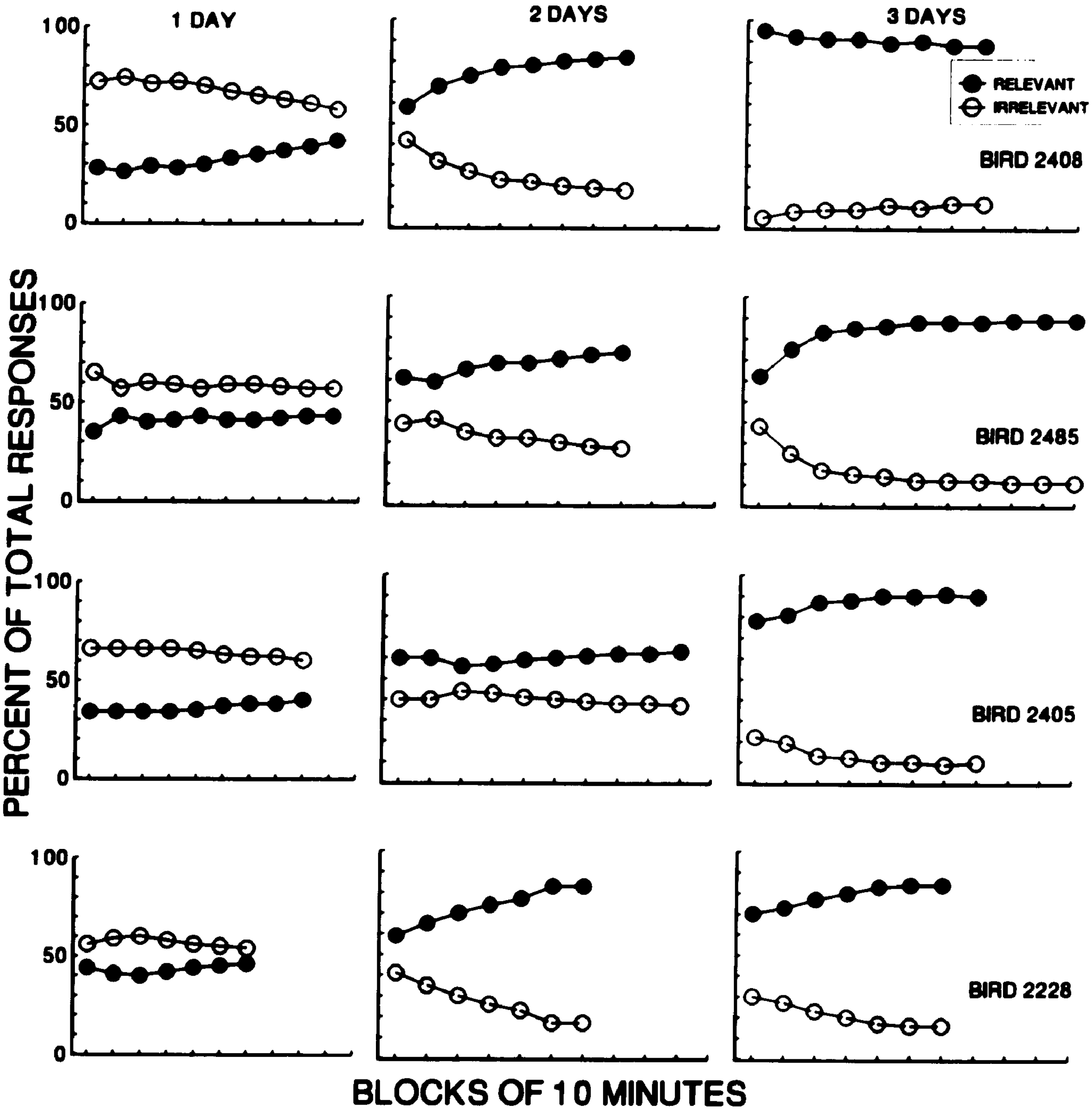

Figure 10. Average percentage of total responses distributed on the relevant and irrelevant operanda at consecutive 10 min intervals in each session of Experiment 3.

relevant, meaning that in at least one or possibly two or three of the previous sessions the relevant operandum was the other one. When the relevant operandum was different in a session than in the immediately previous session(s), the majority of responses occurred on the irrelevant operandum (that is, the operandum that was relevant in the previous session or sessions). Although fewer responses occurred on the relevant operandum than on the irrelevant one in these sessions, on average the number of relevant operandum responses increased and the number of irrelevant operandum responses decreased as the sessions progressed. However, since the percentage of responses on the relevant operandum was lower than the percentage of the total responses on the irrelevant operandum, the contingency was not completely controlling behavior in these sessions.

Control of behavior by the relevant operandum is more evident in the sessions that were preceded by one session with the same relevant operandum (labelled 2 Days in Figure 11), and contingency control is even more clear when the relevant operandum was the same for three consecutive sessions (labelled 3 Days in Figure 11). In these sessions, the average response rates on the relevant operandum were higher than average response rates on the irrelevant operandum at consecutive points as the sessions progressed.

The average discrimination ratios were calculated as in the two previous experiments for the sessions that were the first, second, or third consecutive sessions with the same relevant operandum location. These data are shown in Figure 12. The number of sessions used in the calculation of these averages are listed in Table 5. The discrimination ratios in Figure 12 reiterate the finding that responding was not controlled by the delayed reinforcement contingency when the relevant operandum differed from that in the previous session(s). When the relevant operandum was in a new location, responding occurred on both operanda at approximately equivalent rates. However, a greater proportion of responding occurred on the relevant operandum when it was the same as in one or two previous sessions.

In Figure 13, the cumulative records of responding serve as further evidence that the distribution of responses between the two operanda was dependent on changes in the relevant operandum. The changes in responding as the sessions progressed are illustrated in the cumulative records of responding by Bird 2408 in Sessions 13, 24, and 25. The records were taken from sessions that were the first, second, or third consecutive sessions respectively of responding with the same relevant operandum. On the first day, where the relevant operandum was different than in the previous session(s), responding occurred on both operanda (although responding on the irrelevant operandum decreased as the session progressed). On the second day of responding on the same relevant operandum, there was a period of approximately 10 min at

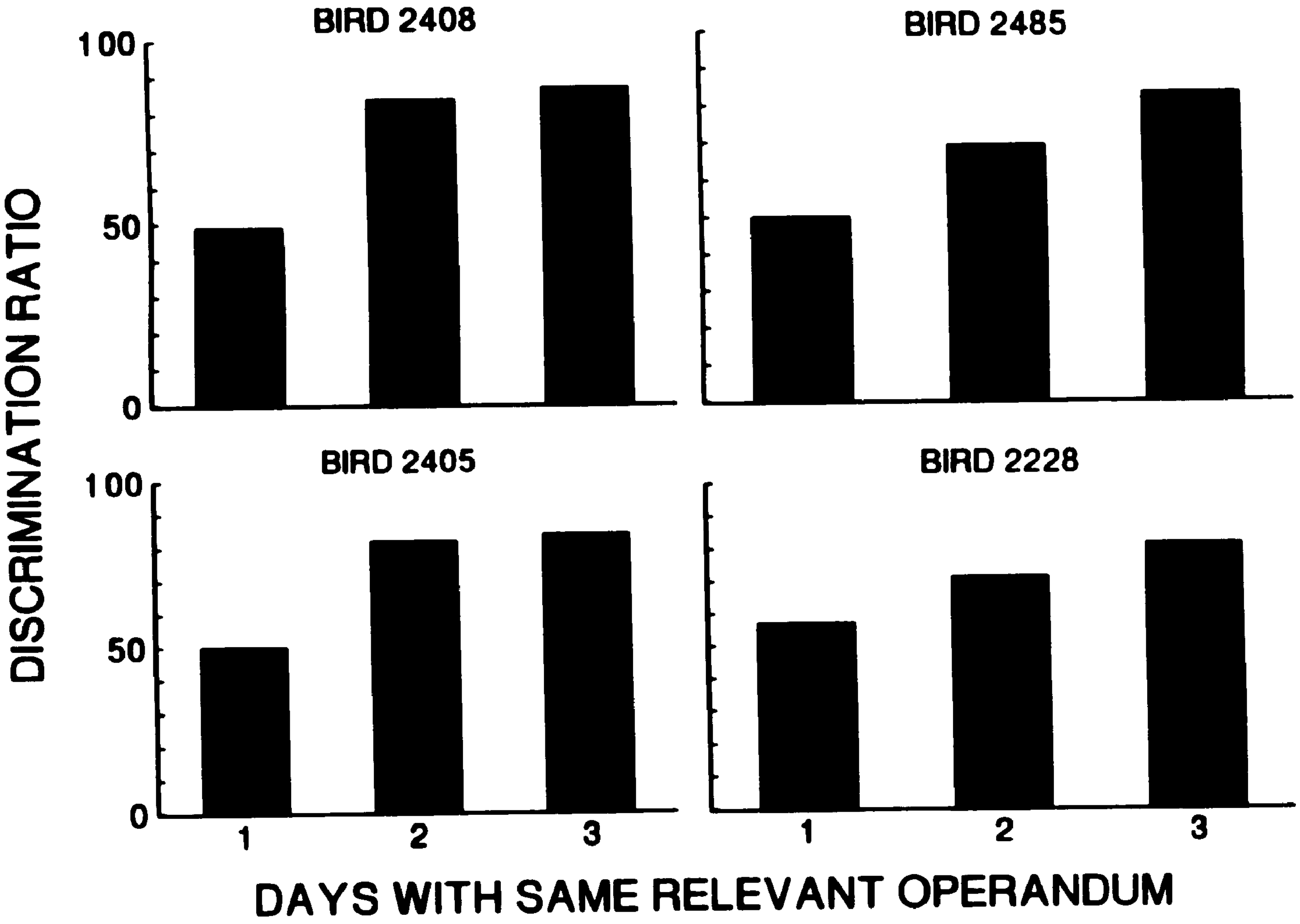

Figure 12. Average discrimination ratios of responding on the relevant operandum in Experiment 3 during sessions that were the first, second, or third consecutive day of responding with the same relevant operandum.

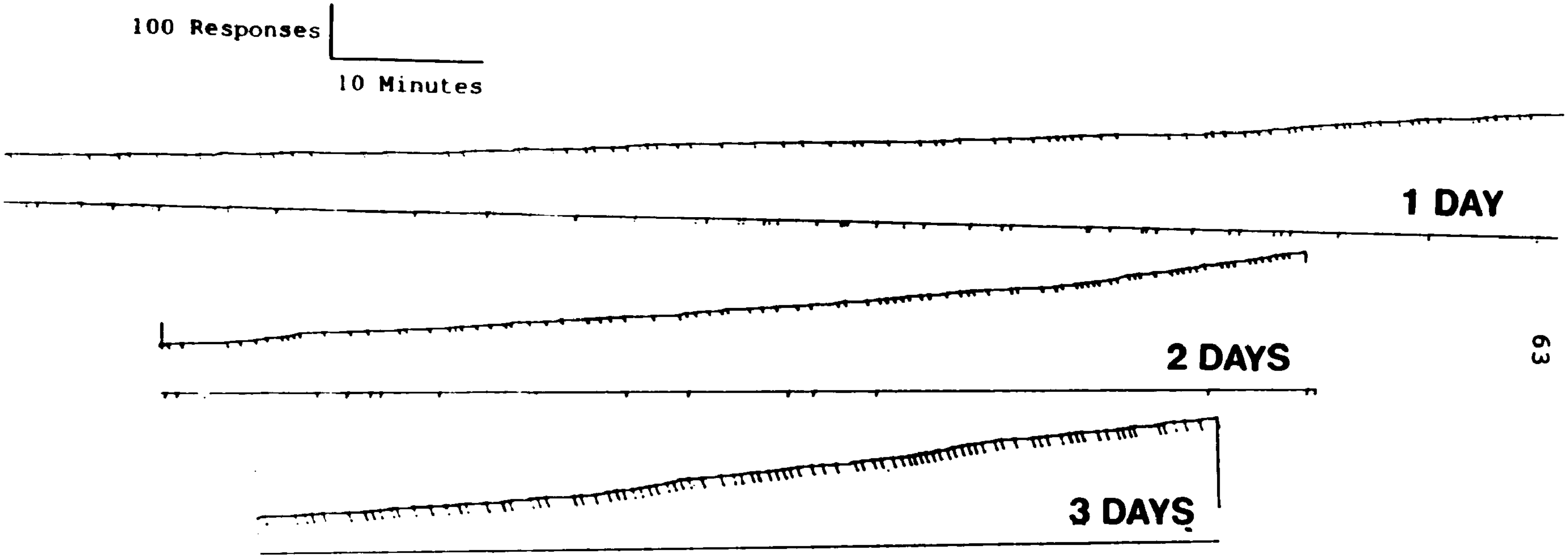

Figure 13. Sample cumulative records of responding for Bird 2408 in sessions that were the first, second, or third consecutive day of responding with the same relevant operandum in Experiment 3. Increments of the top pen indicate relevant operandum responses, deflections represent reinforcer deliveries, and event pen deflections represent irrelevant operandum responses.

the beginning of the session where responses were made exclusively on the relevant operandum, and throughout the session there was little responding on the irrelevant operandum. On the third day of responding on the same relevant operandum there was no responding on the irrelevant operandum in the session presented, showing complete control of responding by the schedule of reinforcement correlated with the relevant operandum in that session.

The control of responding by the delayed reinforcement schedule in Experiment 3 was dependent on the subjects' prior history of responding when a given operandum was relevant. The variability in responding that was observed in this experiment was affected by whether a particular session was the first, second, or third consecutive day of responding with the same relevant operandum. Specifically, a greater proportion of responses occurred on the relevant operandum when it was the same as in the previous session, and an even greater proportion of responding was observed on the relevant operandum when it was the same as in two previous sessions.

General Discussion

Response acquisition with delayed reinforcement was measured in the presence of a relevant and an irrelevant operandum to determine the sensitivity of behavior to the delayed reinforcement contingency. Responding was acquired without prior response shaping or training, supporting conclusions from previous experiments (e.g., Critchfield & Lattal, 1993; Lattal & Gleeson, 1990; Wilkenfield et al., 1992) that the delayed reinforcement contingency is sufficient to control behavior in the absence of stimuli serving as conditioned reinforcers.

Two operanda were available to separate responses controlled by the delayed reinforcement contingency from those that were occurring for other reasons, such as adventitious reinforcement or induction due to food delivery. Control of responding by the delayed reinforcement contingency was measured by comparing the response rates on the relevant operandum with the amount of responding on the irrelevant operandum. There were differences between the experiments as well as differences between conditions within each experiment regarding response rates on the operanda. In Experiment 1, response rates on the relevant operandum were higher than irrelevant operandum response rates in the first DRO 30-s condition for most of the subjects. In this condition the first bar pressed in each session was relevant. The control of responding exhibited by the delayed reinforcement contingency was no longer evident when the conditions changed and the first bar pressed in each session was the irrelevant one. Contingency control improved when the delay intervals were shortened to 10 and 5 s, but responding again was disrupted when delay intervals of 30 s were reinstated.

In most of the sessions in Experiment 2, response rates on the relevant operandum were higher than irrelevant operandum response rates. As in the first experiment, contingency control was adversely affected when the conditions changed and the formerly relevant operandum became the irrelevant one. In Experiment 3, the control of responding by the delayed reinforcement contingency improved when subjects responded on the same relevant operandum in one or two consecutive sessions as opposed to when the relevant operandum was different than in previous sessions. In all three of these experiments, unsignalled changes in the location of the relevant operandum as well as a history of responding on an irrelevant operandum that previously was the relevant one led to decreases in the control of responding by the delayed reinforcement schedule.

It is possible that the observed increases and decreases in response rates on the relevant and irrelevant operanda were not related to contingency control at all but were due to other variables in the experimental situation. For example, responding on the relevant operandum often occurred at higher rates than irrelevant operandum responding, but response rates on the irrelevant operandum may have been suppressed due to the resetting contingency following responding on that operandum. In other words, the delay intervals following responses on the irrelevant operandum that occurred close in time to reinforcer delivery may have effectively punished such responding. If punishment of irrelevant operandum responses was the reason for higher response rates on the relevant operandum, then this would have been the case throughout the experiments. In fact, the punishment of irrelevant operandum responding was unlikely because the resetting delays that followed responses on the irrelevant operandum were shorter than the delays in effect on the relevant operandum. The differences in responding observed across conditions in each experiment indicate that neither type of response was being punished by the resetting contingency.

The apparent insensitivity of responding to the reinforcement contingency observed at times in the present experiments may have been due to arbitrary side preferences, an explanation invoked in stimulus discrimination procedures to explain consistent responding on an operandum regardless of the stimuli correlated with that operandum (Harrison, 1991). Side preferences can occur for no discernable reason following stimulus discrimination training, and must be considered as a possible explanation for responding on the operanda in the present experiments. If responding primarily was the result of arbitrary side preferences, a single operandum would have been preferred consistently throughout different conditions in each experiment. This result would indicate a complete lack of control of responding by the delayed reinforcement contingency. This was not the case, however, as responding occurred at higher rates on the relevant operandum when delay intervals were shortened or when the relevant operandum was the same for several consecutive sessions. Arbitrary side preferences, therefore, were not assumed to affect responding in these experiments.

The results can be related to those of previous experiments where an irrelevant operandum was available. Critchfield and Lattal (1993) and Wilkenfield et al. (1992) reported responding that was similar in form to the reinforced response but was not directly controlled by the reinforcement schedule. In fact, Wilkenfield et al. observed irrelevant operandum response rates that were equal to or greater than relevant operandum response rates in a procedure that almost was identical to the procedure in effect for the first 45 sessions in Experiment 2 for Rats 7 and 8. Because the irrelevant operandum response rates measured by Wilkenfield et al. were higher than those in Experiment 2, the differences in the results between the two experiments should be examined further. One difference between the procedures was the deprivation level of the subjects. In the present experiments, subjects were maintained at approximately 70% of their free-feeding weights, while subjects in the Wilkenfield et al. experiment were maintained at 80%. Lattal and Williams (1995) found that higher deprivation levels can ensure that subjects are more active and thus more likely to respond on an available operandum. Therefore, the subjects at the higher deprivation levels in Experiment 2 might have been expected to respond on both operanda at higher rates than subjects that are less deprived of food.

Segal (1972), however, reported that in addition to being more active, subjects that are more food-deprived also are more responsive to environmental stimuli. That is, the process of deprivation itself not only ensures the effectiveness of the reinforcer, but acts as a discriminative stimulus for the emission of certain responses. Deprivation therefore may raise the probability of some response topographies and increase the responsiveness of behavior to the stimuli that are present when responses are emitted. The higher deprivation levels of the subjects in Experiment 2 appear to have resulted in greater sensitivity to the contingencies of the delayed reinforcement schedule, leading to more responses observed on the operandum correlated with reinforcement relative to irrelevant operandum responses than were made by the less deprived subjects in Wilkenfield et al.'s experiment.

In Experiment 3, relevant response rates increased (and irrelevant response rates decreased) as each session proceeded and as the subjects experienced the consequences for responding on each operandum. This was the same pattern of responding observed across sessions (but within conditions) in Experiment 2. In the beginning of each session (or each condition) of the final two experiments, most of the responding occurred on the operandum that had been correlated with reinforcement in the previous session (or condition). This finding is consistent with a study of spatial memory in pigeons using a procedure similar to that used in Experiment 3. Willson and Wilkie (1993) reinforced responding on one of four available operanda (response keys) in daily sessions where the operandum correlated with the reinforcement schedule varied across sessions. As in Experiment 3, at the beginning of each session Willson and Wilkie's subjects responded most on the key that was correlated with reinforcement in the previous session. The next highest rate of responding occurred on the key that had been correlated with reinforcement two sessions previously, and the third highest response rates occurred on the key that was correlated with reinforcement three sessions before the current one. Although these biases determined responding at the beginning of each session, subjects began responding on the key correlated with the reinforcement schedule at above chance levels after the first two minutes. As each session progressed, irrelevant operandum response rates decreased while response rates on the relevant operandum continued to increase.

The results of Experiments 2 and 3, together with those of Willson and Wilkie (1993), provide information about the lack of control of responding by the delayed reinforcement schedule in Experiment 1. In most of Experiment 1, the last condition of Experiment 2, and certain sessions in Experiment 3, response rates on the irrelevant operandum were equal to or higher than relevant operandum response rates. These results do not necessarily mean that Spence's (1947) and Grice's (1948) conclusions that the delayed reinforcement contingency does not control responding in the absence of close temporal relation between responses and reinforcers were supported. Rather, an analysis of the variables controlling responding in all three of the present experiments indicates that the lack of control of responding by the delayed reinforcement contingency was not due primarily to degraded contiguity between responses and reinforcers or the predominance of food-induced responses. Instead, the procedures used in the present experiments at times hindered the development of control of behavior by the delayed reinforcement contingency, resulting in high rates of responding on the irrelevant operandum that changed according to changes in the procedures that were in effect.

Induction, Mediating Behavior, and Adventitious Reinforcement

In the present experiments, food-induced responses were to be identified as those occurring on the irrelevant operandum at rates that would be approximately equal to those on the relevant operandum, regardless of the procedures in effect. This situation was observed somewhat in the final four conditions of the first experiment, although these results could have been due to the procedure whereby the subjects' behavior determined the relevant operandum. This procedure resulted in frequent changes in the relevant operandum, and such changes were shown in Experiment 3 to affect contingency control. Relevant operandum response rates were consistently higher than irrelevant operandum response rates in the conditions where the shorter delays were in effect. Irrelevant operandum responses occurred at low rates in many of the first sessions of all three experiments, when response acquisition was taking place. If food-induced rather than contingency-controlled responses were occurring in the situations under investigation, induction would have been especially evident during response acquisition (Segal, 1972). Also, if induction was the reason for the general lack of control of responding by the contingencies observed in Experiment 1, it also would have led to less control in the second and third experiments. Though the control of responding by the delayed reinforcement contingency was at times diminished by the procedures used, induction alone does not explain responding in these three experiments.

Although the responses on both operanda were unlikely to have been food-induced, there may have been other controlling variables aside from the delayed reinforcement contingency that affected responding. For example, irrelevant operandum responses could have occurred and been maintained because such responses prevented the subjects from making relevant operandum responses and thereby postponing reinforcement (cf. Schwartz & Williams, 1971). This type of behavior was suggested to contribute to the results of Wilkenfield et al. (1992), who observed responding on an irrelevant operandum at rates that equalled or exceeded relevant operandum response rates. Such responding, labelled mediating behavior (Schwartz & Williams, 1971), was measured in

Experiment 2. The results of sessions where irrelevant operandum responses that occurred during delay intervals had the effect of resetting the delay to reinforcement were compared with sessions where responses on the irrelevant operandum could occur at any time during the delay interval without affecting reinforcer delivery. If irrelevant operandum responses made reinforced responding more efficient, responses on the irrelevant operandum should have been more likely to occur in sessions where they could not reset the delay to reinforcement and even may have been adventitiously reinforced by occurring closer in time to reinforcer delivery than responses on the relevant operandum.

The low rates of irrelevant operandum responding by the end of the first two conditions of Experiment 2 for all subjects supports the conclusion that these responses were not occurring as a function of the response-constraining DRO contingency. Further evidence was provided in Experiment 3, where the number of irrelevant operandum responses decreased as the subjects were exposed to two or three consecutive sessions where the VI schedule was correlated with the same operandum. If irrelevant operandum responses were maintained by the avoidance of postponing reinforcer delivery in the situations examined here, these responses would have occurred at constant rates throughout the experiments rather than decreasing as the delayed reinforcement contingency gained control over behavior.

The results from the first condition of Experiment 2, where the effects of a resetting delay for responding on the irrelevant operandum were compared with responding in the absence of the resetting contingency, also provide insight into the likelihood that irrelevant operandum responses were adventitiously reinforced in the present experiments. Catania and Cutts (1963) observed responding in a two-operandum procedure where responding on one was reinforced according to a VI schedule but no reinforcement was available for responding on the remaining operandum. They found that responding on the irrelevant operandum was maintained by adventitious reinforcement, but the introduction of a resetting delay (ranging from 2 to 15 s in length) following responses on the irrelevant operandum abruptly halted such responding. Irrelevant operandum responding developed and was maintained for subjects that were exposed to a 4.5-s resetting delay contingency for those responses throughout the experiment, but to a lesser extent than for subjects that initially experienced no resetting delay contingency.

The results of Catania and Cutts (1963) suggest that, even though resetting delays of at least 5 s were in effect for irrelevant operandum responding in the present experiments, adventitious reinforcement of such responding still may have occurred. However, the comparison made in Experiment 2 between responding in the presence and in the absence of a resetting delay contingency on the irrelevant operandum suggests otherwise. Rates of irrelevant operandum responding were no higher when the resetting delay contingency was not in effect, making it unlikely that adventitious reinforcement was occurring when delays to reinforcement were initiated by responses on the irrelevant operandum. Also, the 10-s resetting delay contingency used in most of the sessions in the present experiments were longer than the 4.5-s delays that permitted adventitious reinforcement of responding in the experiment by Catania and Cutts. Therefore, even if irrelevant operandum responding was observed to occur at higher rates when no resetting delay was present, it is likely that the adventitious reinforcement of behavior would have been effectively eliminated when 10-s delays were in effect.

Conclusions

The largest number of irrelevant operandum responses were observed in the first experiment. The improvement of contingency control in the presence of shorter delays to reinforcement supports the argument that the degree of temporal contiguity affected responding. That is, the closer in time responses were to reinforcers the better responses were controlled by the contingency. On the other hand, delays of 30 s have been used in several experiments (e.g., Critchfield & Lattal, 1993; Lattal & Gleeson, 1990) and were sufficient in the first condition of each of the present experiments for the acquisition of responding, so it is unlikely that delays of this length prevented the control of responding by the reinforcement contingencies. However, long delays, in combination with the procedure that allowed the location of the relevant operandum to vary irregularly in the first experiment, functioned to make the operandum correlated with the reinforcement schedule less distinguishable in the second and third DRO 30-s conditions of the first experiment.

Increased irrelevant operandum responding in the presence of long delays to reinforcement also could affect conclusions concerning the occurrence of food-induced responses. Although induction was discounted as a primary influence on responding in these experiments because of the relative lack of irrelevant operandum responses during response acquisition, a case still may be made for the presence of food-induced responses occurring on the irrelevant operandum in the remaining conditions of the experiments. The changes in the distribution of responses when the delay intervals were decreased suggests that the lack of control of responding by the delayed reinforcement contingency in some conditions of the present experiments, as measured by the number of irrelevant operandum responses compared to the number of responses on the relevant operandum, was due to the specific procedures used in those experiments rather than the delayed reinforcement contingency itself. Contingency control of responding was facilitated when the procedures used made the relevant and irrelevant operanda more distinguishable. Warner (1990) proposed that there are two functions of the response-reinforcer relation, identified as the direct and indirect effects of reinforcement. Direct effects are those that strengthen or weaken the response. Based on the direct effects of reinforcement alone, it was expected that subjects would respond primarily on the reinforced operandum and at lower rates on the operandum not correlated with reinforcement. Such a distribution of responding occurred in many sessions in the present experiments.

Responses were not so distributed when the procedures affected the indirect, or discriminative, effects of the response-reinforcer relation. Indirect effects allow the subject to identify the source of the reinforcement schedule before the subject's behavior comes under the control of that schedule (Warner, 1990). The relatively high rates of responding on the irrelevant operandum in the remaining sessions of the present experiments at first seem to indicate that the delayed reinforcement contingency was not controlling responding after all. However, in all three experiments the control of responding by the delayed reinforcement contingency varied with variations in the detectability of the relevant operandum. For example, the contingency control of responding was clear for the majority of subjects in the first condition of Experiment 1, where the subjects' behavior and the procedure for determining the relevant operandum resulted in the same relevant operandum in most of the sessions. Control of responding by the delayed reinforcement contingency also was exhibited in Experiment 2, where the relevant operandum always was the same within each condition.

There was some disruption of this control as the conditions changed, but for the most part the delayed reinforcement contingency regained control of responding within a few sessions. The delayed reinforcement contingency controlled responding in Experiment 3 most effectively when the subjects responded on the same relevant operandum for two or three consecutive sessions, as opposed to responding on a relevant operandum that was irrelevant in the previous session or sessions. Contingency control improved in Experiment 1 when the delay intervals were shortened from 30 s to 10 and 5 s, respectively, in the third and fourth conditions. The relatively close temporal relation between responses and reinforcers in the conditions with the shorter delay intervals made the location of the relevant operandum more identifiable than in the remaining conditions, resulting in better contingency control of responding.

The present results can be interpreted in light of Hull's (1932) theory of learning, which postulates that the close temporal relation between a stimulus and a reinforcer as well as the contingent relation of responses and primary or secondary reinforcement are necessary for learning to occur. Hull (1930) and Spence (1956) proposed that, during instrumental conditioning, subjects learn the relation between a response and the reinforcer. Also, through classical conditioning, the stimuli that are present when responding is reinforced come to elicit some of the same responding in anticipation of reinforcer delivery. In the present experiments, experience with responding on the same relevant operandum for several consecutive sessions constituted discrimination training. Spence (1937) assumed such training led to the formation of excitatory and inhibitory stimulus generalization gradients that in the present experiments would have been centered around the relevant and irrelevant operanda, respectively. This discriminative control of responding by the positions of the operanda explains the maintenance of responding on the formerly relevant operandum when contingencies correlated with that operandum changed.

The discrimination between the relevant and irrelevant operanda was formed as the behavior came under the control of the delayed reinforcement contingency, as in the first conditions of Experiments 1 and 2. The discriminative stimuli associated with each of these operanda, such as their position in the chamber, maintained responding as the contingencies changed. This was the case in the second conditions of Experiments 1 and 2, and between sessions in Experiment 3. As the new contingencies associated with each operandum gained control over behavior, new discriminations were formed that continued to maintain behavior even as the contingencies again changed, and so on. These results support Hull's and Spence's theories about the role of classical conditioning in instrumental learning, as well as the importance of a close temporal relation between stimuli and responses as well as responses and reinforcers. Although responding may be acquired and maintained when reinforcement is delayed, procedures such as those used in the present experiments allow other factors (e.g., the stimuli associated with the operanda) to gain more control over responding than may occur when reinforcers are delivered immediately.

The three present experiments extended previous knowledge of the variables affecting response acquisition and maintenance with delayed reinforcement by examining responding in situations using an irrelevant operandum. Together with existing knowledge about the factors influencing the control of responding by delayed reinforcement, these results serve as a demonstration of the control of responding by the contingency in the absence of close temporal contiguity. Specifically, delayed reinforcement is sufficient for the acquisition and maintenance of responding at average delays of 30 s. Results from delayed reinforcement experiments are particularly useful when applied to human behavior, where many of the consequences controlling responding are not immediate. Future experiments, using human as well as non-human subjects, may concentrate on other factors determining responding in delayed reinforcement experiments, such as the longest delays possible that still maintain responding and the factors that affect responding at these longer delay intervals.

Some experimenters (e.g., Schwartz & Williams, 1971) have indicated that irrelevant operandum responding can be maintained by allowing reinforcement of the primary response to occur. The fact that responding on the irrelevant operandum did not serve this function in the current experiments does not mean that such behavior is not beneficial in certain situations. Another line of experimentation stemming from the present experiments may be that geared toward understanding the common features of the situations where this type of behavior does and does not occur, such as the differences between the requirements of DRO and DRL schedules that may lead to differences in the utility of irrelevant operandum responses performed during pauses in responding on the relevant operandum. Finally, more work should be conducted in the area of the discriminative effects of reinforcement schedules and separating these discriminative effects from the direct effects of reinforcement on responding. Procedures using multiple operanda may prove useful in each of these endeavors.

References

Baum, W.M. (1973). The correlation-based law of effect. Journal of the Experimental Analysis of Behavior, 20, 137-153.

Bruner, A., & Revusky, S.H. (1962). Collateral behavior in humans. Journal of the Experimental Analysis of Behavior, 4, 349-350.

Catania, A.C., & Cutts, D. (1963). Experimental control of superstitious responding in humans. Journal of the Experimental Analysis of Behavior, 6, 203-208.

Chung, S.H. (1965). Effects of delayed reinforcement in a concurrent situation. Journal of the Experimental Analysis of Behavior, 8, 439-444.

Critchfield, T.S., & Lattal, K.A. (1993). Acquisition of a spatially defined operant with delayed reinforcement. Journal of the Experimental Analysis of Behavior, 59, 373-387.

Fleshler, M., & Hoffman, H.S. (1962). A progression for generating VI schedules. Journal of the Experimental Analysis of Behavior, 5, 529-530.

Grice, G.R. (1948). The relation of secondary reinforcement to delayed reward in visual discrimination learning. Journal of Experimental Psychology, 38, 1-16.

Harker, G.S. (1956). Delay of reward and performance of an instrumental response. Journal of Experimental Psychology, 51, 303-310.

Harrison, J.M. (1991). Stimulus control. In Iverson, I.H. & Lattal, K.A. (Eds.), Experimental Analysis of Behavior: Part 1 (pp. 251-299). Amsterdam: Elsevier Science Publishers B.V.

Hull, C.L. (1930). Knowledge and purpose as habit mechanisms. Psychological Review, 30, 511-525.

Hull, C.L. (1932). The goal gradient hypothesis and maze learning. Psychological Review, 39, 25-43.

Laties, V.G., Weiss, B., Clark, R.L., & Reynolds, M.D. (1965). Overt "mediating" behavior during temporally spaced responding. Journal of the Experimental Analysis of Behavior, 8, 107-116.

Lattal, K.A., & Gleeson, S. (1990). Response acquisition with delayed reinforcement. Journal of Experimental Psychology: Animal Behavior Processes, 16, 27-39.

Lattal, K.A., & Metzger, B. (1994). Response acquisition by Siamese fighting fish (Betta Splendens) with delayed visual reinforcement. Journal of the Experimental Analysis of Behavior, 61, 35-44.

Lattal, K.A., & Williams, A.M. (1996). Motivational effects on response acquisition with delayed reinforcement. Manuscript submitted for publication.

Logan, F.A. (1952). The role of delay of reinforcement in determining reaction potential. Journal of Experimental Psychology, 43, 393-399.

Nevin, J.A., & Berryman, R. (1963). A note on chaining and temporal discrimination. Journal of the Experimental Analysis of Behavior, 6, 109-113.

Renner, K.E. (1964). Delay of reinforcement: A historical review. Psychological Bulletin, 61, 341-361.

Schwartz, B., & Williams, D.R. (1971). Discrete-trials spaced responding in the pigeon: The dependence of efficient performance on the availability of a stimulus for collateral pecking. Journal of the Experimental Analysis of Behavior, 16, 155-160.

Segal, E.F. (1972). Induction and the provenance of operants. In Gilbert, R.M., & Millenson, J.R. (Eds.), Reinforcement: Behavioral Analyses (pp. 1-34). New York: Academic Press.

Seward, J.P., & Weldon, R.J. (1953). Response latency as a function of change in delay of reward. Journal of Comparative and Physiological Psychology, 46, 184-189.

Skinner, B.F. (1953). Science and Human Behavior. New York: Macmillan.

Spence, K.W. (1937). The differential response in animals to stimuli varying within a single dimension. Psychological Review, 44, 430-444.

Spence, K.W. (1947). The role of secondary reinforcers in delayed reward learning. Psychological Review, 54, 1-8.

Spence, K.W. (1956). Behavior theory and conditioning. New Haven: Yale University Press.

Thorndike, E.L. (1911). Animal Intelligence. New York: Macmillan.

Warner, J.E. (1990). The Discrimination of Delayed and Response-Independent Events. Unpublished master's thesis, West Virginia University, Morgantown, West Virginia.

Wilkenfield, J., Nickel, M., Blakely, E., & Poling, A. (1992). Acquisition of lever-press responding in rats with delayed reinforcement: A comparison of three procedures. Journal of the Experimental Analysis of Behavior, 58, 431-443.

Willson, R.J., & Wilkie, D.M. (1993). Pigeons remember briefly trained spatial location-food associations over extended time periods. Journal of Experimental Psychology: Animal Behavior Processes, 19, 373-379.

Zeiler, M. (1977). Schedules of reinforcement: The controlling variables. In W.K. Honig and J.E.R. Staddon (Eds.), Handbook of Operant Behavior (pp. 201-232). New York: Prentice Hall.

APPENDIX: COMPUTER PROGRAMS

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\Experiment 1:  DISS1.MPC
\Separating Induced and Contingency Controlled Responding Using
\Delayed Reinforcement- This program initiates 30" delays after
\responses on a VI30" schedule and resets this delay with a
\response on the relevant bar.  Responses on the irrelevant bar
\in the last 10" of the scheduled delay reset the delay an
\additional 10".  The first bar pressed is the relevant bar.

\z1=begin VI interval
\z2=  "   "    "
\z3=start delay timer
\z4=end delay timer
\z5=turns off event pen
\z10=relevant bar
\z20=irrelevant bar

\c(1)=relevant response counter
\c(2)=counter for relevant responses that reset the delay
\c(3)=session timer (in secs)
\c(4)=reinforcement counter
\c(5)=irrelevant response counter
\c(6)=counts responses on irrelevant bar that reset the delay
\c(7)=indicates that first response occurred on bar #2
\c(8)=precise time spent in delay (divide by 4 to get total secs)
\c(9)=indicates that first response occurred on bar #1
\c(10)=precise session timer
\c(11)=precise session timer (revised)

list a= 1", 2", 3", 5",6", 7", 9", 11", 12", 14", 16", 18", 21",
23", 26", 29", 32", 36", 40", 45", 52", 59", 69", 85", 127"

^feeder=5
^houselight=6
^event=8
^pip=3
^step=7
^motor=1

dim c=11, b=500, d=500

S.S.1, \main state set
s1,
#start:on ^houselight;on ^motor;z1--->s2
s2,
x#t:--->s3
#z10:add c(1);show 1,resp,c(1)--->sx
#z20:add c(5);show 5,ext,c(5)--->sx
s3,
#z10:add c(1);show 1,resp,c(1)--->s4
```

```
#z20:add c(5);show 5,ext,c(5)--->sx
s4,
20":z3--->s6
#z10:add c(2);show 2,dr,c(2)--->s5
#z20:add c(5);show 5,ext,c(5)--->sx
s5,
.001":--->s4
s6,
10":--->s8
#z10:add c(2);show 2,dr,c(2)--->s4
#z20:add c(6);show 6,dext,c(6)--->s7
s7,
.001":--->s6
s8,
.001":on ^feeder;on ^pip;z4--->s9
#z10:add c(1);show 1,resp,c(1)--->sx
#z20:add c(5);show 5,ext,c(5)--->sx
s9,
.10":off ^feeder;off ^pip;add c(4);show 4,rein,c(4)--->s10
#z10:add c(1);show 1,resp,c(1)--->sx
#z20:add c(5);show 5,ext,c(5)--->sx
s10,
.960":z2--->s2
#z10:add c(1);show 1,resp,c(1)--->s2
#z20:add c(5);show 5,ext,c(5)--->sx

S.S.2, \session timer
s1,
#start:--->s2
s2,
1":add c(3);show 3,secs,c(3)--->sx

S.S.3, \session end
s1,
.025":if c(4)=60 [@stop, @continue]
               @stop:z5;off ^motor--->stopabort
               @continue:--->sx

S.S.4, \variable interval schedule
s1,
#z1:randd x=a--->s2
s2,
#z2:randd x=a--->sx

S.S.5, \determining active and inactive bar
s1,
#r1:add c(9)--->s2
#r2:add c(7)--->s4
s2,
```

```
.030":z10--->s3
s3,
#r1:z10--->sx
#r2:z20--->sx
s4,
.030":z10--->s5
s5,
#r2:z10--->sx
#r1:z20--->sx

S.S.6, \time spent in delay
s1,
#start:--->s2
s2,
#z3:--->s3
s3,
#z4:--->s2
.25":add c(8)--->s4
s4,
.001":--->s3

S.S.7, \cumulative recorder
s1,
#start:--->s2
s2,
#z10:on ^step--->s3
#z20:on ^event--->s4
#z5:--->s5
s3,
.04":off ^step--->s2
s4,
.04":off ^event--->s2
s5,
.01":--->sx

S.S.8, \making session timer more precise
s1,
#start:--->s2
s2,
.25":add c(10);set c(11)=c(10)/4--->sx

S.S.9, \recording relevant responses in real time
s1,
#start:--->s2
s2,
#z10:set b(m) = c(11);add m;if m>499 [@stop, @go]
                               @stop:--->s3
                               @go:set b(m) = -987.987--->sx
s3,
```

```
.01":--->sx

S.S.10, \recording irrelevant responses in real time
s1,
#start:--->s2
s2,
#z20:set d(r) = c(11); add r; if r>499 [@stop, @go]
                                 @stop:--->s3
                                 @go:set d(r) = -987.987--->sx
s3,
.01":--->sx
```

```
\Experiment 1:  DISS1ir.MPC
\Separating Induced and Contingency Controlled Responding Using
\Delayed Reinforcement- This program initiates 30" delays after
\responses on a VI30" schedule and resets this delay with a
\response on the relevant bar.  Responses on the irrelevant bar
\in the last 10" of the scheduled delay reset the delay an
\additional 10".  The first bar pressed is the irrelevant bar.

\z1=begin VI interval
\z2=  "   "    "
\z3=start delay timer
\z4=end delay timer
\z5=turns off event pen
\z10=relevant bar
\z20=irrelevant bar

\c(1)=relevant response counter
\c(2)=counter for relevant responses that reset the delay
\c(6)=session timer (in secs)
\c(5)=reinforcement counter
\c(3)=irrelevant response counter
\c(4)=counts responses on irrelevant bar that reset the delay
\c(7)=indicates that first response occurred on left bar
\c(8)=time spent in delay
\c(9)=indicates that first response occurred on right bar
\c(10)=precise session timer
\c(11)=precise session timer (revised)

list a= 1", 2", 3", 5",6", 7", 9", 11", 12", 14", 16", 18", 21",
23", 26", 29", 32", 36", 40", 45", 52", 59", 69", 85", 127"

\Outputs
^feeder=5
^houselight=6
^event=8
^pip=3
^step=7
^motor=1

dim c=11, b=1000, d=1000, f=65

S.S.1, \main state set
s1,
#start:on ^houselight;on ^motor;z1--->s2
s2,
x#t:--->s3
#z10:add c(1);show 1,resp,c(1)--->sx
#z20:add c(3);show 3,ext,c(3)--->sx
s3,
```

```
#z10:add c(1);show 1,resp,c(1); z3--->s4
#z20:add c(3);show 3,ext,c(3)--->sx
s4,
20":--->s6
#z10:add c(2);show 2,dr,c(2)--->s5
#z20:add c(3);show 3,ext,c(3)--->sx
s5,
.001":--->s4
s6,
10":--->s8
#z10:add c(2);show 2,dr,c(2)--->s4
#z20:add c(4);show 4,dext,c(4)--->s7
s7,
.001":--->s6
s8,
.001":on ^feeder;on ^pip;z4--->s9
#z10:add c(1);show 1,resp,c(1)--->sx
#z20:add c(3);show 3,ext,c(3)--->sx
s9,
.10":off ^feeder;off ^pip;add c(5);show 5,rein,c(5); z15--->s10
#z10:add c(1);show 1,resp,c(1)--->sx
#z20:add c(3);show 3,ext,c(3)--->sx
s10,
.960":z2--->s2
#z10:add c(1);show 1,resp,c(1)--->s2
#z20:add c(3);show 3,ext,c(3)--->sx

S.S.2, \session timer
s1,
#start:--->s2
s2,
1":add c(6);show 6,secs,c(6); if c(6) = 10800 [@stop, @continue]
                              @stop:  z5; off ^motor--->stopabort
                              @continue:--->sx

S.S.3, \session end
s1,
.025":if c(5)=60 [@stop, @continue]
              @stop:z5;off ^motor--->stopabort
              @continue:--->sx

S.S.4, \variable interval schedule
s1,
#z1:randd x=a--->s2
s2,
#z2:randd x=a--->sx

S.S.5, \determining active and inactive bar
s1,
```

```
#r1:add c(9)--->s2
#r2:add c(7)--->s4
s2,
.030":z20--->s3
s3,
#r1:z20--->sx
#r2:z10--->sx
s4,
.030":z20--->s5
s5,
#r2:z20--->sx
#r1:z10--->sx

S.S.6, \time spent in delay
s1,
#start:--->s2
s2,
#z3:--->s3
s3,
#z4:--->s2
1":add c(8); show 8, del, c(8)--->sx

S.S.7, \cumulative recorder
s1,
#start:--->s2
s2,
#z10:on ^step--->s3
#z20:on ^event--->s4
#z5:--->s5
s3,
.04":off ^step--->s2
s4,
.04":off ^event--->s2
s5,
.01":--->sx

S.S.8, \making session timer more precise
s1,
#start:--->s2
s2,
.25":add c(10);set c(11)=c(10)/4--->sx

S.S.9, \recording relevant responses in real time
s1,
#start:--->s2
s2,
#z10:set b(m) = c(11);add m;if m>499 [@stop, @go]
                            @stop:--->s3
                            @go:set b(m) = -987.987--->sx
```

```
s3,
.01":--->sx

S.S.10, \recording irrelevant responses in real time
s1,
#start:--->s2
s2,
#z20:set d(r) = c(11); add r; if r>499 [@stop, @go]
                              @stop:--->s3
                              @go:set d(r) = -987.987--->sx
s3,
.01":--->sx

S. S. 11, \recording reinforcers in real time
s1,
#start:--->s2
s2,
#z15:  set f(h) = c(11); add h; if h>65 [@stop, @go]
                                @stop:--->s3
                                @go:  set f(h) = -987.987--->sx
s3,
.01":--->sx
```

```
\Experiment 2:  DISS3EXT.MPC
\Separating Induced and Contingency Controlled Responding Using
\Delayed Reinforcement- This program initiates 30" delays after
\responses on a VI30" schedule and resets this delay with a
\response on the left (or right) bar.  Responses on the right (or
\left) bar have no consequence.

\z1=begin VI interval
\z2=  "   "    "
\z3=start delay timer
\z4=end delay timer

\c(1)=relevant response counter
\c(2)=counter for relevant responses that reset the delay
\c(4)=irrelevant responses during the delay
\c(6)=session timer (in secs)
\c(5)=reinforcement counter
\c(3)=irrelevant response counter
\c(7)=determines relevant response
\c(8)=time spent in delay
\c(10)=precise session timer
\c(11)=precise session timer (revised)

list a= 1", 2", 3", 5",6", 7", 9", 11", 12", 14", 16", 18", 21",
23", 26", 29", 32", 36", 40", 45", 52", 59", 69", 85", 127"

\Outputs
^feeder=5
^houselight=6
^event=8
^pip=3
^step=7
^motor=1


dim c=11, b=500, d=500, f=65

S.S.1, \main state set
s1,
#start:on ^houselight;on ^motor;z1--->s2
s2,
x#t:--->s3
#r2:add c(1);show 1,resp,c(1)--->sx
#r1:add c(3);show 3,ext,c(3)--->sx
s3,
#r2:add c(1);show 1,resp,c(1); z3--->s4
#r1:add c(3);show 3,ext,c(3)--->sx
s4,
30":--->s6
```

```
#r2:add c(2);show 2,dr,c(2)--->s5
#r1:add c(3);show 4,dext,c(4)--->sx
s5,
001":--->s4
s6,
001":on ^feeder;on ^pip;z4--->s7
#r2:add c(1);show 1,resp,c(1)--->sx
#r1:add c(3);show 3,ext,c(3)--->sx
s7,
10":off ^feeder;off ^pip;add c(5);show 5,rein,c(5); z15--->s8
#r2:add c(1);show 1,resp,c(1)--->sx
#r1:add c(3);show 3,ext,c(3)--->sx
s8,
960":z2--->s2
#r2:add c(1);show 1,resp,c(1)--->s2
#r1:add c(3);show 3,ext,c(3)--->sx

S.S.2, \session timer
s1,
#start:--->s2
s2,
1":add c(6);show 6,secs,c(6); if c(6) = 10800 [@stop, @continue]
                               @stop:--->z5;off ^motor--->stopabort
                                @continue:--->sx

S.S.3, \session end
s1,
025":if c(5)=60 [@stop, @continue]
             @stop:z5;off ^motor--->stopabort
             @continue:--->sx

S.S.4, \variable interval schedule
s1,
#z1:randd x=a--->s2
s2,
#z2:randd x=a--->sx

S.S.5, \time spent in delay
s1,
#start:--->s2
s2,
#z3:--->s3
s3,
#z4:--->s2
1":add c(8); show 8, del, c(8)--->sx

S.S.6, \making session timer more precise
s1,
#start:--->s2
```

```
s2,
25":add c(10);set c(11)=c(10)/4--->sx

S.S.7, \recording relevant responses in real time
s1,
#start:--->s2
s2,
#r2:set b(m) = c(11);add m;if m>499 [@stop, @go]
                              @stop:--->s3
                              @go:set b(m) = -987.987--->sx
s3,
01":--->sx

S.S.8, \recording irrelevant responses in real time
s1,
#start:--->s2
s2,
#r1:set d(r) = c(11); add r; if r>499 [@stop, @go]
                              @stop:--->s3
                              @go:set d(r) = -987.987--->sx
s3,
01":--->sx

S. S.9, \recording reinforcers in real time
s1,
#start:--->s2
s2,
#z15:  set f(h) = c(11); add h; if h>65 [@stop, @go]
                                @stop:--->s3
                                @go:  set f(h) = -987.987--->sx
s3,
01":--->sx

S.S. 10, \Cumulative Recorder
s1,
#start:--->s2
s2,
#r2:on ^step--->s3
#r1:on ^event--->s4
#z5:--->s5
s3,
04":off ^step--->s2
s4,
04":off ^event--->s2
s5,
01":--->sx
```

```
\Experiment 2:  DISS3DRO.MPC
\Separating Induced and Contingency Controlled Responding Using
\Delayed Reinforcement- This program initiates 30" delays after
\responses on a VI30" schedule and resets this delay with a
\response on the relevant bar.  Responses on the irrelevant bar
\reset the delay.

\z1=begin VI interval
\z2=  "   "    "
\z3=start delay timer
\z4=end delay timer

\c(1)=relevant response counter
\c(2)=counter for relevant responses that reset the delay
\c(6)=session timer (in secs)
\c(5)=reinforcement counter
\c(3)=irrelevant response counter
\c(4)=counts responses on irrelevant bar that reset the delay
\c(7)=determines relevant response
\c(8)=time spent in delay
\c(10)=precise session timer
\c(11)=precise session timer (revised)

list a= 1", 2", 3", 5",6", 7", 9", 11", 12", 14", 16", 18", 21",
23", 26", 29", 32", 36", 40", 45", 52", 59", 69", 85", 127"

\Outputs
^feeder=1
^houselight=2

dim c=11, b=500, d=500, f=65

S.S.1, \main state set
s1,
#start:on ^houselight;z1--->s2
s2,
x#t:--->s3
#r1:add c(1);show 1,resp,c(1)--->sx
#r2:add c(3);show 3,ext,c(3)--->sx
s3,
#r1:add c(1);show 1,resp,c(1); z3--->s4
#r2:add c(3);show 3,ext,c(3)--->sx
s4,
30":--->s6
#r1:add c(2);show 2,dr,c(2)--->s5
#r2:add c(4);show 4,dext,c(4)--->s5
s5,
001":--->s4
s6,
```

```
001":on ^feeder;z4--->s7
#r1:add c(1);show 1,resp,c(1)--->sx
#r2:add c(3);show 3,ext,c(3)--->sx
s7,
10":off ^feeder;add c(5);show 5,rein,c(5); z15--->s8
#r1:add c(1);show 1,resp,c(1)--->sx
#r2:add c(3);show 3,ext,c(3)--->sx
s8,
960":z2--->s2
#r1:add c(1);show 1,resp,c(1)--->s2
#r2:add c(3);show 3,ext,c(3)--->sx

S.S.2, \session timer
s1,
#start:--->s2
s2,
1":add c(6);show 6,secs,c(6); if c(6) = 10800 [@stop, @continue]
                               @stop:--->stopabort
                               @continue:--->sx

S.S.3, \session end
s1,
025":if c(5)=60 [@stop, @continue]
               @stop:--->stopabort
               @continue:--->sx

S.S.4, \variable interval schedule
s1,
#z1:randd x=a--->s2
s2,
#z2:randd x=a--->sx

S.S.5, \time spent in delay
s1,
#start:--->s2
s2,
#z3:--->s3
s3,
#z4:--->s2
1":add c(8); show 8, del, c(8)--->sx

S.S.6, \making session timer more precise
s1,
#start:--->s2
s2,
25":add c(10);set c(11)=c(10)/4--->sx

S.S.7, \recording relevant responses in real time
s1,
```

```
#start:--->s2
s2,
#r1:set b(m) = c(11);add m;if m>499 [@stop, @go]
                            @stop:--->s3
                            @go:set b(m) = -987.987--->sx
s3,
01":--->sx

S.S.8, \recording irrelevant responses in real time
s1,
#start:--->s2
s2,
#r2:set d(r) = c(11); add r; if r>499 [@stop, @go]
                              @stop:--->s3
                              @go:set d(r) = -987.987--->sx
s3,
01":--->sx

S. S. 9, \recording reinforcers in real time
s1,
#start:--->s2
s2,
#z15:  set f(h) = c(11); add h; if h>65 [@stop, @go]
                                @stop:--->s3
                                @go:  set f(h) = -987.987--->sx
s3,
01":--->sx
```

```
\Experiment 3:  DISS2c15.mpc
\Pigeons will respond under a concurrent [tandem VI 15-s DRO
\10-s] [EXT] schedule of reinforcement available on two keys.
\The schedules correlated with the keys will be randomly
\determined daily.

\VI 15-s schedule
list b = .38", 1.17", 2", 2.89", 3.83", 4.83", 5.9", 7.05",
8.31", 9.67", 11.8", 12.84", 14.72", 16.87", 19.38", 22.41",
26.2", 31.29", 39.14", 59.94"

\c(1) = number of responses on VI key
\c(2) = number of responses on VI key during delay
\c(3) = number of responses on EXT key
\c(4) = number of responses on EXT key during delay
\c(5) = number of reinforcer deliveries
\c(6) = session timer
\c(7) = if 0, left key is EXT
\c(8) = VI value
\c(9) = precise session timer
\c(10) = precise response and reinforcer timer
\c(12) = delay timer

\inputs
^lkey = 1
^rkey = 3

\outputs
^hopper = 12
^left = 4
^right = 9
^step = 2
^pip = 3
^event = 8
^motor = 6

dim c = 13, d = 1000, f = 1000, g = 120

S. S. 1, \main body
s1,
#start:  on ^left, ^right, ^motor; if p = 1 [@true, @false]
                                   @true:  set c(7) = 1; z4--->s2
                                   @false:  if p = 0 [@yes, @no]
                                            @yes:  set c(7) = 0;
                                                 z5--->s8
                                            @no:  show 11, nono,
                                                p--->sx
s2,
.025":  randd y = b--->s3
```

```
s3,
y#t:--->s4
s4,
#r^lkey:  set c(12) = 10--->s5
s5,
1":  sub c(12); if c(12) = 0 [@continue, @stay]
                                @continue:  off ^right, ^left; on
                                            ^hopper, ^pip; z1--->s6
                                @stay:--->sx
#r^lkey:--->s14
#r^rkey:--->s15
s6,
4":  on ^right, ^left; off ^hopper, ^pip; add c(5); show 5, rein,
c(5); z2;
     if c(5) = 90 [@stop, @continue]
                  @stop:  off ^motor; z9--->stopabort
                  @continue:--->s7
s7,
.01":--->s2
s8,
.025":  randd y = b--->s9
s9,
y#t:--->s10
s10,
#r^rkey:  set c(12) = 10--->s11
s11,
1":  sub c(12); if c(12) = 0 [@continue, @stay]
     @continue:  off ^right, ^left; on ^hopper, ^pip; z1--->s12
     @stay:--->sx
#r^rkey:--->s16
#r^lkey:--->s17
s12,
4":  on ^right, ^left; off ^hopper, ^pip; add c(5); show 5, rein,
c(5); z2;
     if c(5) = 90 [@stop, @continue]
                  @stop:  off ^motor; z9--->stopabort
                  @continue:--->s13
s13,
.01":--->s8
s14,
.025":  add c(2); show 2, VDEL, c(2); set c(12) = 10--->s5
s15,
.025":  add c(4); show 4, EDEL, c(4); set c(12) = 10--->s5
s16,
.025":  add c(2); show 2, VDEL, c(2); set c(12) = 10--->s11
s17,
.025":  add c(4); show 4, EDEL, c(4); set c(12) = 10--->s11

S. S. 2, \session timer
```

```
s1,
#start:--->s2
s2,
1":  add c(6); show 6, secs, c(6); if c(6) = 28800 [@stop,
@continue]
                                              @stop:--->stopabort
                                              @continue:--->sx
#z1:--->s3
s3,
#z2:--->s2

S. S. 3, \response counters
s1,
#start:--->s2
s2,
#z4:--->s3
#z5:--->s4
s3,
#r^lkey:  add c(1); show 1, VI, c(1)--->sx
#z1:--->s6
#r^rkey:  add c(3); show 3, EXT, c(3)--->sx
s4,
#r^rkey:  add c(1); show 1, VI, c(1)--->sx
#z1:--->s7
#r^lkey:  add c(3); show 3, EXT, c(3)--->sx
s5,
.01":--->sx
s6,
#z2:--->s3
s7,
#z2:--->s4

S. S. 4, \real-time counter of reinforcers
s1,
#start:--->s2
s2,
#z1:  set g(p) = c(10); add p; if p>999 [@stop, @go]
                                            @stop:--->s3
                                            @go:  set g(p) = -987.987--->sx
s3,
.01":--->sx

S. S. 5, \precise session timer
s1,
#start:--->s2
s2,
.25":  add c(9); set c(10) = c(9)/4--->sx

S. S. 6, \cumulative recorder
```

```
s1,
#start:--->s2
s2,
#z4:--->s3
#z5:--->s6
s3,
#r^lkey:  on ^step--->s4
#r^rkey:  on ^event--->s5
#z9:--->s9
s4,
.04":  off ^step--->s3
s5,
.04":  off ^event--->s3
s6,
#r^rkey:  on ^step--->s7
#r^lkey:  on ^event--->s8
#z9:--->s9
s7,
.04":  off ^step--->s6
s8,
.04":  off ^event--->s6
s9,
.01":--->sx

S. S. 7, \real-time counter of left key responses
s1,
#start:--->s2
s2,
#r^lkey:  set d(m) = c(10); add m; if m>999 [@stop, @go]
                                  @stop:--->s3
                                  @go:  set d(m) = -987.987--->sx
#z1:--->s4
s3,
.01":--->sx
s4,
#z2:--->s2

S. S. 8, \real-time counter of right key responses
s1,
#start:--->s2
s2,
#r^rkey:  set f(n) = c(10); add n; if n>999 [@stop, @go]
                                  @stop:--->s3
                                  @go:  set f(n) = -987.987--->sx
#z1:--->s4
s3,
.01":--->sx
s4,
#z2:--->s2
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Response acquisition with delayed reinforcement in the presence of an irrelevant operandum

Abstract. Rats and pigeons responded under schedules of delayed reinforcement in three experiments. Two operanda were available but only one was correlated with reinforcement. In Experiment 1, either operandum could be correlated with reinforcement depending on which was pressed first. Due to this procedure the source of reinforcement varied irregularly between sessions. In Experiment 2, the operandum correlated with reinforcement was pre-determined and remained consistent within conditions. In Experiment 3, the source of reinforcement was pre-determined and varied semi-randomly. Responses were acquired without prior response shaping in the first two experiments and maintained in all three using unsignalled, resetting delays to reinforcement. Response rates were higher on the relevant operandum when it was the same as in previous sessions, and higher response rates were exhibited on the irrelevant operandum when it was relevant in the previous sessions. These results indicate that induction does not account for responding under delayed reinforcement, and the control of responding by the delayed reinforcement contingencies is affected by the subjects' history of responding on each operandum.

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