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RESPONSE-REINFORCER RELATIONS AND THE MAINTENANCE OF BEHAVIOR

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The effects on pigeons' key pecking of unsignaled delays of reinforcement and response-independent reinforcement were compared after either variable-interval or differential-reinforcement-of-low-rate baseline schedules. One 30-min session arranging delayed reinforcement and one 30-min session arranging response-independent reinforcement were conducted daily, 6 hr apart. A within-subject yoked-control procedure equated reinforcer frequency and distribution across the two sessions. Response rates usually were reduced more by response-independent than by delayed but response-contingent delivery of reinforcers. Under both schedules, response rates were lower when obtained delays were greater. These results bear upon methodological and conceptual issues regarding comparisons of contingencies that change the temporal response-reinforcer relations.

Key words: variable-interval schedules, differential-reinforcement-of-low-rate schedules, variable-time schedules, response-independent reinforcement, unsignaled delay of reinforcement, contiguity, correlation, key peck, pigeons

The roles of three response–reinforcer relations in response maintenance have been investigated: the delivery of reinforcers (a) immediately following responses, (b) independently of responses, and (c) separated in time from the responses that produce them (delayed reinforcers). Both response-independent and delayed delivery of reinforcers disrupt the temporal response–reinforcer relation, but only the latter procedure retains a dependency between responding and reinforcement. Comparisons of the effects of these two response–reinforcer relations are relevant to discussions of the contributions of response–reinforcer temporal contiguity and response–reinforcer dependency to response maintenance. Most comparisons of these two procedures have found less response-rate reduction in the case of delayed reinforcement (Catania & Keller, 1981; Sizemore & Lattal, 1977; Williams, 1976; but cf. Burgess & Wearden, 1981), lending support to the assertion that "poor response–reinforcer contiguity reduces responding, but cannot eliminate it. As long as it produces food, responding persists" (Baum, 1973, p. 147). However, several features of those experiments limit the generality of the findings. These limitations, in the context of the potential theoretical value of data from such comparisons, provided the impetus for the present experiment.

In studies by Williams (1976) and by Sizemore and Lattal (1977), an unsignaled delay imposed during a variable-interval (VI) schedule decreased pigeons' response rates relative to those maintained by immediate reinforcement. However, results of the two studies differed with respect to the response rates obtained during response-independent delivery of reinforcers. Compared with rates produced by 3- and 6-s unsignaled delays, Sizemore and Lattal subsequently obtained further decreases in response rates with the same subjects under nominally comparable variable-time (VT) schedules of reinforcer delivery. Williams (1976, Experiment 1) found that alternated conditions of delayed and response-independent reinforcement failed to produce differing response rates. Because each condition was in effect for only ten 55-min sessions, in contrast to an average of 25 approximately 60-min experimental sessions for each subject in the Sizemore and Lattal study, there may have been insufficient time for differences to emerge. This was confirmed in a second experiment (Wil-

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liams, 1976, Experiment 2) in which thirty 90-min sessions of exposure to either a 5-s unsignaled delay of reinforcement or a yoked response-independent reinforcement condition usually produced results more similar to those of Sizemore and Lattal.

The duration of unsignaled delays of reinforcement is related functionally to response rates. Sizemore and Lattal (1978) showed that obtained delays (i.e., the actual delay between the reinforcer and the preceding response) consistently were shorter than the nominal, or programmed, delay values, but that the two measures were highly positively correlated. Also, average obtained delays were shorter under nominal 3- or 6-s unsignaled delays than under otherwise equivalent schedules of response-independent delivery of reinforcers (Sizemore & Lattal, 1977). Comparisons of these two response–reinforcer relations have been made only with relatively short nominal unsignaled delays. Whether longer nominal delays of reinforcement yield response rates and obtained delays that approximate those maintained by otherwise equivalent schedules of response-independent reinforcement has not been investigated.

Another relevant variable in experiments comparing delayed and response-independent reinforcement is the sequence of the two conditions. Sizemore and Lattal (1977) exposed birds to the response-independent procedure directly after exposure to delayed reinforcement, as did Catania and Keller (1981) in some conditions. This sequence also was employed with half of the subjects in Williams's (1976) experiment. As a result, the response-independent reinforcement condition was preceded by a condition controlling lower response rate than that preceding the unsignaled-delay condition. Such order effects may have contributed to the lower response rates obtained with the response-independent procedure in each of these experiments.

Williams (1976) employed a between-subjects yoked-control procedure to equate reinforcement frequency and distribution. Reinforcers for one subject on a response-independent reinforcement schedule were delivered according to the frequency and distribution of reinforcers produced by behavior of a second subject on a delayed-reinforcement schedule. However, difficulties with such between-subject yoked-control procedures (Church, 1964) preclude definitive comparisons of the behavioral effects of these two conditions.

In the present experiment, we used a 30-s unsignaled delay, twice as long as any duration previously studied in comparisons with response-independent delivery of reinforcers. We also employed procedures to minimize the confounding features of the studies described above. Reinforcement frequency and distribution were equated across the unsignaled-delay and response-independent conditions by employing a within-subject yoked-control procedure. For each bird, the frequency and distribution of reinforcers in the delayed-reinforcer condition determined the frequency and distribution of reinforcers in the response-independent reinforcement condition. Some variables operating to maintain responding, including response–reinforcer temporal contiguity and dependency, have been suggested to have different effects on high- and low-rate responding (Catania & Keller, 1981). Therefore, delayed and response-independent reinforcement were examined in the context of variable-interval (VI) and differential-reinforcement-of-low-rate (DRL) schedules.

METHOD

Subjects

Six adult male White Carneau pigeons, all experimentally naive at the beginning of the experiment, were each maintained at 80% of their free-feeding weights throughout the experiment.

Apparatus

Two operant conditioning chambers, measuring 30.5 by 31.0 by 38.0 cm, were used. In each, a 2-cm-diameter translucent response key requiring a force of approximately 0.1 N to operate was located on the work panel 25.5 cm from the floor and 6 cm to the right of midline. The key was transilluminated by a blue or amber 28-V bulb except during reinforcement. Reinforcers in all sessions were 3-s periods of access to mixed grain presented in a food hopper located behind a 5.5-cm^2 aperture centered in the work panel, 8 cm above the floor. The aperture was illuminated by a 110-V, 7-W bulb when grain was accessible. Another 110-V, 7-W bulb, located behind a

4.5-cm^2 aperture covered by translucent plastic, provided general chamber illumination throughout the sessions except during reinforcement. This houselight was 3 cm above the floor and 9 cm to the right of the midline. White noise masked extraneous sounds. A PDP 8/A® computer located in an adjacent room controlled the experiment and recorded data.

Procedure

General procedure. Two 30-min sessions were conducted daily, 5 days per week. After preliminary training and exposure to immediate, response-dependent reinforcement in a morning and in an afternoon session each day, the birds were exposed to a nominal 30-s unsignaled delay of reinforcement in one session and to a schedule of response-independent food delivery in the other session each day. Throughout the experiment, the two-sessions-per-day procedure was employed in which the two response–reinforcer relations alternated across sessions. The afternoon session began 6 hr after the morning session. The 6-hr break minimized schedule interactions between the two sessions in a given day. The order of the two conditions across the two daily sessions was determined by a coin toss, with the restriction that the same sequence (e.g., Condition 1 in the morning and Condition 2 in the afternoon session) could not occur for more than 4 consecutive days (see below). Keylight color (blue or amber) was counterbalanced across birds and components.

Training. Each bird was trained to eat from the hopper and key pecking was hand shaped. Three birds then were exposed to a VI schedule (hereafter referred to as VI birds) and 3 birds were exposed to a DRL schedule of reinforcement (hereafter referred to as DRL birds). The VI value was increased gradually over about five sessions before the final baseline schedule value was in effect for the VI birds. The DRL birds were exposed to the final baseline schedule value immediately after pecking was shaped.

Baseline. To control for the effect on reinforcer frequency and distribution of imposing a 30-s delay in the subsequent phase, the baseline schedule of food delivery in both morning and afternoon sessions for the 3 VI birds was a tandem variable-time 60-s fixed interval 30-s schedule (tand VT 60-s FI 30-s). The end of the VT component initiated the 30-s fixed interval, after which the first key peck was followed immediately by food. The baseline schedule in both morning and afternoon sessions for the DRL birds was DRL 20 s. Because the subsequent introduction of a 30-s delay was expected to reduce response rates and thereby increase rather than decrease the frequency of reinforcement, no equivalent 30-s period was imposed during the DRL 20-s baseline schedule. Birds 42 and 45 received 33 days of baseline sessions; Birds 67, 18, 40, and 55 received 20 days.

Yoked delayed and response-independent reinforcer delivery. Following the baseline phase, the contingencies in both morning and afternoon sessions were changed. In one session a 30-s unsignaled delay of reinforcement was introduced, and in the other session response-independent reinforcer delivery was introduced. For each bird, both sessions occurred in the same chamber, and this procedure was in effect for 60 days with the two conditions continuing to alternate across sessions as in the baseline phase. The procedure in effect in the Delay condition for the VI birds was a tandem variable-interval 60-s fixed-time 30-s (tand VI 60-s FT 30-s) schedule of food delivery. In this Delay condition the first key peck after the VI elapsed initiated a nominal 30-s delay, at the end of which food was delivered independently of responding during that 30-s period. That is, responses could occur during the unsignaled delay interval but had no programmed consequences. For the DRL birds, the procedure in the Delay condition was a tandem DRL 20-s FT 30-s schedule of food delivery. That is, a nominal 30-s unsignaled delay occurred between a response meeting the DRL requirement and food delivery; responses that occurred during the 30-s delay period had no programmed consequences.

For all birds, the schedule in the response-independent condition was a VT x s, in which the frequency and distribution of reinforcers, all delivered independently of key pecking, were determined by the frequency and distribution of reinforcers obtained in the Delay session of the preceding day. Figure 1 illustrates the yoking procedure. On the first day after baseline, the session with the response-independent procedure was omitted, and only a session arranging unsignaled delays was conducted. Each interreinforcer interval in this session was recorded and stored. Then, on the second day,

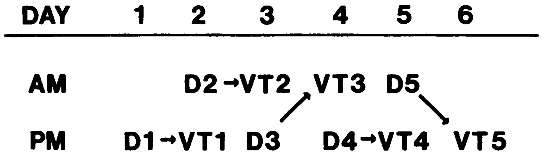

Fig. 1. Schematic indicating the procedure for determining the sequence of VT and Delay components.

Delay Session 2 and VT Session 1 were conducted; on the third day Delay Session 3 and VT Session 2 were conducted. During each VT session, the interreinforcer intervals were generated by the computer using the stored interreinforcer intervals from the preceding day's Delay session, as indicated by the arrows in Figure 1. As a result, the frequency and distribution of reinforcers in VT Session 1 were the same as those obtained in Delay Session 1 on the preceding day. The frequency and distribution of reinforcers in VT Session 2 were identical to those obtained in Delay Session 2, and so forth.

RESULTS

Both delayed and response-independent reinforcer delivery reduced response rates for all birds. Table 1 provides average response rates for the last six sessions of each condition for each bird. By 60 days, average rates were reduced similarly in the VT and Delay conditions for Bird 18, VT rates were higher than Delay rates for Bird 42, and rates were reduced somewhat more in the VT than in the Delay condition for the other 4 birds.

The lower portion of each panel in Figure 2 shows response rates during the last six sessions of baseline and all sessions of VT and delayed food delivery for the 3 VI birds. For all of these birds there was a fairly rapid, substantial reduction in response rates in both conditions following the schedule changes. After this initial decline, response rates fluctuated considerably over the next seven or eight sessions. For Bird 42, response rates thereafter showed little systematic change in either condition, and were approximately equal in the

Table 1

Responses per minute, mean obtained delays, and number of reinforcers per session averaged over the last six sessions of each condition for each bird.

	Bird number	Key color	Condition	Response rate (per minute)	Mean obtained delay (seconds)	Number of reinforcers
VI Birds	42	amber	baseline	55.1	—	19
		blue	baseline	63.4	—	19
		amber	delay	20.7	2.3	18
		blue	VT	23.2	2.5	18
	45	amber	baseline	65.5	—	20
		blue	baseline	55.3	—	19
		amber	delay	2.6	19.8	13
		blue	VT	0.7	85.9	13
	67	blue	baseline	97.1	—	19
		amber	baseline	97.8	—	20
		blue	delay	1.7	17.7	11
		amber	VT	0.2	154.3	11
DRL Birds	18	blue	baseline	15.4	—	2
		amber	baseline	16.8	—	1
		blue	delay	1.1	25.7	12
		amber	VT	1.1	88.3	12
	40	blue	baseline	18.0	—	2
		amber	baseline	20.5	—	4
		blue	delay	2.7	23.1	12
		amber	VT	0.7	117.4	12
	55	amber	baseline	15.9	—	2
		blue	baseline	15.9	—	1
		amber	delay	3.7	16.1	20
		blue	VT	1.9	45.0	20

VT and Delay conditions for the remainder of the experiment. Response rates for Birds 45 and 67 continued to decline. After Session 20, rates consistently were lower (sometimes zero) and usually less variable in the VT than in the Delay condition for Bird 67; for Bird 45, response rates usually were more variable in the Delay than in the VT sessions.

The introduction of the Delay and VT conditions had slightly different effects on response rates after the DRL baseline, as shown in the lower portions of the panels in Figure 3. Response rates of Birds 18 and 55 decreased steadily during the initial sessions. Response rates in the two conditions were similar during some of the subsequent sessions. From Sessions 31 to 54, response rates were higher in the Delay than in the VT condition for Bird 18, but rates in the two conditions were similar during the last six sessions. For Bird 55, response rates were similar in the two conditions from Sessions 15 to 34, then were lower in the VT condition during the remaining sessions, with two exceptions. After a reduction in the first few sessions, response rates for Bird 40 increased for several sessions, and then decreased again in both conditions. After Session 12, response rates in the VT condition usually were slightly lower than in the Delay condition.

Inspection of cumulative records showed that for all 6 birds the patterns of responses were similar in the Delay and VT sessions: Bursts of roughly equal numbers of responses were separated by pauses that also were of approximately equal length for the two conditions. This pattern occurred fairly steadily throughout each session and was not markedly changed over the course of the 60 days of the experiment, except for increases in pauses longer than 10 s.

The upper portions of Figures 2 and 3 show the mean obtained response-reinforcer delays, plotted on a logarithmic scale, for each session of VT and of delayed food delivery. Mean obtained delays during the VT sessions are not shown for Sessions 13 through 15 for Bird 67 and for Session 7 for Bird 45 because of recording failures; points are not shown for both Delay and VT Sessions 8 and 15 for Bird 40 because no reinforcers were obtained by the subject in these sessions. Points also are omitted for VT sessions in which no responding occurred. The nominal delay arranged by the schedule of delayed reinforcement set an upper

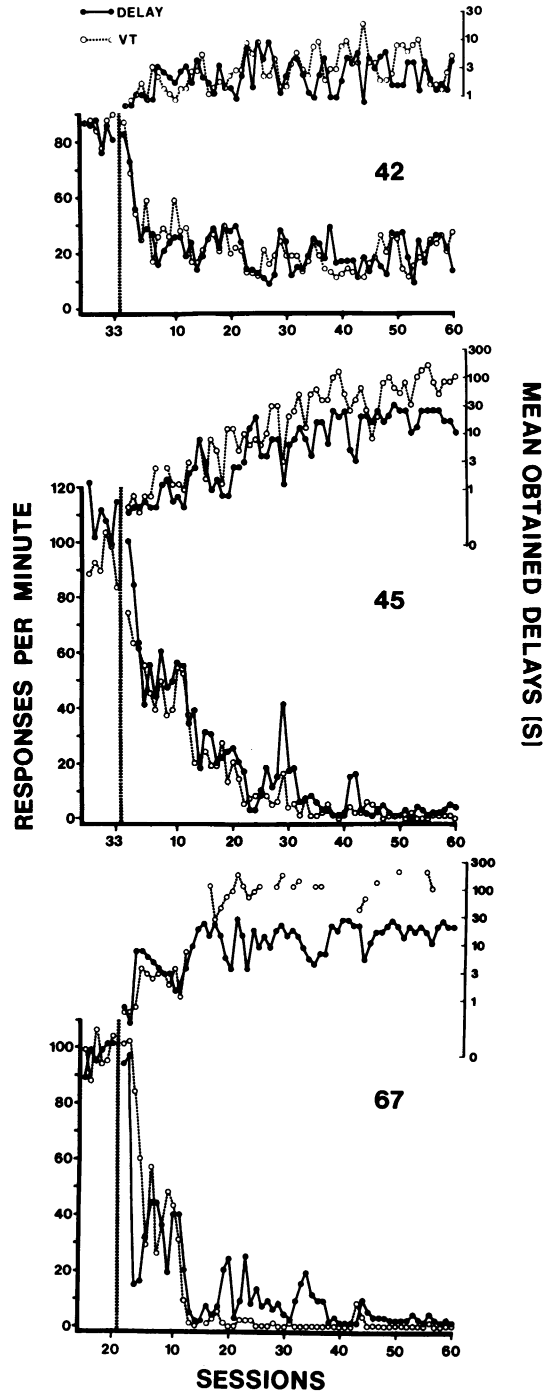

Fig. 2. Responses per minute during the last six baseline sessions and each VT and Delay session for the VI birds (lower data points; left ordinate scale). Mean obtained response-reinforcer delays for each VT and Delay session plotted on a logarithmic (base 10) scale (upper data points; right ordinate scale). As indicated in the text, mean obtained delays are omitted for VT sessions in which no responding occurred.

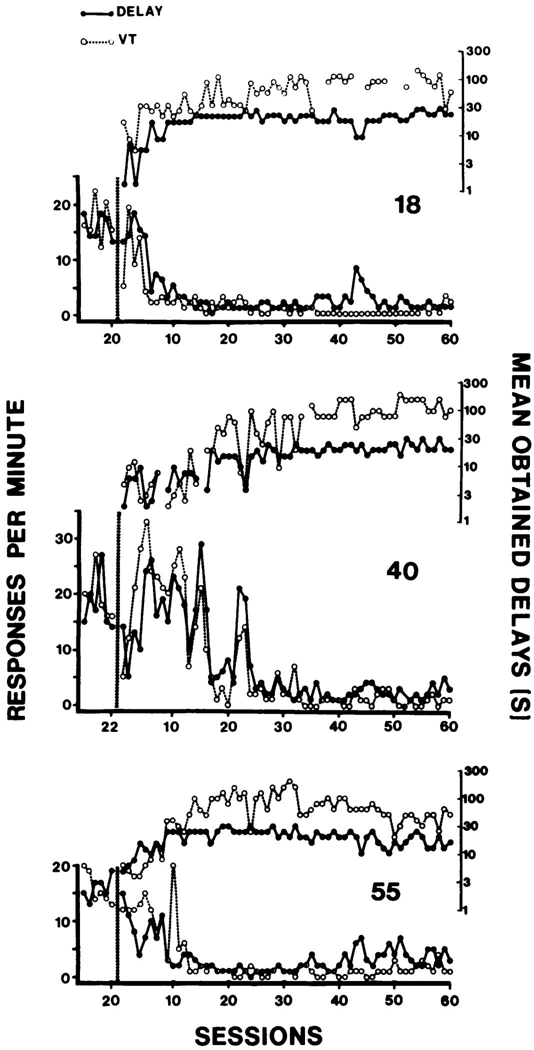

Fig. 3. Responses per minute during the last six baseline sessions and each VT and Delay session for the DRL birds (lower data points; left ordinate scale). Mean obtained response–reinforcer delays for each VT and Delay session plotted on a logarithmic (base 10) scale (upper data points; right ordinate scale). As indicated in the text, mean obtained delays are omitted for VT sessions in which no responding occurred.

limit of 30 s on obtained (actual) delays in these sessions, but because responses occurred during the delay interval, obtained delays often were shorter than 30 s. The upper limit to the individual obtained delays in the VT sessions was the programmed interreinforcer interval. Therefore, obtained delays in these sessions could exceed 30 s. As response rates were reduced by delayed reinforcement, the average interreinforcer intervals in both conditions increased beyond 90 s.

For all 3 VI birds (Figure 2), average obtained delays increased over the initial sessions in both conditions. Mean obtained delays in the two conditions for Bird 42 reached an asymptote after Session 25, although there was considerable variability in this measure across sessions in both conditions. Throughout the experiment, delays were under 30 s and often overlapped between the two conditions for this bird.

Average obtained delays for Birds 45 and 67 differed during the Delay and VT sessions. Average obtained delays increased in both conditions during the initial sessions, and by Session 25 for Bird 45 and Session 16 for Bird 67, a difference in obtained delays between the two conditions was apparent. For most of the remaining sessions, obtained delays were near the maximum value of 30 s in the Delay condition and were substantially longer in the VT condition. In many of the VT sessions there were numerous interreinforcer intervals with no responses. The durations of these no-response interreinforcer intervals were treated as obtained delays and were included in calculating the average delay.

For all 3 DRL birds, average obtained delays were substantially longer in the VT than in the Delay condition throughout most of the experiment (Figure 3). After about Session 15, average delays in the VT condition rarely were shorter than 30 s and were close to 30 s in the Delay condition. Table 1 provides the mean obtained delays over the last six sessions of VT and Delay conditions for all birds. These data include interreinforcer intervals (and entire sessions for Bird 67) in which no responses occurred.

The upper and lower portions of Figures 2 and 3 show that obtained delays and response rates often covaried. Usually, when the average delay was longer in one of the conditions, the response rate was lower in that condition. For Bird 42, nearly equal delays corresponded to nearly equal response rates in the two conditions. However, the data for Bird 18 do not show such a correspondence. Where response rates were equal in the two conditions, there still was a difference in average delays between the two conditions. There were other instances where such correspondence or noncorrespondence between delay differences and rate differences occurred during one or a few sessions, but on the whole the data in Figures 2 and 3 suggest a functional relation between delays and response rates in both conditions of the experiment.

The relation between response rates and obtained delays, and the relation between response rates and presence or absence of dependency, are indicated quantitatively by the correlation coefficients in Table 2. The Pearson *r* value for each subject, computed for all sessions of both conditions combined, indicates that response rates decreased as mean obtained delays increased. The point-biserial *r* value for each bird indicates that the type of session (i.e., Delay or VT) was poorly correlated, if at all, with response rates. The negative value of this correlation coefficient for Bird 42 indicates a slight tendency for higher rates to occur in VT sessions than in Delay sessions.

Figure 4 shows, for each bird, the obtained response–reinforcer delays for successive reinforcers in both conditions for Sessions 1, 30, and 60. In general, differences in response–reinforcer contiguity between the Delay and VT conditions increased over the first 20 to 30 sessions; thereafter, differences in contiguity between the two conditions were fairly stable for most of the birds (cf. Figures 2 and 3). Response–reinforcer contiguity did not change systematically within a session in either the Delay or the VT conditions.

The mean number of reinforcers per session for the last six sessions of each condition is given in Table 1. Because the distribution of reinforcers in the VT condition was determined by the distribution obtained during the Delay condition, the numbers of reinforcers in the two conditions were equal for any given session. Rate of reinforcement was not yoked in the baseline phase but there was little difference in the obtained reinforcement rates between the two baseline conditions. For Birds 45 and 67 reinforcement rates were reduced considerably relative to baseline. There was only a slight decrease in reinforcement frequency relative to baseline for Bird 42. For the DRL birds, however, reinforcement frequency in the Delay and VT conditions was higher than in baseline, a result that was expected as reduced response rates would be more likely to result in more interresponse times meeting the DRL 20-s response requirement.

Table 2

Pearson correlation between response rates and mean obtained delays (i.e., between responses per minute and average delays in seconds computed over each session); point-biserial correlations between response rates and presence or absence of response–reinforcer dependency (with a value of 1 assigned to Delay sessions and a value of 0 assigned to VT sessions); number of sessions included in the correlations; and means and standard deviations of response rates and average obtained delays for each bird.

Bird	Pearson *r*	*N*	Response rate *M*	Response rate *SD*	Average obtained delay *M*	Average obtained delay *SD*	Point-biserial *r*
42	−.49	120	21.70	9.34	3.52	2.95	−.01
45	−.50	118	17.08	21.19	23.01	31.01	.12
67	−.42	111	12.96	22.49	51.11	64.16	.00
18	−.48	120	2.33	3.48	47.82	38.72	.22
40	−.52	116	6.42	8.00	41.99	45.78	.02
55	−.49	120	3.21	3.75	42.65	38.74	.07

DISCUSSION

Responding maintained by VI and DRL schedules of reinforcement was reduced substantially by introducing unsignaled delays and by removing the response–reinforcer dependency. In most instances, both within and across days, response rates were lower in the case of response-independent food delivery. For all birds, however, response rates were related more strongly to mean obtained delays than to the presence or absence of dependency, as indicated by the Pearson and the point-biserial correlation coefficients. The Pearson *r*, a measure of the correlation between response rates and mean obtained delays, was much higher than the point-biserial *r*, a measure of the correlation between response rates and the presence or absence of dependency. Although these two kinds of correlation coefficients may not be strictly comparable, the stronger correlation in the former case for each bird suggests the superiority of temporal contiguity over dependency in predicting, if not controlling, response rates.

The significance of these results for the analysis of response–reinforcer relations in response maintenance is threefold. First, the findings of Catania and Keller (1981), Sizemore and Lattal (1977), and Williams (1976)

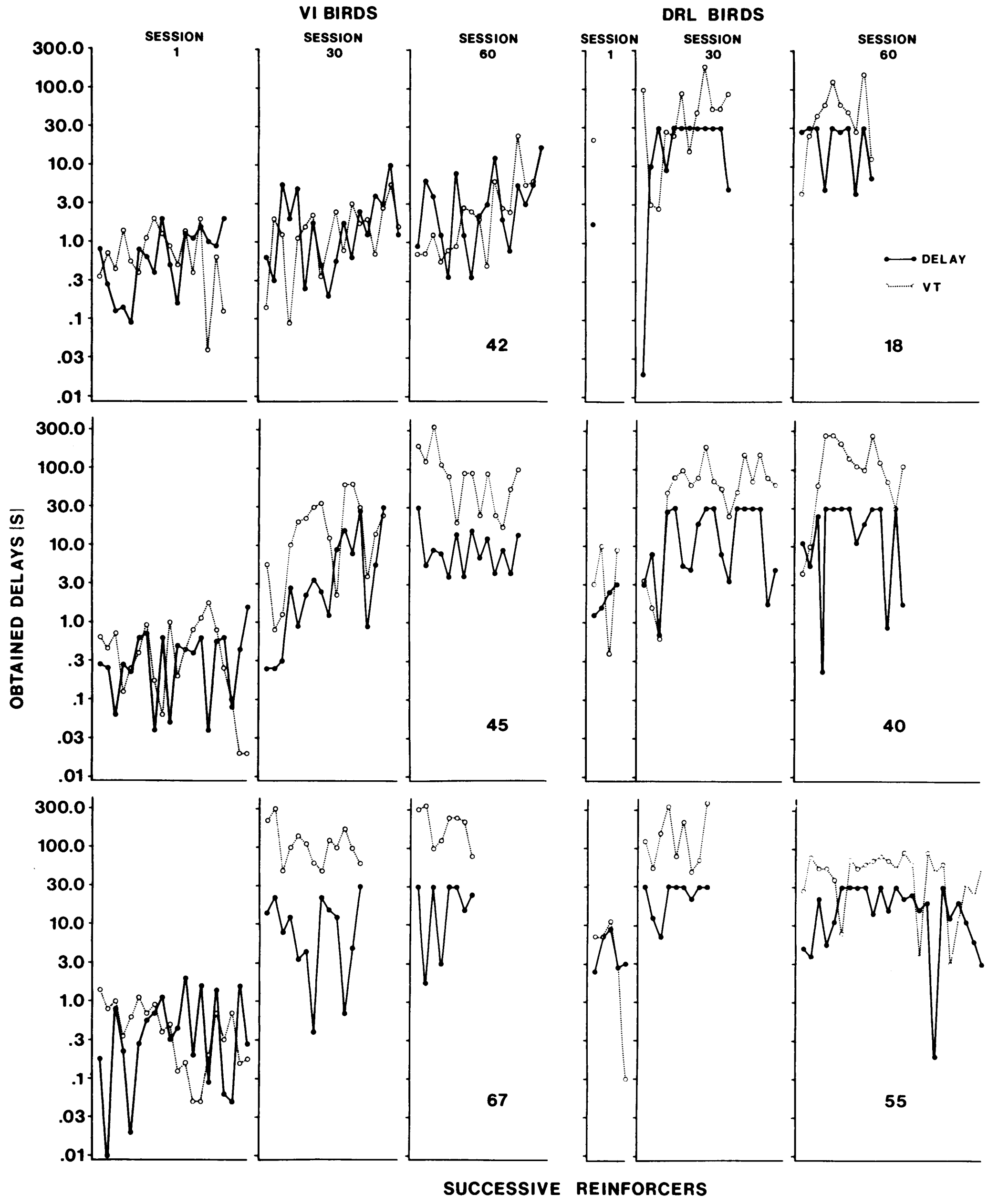

Fig. 4. Obtained response-reinforcer delays (in seconds) in VT and Delay conditions for each successive reinforcer delivered in the 1st, 30th, and 60th sessions. The ordinate scale is logarithmic (base 10).

were extended to longer delays. Second, these findings were obtained using experimental techniques that eliminated several barriers to unambiguous interpretation of those earlier findings. Third, the results reveal more clearly how response rates are related to actual temporal contiguity between responding and food delivery.

Several factors warrant consideration in evaluating the significance of the difference in response rates exhibited by 4 of the 6 birds, between the dependent-delayed and response-independent conditions: the yoking procedure, temporal parameters, and measurement of temporal contiguity. Church (1964) suggested that even within-subject yoking may not control for systematic fluctuation in subject reactivity to independent variables or to extraneous variables. This latter problem could be especially pronounced when response rates are low, as they were in the latter sessions of the present experiment. For example, Brimer (1970) found that low-rate responding was more easily disrupted by extraexperimental chamber noise than was higher rate responding. Church's point is relevant in those instances in which the within-subject yoking occurs across successive conditions of the experiment (for example, conducting Condition A for *n* sessions and then yoking the relevant variable in this condition to Condition B which follows for the next *n* sessions). In the present experiment, however, arranging the semirandom alternation of conditions both within and across days made it unlikely that the small but sustained differences between the Delay and VT response rates were due to systematic differences in subject reactivity.

The temporal parameters of the experiment also must be considered in evaluating the results. As noted, 30-s unsignaled delays were studied because they are longer than those used by Sizemore and Lattal (1977) or by Williams (1976), and because such long nominal unsignaled delays might be expected to yield obtained delays more similar to those obtained with response-independent food delivery. This was true only for Bird 42, whose obtained delays and response rates were nearly equal in the two conditions. Whether 60-s, 90-s, or even longer nominal delays would yield different results is, of course, an empirical question (see Dews, 1960). As obtained delays increase, responding in both conditions is likely to approach zero and, at that point, any differences may be difficult to evaluate. One way to circumvent this difficulty would be to superimpose delayed and response-independent reinforcement against a background of responding maintained well above zero by a third schedule of reinforcement, such as a VI schedule.

The measurement of response-reinforcer contiguity and its relation to response rates is of primary importance in comparing unsignaled delayed and response-independent delivery of reinforcers. In calculating the obtained delays in both conditions of this experiment, each interreinforcer interval was considered separately. Thus, because of the nature of the contingency, each interreinforcer interval in the Delay condition included a maximum obtained delay of 30 s and at least one response. Consideration of each interreinforcer interval separately in the VT condition yielded maximum obtained delay values that often exceeded 30 s. Although there was no responding during many of these interreinforcer intervals, these intervals were treated as obtained delays to facilitate comparison with the Delay condition. There are at least two other ways of addressing interreinforcer intervals without responses. One is to discard them from the analysis. The effect of this would be to shorten the mean obtained delays. But if these intervals were discarded, they also would have to be discarded in the calculation of response rates. This would artificially elevate the response rates shown in Figures 2 and 3. Another difficulty is that discarding these interreinforcer intervals involves the questionable assumption that such intervals are without behavioral effects. For example, Hammond (1980) showed that conditions in which reinforcement was equally probable for responding and for not-responding (in 1-s intervals) resulted in lower response rates than conditions in which reinforcement did not occur after intervals of not-responding (see also Catania & Keller, 1981). Another alternative is to count as the delay the time from the last response, even if there already has been a reinforcer since that response. This procedure would make the mean obtained delays in the VT condition somewhat greater than they now appear in Figures 2 and 3. Also, the delay could include additional reinforcers, a situation not possible in the delay-of-reinforcement arrangement. Although there may be positive features to each of these alternatives, our choice was a middle ground between them and was an attempt to make parallel measurements in the VT and Delay conditions.

A related issue concerns the appropriate descriptive statistic for the analysis of the obtained delays. Figures 2 and 3 depict the relation between response rates and obtained delays in each session, both expressed as arithmetic means. In describing the obtained delays within a session other measures are possible, such as harmonic or geometric means or medians of obtained delays. Because such measures tend to deemphasize the effects of extreme values, they would not be much different from the arithmetic mean in the case of the Delay sessions but often would represent the obtained delays in the VT sessions as shorter than they appear when presented as arithmetic means.

There are two interpretations of the contribution of the temporal response–reinforcer relation to response maintenance. One emphasizes temporal contiguity, whereas the other emphasizes the correlation between rates of responding and rates of reinforcement as a primary determinant of behavior. In this latter account, temporal contiguity operates as an indirect variable to enhance the correlation that is ensured by the dependency between responding and reinforcement. Both accounts predict that delayed response-dependent food delivery would produce lower rates of responding than those obtained with immediate response-dependent food delivery. Interpretations emphasizing the role of temporal contiguity predict that response rates would be lower under conditions of response-independent food delivery than under dependent but delayed food delivery only if there are longer obtained delays between responses and reinforcers. A correlational emphasis, on the other hand, predicts that rates of responding during schedules of response-independent food delivery would be lower than those obtained with either immediate or delayed response-dependent food delivery because of the absence of a correlation between responding and the occurrence of reinforcers. The response-rate data for 4 of the 6 birds are consistent with predictions made by either account. The data for Bird 18 are somewhat difficult to interpret within either framework, but the performance of Bird 42 more clearly supports the view that temporal response–reinforcer contiguity is primary in controlling responding.

One criticism of a correlational analysis is that it does not specify the time frame over which responding and reinforcement are correlated (Williams, 1983), making it difficult to operationalize different correlations. Furthermore, given the premise of this account that response-independent delivery of reinforcers involves a zero correlation between responding and reinforcement, it is surprising that Birds 42 and 18 exhibited similar response rates in the Delay and VT conditions in the final sessions. Whatever the time frame over which events are correlated, sixty 30-min sessions seem to be sufficient for the greater rate-reducing effects of a zero correlation to emerge. That this did not occur reliably in the present experiment casts some doubt on the generality of such an account.

Accounts emphasizing the primacy of temporal contiguity also have not yet fully addressed the issue of time frames and related problems. The demonstration of a relation between response rates and temporal contiguity is not a specification of the manner in which such delays affect responding. The sequence of delays may exert an effect on responding apart from that described by the functional relations between responding and the mean, range, or distribution of those delays. For example, some number of obtained delays of any particular duration occurring in succession may affect responding differently than the same number of delays of the same duration evenly distributed throughout the session. Other questions in the analysis of contiguity effects concern the period over which delayed reinforcers affect behavior and how such effects relate to individual delays, the distribution of delays, the sequence of delays, and the average delay. For example, does a particular delay or distribution of delays affect responding over the next few seconds, the next several minutes, the remainder of the session, or over the next several sessions? Perhaps it is the average delay over some period of time within the session rather than a particular delay or sequence or distribution that affects responding. The answers to such questions must await further experimental analysis, but this does not detract from the demonstrated relation between temporal contiguity and response rates irrespective of response–reinforcer dependency.

The utility of any theoretical account of reinforcement rests on its logical strengths, its heuristic value, and its congruence with existing data. The logical strengths of both correlation- and temporal-contiguity-based views have been delineated (Baum, 1973; Hawkes & Shimp, 1975; Williams, 1983). Heuristic value must be balanced against the difficulty of translating concepts into experimental operations; as noted, both conceptual views are open to criticism on these grounds. The fact remains that no theoretical account can ignore empirical evidence of the relation between response–reinforcer temporal contiguity and response rates. Indeed, the adequacy of theoretical formulations in addressing these relations is an important standard by which their utility may be evaluated.

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