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RESPONDING OF PIGEONS UNDER VARIABLE-INTERVAL SCHEDULES OF SIGNALED-DELAYED REINFORCEMENT: EFFECTS OF DELAY-SIGNAL DURATION

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Two experiments with pigeons examined the relation of the duration of a signal for delay ("delay signal") to rates of key pecking. The first employed a multiple schedule comprised of two components with equal variable-interval 60-s schedules of 27-s delayed food reinforcement. In one component, a short (0.5-s) delay signal, presented immediately following the key peck that began the delay, was increased in duration across phases; in the second component the delay signal initially was equal to the length of the programmed delay (27 s) and was decreased across phases. Response rates prior to delays were an increasing function of delay-signal duration. As the delay signal was decreased in duration, response rates were generally higher than those obtained under identical delay-signal durations as the signal was increased in duration. In Experiment 2 a single variable-interval 60-s schedule of 27-s delayed reinforcement was used. Delay-signal durations were again increased gradually across phases. As in Experiment 1, response rates increased as the delay-signal duration was increased. Following the phase during which the signal lasted the entire delay, shorter delay-signal-duration conditions were introduced abruptly, rather than gradually as in Experiment 1, to determine whether the gradual shortening of the delay signal accounted for the differences observed in response rates under identical delay-signal conditions in Experiment 1. Response rates obtained during the second exposures to the conditions with shorter signals were higher than those observed under identical conditions as the signal duration was increased, as in Experiment 1. In both experiments, rates and patterns of responding during delays varied greatly across subjects and were not systematically related to delay-signal durations. The effects of the delay signal may be related to the signal's role as a discriminative stimulus for adventitiously reinforced intradelay behavior, or the delay signal may have served as a conditioned reinforcer by virtue of the temporal relation between it and presentation of food.

Key words: brief stimulus, conditioned reinforcement, signal duration, signaled delay of reinforcement, unsignaled delay of reinforcement, variable-interval schedules, key peck, pigeons

It is generally agreed that an important aspect of reinforcement is the close temporal proximity of responses and reinforcers (Mackintosh, 1974, p. 159), and attempts to demonstrate the fundamental importance of reinforcement immediacy are numerous in experimental psychology (see reviews by Renner, 1964, and Tarpy & Sawabini, 1974). With respect to schedule-maintained operant behavior, it is clear that even short unsignaled delays to reinforcement can result in much lower rates of responding than those observed when reinforcement is presented immediately (Catania & Keller, 1981; Schaal & Branch, 1988; Sizemore & Lattal, 1977, 1978; Williams, 1976). On the other hand, response rates remain near levels obtained with immediate reinforcement across a wide range of delay durations when the response that begins the delay also produces an immediate change in exteroceptive stimulation, that is, when delays are signaled (Ferster, 1953; Lattal, 1984; Pierce, Hanford & Zimmerman, 1972; Richards, 1981; Richards & Hittesdorf, 1978; Schaal & Branch, 1988). It has been suggested that the delay signal serves a conditioned reinforcing function, thus bridging the gap between behavior and its maintaining event (Ferster, 1953; Grice, 1948; Spence, 1947).

The disparate effects on operant behavior of unsignaled and signaled delays to reinforcement may be related to phenomena of respondent conditioning. For example, in trace conditioning a conditional stimulus (CS) is first presented, then removed. An unconditional stimulus (US) is presented after a CS–US interval has elapsed. The CS–US interval may

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correspond to the delays to reinforcement noted above. A general result is that, at some minimum CS–US interval, trace conditioning is less effective in producing conditional responding than procedures in which the CS is presented and remains until the US is presented (commonly known as delay conditioning; see Mackintosh, 1974, p. 57). The difference between these two respondent conditioning procedures has been demonstrated in experiments involving the conditioned salivation of dogs (Ellison, 1964), the nictitating membrane reflex of rabbits (Schneiderman, 1966), conditioned suppression of lever pressing of rats (Kamin, 1965), and the key pecking of pigeons in autoshaping procedures (Newlin & LoLordo, 1976). Because respondent conditioning operations can result in CSs becoming conditioned reinforcers (Bersh, 1951; Ellison & Konorski, 1964; Jenkins, 1950; Stein, 1958), and the conditioned reinforcing efficacy of such a CS is a decreasing function of the delay arranged between presentation of it and presentation of a US (Jenkins, 1950), the role in the maintenance of operant behavior of temporal/correlative relationships between delay signals and reinforcement is worth investigating.

Schaal and Branch (1988) showed that comparisons of the eliciting functions of trace CSs with delay CSs in respondent conditioning experiments bear a resemblance to comparisons (using schedule-controlled behavior) of the reinforcing functions of brief delay signals with signals that last the entire delay (i.e., complete delay signals). In their experiments, the pecking of pigeons was maintained first under a variable-interval (VI) 60-s schedule. Unsignaled delays resulted in decreased response rates in all subjects, with larger decreases with longer delays. When a brief (0.5-s) change in key color was presented immediately after the peck that began the delay, response rates increased to near baseline levels when delays were relatively short (i.e., 1, 3, or 9 s), but decreased to low levels when delays were lengthened to 27 s. In Experiment 2 response rates when delays were 27 s decreased to low levels under delay conditions with brief signals but were maintained near baseline levels when delays were signaled completely (a result that resembles the trace-CS vs. delay-CS effect noted above).

These results raise the question of how increases in the proportion of the delay that is signaled affect response rates. When a 0.5-s delay signal began a 27-s delay to reinforcement, very low response rates were observed; when the delay signal lasted the entire (27-s) delay, rates near those obtained with immediate reinforcement were observed. This result suggests that this delay value (27 s) provides a condition that would allow detection of the effects of lengthening the delay signal. Two experiments with pigeons were performed to examine the relation of delay-signal duration to rates of key pecking. The first employed a multiple schedule comprised of two components with equal VI values and programmed delays. In one component, a short (0.5-s) key color change (brief signal) was increased in duration, across phases, until it remained illuminated throughout the delay. In the second component the duration of the delay signal was equal initially to the length of the programmed delay (27 s) and was decreased across phases, by amounts equal to the increases in the signal duration in the other component, until its duration was 0.5 s. Response rates within components were compared across conditions and between components during each delay condition to determine the effects on responding of changes in delay-signal duration. Two questions were posed. First, would response rates prior to delays vary as a function of the duration of the delay signal regardless of previous experience with complete delay signals, or, given such experience, could near-baseline levels of responding be maintained by gradually decreasing the duration of the delay signal? Second, would the function relating delay-signal duration to predelay response rates reveal a threshold signal duration at which baseline response rates would be reached abruptly, or would it increase more gradually across signal durations?

EXPERIMENT 1

METHOD

Subjects

Three adult male White Carneau pigeons (numbered 269, 422, and 407) were maintained at approximately 80% of their free-feeding weights. They were maintained at these weights via supplemental feeding as necessary after daily sessions. The pigeons had had previous experience with unsignaled, briefly signaled, and completely signaled delays to reinforcement of various durations, under schedule conditions nearly identical to the ones employed here (Schaal & Branch, 1988, Experiment 2). Except during experimental sessions, pigeons were housed individually in a temperature-controlled colony with a 16:8 hr light/dark cycle. They had continuous access to water and health grit in their home cages.

Apparatus

Sessions were conducted in a custom-built conditioning chamber for pigeons. The space in which the pigeons were studied measured 30 cm wide by 31 cm long by 31 cm deep. All walls were painted flat black except for the front, which was a brushed aluminum panel equipped with three horizontally aligned 2-cm diameter response keys (R. Gerbrands Co.) centered 22 cm above a hardware-cloth floor. A static force of 0.14 N or more on the center key (the only one used in this experiment), which was located 15.5 cm from either edge of the front wall, produced a click from a relay and was counted as a response. Four 1.1-W 28-Vdc lamps, covered with green, red, blue or white translucent caps, could illuminate the response key from behind. The two side keys remained dark and inoperative throughout the experiment. Mixed grain could be obtained by means of a solenoid-driven grain feeder through an aperture (6 cm by 5 cm) located below the center key. A 1.1-W 28-Vdc lamp lit the feeder when it was operated, while all other lamps were extinguished. Identical 1.1-W 28-Vdc lamps, located in the upper corners of the front panel and mounted behind reflectors that prevented direct downward illumination, served as houselights. White noise, which was continuously present in the room where the chamber was located, and noise from a ventilation fan mounted on the chamber ceiling helped to mask extraneous sounds. A pigeon could be observed through a fish-eye peephole on the chamber door. A Digital Equipment Corporation PDP-8e® minicomputer, located in a separate room and programmed with SUPERSKED® software (Snapper & Inglis, 1978), programmed contingencies and collected data. Cumulative records of key pecking during sessions were provided by a Gerbrands cumulative recorder.

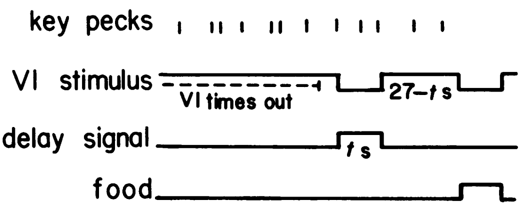


Fig. 1. Diagram of the basic procedure for Experiments 1 and 2. After each VI expired, a key pack produced a delay signal, which remained for *t* seconds. This signal was followed by the stimulus conditions in effect during the VI for 27 − *t* s. This was followed by presentation of food, followed by the next VI.

Procedure

Before this experiment the pigeons' response rates had been maintained at nearly equal levels across components under a schedule identical to the one employed in the first condition of this experiment except that a 9-s delay to food was in operation. In the first condition, pigeons' key pecking was maintained under multiple VI schedules of signaled-delayed reinforcement. Figure 1 illustrates the basic procedure. The first peck after each interval of the VI 60 s elapsed began a 27-s delay to reinforcement and produced a change in key color that remained for some portion of the delay (*t*), then was replaced by the key color present during the VI for the remainder of the delay (27 − *t* s). Responses during delay periods produced feedback clicks and were counted, but had no other effect. When 27 s elapsed, 3-s access to mixed grain was allowed regardless of the pigeon's behavior. In the terminology described by Zeiler (1977), the resulting schedule can be labeled a multiple chained VI 60-s fixed-time (FT) 27-s chained VI 60-s FT 27-s schedule. The response key was lit green during the VI and the signal–food interval (SFI) of Component 1 and was lit red during these periods in Component 2. Both VI schedules consisted of 30 intervals determined by Catania and Reynolds' (1968, Appendix II) constant-probability method. The intervals were selected randomly without replacement by the computer. Components ended after one of three variable lengths of time had elapsed (6, 10, or 14 min; *M* = 10 min), excluding reinforcement and delay periods. Consequently, components could not end during a delay. If a component ended during an interval, the time elapsed in that interval counted toward completion of the interval when the component reappeared (unless it was the last component of the session). Component durations were selected randomly without replacement by the computer, and each duration occurred once per session. Component 1 (green key) always began the session, and the session ended after both components had been presented three times. Components were separated by 1-min blackout periods (all lights in the chamber extinguished). Experimental sessions were conducted 7 days a week.

In the first condition of the experiment, the delay-signal duration (*t*) in Component 1 was 0.5 s, and in Component 2 it was 27.0 s (i.e., the signal remained on for the entire delay). For Pigeons 269 and 422 the Component 1 signal was a white key and the Component 2 signal was a blue key; for Pigeon 407 the brief- and complete-signal colors were reversed. When rates of pecking stabilized, the duration of the signal in Component 1 was lengthened to 1.5 s, and the duration of the delay signal in Component 2 was shortened to 25.5 s. In the next phases the duration of the Component 1 signal was lengthened and the duration of the Component 2 signal was shortened, each time by equal values. For example, when stable response rates were observed when the signals were 1.5 s in Component 1 and 25.5 s in Component 2, the signals were lengthened to 3.0 s in Component 1 and shortened to 24.0 s in Component 2. The programmed delay to reinforcement remained 27.0 s throughout the experiment. Stable key-peck rates, as determined by daily visual inspection of response rates and cumulative records, were required before signal durations were altered. The values of the delay-signal durations in both components, the order of the conditions in which they were presented, the number of sessions per condition, and mean rates of food presentation obtained in the last five sessions of each condition are shown in Table 1. Some intermediate durations of the delay signals (i.e., 9.0, 13.5, and 18.0 s) were not tested with Pigeon 269, because response rates for this pigeon when the signal duration in Component 1 was 6.0 s were near those observed when the delay was completely signaled. When the signal in Component 1 had been lengthened such that it remained on the entire delay and the signal in Component 2 had been shortened to 0.5 s and response rates became stable, delay signals in both components were removed, resulting in 27-s unsignaled delays to reinforcement in each component.

Overall response rates, not including time or responses during the delay, were computed daily. Each obtained or actual delay to reinforcement was collected individually, from which an average delay was computed. The numbers of responses during and after the brief signal and during the complete signal also were collected separately, as were rates of primary reinforcement in both components.

RESULTS

Figure 2 shows cumulative records for Pigeon 269 obtained during the final session of three delay-signal-duration conditions. Except for some differences in patterns of responding during the delays (which will be discussed below) these records are representative of the performance of all 3 pigeons. In the first condition (Component 1 with a 0.5-s signal, Component 2 with a 27.0-s signal; top panel) responding was maintained at low rates in the component with the brief delay signal (bottom pen in upper position) relative to the response rates observed in the component in which the entire delay was signaled. Patterns of responding prior to the delay were typical of those usually observed under VI schedules, except that in Component 1 responding was much less steady. As the delay signal was increased in duration, response rates increased and patterns of responding became more steady (see middle panel, obtained from the condition in which the duration of the signal in Component 1 was 6.0 s and the duration of the signal in Component 2 was 21.0 s). Because the cumulative recorder was in operation throughout the delays, one can observe the emergence in Pigeon 269 of extremely rapid responding just prior to food presentations (note arrows). To summarize, the cumulative records show increasing response rates and more steady patterns of responding as delay-signal durations were lengthened, decreasing rates and less steady patterns as delay-signal durations were shortened, and the emergence of very rapid pecking prior to food at some delay-signal durations.

The effects on response rates of changing the duration of the delay signal are summarized in Figure 3, which depicts the means of rates obtained in the last five sessions of each

Table 1

Order of conditions, number of sessions per condition, and mean reinforcers per minute obtained in the last five sessions of each condition in Component 1 (in which the duration of the delay signal was increased across conditions) and Component 2 (in which the duration of the delay signal was decreased across conditions) of Experiment 1.

		Delay-signal duration (s)		Reinforcers per minute	
Subject	Sessions	Component 1	Component 2	Component 1	Component 2
269	44	0.5	27.0	0.65	0.67
422	38	0.5	27.0	0.64	0.66
407	54	0.5	27.0	0.63	0.67
269	31	1.5	25.5	0.63	0.66
422	32	1.5	25.5	0.63	0.66
407	26	1.5	25.5	0.57	0.66
269	35	3.0	24.0	0.66	0.67
422	37	3.0	24.0	0.66	0.67
407	35	3.0	24.0	0.61	0.66
269	36	6.0	21.0	0.67	0.66
422	39	6.0	21.0	0.66	0.66
407	37	6.0	21.0	0.64	0.67
269	—	—	—	—	—
422	63	9.0	18.0	0.65	0.66
407	62	9.0	18.0	0.65	0.66
269	—	—	—	—	—
422	34	13.5	13.5	0.67	0.68
407	51	13.5	13.5	0.64	0.65
269	—	—	—	—	—
422	63	18.0	9.0	0.67	0.66
407	63	18.0	9.0	0.65	0.64
269	115	21.0	6.0	0.66	0.66
422	56	21.0	6.0	0.66	0.66
407	42	21.0	6.0	0.67	0.66
269	78	24.0	3.0	0.65	0.65
422	65	24.0	3.0	0.66	0.63
407	16	24.0	3.0	0.65	0.64
269	56	25.5	1.5	0.65	0.65
422	19	25.5	1.5	0.66	0.61
407	65	25.5	1.5	0.65	0.66
269	69	27.0	0.5	0.66	0.65
422	30	27.0	0.5	0.65	0.65
407	31	27.0	0.5	0.65	0.58

condition. Looking first at Component 1, in which the duration of the delay signal was increased across conditions, for all 3 pigeons rates of key pecking increased as the duration of the delay signal was increased. For Pigeon 269, response rates in Component 1 increased sharply as signal duration was increased and were nearly equal in the two components when the Component 1 signal was 6.0 s and the Component 2 signal was 21.0 s. Response rates increased more gradually across signal durations for the other 2 birds. In Component 2, in which the duration of the delay signal was decreased across conditions, response rates remained high across signal durations that maintained substantially lower response rates in Component 1. This is particularly apparent when comparing rates obtained in the two components when signal durations were relatively short. Although the differences varied in magnitude across subjects, in most cases response rates in the component in which the signal duration was decreased gradually (i.e., Component 2) were higher than those observed at the same signal durations when the signal was lengthened gradually (as in Component 1). For Pigeons 269 and 422, response rates also differed across components during phases in which the signal durations were 18.0 s (for Pigeon 422) or 21.0 s (for Pigeon 269)

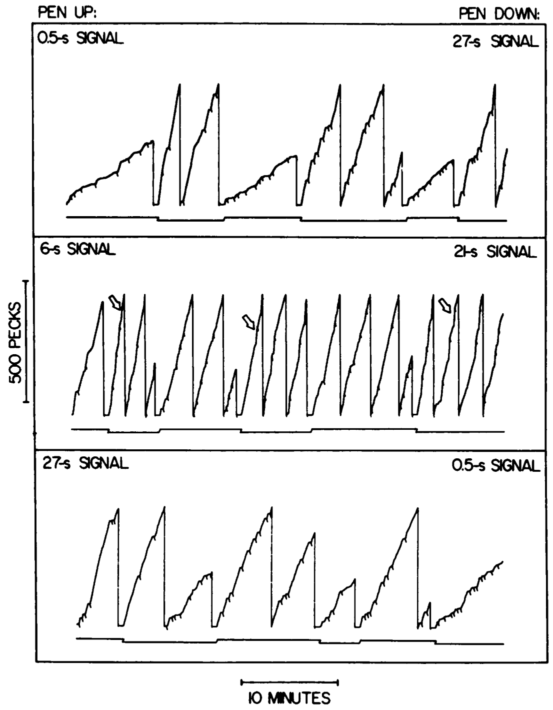


Fig. 2. Cumulative records from the final sessions of the phases indicated for Pigeon 269. Delay-signal durations are indicated in the upper left corners of each panel for Component 1 (event pen in the up position) and in the upper right corners of each panel for Component 2 (event pen down). Arrows in the middle panel indicate periods of rapid pecking prior to food presentations. Short, diagonal pen deflections indicate food presentations. The cumulative recorder operated during delays.

to 27.0 s. These differences across components were not related systematically to the order of presentation of delay-signal durations, however, because rates were higher in Component 1 for Pigeon 422 and higher in Component 2 for Pigeon 269 during these phases.

Responding during the delays was related in a less orderly fashion to delay-signal duration. Figure 4 shows these rates (in pecks per second), obtained for all 3 subjects during the delay signal and during the interval between signal offset and food presentation (SFI) at all delay values in both components. Rates during the delay signals for Pigeons 269 and 422 follow roughly similar patterns, with the highest rates observed when the delay signal was 0.5 s long. This may reflect a spillover of short interresponse-time responses from the VI. For Pigeon 407, however, this pattern was not observed. In addition, rates during the de-

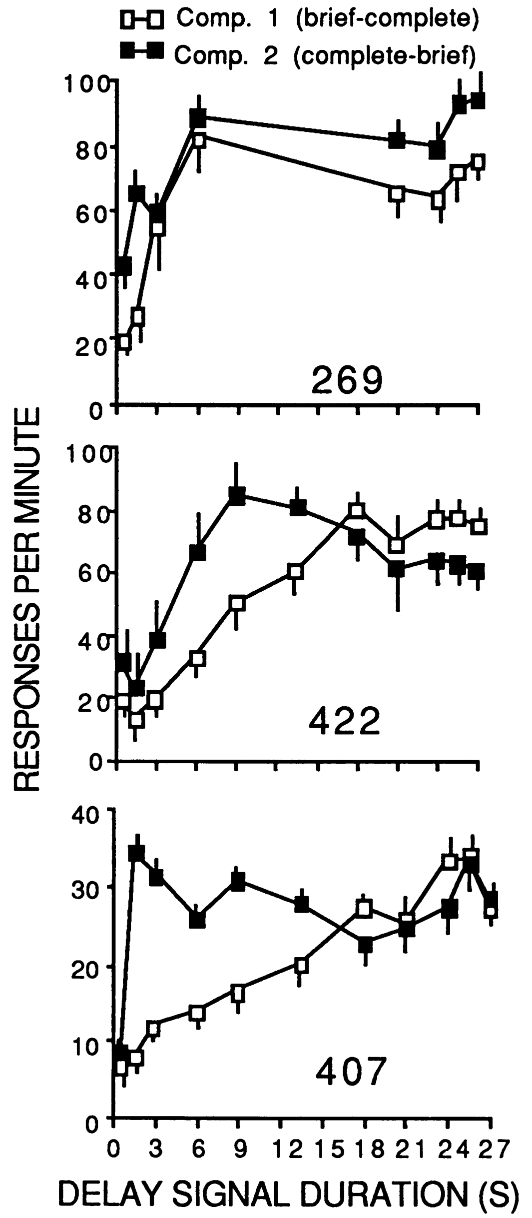


Fig. 3. Rates of key pecking (responses per minute) during VI periods for all 3 subjects under each delay-signal-duration condition. Points depict the means of rates obtained in the last five sessions of each phase; vertical bars represent one standard deviation. Rates obtained as the delay-signal duration was increased across phases (i.e., Component 1) are depicted by open squares; rates obtained as the delay signal was decreased in duration (i.e., Component 2) across phases are depicted by filled squares. See Table 1 for precise values of delay-signal durations.

lay signals were not equal across components at the same signal durations.

Extremely high response rates, noted by the arrows on the cumulative record in Figure 2, are quantified more precisely in the right side panels of Figure 4. For Pigeon 269, response rates approaching seven pecks per second were observed during the SFIs that followed delay-signal durations of 21.0 to 25.5 s (because the signal remained lit during the entire delay when the signal was 27.0 s, no "after-signal" rates are shown for this signal duration). Relatively high response rates were observed during SFIs for the other 2 subjects as well, but were not specifically correlated with certain signal durations across components. For example, rates were high during SFIs for Pigeon 407 when the delay signal was relatively long in Component 1, but were high when the delay signal was relatively short in Component 2. This means that these rates were highest in both components during a single phase with quite different delay-signal durations (e.g., Component 1 signal duration was 21.0 s, Component 2 signal duration was 6.0 s). Finally, for Pigeon 422 no consistent pattern of response rates during the SFIs was obtained.

Figure 5 depicts response rates obtained during each session of the final phase, in which delays were unsignaled (i.e., signals in both components were removed). Response rates in the final session of the previous phase are plotted over the "S" on the *x* axis. Response rates decreased in the first session, and across the seven sessions of this phase reached very low levels (i.e., usually less than five pecks per minute).

Despite the large differences in response rates between components, reinforcement frequencies across conditions were very similar, as shown in Table 1. Also, mean obtained delays (i.e., the average actual time between the final peck before food delivery and food) were computed for the last five sessions of each delay-signal condition and are shown in Table 2. Mean obtained delays were related, very roughly, to rates of responding prior to the delay, with shorter delays often accompanying higher predelay rates. This relationship was violated often, however. Note, for example, the long obtained delays when predelay rates were high (e.g., Component 2 during the 27-s signal condition for Pigeon 407, and Component 1 during the 27-s signal condition for Pigeon 269). In addition, obtained delays were not well correlated with the duration of the delay signal alone, as indicated by the disparities between obtained delays during the condition in which both signal durations were 13.5 s for Pigeons 407 and 422.

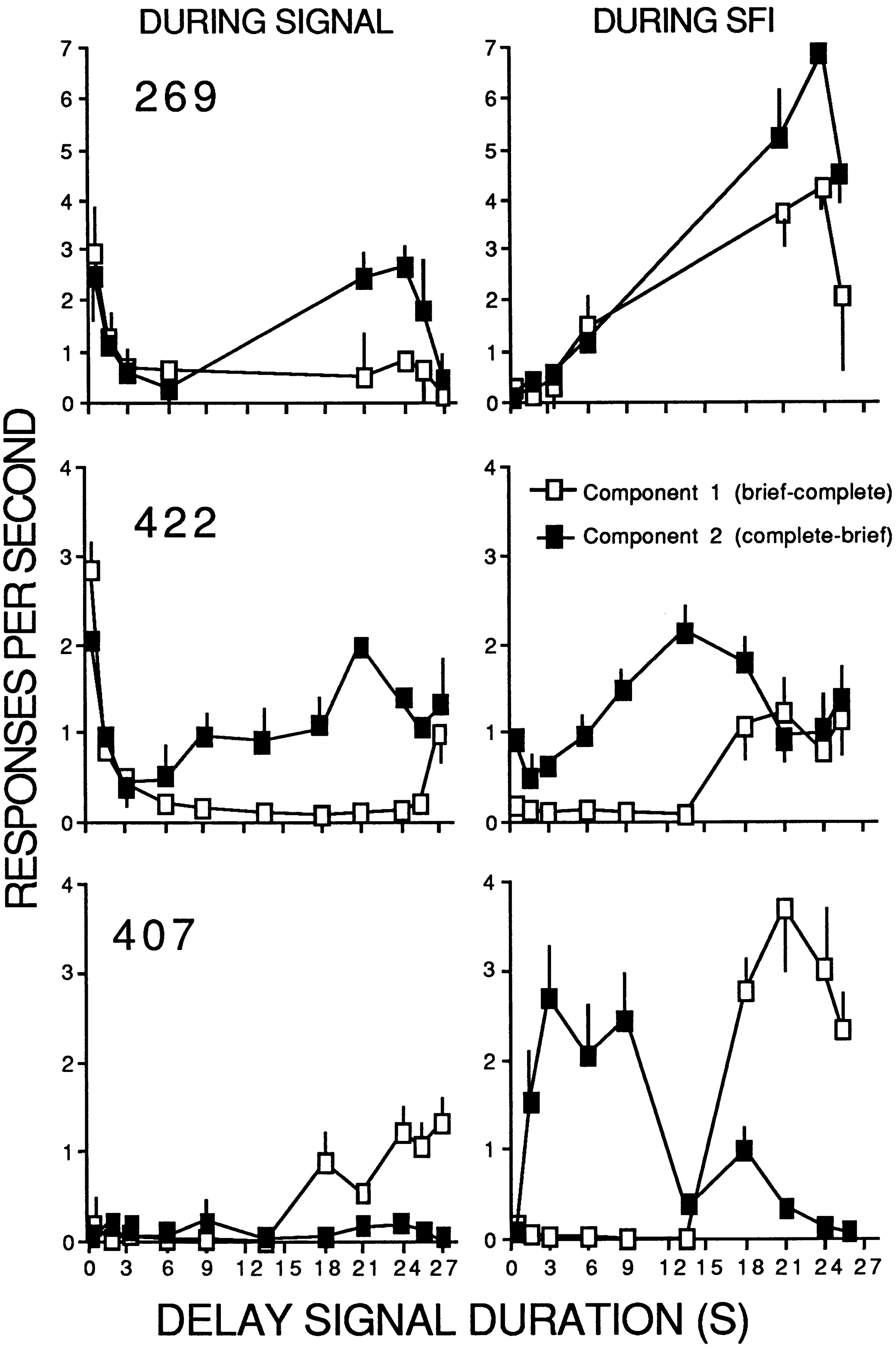
Table 2

Means (and standard deviations in parentheses) for each subject of the average obtained delays in each component for the last five sessions of each delay-signal condition in Experiment 1.

Component	Signal duration (s)	Mean obtained delays (s)		
		S269	S422	S407
1	0.5	10.1 (3.5)	11.1 (2.4)	8.1 (2.5)
2	27.0	15.9 (3.3)	0.9 (0.5)	25.6 (1.5)
1	1.5	14.8 (0.7)	9.9 (2.0)	17.2 (3.0)
2	25.5	0.4 (0.0)	1.1 (0.4)	9.6 (1.7)
1	3.0	11.7 (4.4)	15.6 (0.9)	21.7 (2.7)
2	24.0	0.2 (0.1)	1.3 (0.1)	10.1 (2.1)
1	6.0	1.5 (0.8)	16.3 (1.9)	22.8 (2.3)
2	21.0	0.2 (0.0)	2.3 (0.2)	7.3 (2.6)
1	9.0	—	19.5 (1.7)	24.9 (1.2)
2	18.0	—	1.2 (0.6)	1.6 (0.8)
1	13.5	—	15.1 (2.1)	26.1 (0.8)
2	13.5	—	0.9 (0.3)	5.1 (1.7)
1	18.0	—	3.5 (1.1)	0.5 (0.1)
2	9.0	—	3.2 (2.5)	0.4 (0.1)
1	21.0	0.2 (0.1)	2.6 (0.8)	0.7 (0.4)
2	6.0	3.1 (0.3)	5.9 (2.5)	2.1 (1.9)
1	24.0	0.2 (0.0)	2.8 (0.4)	0.9 (0.5)
2	3.0	8.7 (1.7)	7.8 (1.6)	1.6 (1.6)
1	25.5	2.6 (0.7)	2.3 (1.2)	0.6 (0.3)
2	1.5	9.6 (1.5)	12.7 (1.3)	2.0 (1.6)
1	27.0	24.5 (1.8)	1.5 (1.1)	0.7 (0.4)
2	0.5	16.8 (1.9)	9.5 (2.2)	11.4 (2.3)

DISCUSSION

Low response rates observed under a VI 60-s schedule with a 27-s delay signaled by a 0.5-s change in key color (Component 1, first condition) increased gradually as the duration of the delay signal was increased across phases (see Figure 2). Relatively high rates observed when the entire delay was signaled (Component 2, first phase) decreased as the delay-signal duration was decreased, but frequently did not match levels observed in Component 1 when the same signal duration was in operation. In fact, during Component 2 response rates decreased very little until the shortest


DURING SIGNAL
DURING SFI
269
422
407
RESPONSES PER SECOND
Component 1 (brief-complete)
Component 2 (complete-brief)
0
1
2
3
4
5
6
7
0 3 6 9 12 15 18 21 24 27
DELAY SIGNAL DURATION (S)

signal durations (e.g., 6.0 s to 0.5 s) were in operation. It may be concluded, then, that although response rates under these conditions were an increasing function of delay-signal duration, the shape of the function depended on factors other than the signal durations alone. Measures of responding during the delay (see Figure 4) revealed, at different signal durations in different subjects, extremely high rates of key pecking. The relationship of these high rates to signal durations varied greatly across subjects, however. Pigeon 407's rates during the SFIs were high during the same phases (and, consequently, at different delay-signal durations); Pigeon 269's rates during the SFIs were high under the same delay-signal durations (and, consequently, during different phases); and Pigeon 422 showed no consistent relationships between key pecking rates and delay-signal durations or phases. The circumstances responsible for these very high rates of key pecking cannot be determined from the results of the present experiments. For now it should be stressed that the occurrence of these bouts of rapid responding seemed to bear no specifiable relation to the rates of responding maintained prior to the delay.

The variables responsible for the higher predelay response rates under identical delay-signal-duration conditions depending on whether the delay signal is decreased (from 27 s) or increased (from 0.5 s) in duration also cannot be determined with certainty based on the present results, but several possibilities exist. One of these, reinforcement rate, can be ruled out because of the similarity across delay-signal-duration conditions in obtained frequencies of primary reinforcement (see Table 1). It is also possible that response rates remained relatively high because of prolonged exposure of the pigeons to delayed reinforcement conditions; their behavior may have become less sensitive to the effects of the delays themselves. This possibility was tested following the phases in which delay-signal durations were manipulated by removing the delay sig-

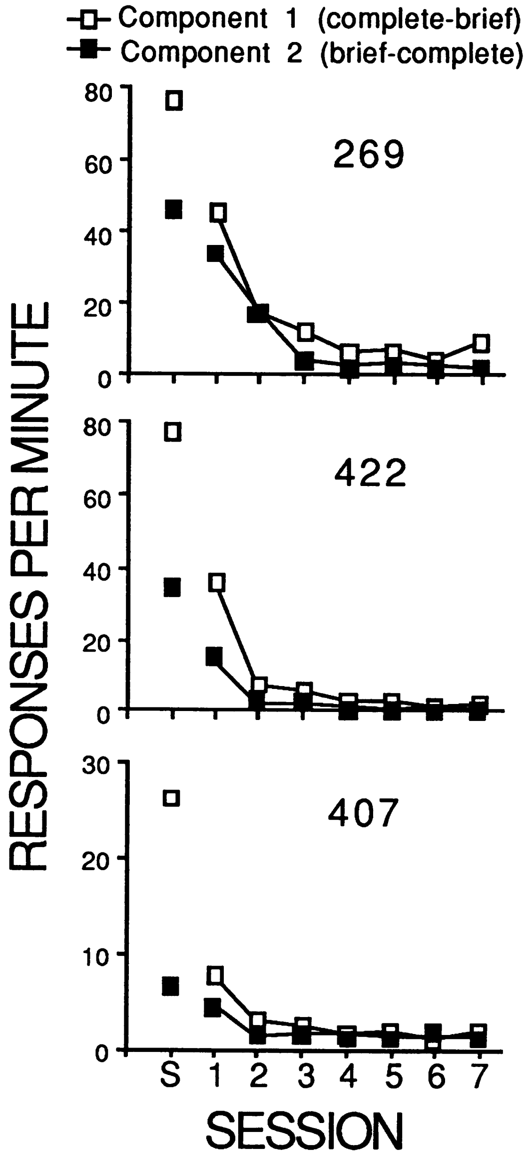


Fig. 5. Rates of key pecking (responses per minute) during VI periods for all 3 subjects under conditions of 27-s unsignaled delay to reinforcement. Rates obtained in Component 1 are depicted by open squares; rates obtained in Component 2 are depicted by filled squares. Points above the "S" are from the final sessions of the previous phase.

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Fig. 4. Rates of key pecking (responses per second) during delay signals (below "DURING SIGNAL") and during signal-food intervals (below "DURING SFI") for all 3 subjects under each delay-signal-duration condition. Points depict the means of rates obtained in the last five sessions of each phase; vertical bars represent 1 standard deviation. Rates obtained as the delay-signal duration was increased across phases (i.e., Component 1) are depicted by open squares; rates obtained as the delay signal was decreased in duration (i.e., Component 2) across phases are depicted by filled squares. See Table 1 for precise values of delay-signal durations.

nals completely; this phase is not listed in Table 1. Figure 5 shows that response rates fell to very low levels in only seven sessions when 27-s delays to reinforcement were unsignaled, thus eliminating this possibility.

There are several possible explanations for the higher response rates observed as the delay signal was decreased in duration that cannot be eliminated given the design of Experiment 1. One is that the pigeons' experience with delay signals that terminated near in time to primary reinforcement modified the function of the stimulus so that when it was presented for a short time it was more likely to serve as a conditioned reinforcer, thereby maintaining higher predelay rates. The possibility that behavior under the two components of the multiple schedule interacted in some way (e.g., Reynolds, 1961) also cannot be discounted, although the form of the interaction and the variables responsible for it are difficult to characterize. It may be, too, that conditions introduced following conditions that maintain high response rates tend to maintain higher rates than the same conditions introduced following conditions that maintained lower response rates. Weiner (1964), for example, showed that response rates of humans under a fixed-interval (FI) schedule of reinforcement were comparatively high following experience with fixed-ratio (FR) schedules (which maintained relatively high response rates) and were comparatively low following experience with a differential-reinforcement-of-low-rate (DRL) schedule (which maintained relatively low rates). This effect has also been obtained with rats (Urbain, Poling, Millam, & Thompson, 1978). Perhaps response rates in the present study were higher as the duration of the delay stimulus was decreased than they were under the same signal-duration conditions as the signal was increased in duration because, in the former case, response rates prior to the transition were higher. A related, but not identical, possibility is that the gradual transition from completely signaled delay to reinforcement to briefly signaled delay to reinforcement facilitated the maintenance of high response rates across a wider range of delay-signal durations.

Experiment 2 was conducted to test the possibilities discussed above. First, a single schedule was used instead of a multiple schedule, thus determining whether a multiple-schedule interaction was responsible for the results of Experiment 1. Second, after the delay signal was increased gradually across phases from 0.5 s to 27 s (as in Component 1 of the schedule used in Experiment 1), transitions were made abruptly from the completely-signaled-delay condition to conditions with shorter signal durations. It was reasoned that, if the hypothesis is correct that the signal must be decreased in duration gradually in order to maintain higher response rates across a greater range of signal durations, then an abrupt transition to a shorter delay signal should result in response rates similar to those observed at the same signal duration as the signal was being lengthened. Third, transitions were made to 0.5-s signaled-delay conditions from conditions that maintained very low response rates (i.e., unsignaled-delayed reinforcement) both prior to and following exposure of the pigeons to completely-signaled-delay conditions. If response rates under these two briefly-signaled-delay conditions were comparable, we may conclude that the effect of history observed in Experiment 1 may have been a function of the preceding response rate rather than the history of exposure to conditions with delay-signal durations that maintained high response rates.

EXPERIMENT 2

METHOD

Subjects and Apparatus

Three adult male White Carneau pigeons (Pigeons 165, 190, and 844) were maintained at approximately 80% of their free-feeding weights. The pigeons had previous experience with unsignaled and briefly signaled delays to reinforcement of various durations under schedule conditions nearly identical to the ones employed here (Schaal & Branch, 1988, Experiment 1). They had also experienced transitions from a condition in which a VI 60-s schedule operated with houselights illuminated to one in which houselights were not illuminated. Except during experimental sessions, pigeons were housed individually in a temperature-controlled colony with a 16:8 hr light/dark cycle. They had continuous access to water and health grit in their home cages.

The apparatus was the same as that used in Experiment 1.

Procedure

Because the pigeons had been trained to peck the key for previous experiments, the first condition of the present experiment was introduced directly. The pigeons had been pecking the key under a VI 60-s schedule of food reinforcement (4-s presentation of a hopper filled with mixed grain). The VI schedule consisted of 30 intervals determined by Catania and Reynolds' (1968, Appendix II) constant-probability method. The intervals were selected randomly without replacement by the computer. A 27-s unsignaled delay to reinforcement was then appended to the VI during the first condition of the present experiment. Specifically, after the scheduled interval timed out, the next response began a 27-s delay, with no change in external stimuli and during which responses were without programmed consequences (except for the feedback relay click that followed all key pecks). At the end of the delay, access to grain was provided independent of any further responding. In the terminology described by Zeiler (1977), the resulting schedule can be labeled a tandem VI 60-s FT 27-s schedule. Sessions lasted until 30 reinforcers were delivered or 105 min had elapsed, whichever came first (only Pigeon 190, during the final sessions of the condition with unsignaled delays, allowed the session to terminate after 105 min) and were conducted 7 days a week.

Table 3

Order of conditions, number of sessions per condition, and reinforcers per minute (means of last five sessions of each condition) for each pigeon in Experiment 2.

	Subject					
	190		165		844	
Signal length (s)	Sessions	SR/min	Sessions	SR/min	Sessions	SR/min
0[a]	50	0.25	46	0.40	48	0.53
0.5	25	0.62	25	0.44	25	0.62
1.5	23	0.63	16	0.43	19	0.61
3.0	32	0.64	12	0.45	36	0.62
6.0	27	0.65	24	0.52	28	0.63
9.0	10	0.65	17	0.58	10	0.64
13.5	19	0.66	12	0.57	17	0.65
18.0	19	0.65	18	0.63	31[b]	0.64
21.0	11	0.64	31	0.65	14	0.65
24.0	85	0.65	17	0.65	26	0.65
25.5	12	0.67	64	0.64	14	0.65
27.0	19	0.66	16	0.64	23	0.66
3.0	39	0.64	—	—	—	—
6.0	—	—	—	—	26	0.65
18.0	—	—	45	0.65	—	—
27.0	26	0.65	34	0.65	17	0.65
6.0	—	—	59	0.64	—	—
13.5	—	—	—	—	13	0.64
27.0[c]	—	—	29	0.66	26	0.66
0.5[c]	28	0.65	21	0.55	43	0.61
0[a,c]	15	0.32	15	0.38	18	0.55
0.5[c]	21	0.63	28	0.55	22	0.62

[a] Unsignaled 27-s delay.

[b] Removed from experiment for 37 days during this condition due to leg fracture.

[c] Not plotted in Figures 7 and 8.

When response rates were stable, conditions were changed such that the peck that began the 27-s delay also produced a change in key color (from green to red) for 0.5 s, after which the VI stimulus (green key) was reinstated until food reinforcement was presented. All other circumstances were identical to those in effect in the previous condition. When stable response rates were observed, the duration of the delay signal was increased to 1.5 s; the programmed delay remained 27 s, as in Experiment 1. Delay-signal durations were increased gradually across conditions until the signal was presented during the entire delay (i.e., 27 s). Following this phase, delay-signal durations that maintained response rates at approximately 50% of the rates observed when the entire delay was signaled were introduced. Delay-signal durations tested during this condition were 18 s for Pigeon 165, 3 s for Pigeon 190, and 6 s for Pigeon 844. During the next condition the entire delay was signaled again. The final phases consisted of tests of other delay-signal-duration conditions, including transitions from completely-signaled-delay and unsignaled-delay conditions to conditions with 0.5-s signaled delays for each subject. The conditions of Experiment 2 are summarized, along with reinforcement rates obtained in the final session of each phase, in Table 3. Response rates were considered stable when inspection of daily plots and cumulative records revealed very little day-to-day variability, with no upward or downward trends.

Overall response rates, not including time or responses during the delay, were computed daily. Each obtained or actual delay to reinforcement (i.e., the time between food presentation and the last peck to precede it) was collected individually. The numbers of re-

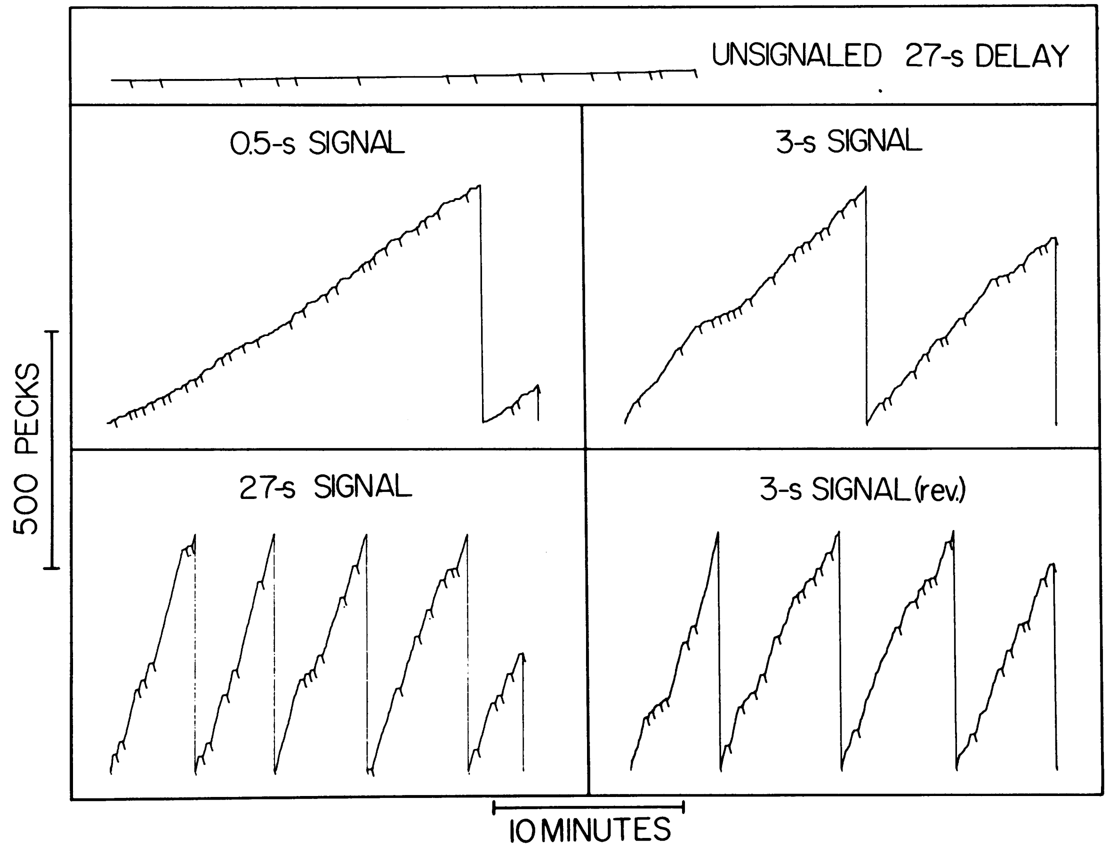

Fig. 6. Cumulative records from the final sessions of the phases indicated for Pigeon 190. Delay-signal durations are indicated in each panel. Performance from the second exposure to conditions with 3-s delay-signal duration is depicted by the record in the lower right corner, marked "3-s SIGNAL (rev.)." Short, diagonal pen deflections indicate food presentations. The cumulative recorder operated during delays.

sponses during and after the brief stimulus also were collected separately.

RESULTS

Cumulative records from the last session of the 27-s unsignaled delay condition, the condition with 0.5-s delay signals, the condition in which the entire delay was signaled, and the first and second conditions in which a 3-s stimulus change signaled the delay are shown for Pigeon 190 in Figure 6. Except for the top panel, records are representative of the performance of all 3 subjects. The top panel shows a portion of the cumulative record obtained from the final session of the first condition with unsignaled delays. Pigeon 190 was the only subject whose response rates increased when the 0.5-s delay signal was added; the increase in rate for this subject was substantial, from near zero during the initial unsignaled-delay condition to approximately 15 pecks per minute at the end of the subsequent 0.5-s signal-duration condition. For the other 2 subjects there were no appreciable differences between response rates following the initial transition from unsignaled-delay conditions to conditions in which the delay signal was 0.5 s (see also Figure 9). As in Experiment 1, response rates increased and patterns of responding grew more steady as the duration of the signal was increased, as is evident from the data in the lower left panel in which the entire delay was signaled. Also presented for comparison are records from the initial 3-s delay-signal condition, during which response rates were approximately half of those obtained during the condition with 27-s signals, and the second 3-s delay-signal condition (lower right panel), which followed immediately the first condition with 27-s signals. Response rates were higher and patterns of responding more steady during the second exposure to this delay-signal condition.

Response rates across delay-signal conditions are summarized in Figure 7. The means of the response rates obtained in the final five sessions of each phase are shown. As in Experiment 1, response rates were an increasing function of delay signal duration for all 3 subjects. Also as in Experiment 1, there was some variability across subjects with respect to the magnitude of the increases in response rates as each delay-signal duration was tested, with rates for Pigeon 165 increasing very gradually across conditions and rates for Pigeon 190 increasing more abruptly. In each case, when shorter signal-duration conditions were tested following exposure to completely-signaled-delay conditions, response rates were higher than when these delay-signal conditions were presented initially. This difference in response rates under identical signal-duration conditions as a function of experience with long delay signals was also observed in Component 2 of Experiment 1.

Figure 8 depicts response rates during the delay. Rates during the delay signal were highest for each subject when the signal was 0.5 s (left panels). Response rates both during and after the delay signal tended to decrease as the delay signal was lengthened. With one exception response rates were much lower across delay periods than those observed in Experiment 1. The exception was Pigeon 165, for whom within-delay rates during the second exposure to the 18-s delay signal increased relative to rates observed during the first exposure to this condition (just over two pecks per second during the SFI). For the other 2 subjects, rates during the second exposures to their respective delay-signal-duration conditions were comparable to those observed during the first exposures to these conditions.

Figure 9 depicts the means and ranges of response rates from the last five sessions of the 0.5-s signaled-delay conditions tested in this experiment, as well as rates obtained in the preceding conditions. The left portions show response rates obtained under the initial exposure to 0.5-s signaled-delay conditions (which followed conditions with unsignaled delays). Very small increases in response rates

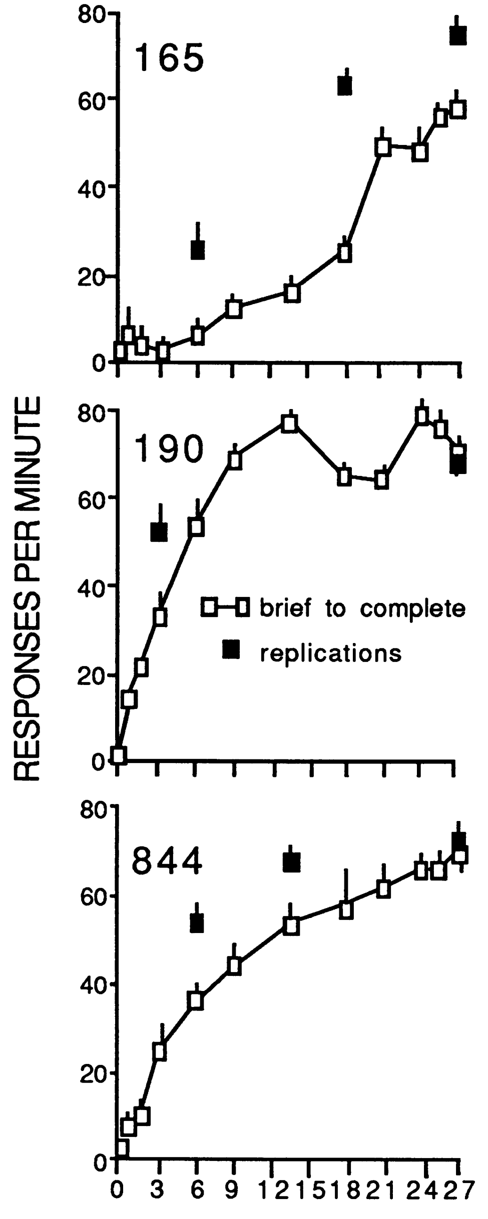

Fig. 7. Rates of key pecking (responses per minute) during VI periods for all 3 subjects under each delay-signal-duration condition. Points depict the means of rates obtained in the last five sessions of each phase; vertical bars represent standard deviations. Rates obtained as the delay-signal duration was increased across phases are depicted by open squares; rates obtained during replications of conditions with shorter delay signals are depicted by filled squares. See Table 3 for precise values of delay-signal durations.

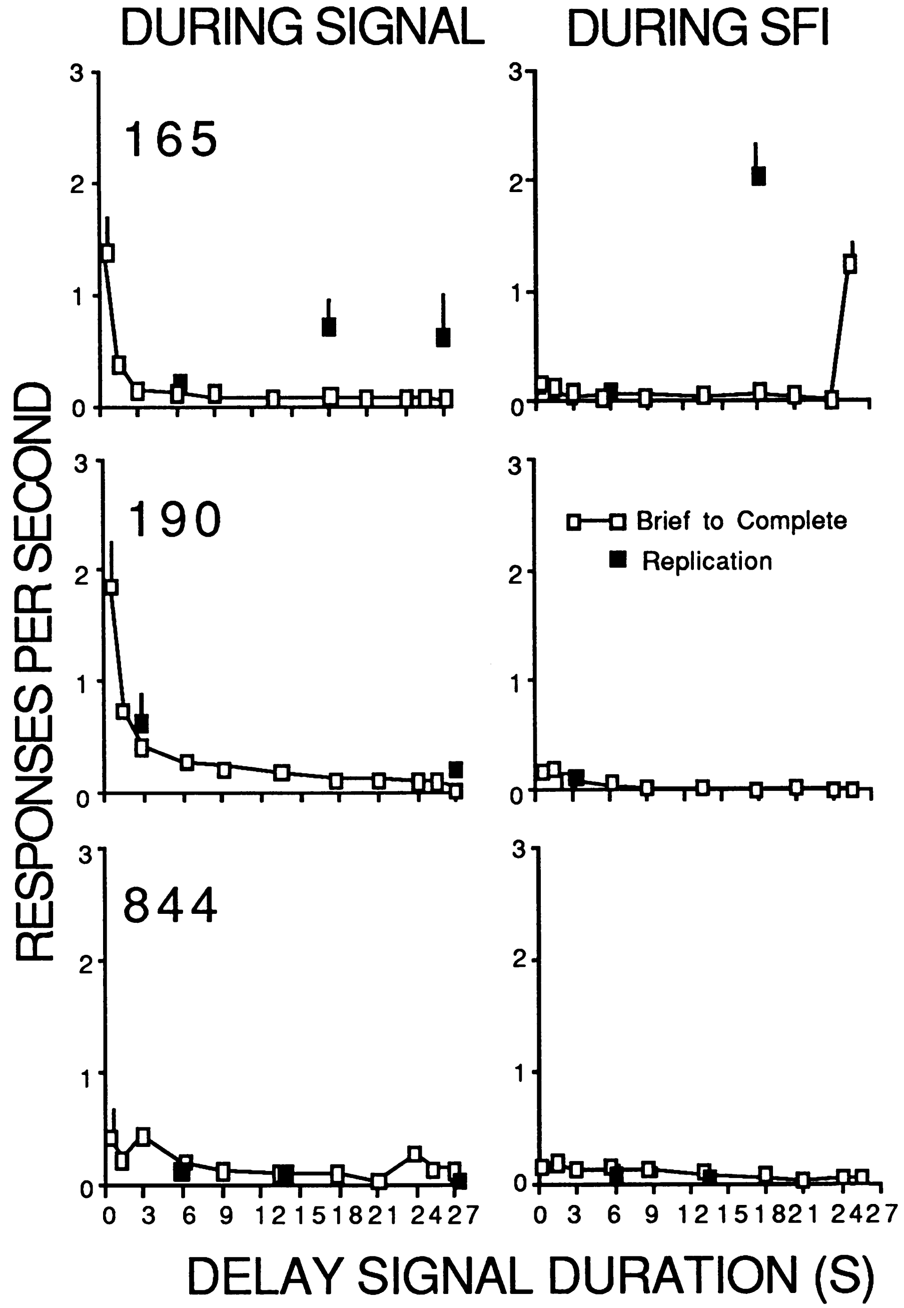

Fig. 8. Rates of key pecking (responses per second) during delay signals (below "DURING SIGNAL") and during signal-food intervals (below "DURING SFI") for all 3 subjects under each delay-signal-duration condition. Points depict the means of rates obtained in the last five sessions of each phase; vertical bars represent one standard deviation. Rates obtained as the delay-signal duration was increased across phases are depicted by open squares; rates obtained during replications of shorter delay-signal durations are depicted by filled squares. See Table 2 for precise values of delay-signal durations.

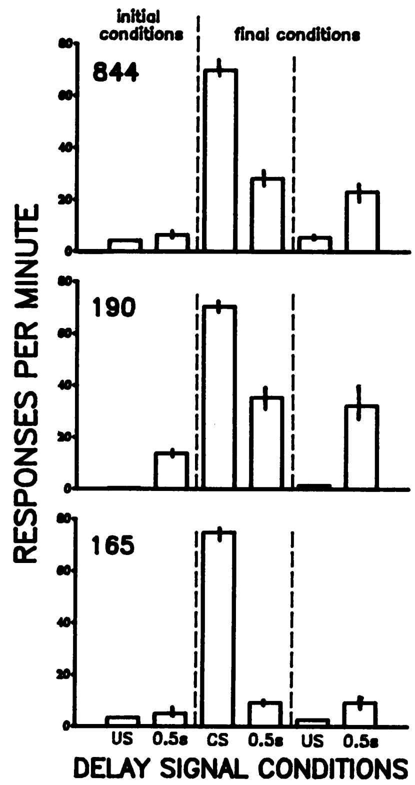

Fig. 9. Means of response rates from the last five sessions of the 0.5-s signaled-delay conditions tested in Experiment 2. The leftmost portions show response rates obtained under the initial exposures to unsignaled-delay ("US") and 0.5-s signaled-delay ("0.5 s") conditions. Rates obtained under 0.5-s signal conditions that followed completely signaled-delay ("CS") conditions are depicted in the middle portions, and the rightmost portions depict rates during and following a second exposure to unsignaled-delay conditions. Vertical bars indicate ranges.

can be seen for Pigeons 844 and 165; on the other hand, Pigeon 190's rate of pecking increased from less than 1.0 peck per minute to over 15 pecks per minute. Following exposure to completely-signaled-delay conditions (middle portions), response rates under the 0.5-s signal conditions were over twice those observed initially. A subsequent unsignaled-delay condition preceded another transition to 0.5-s signal conditions (right portions). Although response rates obtained in the second unsignaled-delay condition approximated those observed when these conditions were first in effect, the subsequent condition with 0.5-s signals maintained rates nearly equal to those obtained following the transition from completely-signaled-delay conditions.

Table 4

Means (and standard deviations in parentheses) for each subject of the average obtained delays for the last five sessions of each delay-signal condition in Experiment 2.

Delay-signal duration (s)	Mean obtained delays (s)		
	S165	S190	S844
0	17.6 (2.9)	25.9 (0.6)	11.4 (3.5)
0.5	16.3 (6.9)	12.6 (1.5)	7.1 (2.2)
1.5	20.2 (3.7)	9.1 (1.5)	9.0 (2.4)
3.0	21.5 (2.6)	15.2 (4.7)	16.0 (0.3)
6.0	22.1 (2.2)	23.1 (0.7)	18.1 (3.4)
9.0	19.4 (2.5)	24.5 (1.0)	18.5 (2.6)
13.5	21.5 (1.2)	23.0 (0.3)	20.3 (1.9)
18.0	22.4 (1.2)	24.9 (0.9)	19.3 (1.6)
21.0	25.9 (0.8)	24.3 (1.5)	20.7 (1.4)
24.0	26.4 (0.5)	25.5 (0.7)	11.3 (1.6)
25.5	5.5 (1.7)	24.8 (0.8)	12.5 (1.5)
27.0	26.7 (0.4)	25.5 (0.5)	12.3 (2.5)
3.0	—	20.1 (3.1)	—
6.0	—	—	18.6 (2.3)
18.0	1.9 (1.5)	—	—
27.0	17.9 (4.7)	21.9 (1.0)	22.8 (0.9)
6.0	21.8 (0.9)	—	—
13.5	—	—	21.9 (1.2)
27.0	4.7 (2.6)	—	25.3 (1.0)
0.5	16.3 (6.9)	9.5 (1.5)	11.8 (3.0)
0.0	21.9 (0.9)	22.4 (1.1)	8.2 (1.4)
0.5	17.9 (1.7)	18.3 (1.7)	16.6 (1.3)

Reinforcement frequencies (see Table 3) for Pigeons 190 and 844 increased relative to both unsignaled-delay conditions when the 0.5-s delay-signal conditions were introduced, but remained relatively unchanged throughout the rest of the experiment. For Pigeon 165 reinforcement frequencies increased as gradually as did response rates, approximating their highest levels during the first exposure to the 18-s signal condition. Thereafter, reinforcement rates for this subject did not change appreciably. Finally, average obtained delays to reinforcement (means of last five sessions ±1 *SD*) are presented in Table 4. As in Experiment 1, no consistent pattern is revealed in the relation of obtained delays to delay-signal duration.

DISCUSSION

As observed in Experiment 1, response rates prior to signaled 27-s delays to reinforcement increased in each of 3 subjects as the duration of the delay signal was increased across conditions. When pigeons were exposed to conditions with shorter delay signals following exposure to a condition in which the entire delay was signaled, response rates were higher than those observed under identical signal conditions prior to exposure to the long signals, again reproducing effects observed in Experiment 1. Gradual transitions from long to short signals were not required to produce this effect. Also, because the effect was demonstrated using a single schedule, the possibility that a form of multiple-schedule interaction was involved in the similar effect in Experiment 1 is eliminated. Finally, rates observed under 0.5-s signaled-delay conditions were higher following exposure to completely-signaled-delay conditions regardless of the response rates obtained just prior to transitions to this condition. This effect was also obtained in 2 of the 3 pigeons in Experiment 1 (i.e., 269 and 422; see Figure 3). It may be concluded, therefore, that some aspect of the subject's intervening history with longer delay signals other than preceding response rates was responsible for this effect.

As in Experiment 1, changes in reinforcement frequency (see Table 3) can be ruled out of consideration in explaining the changes in key-pecking rates under identical signal-duration conditions, because for Pigeons 190 and 844 reinforcement rates did not change appreciably after the 0.5-s signal condition. It is notable, however, that the largest difference in response rates between the first and second exposures to the shorter signal-duration conditions was for Pigeon 165 (at the 18-s signal condition). Reinforcement frequencies were lower for this subject during the condition prior to the first 18-s signal condition (i.e., the 13.5-s signal condition) than those obtained during the 27-s signal condition in effect prior to the second exposure to the 18-s signal condition. Also, reinforcement frequencies obtained for Pigeons 180 and 844 under the second condition with unsignaled delays were slightly higher than those obtained during the first exposure to this condition. It is possible, therefore, that the transition from a higher reinforcement frequency rather than from a lower frequency to the 0.5-s delay-signal conditions contributed to the magnitude of the differences between the rates obtained in the replications of these shorter delay signals. Reinforcement frequencies obtained in Experiment 1 and those for Pigeons 190 and 844 in Experiment 2, however, indicate that differences in reinforcement rates were not required to produce many of the differences observed in response rates under identical signal conditions.

Although the effects on predelay response rates of lengthening the duration of the delay signal were very similar to those observed in Experiment 1, measures of response rates during delays revealed large differences between the results of the two experiments. Whereas in Experiment 1 each subject pecked at rapid rates during the SFIs at various delay-signal durations (see Figure 4), in Experiment 2 relatively high response rates during the SFIs were observed only during the 25.5-s and the second 18-s signal-duration conditions for Pigeon 165 (see Figure 8). Again, the main effect of increasing the duration of the delay signal was to increase predelay response rates; other dependent variables (i.e., rates of responding during the delays, average delays) bore less consistent relations to the duration of the delay signal.

GENERAL DISCUSSION

In the experiments reported here, the rate of pigeons' key pecking was an increasing function of the duration of the keylight stimulus that signaled a 27-s delay to reinforcement. Higher response rates under signaled-delay-to-reinforcement conditions relative to those observed under unsignaled-delay conditions that have been reported often (e.g., Lattal, 1984; Richards, 1981; Richards & Hittesdorf, 1978; Schaal & Branch, 1988). However, no previous research has shown predelay rates of responding to be an orderly function of the proportion of the delay signaled.

As suggested previously, the conditioned reinforcing function of the delay signal may be related to its temporal relationship (i.e., the respondent relationship) to food reinforcement. Specifically, the temporal parameters under which keylight stimuli come to elicit key pecking in autoshaping procedures (particularly trace autoshaping, e.g., Kaplan, 1984; Lucas, Deich, & Wasserman, 1981; Newlin & LoLordo, 1976) may be similar to the temporal parameters under which response-dependent delay signals served as conditioned reinforcers in the experiments reported here. Some support for this notion may be found in the comparison of two of the results of experiments by Schaal and Branch (1988) with two of the results reported by Newlin and LoLordo

(1976). First, Schaal and Branch showed that predelay rates of key pecking were maintained at higher levels when 0.5-s signaled delays were short (i.e., 1 s, 3 s, and 9 s) compared to rates obtained when delays were long (27 s). Newlin and LoLordo showed that acquisition of key pecking was more rapid and higher rates of key pecking were maintained when the CS–US interval in trace autoshaping was short (4 s) relative to when it was long (24 s). Second, completely signaled delays maintained high response rates at longer delay values (i.e., 27 s) than signals that lasted 0.5 s (Schaal & Branch, 1988; the present study). Likewise, Newlin and LoLordo showed that delay conditioning (i.e., conditioning in which the CS remains until the presentation of the US) resulted in faster acquisition and more rapid pecking than trace conditioning.

Given this interpretation, one might expect that pecking during delays would bear some relationship to rates maintained prior to delays (reflecting the conditional stimulus functions of the delay signal; cf. Ellison & Konorski, 1964). Key pecking during the delay signal, however, did not vary systematically with delay duration (Schaal & Branch, 1988) or signal duration (the present experiments). In addition, although predelay rates increased as signal duration was increased in the present study, autoshaping experiments in which the duration of the CS was manipulated (e.g., Gibbon, Baldock, Locurto, Gold, & Terrace, 1977; Perkins et al., 1975) found that trials to acquisition in delay-conditioning procedures was a negatively accelerated, decreasing function of CS duration. It should be noted that these experiments employed delay conditioning methods, thus confounding CS duration with CS onset and food times; in the present experiments the "CS," or signal, duration was increased without changing time from signal onset to food. Despite these procedural differences it appears that previous results from respondent conditioning procedures do not completely support a strict respondent-conditioning interpretation of the present results (i.e., one in which stimuli that elicit key pecks also reinforce pecks that produce them and vice versa). However, it may be that the respondent relations between the delay signal and food determine only *whether* the signal acquires some function. The function that is observed (e.g., conditioned reinforcing or peck eliciting) may depend on other procedural factors, namely whether the signal is presented dependent on or independent of key pecking. Future experiments will explore other relationships among pecking, delay signals, and food presentation in order to determine the usefulness of this interpretation.

As noted above, interpretation of these results in terms common to respondent conditioning is compromised by the fact that intradelay pecking (which might be expected to be "elicited" if the delay signal acquires CS-like functions) was not related systematically to predelay behavior. This suggests that pecking during the delay was independent of conditions that systematically modified predelay behavior. More direct support for this conclusion is provided by Pierce et al. (1972). The lever pressing of rats was maintained under a VI 60-s schedule of signaled-delayed reinforcement, and the contingencies relating lever pressing to food presentation during the delay were varied. Conditions in operation during the delay had substantial effects on lever pressing during the delay (e.g., rates were low when each response reset the delay and were relatively high and temporally patterned when the delay was an FI schedule), but predelay response rates were not affected by intradelay contingencies. Predelay response rates decreased as the duration of the programmed delay was increased, indicating that lever pressing was affected by delays to reinforcement, no matter how they were arranged. It is not surprising, then, that key pecking during the delays in the present study seemed to bear little relation to response rates prior to the delays.

Although higher rates under signaled-delay conditions usually have been discussed in terms of conditioned reinforcement of responding by the immediate presentation of the delay signal (e.g., Ferster, 1953; Lattal, 1984), Richards (1981) provided an interesting alternative interpretation. He suggested that rates of responding decreased under unsignaled-delay conditions because behavior other than key pecking was accidently reinforced at the end of each delay. This "superstitious" behavior competed with key pecking during the VI, resulting in decreased response rates. This interpretation of the effects of unsignaled delays to reinforcement is common (e.g., Sizemore & Lattal, 1977), but Richards went on to suggest that adventitious reinforcement is involved in signaled delays to reinforcement as well. Specifically, other responses are accidentally reinforced at the end of signaled delays, but because they are reinforced in the presence of a distinctive stimulus they do not generalize to VI periods, and hence do not decrease predelay response rates by competition. A similar interpretation that does not refer to superstitious behavior characterizes the delay as a signaled period of extinction ("extinction" here referring to the absence of a contingency between responding and reinforcement). As noted by Catania and Keller (1981), delayed-reinforcement conditions share some of the properties of response-independent reinforcement (e.g., the likelihood that pecks and food will be discontiguous). If the signaled-delay periods of the present experiments can be characterized as extinction periods, then, as Richards suggests, generalization to VI periods should decrease VI response rates.

Richards (1981) also noted that a way to test this notion would be to make delay periods gradually more different from predelay periods; superstitious responding (or extinction) should generalize more to VI periods (and hence decrease rates of key pecking) as delay periods are made more similar to VI periods. The present experiments may be thought of as attempts to make delay periods gradually more different from VI periods by increasing the proportion of the delay in which a distinctive stimulus (i.e., the delay signal) is present. Rates of key pecking may have been lower as the signal duration was decreased because accidentally reinforced behavior competed with key pecking; as the signal was increased in duration extinction or accidentally reinforced behavior was under greater discriminative control of the delay signal and thus competed less with key pecking during the VI period. Perhaps the variability in the measured aspects of responding during delays (i.e., responses per second, Figures 4 and 8, and obtained delays, Tables 2 and 4) reflects the variability in response–reinforcer relations that would likely prevail under conditions in which reinforcers are presented independently of response. However, these notions remain speculative in the absence of data on behavior other than key pecking.

Finally, in each subject's case, response rates under identical delay-signal-duration conditions were higher following exposure to completely-signaled-delay conditions than prior to such exposure. The relation primarily responsible for this effect cannot be determined precisely from the present study, but it is possible that the offset of the delay signal nearer in time to the presentation of food constituted a pairing of the two stimuli (in the respondent conditioning sense; e.g., Bersh, 1951; Jenkins, 1950), thus increasing the conditioned reinforcing efficacy of the brief delay signal. Experiments employing second-order schedules have shown a similar effect of a history of pairing. Marr and Zeiler (1974), for example, superimposed various schedules of brief (i.e., 0.5 s) stimulus presentation on an FI 15-min schedule of food reinforcement with pigeons. Previously food-paired brief stimuli maintained higher response rates and more FI-like patterns of responding under nonpaired conditions than never-paired stimuli. This irreversible effect of pairing brief stimuli with food has been noted in other studies employing second-order schedules of brief-stimulus presentation (e.g., Cohen & Lentz, 1976; de Lorge, 1967) and bears a sufficient resemblance to the effects of the present experiments to warrant speculation that similar processes are involved.

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