

RESISTANCE TO CHANGE OF RESPONDING MAINTAINED BY UNSIGNALLED DELAYS TO REINFORCEMENT: A RESPONSE-BOUT ANALYSIS

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Previous experiments have shown that unsignaled delayed reinforcement decreases response rates and resistance to change. However, the effects of different delays to reinforcement on underlying response structure have not been investigated in conjunction with tests of resistance to change. In the present experiment, pigeons responded on a three-component multiple variable-interval schedule for food presented immediately, following brief (0.5 s), or following long (3 s) unsignaled delays of reinforcement. Baseline response rates were lowest in the component with the longest delay; they were about equal with immediate and briefly delayed reinforcers. Resistance to disruption by pre-session feeding, response-independent food during the intercomponent interval, and extinction was slightly but consistently lower as delays increased. Because log survivor functions of interresponse times (IRTs) deviated from simple modes of bout initiations and within-bout responding, an IRT-cutoff method was used to examine underlying response structure. These analyses suggested that baseline rates of initiating bouts of responding decreased as scheduled delays increased, and within-bout response rates tended to be lower in the component with immediate reinforcers. The number of responses per bout was not reliably affected by reinforcer delay, but tended to be highest with brief delays when total response rates were higher in that component. Consistent with previous findings, resistance to change of overall response rate was highly correlated with resistance to change of bout-initiation rates but not with within-bout responding. These results suggest that unsignaled delays to reinforcement affect resistance to change through changes in the probability of initiating a response bout rather than through changes in the underlying response structure.

Key words: behavioral momentum theory, resistance to change, unsignaled delay of reinforcement, multiple schedules, bouts, key peck, pigeon

Resistance to change is a measure of the persistence of responding during conditions of disruption relative to steady-state baseline responding (Nevin, 1992). Considered a measure of response strength, resistance to change typically has been examined using multiple schedules of reinforcement. Disrupters have included feeding subjects prior to an experimental session (hereafter referred to as pre-session feeding), intercomponent interval (ICI) response-independent food presentations, and extinction. Responding usually is more resistant to disruption (expressed as change relative to baseline) in components with higher rates or magnitudes of reinforcement (e.g., Nevin, 1974).

The relation between reinforcement rate and resistance to change has been described using an analogy between behavior and physical momentum (Nevin & Grace, 2000; Nevin, Mandell, & Atak, 1983). Behavioral momentum theory suggests that resistance to change is analogous to physical mass and response rate is analogous to the velocity of a moving object. Similar to the independence of velocity and mass in classical physics, behavioral momentum theory suggests that response rates and resistance to change are independent aspects of behavior. Resistance to change is determined by the relation between the discriminative stimulus and the rate of reinforcement in the presence of that discriminative stimulus (i.e., a Pavlovian stimulus-reinforcer relation). Further, behavioral momentum theory also suggests that resistance to change is independent of the response-reinforcer contingency that governs response rates (i.e., operant response-reinforcer relation; Nevin, Tota, Torquato, & Shull, 1990; see Nevin & Grace, 2000, for a review).

Several experiments, however, have shown that manipulations of the response-reinforcer

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contingency do affect resistance to change when stimulus–reinforcer relations are equal across multiple-schedule components (Doughty & Lattal, 2001; Lattal, 1989; Nevin, Grace, Holland, & McLean, 2001; Reed & Doughty, 2005). Results from experiments in which equal rates of unsignaled delayed and immediate reinforcers are presented in different components of a multiple schedule provide clear examples inconsistent with the predictions of behavioral momentum theory (e.g., Bell, 1999; Grace, Schwendiman, & Nevin, 1998; Reilly & Lattal, 2004). With unsignaled, nonresetting delays to reinforcement, the response that meets a reinforcement schedule requirement starts a delay that is timed independently of further responding during the delay and produces no change in stimulus conditions (e.g., Sizemore & Lattal, 1977, 1978; Williams, 1976). Thus, unsignaled delays of reinforcement degrade the response–reinforcer relation by inserting a delay between the response that fulfills the reinforcement-schedule requirement and the delivery of the reinforcer. Unsignaled delays purportedly do not degrade stimulus–reinforcer relations relative to immediate reinforcement because equal rates of reinforcement typically are presented in the presence of component stimuli regardless of the duration of the delay. For instance, Grace *et al.* exposed pigeons to a multiple VI 40-s VI 37-s schedule with an unsignaled 3-s delay of reinforcement in the latter component. Consistent with previous findings, response rates maintained by delayed reinforcement were lower than those maintained by immediate reinforcement (e.g., Catania & Keller, 1981; Richards, 1981; Sizemore & Lattal, 1977, 1978; Williams, 1976). Further, resistance to pre-session feeding and extinction generally was lower in the component with delayed reinforcement than in the component with immediate reinforcement. These results show that degrading the operant response–reinforcer relation can negatively affect both response rate and resistance to change even in the absence of a change in reinforcement rates.

There has been little investigation of how different durations of unsignaled delays to reinforcement affect resistance to change. Bell (1999) found no systematic differences between subjects in response rate or resistance to change between unsignaled delays of 3 and

8 s. Such long delays typically produce similar decreases in response rates relative to responding maintained by immediate reinforcement (see Schneider, 1990, for a review) and, therefore, may have constrained any differences in resistance to change by floor effects. In addition, between-subject comparisons may not be sufficiently sensitive to potential differences in resistance to change, and within-session comparisons may be necessary (cf. Cohen, 1998).

Delay durations that have been shown to produce greater differences in steady-state responding than those used by Bell (1999) might better generate detectable differences in resistance to change. Brief delays (i.e., 0.5 s), for instance, often have been shown to produce increases in overall response rates and to affect the underlying pattern of responding by increasing the proportion of short IRTs (< 0.5 s) relative to responding maintained by immediate reinforcement (Arbuckle & Lattal, 1988; Lattal & Ziegler, 1982; Richards, 1981; Shahan & Lattal, 2005; Sizemore & Lattal, 1978). Arbuckle and Lattal suggested that brief delays alter the functional response unit from a single response to a burst of several responses. It is unknown whether these changes in response rate and underlying structure are indicative of changes in response strength as measured by resistance to change. This picture is complicated by the fact that longer delays (i.e., 3 s) also have been shown to increase proportions of short IRTs relative to immediate reinforcement but tend to produce lower response rates (Schaal, Shahan, Kovera, & Reilly, 1998; Shahan & Lattal, 2005) and lower resistance to change (Bell, 1999; Grace *et al.*, 1998).

Due to the differences in the underlying structure of responding maintained by immediate and different unsignaled delayed reinforcement (Arbuckle & Lattal, 1988), it may be informative also to examine responding at that level to understand how different unsignaled delays affect resistance to change. Responding maintained by VI schedules has been shown to occur in two modes—bout initiations (i.e., visits) and within-bout responding (i.e., response engagement; Baum, 2002; Baum & Rachlin, 1969; Blough, 1963; Davison, 2004; Mellgren & Elmsore, 1991; Nevin & Baum, 1980; Pear & Rector, 1979; Shull, Gaynor, & Grimes, 2001). In rats nose

poking and lever pressing for food, differences in reinforcement rates have been shown to affect bout-initiation rates, whereas adding a small ratio response requirement to the end of a VI schedule increases within-bout responding (Shull, Gaynor, & Grimes, 2001, 2002; Shull & Grimes, 2003). Conditions of disruption have been shown to decrease bout-initiation rates relative to baseline, whereas within-bout responding tends to be less affected (Shull, 2004; Shull et al., 2002). The effects of delayed reinforcement on bout initiations and within-bout responding have not been examined either during baseline conditions or under conditions of disruption. Thus, the present study examined the effects of immediate, briefly delayed (0.5 s), and longer-delayed (3 s) reinforcement on overall response rates and response bouts during baseline and under conditions of disruption in a three-component multiple schedule.

METHOD

Subjects

The subjects were 4 homing pigeons maintained at approximately 80% of their free-feeding weights (± 15 g) by postsession feeding as necessary. All pigeons had previous experience with a multiple-schedule procedure similar to that used in the present experiment. When not in experimental sessions, pigeons were housed in individual cages in a temperature-controlled colony with a 12:12 hr light/dark cycle. All pigeons had free access to water in their home cages.

Apparatus

Four sound-attenuating chambers were used. The chambers were constructed out of clear plastic and aluminum and measured 29 cm long \times 26 cm wide \times 29 cm high. Each chamber had one response key centered on the front wall 16 cm above the floor. Response keys measured 2.5 cm in diameter and required a force of about 0.1 N to operate. The key could be illuminated from behind with red, green, and white light via a 28-V DC bulb. A 28-V DC lamp centered above the key and 33 cm from the floor of the chamber served as a houselight. A 6 cm \times 5 cm aperture directly below the response key and 5 cm from the chamber floor allowed access to a solenoid-

operated hopper filled with pigeon chow. During hopper presentations, the opening was lit with a white light, and the houselight and keylight were extinguished. A ventilation fan masked extraneous sounds. Control of experimental events and data recording were conducted with a microcomputer using Med Associates[®] interfacing and software.

Procedure

A three-component multiple schedule with equal rates of reinforcement in each component was used. The variable-interval schedules in operation in each component were composed of 13 intervals (Fleschler & Hoffman, 1962) selected without replacement. A component signaled by a white keylight arranged immediate reinforcers (hereafter Immediate component) according to a VI 60-s schedule. The other two components arranged reinforcers according to unsignaled, nonresetting delays to reinforcement. In both delay components, the first response after the VI had elapsed started a fixed-time (FT) schedule (i.e., the delay). Food was presented independently of further responding during the FT schedule and no exteroceptive stimulus changes accompanied the delay. A component signaled by the green keylight arranged reinforcers according to a tandem VI 59.5-s FT 0.5-s schedule of reinforcement (hereafter Brief component). A component signaled by the red keylight arranged reinforcers according to a tandem VI 57-s FT 3-s schedule of reinforcement (hereafter Long component).

The first component in each session was randomly chosen. Components followed in a random sequence for the remainder of the session with the restriction that the same component could not occur more than twice in a row. All components were 60 s long and separated by a 20-s ICI during which all keylights and the houselight were extinguished. Components scheduled to terminate during a delay of reinforcement or hopper presentation were held until after the hopper presentation. Reinforcers scheduled but not obtained before the end of one component were held until the next occurrence of that component and were presented following the first response. All hopper presentations were 2 s long, and time during food hopper presentations was excluded from the timing of

Table 1

Number of baseline sessions in each condition, obtained reinforcers per min, and mean obtained delays. Obtained reinforcers (SR) per min are averaged across the final six sessions of baseline prior to disruption for the Immediate, Brief, and Long components. Baselines (BL) are indicated by the following disrupter (pre-session feeding [PF], ICI VT food [VT], and extinction [EXT]). Mean obtained delays are calculated across the final six sessions of baseline prior to disruption for the Brief and Long components. *SDs* are in italics. Conditions are presented in the order they occurred.

Subject	Condition	Sessions	Immediate	Brief		Long	
			SR per min	SR per min	Obt delay	SR per min	Obt delay
39	PF 30 g BL	40	0.93 <i>0.04</i>	0.95 <i>0.08</i>	0.18 <i>0.09</i>	0.90 <i>0.09</i>	1.08 <i>0.92</i>
	VT 15-s BL	13	0.96 <i>0.10</i>	0.87 <i>0.10</i>	0.18 <i>0.12</i>	0.84 <i>0.10</i>	1.32 <i>0.97</i>
	EXT BL	36	0.84 <i>0.10</i>	0.87 <i>0.10</i>	0.23 <i>0.13</i>	0.95 <i>0.10</i>	1.32 <i>0.96</i>
	VT 5-s BL	17	0.92 <i>0.05</i>	0.92 <i>0.12</i>	0.18 <i>0.11</i>	0.83 <i>0.15</i>	1.23 <i>0.87</i>
	PF 30 g BL	38	0.92 <i>0.11</i>	0.92 <i>0.07</i>	0.14 <i>0.05</i>	0.94 <i>0.09</i>	0.57 <i>0.45</i>
97	VT 15-s BL	7	0.90 <i>0.11</i>	0.81 <i>0.09</i>	0.15 <i>0.04</i>	0.90 <i>0.09</i>	0.46 <i>0.33</i>
	EXT BL	18	0.93 <i>0.07</i>	0.96 <i>0.09</i>	0.15 <i>0.04</i>	0.91 <i>0.09</i>	0.49 <i>0.48</i>
	VT 5-s BL	14	0.90 <i>0.05</i>	0.96 <i>0.04</i>	0.19 <i>0.04</i>	0.91 <i>0.11</i>	1.01 <i>0.76</i>
	PF 30 g BL	37	0.90 <i>0.07</i>	0.90 <i>0.09</i>	0.19 <i>0.02</i>	0.84 <i>0.09</i>	1.10 <i>0.84</i>
	VT 15-s BL	22	1.00 <i>0.05</i>	0.86 <i>0.15</i>	0.20 <i>0.02</i>	0.97 <i>0.07</i>	1.07 <i>0.91</i>
202	EXT BL	18	0.96 <i>0.07</i>	0.95 <i>0.06</i>	0.20 <i>0.03</i>	0.75 <i>0.13</i>	1.74 <i>0.98</i>
	VT 5-s BL	8	0.90 <i>0.11</i>	0.80 <i>0.13</i>	0.20 <i>0.02</i>	0.75 <i>0.10</i>	1.85 <i>0.97</i>
	PF 30 g BL	37	0.92 <i>0.05</i>	0.90 <i>0.12</i>	0.19 <i>0.02</i>	0.88 <i>0.12</i>	0.81 <i>0.84</i>
	VT 15-s BL	12	0.87 <i>0.13</i>	0.90 <i>0.05</i>	0.18 <i>0.04</i>	0.89 <i>0.09</i>	1.01 <i>0.79</i>
	EXT BL	10	0.86 <i>0.12</i>	0.86 <i>0.08</i>	0.18 <i>0.03</i>	0.91 <i>0.12</i>	1.07 <i>0.88</i>
217	VT 5-s BL	12	0.93 <i>0.10</i>	0.92 <i>0.09</i>	0.19 <i>0.02</i>	0.87 <i>0.10</i>	1.27 <i>1.03</i>
	VT 15-s BL	6	0.84 <i>0.10</i>	0.92 <i>0.11</i>	0.19 <i>0.03</i>	0.80 <i>0.13</i>	0.88 <i>0.95</i>
	Mean		0.91 <i>0.08</i>	0.90 <i>0.09</i>	0.18 <i>0.05</i>	0.87 <i>0.10</i>	1.07 <i>0.82</i>

all events. Sessions ended after each component was presented 12 times.

Baseline conditions continued until response rates were judged stable across at least six sessions according to visual inspection (i.e., absence of reliable trend and excessive session-to-session variability). Following stability, resistance to change was tested using pre-session feeding, extinction, and two values of ICI response-independent food as disruptors. Each disruption condition was separated by at least six baseline sessions. Table 1 shows the

number of baseline sessions during each condition prior to disruption and the order of disrupter presentation. The prefeeding tests consisted of 5 consecutive days on which subjects were fed 30 g of food 30 min prior to the experimental session. Extinction tests consisted of 5 consecutive days in which keylight colors remained as in baseline; however, no reinforcers were delivered in any of the components. Response-independent ICI food tests consisted of 5 consecutive days of exposure to a variable-time (VT) 15-s schedule

during the ICI in one condition and a VT 5-s schedule in the other condition. The effects of each disruptor were assessed once per pigeon with the exception of Pigeon 217. This bird underwent a replication of the VT 15-s disruption condition to examine whether an anomalous result obtained in the first exposure was replicable. Experimental sessions were conducted 7 days a week at approximately the same time each day.

RESULTS

Response Rate Analyses

Mean response rates from the last six sessions of baseline prior to disruption conditions and response rates from each session of disruption are presented in the Appendix. Figure 1 shows mean response rates in each component across successive conditions of baseline for each pigeon. With the exception of the third baseline condition for Pigeon 97, response rates in the Long component were consistently lower than response rates in the other two components across all conditions and pigeons. There were no consistent differences in response rates across the Immediate and Brief components. Response rates in the Brief component were higher than in the Immediate component in 9 of 17 comparisons.

Figure 2 shows an analysis of resistance to change of overall response rates disrupted by pre-session feeding, both values of ICI VT food, and extinction. Each data point represents the mean of the logarithms (log) of the proportions of baseline response rates for the five sessions of each disruption condition in one component plotted as a function of mean log proportion of baseline response rates in another component. The components being compared are indicated on their respective axes in each panel. (In the second and third sessions of VT 5-s disruption for Pigeon 202, response rates or one of the measures from the bout analyses [see below] dropped to zero for at least one of the components and are excluded from all analyses, but are included in the Appendix.) The magnitude of disruption is indexed by how far the symbols decrease from the origin down along the y-axis and to the left along the x-axis. The dashed diagonal line represents where symbols would fall if responding in the compared components

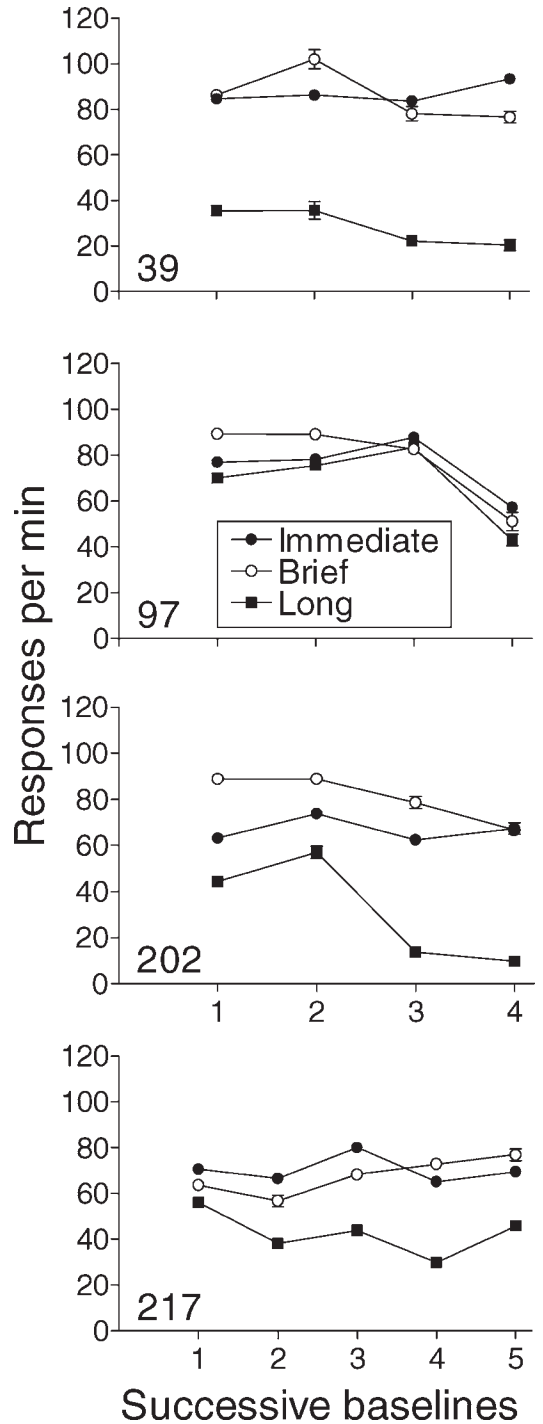


Fig. 1. Mean responses per min across successive baseline conditions for the Immediate, Brief, and Long components. Means are calculated over the last six sessions of baseline prior to disruption. Error bars represent ± 1 SD.

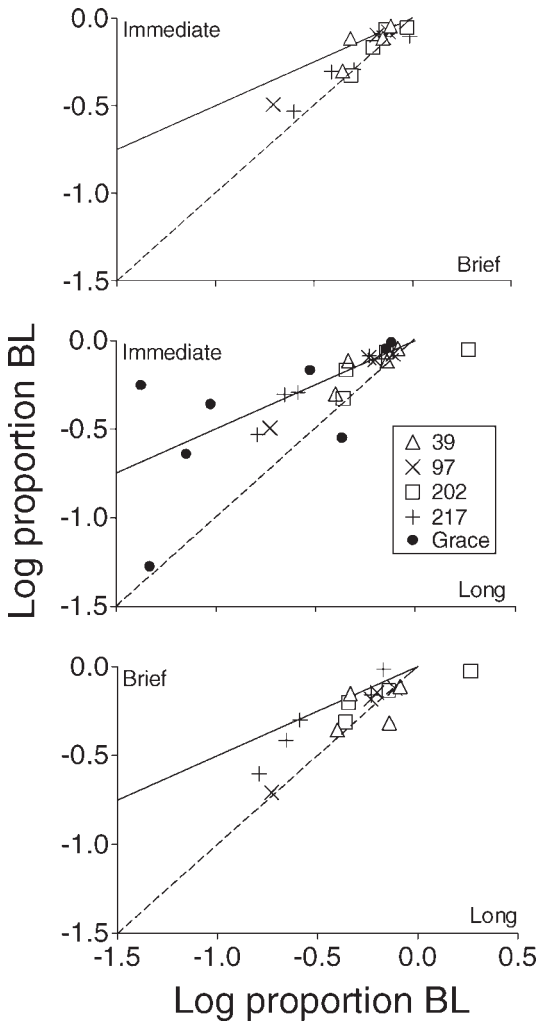


Fig. 2. Mean log proportion of baseline response rates in one component relative to mean log proportion of baseline response rates in another component. The component corresponding to the y -axis is located in the upper-left corner of each panel, and the component corresponding to the x -axis is located in the lower-right corner. The middle panel also shows data from Grace *et al.* (1998). Solid lines in each panel provide an idea of the magnitude of relative resistance to change across components of the present experiment by showing where data points would fall if the sensitivity of relative resistance to change to a reinforcement-rate ratio of 4:1 were a typical value of 0.5 (see text for more explanation). Note that the x -axis is longer than the y -axis.

were equally disrupted. Thus, data points falling above the diagonal line indicate that responding was more resistant to change in the component represented by the y -axis. The solid lines are included to provide a reference by which the magnitude of the differences in

resistance to change with different delays in the present experiment might be compared to results typical of responding maintained by different reinforcement rates. Nevin, McLean, and Grace (2001) suggested that sensitivity of relative resistance to change to relative baseline reinforcement rates can be estimated for a given pair of schedules provided that the disrupter is applied equally across components:

$$\log\left(\frac{Bx_1}{Bo_1}\right) = \left(\frac{R_2}{R_1}\right)^a \left[\log\left(\frac{Bx_2}{Bo_2}\right)\right] \quad (1)$$

where $\log(Bx_1/Bo_1)$ and $\log(Bx_2/Bo_2)$ are log proportions of baseline in two components, R_2 and R_1 are the baseline reinforcement rates in those components, and the parameter a represents sensitivity of relative resistance to change to relative reinforcement rates. The solid reference line was constructed by assuming a 4:1 difference in reinforcement rates across two components and sensitivity to relative reinforcement rates set at a typical value of 0.5 (see Nevin, 2002).

The top panel of Figure 2 compares mean log proportion of baseline response rates in the Immediate and Brief components. In 14 out of 17 instances, data points fall above the dashed diagonal line. Although these effects were quite small, resistance to change consistently was slightly greater in the Immediate component than in the Brief component. The middle panel shows the clearest result in that responding was more resistant to change in the Immediate component than in the Long component in 16 out of 17 instances. The exception was a large increase in response rates relative to baseline in the Long component for Pigeon 202 in extinction. By way of comparison, the filled circles represent mean log proportion of baseline response rates under pre-session feeding and extinction conditions across four pigeons from Grace *et al.* (1998). Scheduling reinforcers immediately and according to a 3-s delay in the present experiment produced differences in resistance to change similar to those obtained by Grace *et al.* with the same delay duration. In addition, many of the data points from the present experiment and from Grace *et al.* that compare resistance to change of responding maintained by immediate and 3-s delayed reinforcement fall near the solid line repre-

senting predicted values of resistance to change from Equation 1. This outcome suggests that the magnitude of effects were comparable to those found with a 4:1 difference in reinforcement rate across components and a sensitivity value in Equation 1 equal to 0.5. The bottom panel shows that, in 13 out of 17 instances, responding in the Brief component was somewhat more resistant to change than responding in the Long component. Again, these differences were small, but consistent. The clear exceptions located below the diagonal were for Pigeons 202 in extinction and for Pigeon 39 with ICI VT 5-s food. Overall, these results suggest that responding tended to be somewhat less resistant to change with longer delays. Additionally, there were no systematic differences in disruption produced by the different disrupters.

Baseline mean obtained delays for successive baseline conditions are presented in Table 1. Obtained delays were calculated as the time between the last response prior to reinforcement and presentation of the reinforcer. Mean obtained delays were zero in the Immediate component and increased across the Brief and Long components. Mean obtained delays were shorter than scheduled delays in the Brief and Long components (Brief: $M = 0.18$, $SD = 0.02$; Long: $M = 1.07$, $SD = 0.38$) but were ordinally related to scheduled delays. Because obtained delays and scheduled delays were ordinally related, resistance to change examined as a function of obtained delays, rather than component, produced results consistent with those in Figure 2 (data not shown).

Table 1 also presents mean reinforcement rates in the six sessions of baseline prior to disruption for all the pigeons across the three components. Obtained baseline reinforcement rates averaged across all pigeons slightly decreased as scheduled delays increased across the three components. The differences in obtained reinforcement rates across components, however, were smaller than those from Grace et al. (1998; see their Table 2) and this overall trend was not consistent across individual pigeons.

IRT Analyses

Although the above analyses allow an examination of the effects of reinforcement-delay contingencies and conditions of disruption

on overall response rates, they do not show how those variables affect underlying response structure. Shull et al. (2001) suggested that presenting a frequency distribution of IRTs in a log survivor plot allows responding to be assessed as a bimodal distribution of bout initiations and within-bout responding (i.e., "broken-stick" appearance). For the purpose of estimating bout-initiation rate, within-bout response rate, and responses per bout, a semi-logarithmic plot of the proportion of IRTs greater than t s often appears adequately described by the sum of two exponential functions (Shull, 2004; Shull, Grimes, & Bennett, 2004; but see Davison, 2004; Shull, 2004, for exceptions). In such analyses, the slope of the left limb has been used to estimate within-bout response rate. The slope of the right limb estimates bout-initiation rate. The point where the right limb intercepts the y-axis has been used to estimate the number of responses per bout.

Figure 3 shows log survivor plots from the present experiment pooling all IRTs within each component from the last six sessions of baseline prior to pre-session feeding. IRTs were recorded with a resolution of 0.01 s. IRTs ranging from 0 to 1 s were separated into 0.2-s bins, and IRTs greater than 1 s were separated into 1-s bins. Clearly, the log survivor plots from the present experiment do not conform to a clear bimodal distribution with simple exponential left and right limbs. Consistent with some previous findings (see Blough, 1963; Davison, 2004; Palya, 1992), there were few IRTs under 0.2 s in all cases, which precluded fitting the double-exponential function to the present data. Overall, the log survivor functions provide inconsistent evidence that responding occurred in two modes of bout initiations and within-bout responses. For instance, there is clear evidence of a left limb that "breaks" into a right limb for Pigeon 217 (all components), Pigeon 202 (Brief and Long components), and Pigeon 39 (Brief component). For Pigeon 97 (all components) and Pigeon 39 (Immediate component), all responding appears to follow a single exponential distribution, suggesting that responding may be composed of bout initiations alone. Even if responding was composed of two modes, the similarity in slope across the entire function precludes any definitive conclusions. Nevertheless, longer IRTs that make up the

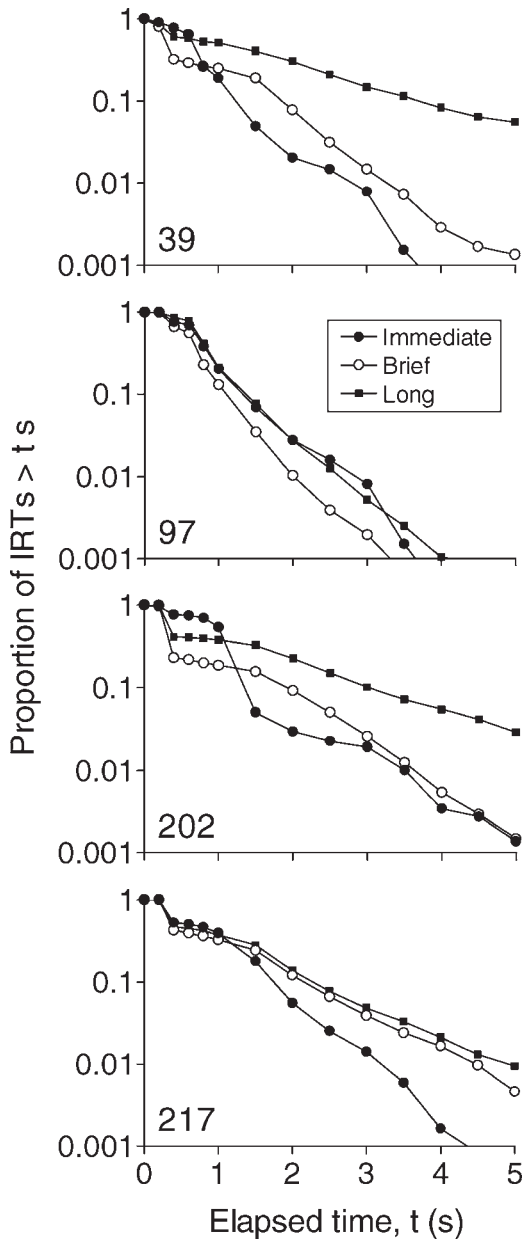


Fig. 3. Log survivor plots of IRTs pooled from the final 6 baseline sessions of each component prior to pre-session feeding. Immediate (filled circles), Brief (open circles), and Long (filled squares) component IRT proportions are plotted every 0.2 s from 0 to 1 s and every 1 s from 1 to 5 s for each pigeon.

right limbs were exponential in appearance (see also Shull, 2004; Shull *et al.*, 2004) and slopes tended to be less steep as scheduled delays increased. This suggests that bout-initiation rates were highest in the Immediate

component, followed by the Brief component, and then the Long component. The exception is Pigeon 97, in which the right limb for the Brief component was steepest, and there were no systematic differences between right limbs in the Immediate and Long components.

Although responding did not always fall within modes of bout initiations and within-bout responding, assessing the patterns of responding during baseline and disruption conditions still may provide insight into why resistance to change tended to decrease as delays increased. As an alternative to fitting double-exponential functions to the log survivor functions, an IRT-cutoff method (Mellgren & Elmsore, 1991) was used to estimate bout-initiation rates, within-bout response rates, and responses per bout (see Shull *et al.*, 2001, for a discussion). Because there was not always a clear bimodal pattern of responding, there is the risk that the IRT-cutoff method may incorrectly estimate bout-initiation rates or artificially create two response classes that do not differ meaningfully. Nevertheless, other investigators have shown that changes in overall response rates are due to changes in long rather than short IRTs (Blough, 1963; Schaub, 1967) and, therefore, the IRT-cutoff method may provide at least a general picture of how the present manipulations affected response patterns. Consistent with Shull *et al.* (2002), we selected 1 s as the cutoff criterion for all the pigeons. Thus, responses ending in IRTs greater than 1 s were classified as bout initiations, whereas responses ending in IRTs equal to or less than 1 s were classified as within-bout responses. Bout-initiation rates were calculated by dividing the number of responses that terminated an IRT greater than 1 s by the sum of the IRTs greater than 1 s (within-bout IRTs were removed from the bout-initiation time base). Within-bout response rates were calculated by dividing the number of responses that terminated an IRT less than or equal to 1 s by the sum of the IRTs less than 1 s. Responses per bout were calculated by dividing the number of within-bout IRTs (i.e., IRTs \leq 1 s) by the number of bout-initiation IRTs (i.e., IRTs $>$ 1 s). Repeating the analysis, using cutoff values of 0.5 and 1.5 s, yielded similar results.

Mean bout-initiation rates, within-bout rates, and responses per bout from the last six

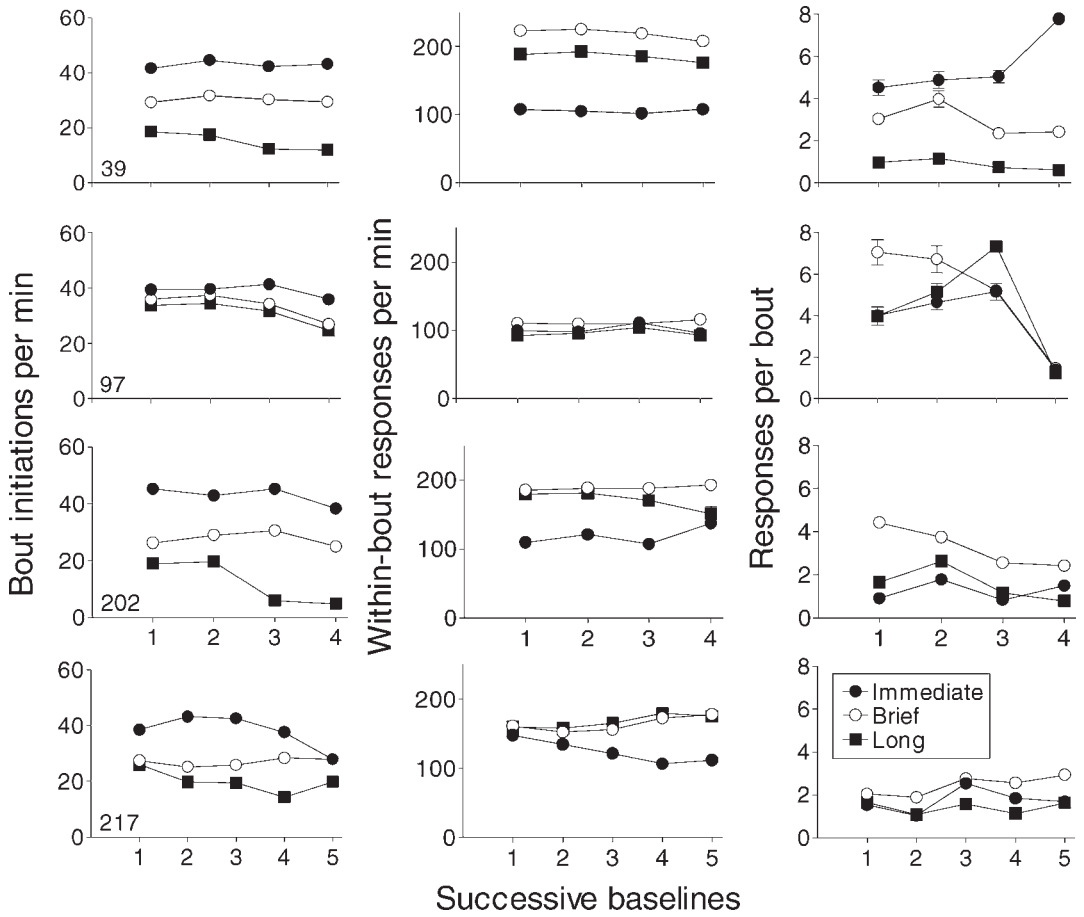


Fig. 4. Estimates of mean bout-initiations per min (left column), within-bout responses per min (middle column), and responses per bout (right column) across successive baseline conditions for the Immediate, Brief, and Long components. Means are calculated over the last six sessions of baseline prior to disruption. Error bars represent $\pm 1 SD$. Data appear as in Figure 1.

sessions of baseline and from all sessions of disruption are presented in the Appendix. The left column of Figure 4 shows bout-initiation rates across successive baselines prior to each condition of disruption. Bout-initiation rates were higher in the Immediate component, followed by the Brief component, and then the Long component in all cases except for the Immediate and Brief components in the final baseline condition for Pigeon 217. Thus, bout-initiation rates decreased as scheduled delays increased, consistent with the decreases in slopes of the right limbs in Figure 3. The middle column shows within-bout response rates across successive baselines. With the exception of Pigeon 97, within-bout response rates tended to be lowest in the Immediate

component with no clear systematic differences between Brief and Long components. The right column shows responses per bout across successive baselines. Responses per bout tended to be higher during conditions in which overall response rates were higher in the Brief component for Pigeons 202 and 217 and during the first two baselines for Pigeon 97. There were no systematic differences for the Immediate and Long components across pigeons.

Figure 5 shows resistance-to-change analyses of bout-initiation rate (left column), within-bout response rate (center column), and responses per bout (right column). As previously mentioned, zero-value data from VT-5 disruption for Pigeon 202 have been excluded

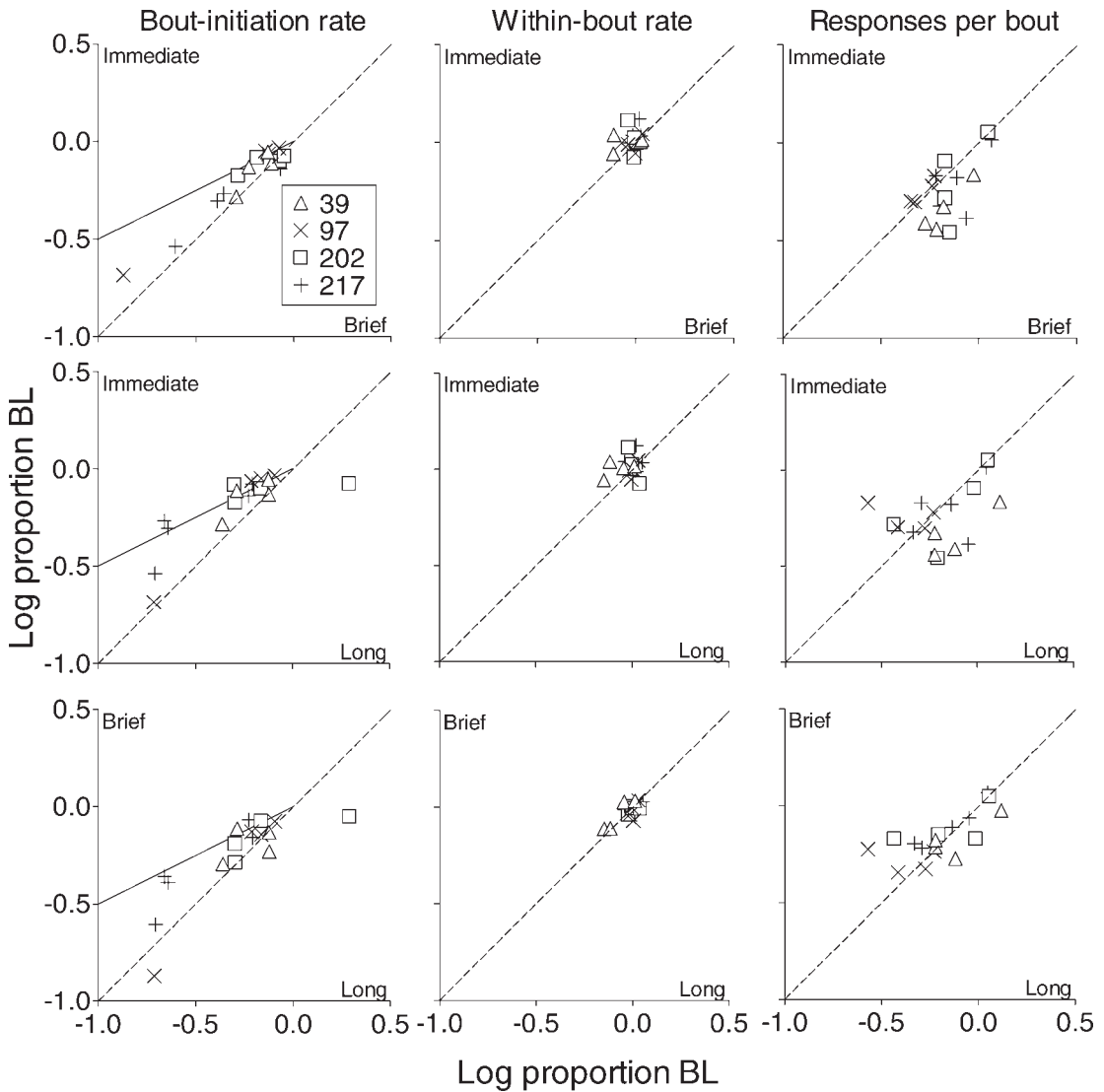


Fig. 5. Mean log proportion of baseline bout-initiation rates (left column), within-bout rates (middle column), and responses per bout (right column) in one component relative to bout-initiations per min, within-bout responses per min, and responses per bout in another component. Axes and data appear as in Figure 2.

and are included in the Appendix. The patterns of disruption of bout-initiation rates appear similar to those from overall response rates (see Figure 2) in that resistance to change appeared at least somewhat related to scheduled delay. Bout initiations tended to be more resistant to change in the Immediate component than in the Brief component (left—top panel; 14 out of 17 instances) as indicated by the data points tending to fall above the diagonal. In addition, bout initia-

tions tended to be more persistent in the Immediate component than in the Long component (left—middle panel; 15 out of 17 instances). Consistent with the results from overall response rates, in one instance corresponding to extinction, bout-initiation rates increased in the Long component for Pigeon 202. Finally, bout initiations in the Brief component tended to be more resistant to change than in the Long component (left—bottom panel; 13 out of 17 instances), again

with the exception of the increase in rates corresponding to extinction for Pigeon 202. Therefore, the overall pattern of disruption of bout initiation rates was almost identical to the results obtained with overall response rates (see Figure 2). As described above for Figure 2, the solid lines provide a comparison of the magnitude of relative disruption in the present experiment to hypothetical relations with a fourfold difference in reinforcement rate across components and sensitivity set at 0.5. The magnitude of the effect was very similar to that with overall response rates, supporting the claim that the disruption of overall response rates was similar to that of bout-initiation rates. The center column shows log proportion of baseline within-bout response rates across the components. All data points tend to fall at or about the origin, indicating that within-bout response rates generally did not decrease during disruption. Resistance to change of responses per bout (right column) was not systematically affected by disruption. Responses per bout in the Brief component tended to be more resistant to change than in the Immediate component (right—top panel); however, responses per bout tended to be equally disrupted in the other comparisons.

Figure 6 shows log proportion of baseline bout initiations (top panel), within-bout response rates (middle panel), and responses per bout (bottom panel) as a function of log proportion of baseline response rates. Disruption of bout-initiation rates was highly correlated with disruption of overall response rates, $F(1, 49) = 190.0, p < 0.0001$ (see figure for r^2 values), whereas disruption of within-bout rates was not significantly correlated, $F(1, 49) = 0.003, p = 0.86$. Because of the 1-s cutoff, within-bout response rate was constrained by definition to be at least 60 responses per min. Thus, the constancy in within-bout response rate is likely due in part to the use of the cutoff method. Yet given the fact that within-bout rates were reliably above 60 per min during disruption (see Appendix), it is unlikely that the constraints could account for all the constancy found here. Disruption of responses per bout was significantly correlated with disruption of overall response rates, $F(1, 49) = 8.64, p = 0.005$, although this correlation with disruption in overall response rates was much smaller than with bout-initiation

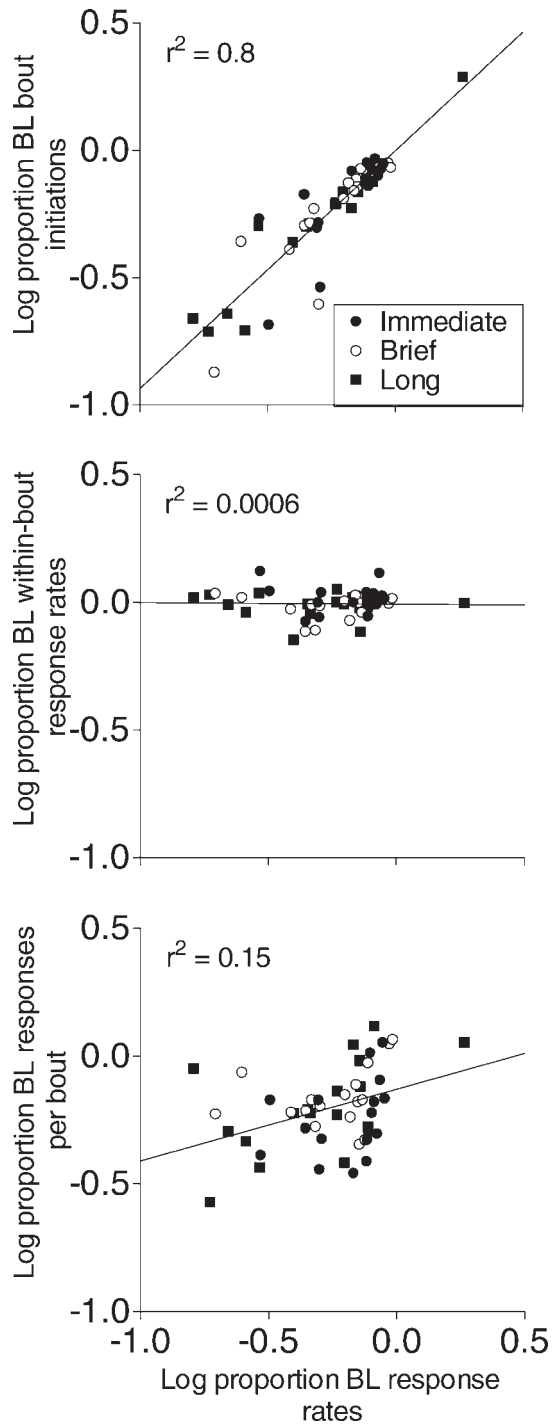


Fig. 6. Mean log proportion of baseline bout-initiation rates (top panel), within-bout rates (middle panel), and responses per bout (bottom panel) in each component plotted as a function of mean log proportion of baseline response rates in each component.

rates (see also Shull, 2004; Shull *et al.*, 2002). Thus, disruptions of overall response rates were strongly related to bout-initiation rate, weakly related to changes in responses per bout, and unrelated to changes in within-bout rates.

DISCUSSION

The results from the present experiment are consistent with other studies showing that unsignaled delays of reinforcement decrease resistance to change when similar rates of reinforcement are arranged (e.g., Bell, 1999; Grace *et al.*, 1998). In addition, the present experiment extended these results to include unsignaled delays of 0.5 and 3 s. Bell found that, although responding maintained by immediate reinforcement was consistently more persistent than responding maintained by 3- or 8-s delays between subjects, there were no differences in resistance to change when the delay components were compared. One possible explanation is that 3- and 8-s delays are both relatively long delays (see Richards, 1981; Sizemore & Lattal, 1978) and may therefore have produced asymptotic decreases in resistance to change. Regardless, the finding that resistance to change was at least somewhat differentially affected by differences in response-reinforcer contiguity in the present experiment is inconsistent with the predictions of behavioral momentum theory (cf. Nevin & Grace, 2000). Specifically, resistance to change should be determined by stimulus-reinforcer relations but unaffected by response-reinforcer relations (e.g., delayed reinforcement).

The response-bout analyses were conducted because unsignaled delays have been shown to alter the underlying response structure of steady-state responding (Arbuckle & Lattal, 1988; Shahan & Lattal, 2005). Therefore, it was hypothesized that the previously observed differences in resistance to change of responding maintained by immediate and delayed reinforcement (Bell, 1999; Grace *et al.*, 1998) may have been due to the differential effects of conditions of disruption on underlying response structure. Examining underlying response structure using log survivor plots and a double-exponential model (Shull & Grimes, 2003) failed because responding was not consistently composed of two separate modes

(see Figure 3). Even when responding did appear to occur in bouts (e.g., for Pigeon 217), the log survivor functions did not conform to simple double exponential functions that previously have been observed with rats lever pressing and nose poking for food (e.g., Shull & Grimes, 2003; Shull *et al.*, 2001, 2002; Shull *et al.*, 2004).

Two notable deviations in the present log survivor functions may be due to differences between rats and pigeons. First, very short IRTs within 0.2 s were observed for all pigeons in the present experiment. Such short IRTs previously have been observed in log survivor functions with pigeons responding for food (see Davison, 2004) and may be attributable to a response topography unique to birds pecking keys (see Killeen, Hall, Reilly, & Kettle, 2002; Palya, 1992, for discussions). The second notable difference was that the log survivor functions from the present experiment occasionally appeared to consist of a single exponential function (e.g., for Pigeon 97), which could occur if bouts generally consisted only of a single response. Alternatively, responding could have consisted of two separate processes, with bout initiations and within-bout responses being composed of similar distributions (i.e., similar slopes for the left and right limbs). If responding did consist of two processes, one possible reason that the patterns of responding were not consistently bimodal in the present experiment may have been due to relatively high response rates. A large majority of the log survivor functions fell within 5 to 7 s (see Figure 3; see also Davison, 2004), whereas functions from previous experiments with rats nose poking have ranged anywhere from 20 to 250 s (see Shull, 2004; Shull *et al.*, 2002). Any deviations from simple double-exponential functions that would appear minor under less constrained ranges could become magnified under the ranges found in the present experiment. Recently, Shull (2005) reanalyzed archival data plotting response rates from rats and pigeons over a range of reinforcement rates using Herrnstein's (1970) hyperbolic equation. He found that response rates in pigeons tended to be higher and of a much more limited range across reinforcement rates than in rats. One interpretation of these differences noted by Shull is that the rate of all undefined reinforcement (R_o) may be lower for pigeons than rats, which may account

for the different ranges of log survivor plots. If this is the case, then scheduling much lower reinforcement rates (e.g., 10 per hr) in experiments with pigeons may produce less constrained log survivor functions that are more similar to those previously found with rats.

Deviations from double-exponential functions may preclude clear interpretations of bout analyses at a fine-grain level of analysis and, therefore, the results from the IRT-cutoff method can only be offered as suggestive rather than definitive. The order derived from these analyses, however, may be useful in providing an approximation for understanding the general effects of different reinforcement contingencies on responding. For instance, across components of a multiple schedule, changes in reinforcement rates (Shull et al., 2002; Shull et al., 2004), reinforcement delay (the present experiment), and conditions of disruption (Shull, 2004; Shull et al., 2002; the present experiment) have been shown to affect overall response rates primarily by changes in bout-initiation rates. Also, both the present experiment and Shull and colleagues (e.g., Shull, 2004; Shull et al., 2002) have found that changes in overall response rates during conditions of disruption were inconsistently related to changes in within-bout responding (see also Blough, 1963; Schaub, 1967, for similar findings). The ability to detect such similar effects across the present and previous experiments provides support for the generality of these effects and for a two-mode process in the present data. However, additional replications using both pigeons and rats responding under immediate- and delayed-reinforcer contingencies and conditions of disruption are needed to definitively establish the generality of these effects.

The bout analyses used in the present experiment suggested orderly relations that were not apparent in overall response rates. For instance, there were no systematic differences in baseline response rates between the Immediate and Brief components; however, baseline bout-initiation rates were consistently lower in the Brief component. In addition, when responses per bout were higher in the Brief component, response rates tended to be higher in that component. This outcome is consistent with the notion that brief un-

signaled delays alter the functional unit of responding (see Arbuckle & Lattal, 1988). Further, the findings that a) baseline bout-initiation rates decreased as delays increased across components and b) resistance to change also tended to decrease as delays increased, suggest that unsignaled delays decrease response-unit strength relative to responding maintained by immediate reinforcement despite the fact that 0.5-s delays sometimes produced response-rate increases. Because baseline bout-initiation rates tend to be lower under similar conditions in which resistance to change is lower, bout-initiation rates, like resistance to change, might provide a baseline measure of response strength that does not suffer from the complexities of absolute response rates (cf. Nevin, 1974).

Although several hypotheses have been offered (see Doughty & Lattal, 2001; Grace et al., 1998), it remains unclear exactly how unsignaled delays decrease resistance to change. Unsignaled delays do not obviously degrade stimulus-reinforcer relations because reinforcers are consistently presented in the discriminative context, regardless of the delay duration. Grace et al. hypothesized that discriminated periods of nonreinforcement could produce conditioned-inhibitory control that degrades the component stimulus-reinforcer relation. With unsignaled delays, any response that occurs outside the delay interval will not be contiguous with reinforcement because the delay interval necessarily will follow. Thus, with the exception of time within the delay interval, all time spent in the discriminative context indicates that responding cannot be contiguous with reinforcement. Therefore, the discriminative context may acquire inhibitory control, as has been suggested with initial periods of fixed-interval (FI) schedules of reinforcement (cf. Carr & Reynolds, 1974; Palya, 1993). As with longer FI schedules, longer delays may produce greater inhibitory control. Additionally, the lower bout-initiation rates during baseline and disruption with increasing delays in the present experiment suggest that longer delays affect bout initiations more than within-bout responding. This is consistent with the suggestion by Shull et al. (2004) that ratio response requirements at the end of VI schedules (see Lattal, 1989) may function to decrease

bout-initiation rate and resistance to change by delaying reinforcer presentation from bout initiation. Therefore, examining how reinforcement contingencies affect the underlying structure of responding could provide an important step toward understanding how contingencies affect response-unit strength.

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APPENDIX

Response rates, and estimates of bout-initiation rates, within-bout rates, and responses per bout during baseline and disruption conditions are presented. Mean response rates are presented for the final six sessions of each baseline condition and SDs are below in italics. Conditions are presented in the order they occurred. Asterisks indicate data excluded from all analyses.

Subject	Cond	Response rate			Bout-initiation rate			Within-bout rate			Responses per bout		
		Immediate	Brief	Long	Immediate	Brief	Long	Immediate	Brief	Long	Immediate	Brief	Long
39	PF 30 g BL	84.55	86.29	35.43	41.67	29.31	18.69	107.88	223.36	188.55	4.53	3.03	0.97
		<i>5.69</i>	<i>2.33</i>	<i>3.86</i>	<i>1.38</i>	<i>0.91</i>	<i>1.81</i>	<i>3.88</i>	<i>12.15</i>	<i>11.61</i>	<i>0.90</i>	<i>0.25</i>	<i>0.13</i>
	30 g	51.45	78.09	24.31	33.09	27.07	15.39	96.90	214.33	160.46	1.09	2.82	0.52
	30 g	30.55	43.72	15.87	14.35	16.07	8.95	95.12	196.50	144.08	1.57	2.09	0.72
	30 g	37.49	29.48	11.15	17.86	12.78	6.72	91.43	164.25	126.69	1.75	1.41	0.47
	30 g	40.86	14.79	7.24	18.87	6.19	3.91	99.44	128.42	105.42	1.85	1.22	0.51
	30 g	55.76	54.34	17.77	30.09	20.94	9.87	89.26	171.14	140.52	2.12	2.17	0.72
	VT 15-s BL	86.27	101.97	35.67	44.66	31.74	17.47	105.39	225.83	193.05	4.88	3.98	1.14
		<i>3.52</i>	<i>10.43</i>	<i>9.38</i>	<i>1.33</i>	<i>2.22</i>	<i>3.03</i>	<i>1.50</i>	<i>11.95</i>	<i>17.46</i>	<i>0.95</i>	<i>0.95</i>	<i>0.36</i>
	VT 15 s	68.06	70.31	16.93	39.67	23.30	9.29	95.74	225.15	164.16	2.30	2.80	0.68
	VT 15 s	62.89	71.26	12.43	33.16	22.69	6.80	108.41	235.03	169.98	2.02	2.91	0.60
	VT 15 s	67.23	75.51	16.35	32.22	25.83	9.42	117.81	243.36	192.98	2.41	2.66	0.61
VT 15 s	67.91	78.00	16.94	33.90	27.29	9.46	112.56	236.74	187.99	2.40	2.64	0.67	
VT 15 s	64.99	65.49	20.72	34.10	23.50	10.62	101.02	261.89	157.46	2.39	2.25	0.89	
EXT BL	83.61	78.14	22.24	42.44	30.32	12.37	101.87	219.51	185.84	5.05	2.35	0.72	
	<i>2.38</i>	<i>7.68</i>	<i>4.20</i>	<i>1.93</i>	<i>1.88</i>	<i>1.45</i>	<i>1.99</i>	<i>19.86</i>	<i>19.78</i>	<i>0.71</i>	<i>0.34</i>	<i>0.27</i>	
EXT	88.08	80.92	32.92	43.06	30.11	16.04	104.58	282.34	227.23	6.11	2.31	1.15	
EXT	80.00	79.67	20.00	41.44	29.57	9.71	109.29	271.98	204.07	3.27	2.34	1.05	
EXT	78.17	78.67	19.50	41.89	27.37	10.61	107.41	276.14	199.20	2.99	2.56	0.82	
EXT	66.58	43.08	11.08	33.69	15.85	5.90	105.22	199.01	189.30	2.51	2.10	0.81	
EXT	65.50	36.92	14.00	29.76	14.52	7.16	100.20	174.75	142.24	3.28	1.85	0.94	
VT 5-s BL	93.35	76.58	20.42	43.30	29.46	12.09	108.11	207.70	176.09	7.78	2.43	0.60	
	<i>1.10</i>	<i>5.94</i>	<i>5.97</i>	<i>1.60</i>	<i>1.96</i>	<i>3.40</i>	<i>1.20</i>	<i>11.56</i>	<i>10.55</i>	<i>0.52</i>	<i>0.43</i>	<i>0.14</i>	
VT 5 s	71.52	55.29	15.30	23.35	18.53	7.94	135.05	189.54	114.55	4.22	2.63	0.81	
VT 5 s	87.41	54.89	24.57	40.10	24.90	15.75	117.09	151.71	120.13	4.42	1.75	0.55	
VT 5 s	75.94	33.86	17.16	36.20	18.50	11.52	114.67	132.28	102.06	3.08	0.97	0.40	
VT 5 s	67.35	23.66	10.28	34.52	12.18	6.64	112.44	163.54	144.79	2.25	0.92	0.32	
VT 5 s	57.62	28.45	10.52	28.59	15.17	6.57	113.96	176.72	218.79	1.95	0.88	0.34	

APPENDIX
(Continued)

Subject	Cond	Response rate			Bout-initiation rate			Within-bout rate			Responses per bout		
		Immediate	Brief	Long	Immediate	Brief	Long	Immediate	Brief	Long	Immediate	Brief	Long
97	PF 30 g BL	77.02	89.22	70.09	39.38	35.93	33.75	99.38	110.33	92.82	4.01	7.04	3.98
		2.90	5.19	5.15	0.81	1.29	0.93	2.42	2.72	4.00	0.63	1.49	1.08
		64.19	63.70	52.20	38.51	26.14	27.87	87.98	101.43	88.09	2.27	3.49	1.88
		57.90	62.65	49.54	36.20	27.32	26.47	90.79	113.35	89.15	1.53	2.65	1.73
		58.45	62.83	39.00	34.11	23.93	22.70	87.22	112.88	89.14	2.00	3.36	1.10
		56.55	61.55	43.19	31.71	25.12	25.12	82.99	107.47	88.30	2.27	3.08	1.25
		61.97	68.25	37.56	36.22	26.68	15.99	89.64	116.80	102.82	2.13	3.43	1.88
		78.21	89.08	75.51	39.66	37.45	34.41	97.74	109.55	95.31	4.63	6.71	5.14
		2.56	5.31	3.77	1.22	1.36	0.36	3.09	3.54	1.91	0.87	1.59	1.02
		68.08	78.00	58.01	37.39	34.76	28.30	92.53	105.36	90.26	2.88	4.29	2.61
	VT 15 s	63.68	71.23	61.44	36.27	31.65	30.89	91.32	103.29	88.41	2.32	3.62	2.86
	VT 15 s	65.00	75.17	60.82	36.46	33.94	27.57	97.40	100.35	90.96	2.20	4.27	3.23
	VT 15 s	62.92	55.60	49.02	36.58	27.88	24.59	97.44	94.80	91.87	1.91	2.13	1.91
	VT 15 s	67.91	59.15	63.27	37.16	29.71	27.90	101.30	98.00	96.86	2.35	2.26	3.28
	EXT BL	87.76	82.67	83.43	41.35	34.21	31.78	111.07	109.95	104.08	5.15	5.20	7.33
		5.67	2.68	2.68	2.19	1.32	0.90	2.56	5.85	4.04	1.01	0.58	0.70
	EXT	81.08	68.00	66.58	38.00	26.92	29.48	107.28	116.36	102.31	4.37	3.52	3.43
	EXT	62.83	38.33	37.25	25.34	13.80	15.69	123.51	123.74	114.27	2.88	2.45	1.92
	EXT	32.25	13.50	12.75	6.60	3.96	5.30	135.70	122.72	103.23	4.89	2.48	1.51
	EXT	15.25	6.50	6.50	3.79	1.47	2.33	113.77	121.68	105.68	3.24	3.24	1.63
	EXT	7.08	4.92	4.42	1.90	0.95	1.53	137.59	111.34	134.60	2.55	4.09	1.83
	VT 5-s BL	57.33	51.14	43.06	35.94	26.98	24.60	95.29	115.83	93.12	1.40	1.46	1.23
		4.38	9.92	6.03	1.67	3.17	2.83	5.71	5.83	6.06	0.35	0.48	0.26
	VT 5 s	62.31	60.34	55.11	35.20	27.78	27.78	94.93	108.33	99.92	2.09	2.42	1.98
	VT 5 s	44.66	33.01	24.39	30.68	19.25	16.33	91.35	99.28	93.09	0.81	0.89	0.51
	VT 5 s	53.44	39.20	25.24	35.33	23.87	15.00	93.10	99.52	83.98	1.11	0.91	0.77
	VT 5 s	38.74	26.01	18.60	29.37	17.08	12.08	91.11	87.86	83.33	0.48	0.60	0.48
	VT 5 s	35.56	21.37	15.86	26.15	15.09	9.57	104.06	97.51	109.93	0.48	0.37	0.54

APPENDIX
(Continued)

Subject	Cond	Response rate			Bout-initiation rate			Within-bout rate			Responses per bout		
		Immediate	Brief	Long	Immediate	Brief	Long	Immediate	Brief	Long	Immediate	Brief	Long
202	PF 30 g BL	63.13 3.25	88.89 4.90	44.31 5.62	45.34 1.90	26.22 1.34	18.96 2.60	109.58 7.56	185.46 8.08	179.52 6.09	0.90 0.34	4.41 0.53	1.65 0.29
	30 g	55.53	82.05	35.28	40.56	24.34	16.44	148.58	179.30	172.75	0.54	4.16	1.29
	30 g	60.26	63.52	41.40	34.98	20.47	15.26	146.44	170.87	169.50	1.17	3.14	2.07
	30 g	57.56	64.66	26.34	34.51	20.83	10.30	141.48	168.51	170.64	1.06	3.21	1.64
	30 g	51.68	72.53	30.49	39.38	27.08	14.09	130.86	168.10	173.51	0.47	2.80	1.25
	30 g	46.86	48.62	27.91	31.65	19.22	10.20	146.90	160.95	165.01	0.65	2.00	1.84
	VT 15-s BL	73.84	88.84	56.98	42.95	28.96	19.67	121.22	188.25	181.03	1.76	3.74	2.63
		4.18	5.49	6.53	2.90	1.47	2.77	4.36	4.70	4.33	0.24	0.37	0.50
	VT 15 s	66.82	67.99	32.31	42.26	21.97	12.15	126.16	191.30	178.15	1.16	3.07	1.83
	VT 15 s	49.40	63.93	35.24	34.34	21.18	11.71	119.32	193.65	173.21	0.69	2.85	2.29
	VT 15 s	50.72	51.15	22.41	37.34	16.66	8.59	120.44	183.09	184.16	0.56	2.67	1.54
	VT 15 s	46.84	48.31	31.33	32.50	17.27	12.89	127.65	189.98	177.29	0.64	2.23	1.55
	VT 15 s	40.29	50.68	13.91	32.76	16.95	5.94	113.31	196.05	180.00	0.31	2.51	1.16
	EXT BL	62.37	78.60	13.88	45.35	30.62	6.03	107.09	187.67	170.41	0.83	2.55	1.15
		1.78	6.28	1.08	1.12	1.61	0.96	8.34	10.33	17.17	0.10	0.30	0.27
	EXT	74.25	86.08	20.58	42.35	32.17	9.19	110.85	189.20	191.61	2.15	2.99	1.26
	EXT	62.33	87.92	37.83	42.43	32.14	15.40	112.12	186.99	162.95	0.98	3.19	1.80
	EXT	52.08	74.33	25.75	42.42	30.35	13.00	104.03	182.60	165.86	1.01	2.71	1.16
	EXT	52.08	74.33	25.75	38.78	26.57	13.60	115.82	182.15	151.13	0.57	2.95	0.98
	EXT	40.25	52.25	21.08	27.58	18.31	8.84	125.46	188.13	179.44	0.63	2.48	1.45
	VT 5-s BL	67.44	66.69	9.70	38.32	25.04	4.85	137.11	192.66	151.14	1.47	2.41	0.79
		6.13	5.57	4.46	3.04	1.52	3.14	12.04	7.50	27.75	0.44	0.33	0.39
	VT 5 s	28.62	38.46	2.76	15.90	14.02	1.60	118.79	209.57	182.74	0.96	1.96	0.32
	VT 5 s*	0.00	0.00	0.00	0.00	0.00	0.00	200.00	206.90	200.00	0.00	0.00	0.00
	VT 5 s*	24.55	27.18	0.84	14.74	10.17	0.17	155.70	175.55	0.00	0.72	1.76	0.00
	VT 5 s	36.60	42.12	5.45	44.03	16.62	2.92	118.96	183.03	152.73	1.65	1.81	0.41
	VT 5 s	30.52	21.20	5.10	24.33	9.38	3.16	108.76	175.53	159.70	0.29	1.22	0.19

APPENDIX
(Continued)

Subject	Cond	Response rate			Bout-initiation rate			Within-bout rate			Responses per bout		
		Immediate	Brief	Long	Immediate	Brief	Long	Immediate	Brief	Long	Immediate	Brief	Long
217	PF 30 g BL	70.60	63.74	56.07	38.48	27.36	25.96	147.45	161.12	159.66	1.54	2.05	1.66
		<i>2.69</i>	<i>3.83</i>	<i>2.12</i>	<i>1.03</i>	<i>1.21</i>	<i>1.34</i>	<i>6.41</i>	<i>4.00</i>	<i>8.37</i>	<i>0.18</i>	<i>0.20</i>	<i>0.08</i>
	30 g	57.35	48.19	33.92	33.77	20.48	18.23	129.46	149.40	139.23	1.18	1.83	1.01
	30 g	26.03	15.56	5.93	14.35	7.62	2.86	146.72	142.81	161.90	0.90	0.91	0.52
	30 g	45.95	30.09	19.36	24.29	13.41	9.09	148.67	161.23	162.52	1.22	1.34	1.08
	30 g	41.06	19.35	11.58	22.66	9.77	6.13	149.08	148.09	155.52	1.05	0.94	0.71
	30 g	18.31	20.83	6.38	9.60	8.40	2.51	163.27	156.53	162.30	0.91	1.43	1.07
	VT 15-s BL	66.55	56.85	38.12	43.10	25.08	19.72	134.18	152.29	157.80	1.03	1.89	1.10
		<i>3.86</i>	<i>6.13</i>	<i>3.61</i>	<i>1.64</i>	<i>0.92</i>	<i>1.63</i>	<i>5.21</i>	<i>8.60</i>	<i>2.12</i>	<i>0.18</i>	<i>0.41</i>	<i>0.20</i>
	VT 15 s	51.92	49.94	25.42	33.30	21.08	12.83	119.09	152.29	166.57	0.92	1.86	1.04
	VT 15 s	58.79	53.23	23.42	34.65	21.63	12.21	117.63	152.34	147.09	1.31	2.07	0.94
	VT 15 s	45.17	60.09	29.66	28.14	22.15	12.21	139.08	171.22	181.85	0.83	2.46	1.51
	VT 15 s	49.91	59.48	25.28	29.39	22.39	10.08	144.10	164.20	174.46	1.00	2.41	1.54
	VT 15 s	57.41	52.54	25.01	31.57	20.34	11.46	133.45	150.43	157.00	1.36	2.25	1.20
	EXT BL	80.07	68.38	43.95	42.46	25.81	19.40	121.06	155.63	164.89	2.53	2.77	1.58
		<i>4.62</i>	<i>3.89</i>	<i>5.73</i>	<i>1.88</i>	<i>0.71</i>	<i>1.84</i>	<i>4.36</i>	<i>5.40</i>	<i>9.11</i>	<i>0.47</i>	<i>0.30</i>	<i>0.26</i>
	EXT	82.25	61.42	33.08	46.69	23.57	16.99	120.23	166.73	164.01	2.28	2.45	1.10
	EXT	50.50	54.75	29.17	27.47	19.03	15.41	116.46	162.17	154.99	1.40	2.73	1.01
	EXT	18.25	16.67	9.33	10.13	6.41	5.15	143.33	154.12	118.42	0.81	1.63	0.70
	EXT	6.17	2.83	0.42	2.80	1.01	0.25	146.45	117.81	176.47	1.00	1.17	0.33
	EXT	15.33	9.08	4.83	7.74	3.70	2.36	137.26	156.47	144.81	0.99	1.35	0.82
	VT 5-s BL	65.18	72.89	29.88	37.60	28.33	14.38	106.38	172.61	179.33	1.85	2.57	1.13
		<i>4.18</i>	<i>4.80</i>	<i>2.27</i>	<i>3.28</i>	<i>1.85</i>	<i>0.98</i>	<i>8.82</i>	<i>7.14</i>	<i>5.55</i>	<i>0.53</i>	<i>0.19</i>	<i>0.07</i>
	VT 5 s	40.17	38.53	10.74	28.01	12.50	3.77	101.95	179.58	197.29	0.64	2.43	1.47
	VT 5 s	32.47	33.32	7.32	21.03	11.28	3.28	146.17	186.90	185.07	0.64	2.17	0.82
	VT 5 s	35.90	46.59	12.19	19.84	14.59	4.59	164.41	180.55	182.57	0.96	2.73	1.42
	VT 5 s	24.69	31.03	5.79	13.94	10.21	2.41	162.80	179.75	195.18	0.82	2.24	0.96
	VT 5 s	34.90	35.43	4.94	21.25	14.10	2.23	140.21	175.43	178.32	0.78	1.69	0.65
	VT 15-s BL	69.58	76.86	45.90	41.62	27.86	19.85	111.51	177.63	175.19	1.69	2.94	1.64
		<i>3.20</i>	<i>6.12</i>	<i>4.52</i>	<i>2.20</i>	<i>1.96</i>	<i>1.64</i>	<i>6.05</i>	<i>2.62</i>	<i>3.64</i>	<i>0.24</i>	<i>0.32</i>	<i>0.18</i>
	VT 15 s	52.22	50.66	23.27	30.11	17.90	9.52	125.02	189.26	193.84	1.19	2.34	1.42
	VT 15 s	54.57	49.92	28.55	36.52	19.09	13.45	97.28	182.97	194.32	1.04	2.05	1.16
	VT 15 s	55.52	58.89	34.19	36.27	21.58	15.05	108.76	189.78	194.30	1.01	2.36	1.40
	VT 15 s	63.56	51.09	25.25	37.07	17.10	11.54	136.41	197.51	200.88	1.27	2.50	1.20
	VT 15 s	59.04	56.42	24.69	34.63	21.41	12.84	141.97	188.19	204.36	1.14	2.19	0.88