JOURNAL OF APPLIED BEHAVIOR ANALYSIS 2009, **42,** 295–307 NUMBER 2 (SUMMER 2009)

EFFECTS OF RESPONSE SPACING ON ACQUISITION AND RETENTION OF CONDITIONAL DISCRIMINATIONS

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Pigeons were exposed to a repeated acquisition procedure in which no delays were imposed and rate of responding was relatively high. They also were exposed to conditions in which delays were arranged between trials within chains or between completed chains, and rates of responding were lower. Number of trials, rate of reinforcement, difficulty of the discrimination, and motivating operations were held constant. Terminal accuracy was highest under the no-delay condition, in which rate of responding was highest. Effects of trial spacing on retention were mixed and depended on whether delays were imposed between trials within chains or between completed chains. These findings provide basic-research support for the rapid presentation of trials in direct instruction and for rate building in precision teaching.

DESCRIPTORS: conditional discrimination, fluency, rate building, repeated acquisition of response chains

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Behavior analysts have made many significant contributions to education (e.g., Neef et al., 2004). One instructional method commonly used by behavior analysts and a cornerstone of precision teaching is rate building (Binder, 1996; Péladeau, Forget, & Gagné, 2003). This procedure involves establishing fast, accurate, and repeated performance of learned skills, usually to a defined criterion (Doughty, Chase, & O'Shields, 2004). Criterion-level performance is referred to as *fluency*, which is defined by Binder as "the fluid combination of accuracy plus speed that characterizes competent performance" (p. 164). Training to fluency is claimed to enhance the retention and endurance of discriminated operants (Haughton, 1972), and a sizable applied literature supports the benefits of establishing performance that is both fast and accurate.

Doughty et al. (2004) recently reviewed this literature. They concluded that although the applied benefits of rate-building procedures are well established, it is very difficult to ascertain the effects of establishing a high rate of responding relative to a lower rate, because rate of responding typically is confounded with rate of reinforcement, number of learning opportunities (i.e., training trials), or both. Research not directly concerned with fluency suggests that both of these variables may influence results. For example, although the separate effects of reinforcement rate and number of learning opportunities were not determined, a meta-analysis of the effects of overlearning (Driskell, Willis, & Cooper, 1992), which involves further study past one perfect (error-free) trial (Rohrer, Taylor, Pashler, Wixted, & Cepeda, 2005), reported a moderate effect size (Cohen's D of 0.753) for continued practice on retention measures.

Also, several studies have shown that rate of reinforcement is directly related to the momentum (resistance to disruption) or endurance of stimulus-controlled operant responding (e.g., Nevin, 1992). This effect is evident in a study by Dube and McIlvane (2002), who trained people with developmental disabilities to make two-choice simultaneous discriminations under fixed-ratio (FR) 1 (each correct response was reinforced) or one of two variable-ratio (VR) reinforcement schedules, VR 2 or VR 4 (on average, every second or every fourth response was reinforced, respectively). After responding was stable, the discriminations were reversed.

The reported data were collected as part of the doctoral dissertation of Matthew Porritt. We thank Claus Globig for his help with data collection.

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doi: 10.1901/jaba.2009.42-295

Most participants made more errors following reversal in the FR 1 component than in the VR 2 or VR 4 component, suggesting that performance was more resistant to change when reinforcement rate was higher. Given that reinforcement rate and number of trials can influence performance on conditional discrimination tasks, it is worthwhile to examine the effects of rate building while these variables are held constant, and 3 of the 48 articles examined by Doughty et al. (2004) did so.

Evans, Mercer, and Evans (1983) had different groups of people practice a nonsense syllable (consonant-vowel-consonant) recognition task to a criterion of 40, 60, or 80 responses per minute. After the rate criterion was reached, the 40 and 60 responses per minute groups were allowed to practice slowly until they reached the same number of trials as the 80 responses per minute group. Experimenters delivered praise after each 1-min timing, so putative reinforcement rate was equivalent across groups. Evans and Evans (1985) replicated this experiment with 60, 90, and 120 responses per minute groups. In the experiment by Evans et al., the 80 responses per minute group did the best on posttests, and the 60 responses per minute group did the worst. In the replication, the 90 responses per minute group demonstrated the highest accuracy on posttests, and the 120 responses per minute group did the worst. Neither study examined retention or endurance, purported characteristics of fluent performance.

Shirley and Pennypacker (1994) trained 2 people on two spelling lists. The first list was trained to a rate and accuracy criterion, and the second was trained to an accuracy-only criterion. The number of trial presentations was equivalent for each list. The researchers found a small difference in retention in favor of the rate-trained list, but only for 1 of the 2 participants.

The inconsistent results from the three studies that manipulated response rate while controlling for reinforcement rate and number of trials (Evans & Evans, 1985; Evans et al., 1983; Shirley & Pennypacker, 1994) raise questions about the value of establishing high-rate responding per se. Therefore, examination of whether variables that influence response rate also influence accuracy of the acquisition of conditional discriminations when establishing operation (EO) level, number of trials, reinforcement rate, and difficulty of discriminations are controlled is of applied significance. Repeated acquisition of behavior chains is a task that can be used to maximize experimental control while the effects of response rate are examined. However, the experimenter does not control a subject's response rate under the repeated acquisition procedure unless delays are programmed between trials within a chain or between chains. However, the procedure can be modified readily such that a range of different response rates are engendered under conditions that hold constant reinforcement rate, number of trials, difficulty of the conditional discriminations to be mastered, and level of relevant motivating operations (Laraway, Snycerski, Michael, & Poling, 2003). As noted previously, reinforcement rate and number of trials may affect accuracy regardless of response rate. Difficulty of the discrimination may do likewise, and this variable is difficult to hold constant in applied settings in which the discriminations that are arranged are based on educational (and other) needs of participants.

Precision teachers, who consistently emphasize the importance of establishing fluent responding, characteristically engage in activities intended to serve as EOs (Laraway et al., 2003) for the consequences of their students' correct responding (Binder, 1996; Doughty et al., 2004). Although relevant data are lacking, it may be the case that EO levels differ under conditions in which high and low rates of responding are generated. If so, this variable, like number of training trials and reinforcement rate, could confound the results of applied studies that examine the effects of rate building.

By allowing response rate to be manipulated while controlling for the effects of a number of extraneous variables, the repeated acquisition procedure is useful for examining how variables that affect response rate influence accuracy. Unfortunately, examination of how rate and accuracy covary under a repeated acquisition procedure requires many exposures to relatively long experimental sessions during which a consistently effective positive reinforcer is available under tightly controlled conditions. Although the repeated acquisition procedure can be used with humans (e.g., Kamien, Bickel, Higgins, & Hughes, 1994; Rush, Frey, & Griffiths, 1999), practical (and in some cases ethical) considerations make such research difficult or impossible. In the present study, we first ascertained pigeons' rates of responding under a repeated acquisition procedure when accuracy was high and no delays were imposed. Then we lowered rates by imposing delays either between trials within a chain or between chains to determine whether these manipulations affected acquisition and retention of the conditional discrimination. In this way, we examined whether accuracy was higher under conditions that generated a higher rate of responding without altering the rate of reinforcement or number of trials arranged. We held motivation for the reinforcer relatively constant across conditions by keeping food deprivation, the primary EO for the scheduled reinforcer, at a level that reduced body weights to 85% of free-feeding levels. Because it would have been difficult, if not impossible, to conduct this experiment with humans, we studied pigeons, which respond well under repeated acquisition (e.g., Picker & Poling, 1984) and have long been favored subjects in the experimental analysis of behavior (Ator, 1991).

METHOD

Subjects

Six female White Carneau pigeons (*Columba livia*), maintained at 80% ($\pm$15 g) of free-feeding body weights, served as subjects. The birds were obtained from Palmetto Pigeon Plant and were retired breeders approximately 5 years of age. They were housed in home cages located in an animal colony with a 12-hr light/12-hr dark cycle. Grit and water were freely available in the home cages. Our institutional animal care and use committee approved animal care methods and experimental procedures.

Apparatus

Experimental sessions were conducted in four MED Associates operant test chambers (30 cm high, 25 cm wide, and 30 cm long). Each chamber was outfitted with three pecking keys located 21 cm from the floor. The keys were separated by 6 cm; were about 2 cm in diameter; and could be lit from the back with green, red, or white light. Located below the pecking keys was an opening (7 cm by 7 cm) that allowed access to mixed grain when the food hopper was raised. When the hopper was raised, the opening was illuminated. A 7-W bulb (houselight) located in the ceiling provided ambient interior illumination during sessions. The chambers were located in sound-attenuating boxes, and a fan provided ventilation and masking noise during sessions. An IBM-compatible computer using MED-PC software controlled experimental events and collected data.

Procedure

Using procedures similar to those described by Picker and Poling (1984), each pigeon initially was trained to peck each of the response keys when lighted in green, red, or white. Following initial training, they were exposed to a repeated acquisition (of behavior chains) procedure similar to that described by Thompson (1973). This procedure required the subject to learn a spatially defined sequence of responses that was varied to provide a repeatable within-subject measure of learning.

When first exposed to the repeated acquisition procedure, the pigeons were required to complete a three-link chain schedule to receive food. During the first link of the chain, all three pecking keys (left, center, right) were lit red, and one key (e.g., the left) was designated as correct. A response on the correct key immediately turned off the keylights and advanced the schedule to the next link, during which the keys were lit green and the position of the correct key changed (e.g., to the right). A response on the correct key again turned off the keylights and advanced the chain schedule to the third and final link, in which the keys were lit white and one key (e.g., the center) was designated as correct.

During training, a response on the correct key in the third link of the chain darkened the keys and raised the food hopper for 3.5 s, after which the first link was presented again. Incorrect responses in each link were followed by a 1-s time-out, during which the keys and the houselight were turned off; after this, the link was re-presented. The position of the correct key during each link of the chain stayed the same during the course of a session. Positions of correct keys were determined at random each session, except that no position was designated as correct for two consecutive links, and no position–color combination was repeated across consecutive sessions. Throughout the study, sessions were conducted 7 days per week at about the same time each day, during the light part of the cycle. Sixty training sessions were conducted; each lasted for 60 min.

Following training, three position sequences that generated consistent performance during training were selected for use as training sequences in the experiment proper. These sequences were right (R), center (C), left (L), LRC, and CLR. A distracter sequence based on each of these sequences also was generated. Previous experiments in our laboratory suggested that subjects sometimes discriminated subsequent responses based on the location of the first correct response. To prevent this, we trained RLR, LCL, and CRC as distracter sequences. The location of the first correct response, but not of correct subsequent responses, was the same in these distracter sequences as in the sequences of primary interest. For all birds, the order of colors during distracter and training sequences was the same throughout the experiment.

In each session, three components were arranged in sequence. The first and second components consisted of 15 and 75 chain completions, respectively. The first component was a measure of retention, in that the pigeons were required to complete 15 chains in which the sequence of correct responses (e.g., LCR) was the same as in the final training component of the previous session. The middle component trained them with a distracter sequence. The final component trained the pigeons with one of the three response sequences each session.

Three experimental conditions, involving (a) no delays, (b) within-chains delays, and (c) between-chains delays, were of interest. During the no-delay condition, the chain schedule was arranged as in training, except that food was available under a variable-interval (VI) 50-s schedule. Under this schedule, the third (and final) response in the chain could be reinforced with food delivery on average once every 50 s, with specific intervals between food availabilities arranged arithmetically around this mean. The third daily component under the no-delay condition ended when a pigeon completed four consecutive bins of five chains, with each bin completed in less than 45 s. This rate criterion was determined by examining performance in training sessions that produced fast and accurate responding.

During the within-chains delay condition, a 5-s interval was imposed between each correct response and presentation of the next link in the chain. The keylights were darkened as usual during this interval, but the house light stayed lit. Except for this difference, conditions were equivalent in the no-delay and within-chains delay conditions. The third component under the within-chains delay condition ended when the bird completed the same number of responses as it emitted in a prior and corresponding rate-building session (the term *rate building* designates experimental conditions in which no delays were arranged). Thus, a within-subject yoking procedure was used to ensure that number of responses, and hence number of trials, were equal under the two arrangements. The use of a VI 50-s schedule to arrange food deliveries ensured approximately equal rates of reinforcement under all training procedures.

During the between-chains delay condition, a 15-s interval was imposed between completion of the third link of a chain and subsequent exposure to the first link of that chain. The keylights were darkened as usual during this interval, and the houselight remained lit. Under this procedure, completion of the first and second link led immediately to presentation of the subsequent links. As with the within-chains delay condition, a yoking procedure was used to ensure that number of trials in a particular session were equal to those in a comparable rate-building session.

Experimental conditions alternated in the order shown in Figure 1. Each condition was in effect for three consecutive sessions. For each bird, each of the three position sequences was arranged for one of these sessions. Four birds were exposed to all conditions of interest; 2 others were exposed only to the no-delay and between-chains delay conditions.

Response Measure

For each session, total responses, total correct responses, session time in seconds, latency to respond, and reinforcers delivered were recorded for each chain completed by each pigeon. These data were used to calculate percentage of correct responses (correct responses divided by total responses), latency to respond (time from illumination of the keys to the emission of a response), responses per second (response rate, total responses emitted in a component divided by total seconds in that component), and reinforcers delivered per hour (reinforcement rate).

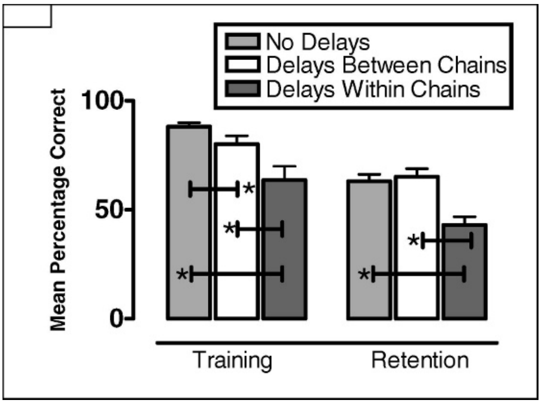

Figure 1. Mean percentage of correct responses during the last five chains of the training components (left) and the first five chains of the retention (right) components under each of the three experimental conditions. Asterisks indicate statistically significant ($p < .05$) differences between the indicated group means.

RESULTS

Figure 1 shows mean percentage of correct responses (±95% confidence intervals) for all birds combined during the last five chains of the training component and during the first five chains of the retention component, respectively. The former measure depicts how well the conditional discrimination was acquired, and the latter shows how well it was retained 23.5 hr after training. In Figure 1, data for all exposures to a given condition are combined.

Mean accuracy during the training component was substantially higher during the no-delay condition (88.2%) than during the within-chains delay condition (63.6%). Mean accuracy during the no-delay condition also was higher than accuracy during the between-chains delay condition (79.7%), although mean accuracy during the between-chains delay condition was higher than mean accuracy during the within-chains delay condition. Mean retention accuracy was similar under the no-delay

(63.1%) and between-chains delay conditions (65.5%) and was substantially lower under the within-chains delay condition (43.1%).

Group training data were analyzed by means of three-factor repeated measures analysis of variance, with condition (no delay, between-chains delay, within-chains delay), position sequence, and subjects as factors. With respect to accuracy, there was a significant effect of condition, $F(2, 142) = 44.61$, $p < .001$, but not of the other factors ($p > .05$) or their interaction ($p > .05$). Bonferroni planned comparisons indicated significant ($p < .05$) differences among all condition means (Figure 1).

Group retention data were analyzed in the same fashion as training data. With respect to accuracy, there was a significant effect of condition, $F(2, 142) = 26.62$, $p < .001$, but not of the other factors ($p > .05$) or their interaction ($p > .05$). Bonferroni planned comparisons revealed that the mean percentages correct during the within-chains delay condition were significantly lower ($p < .05$) than the mean percentages correct during the no-delay and between-chains delay conditions (Figure 1).

To compare performance late in one session to performance early in the next session, arranged a day later, with the same required response sequence, retention data were further analyzed by calculating percentage of accuracy retained relative to the training condition. Retained accuracy was calculated by dividing accuracy during retention sessions minus 33% chance accuracy by accuracy during training sessions minus 33% and converting this ratio to a percentage. Resulting values were 54.5%, 15.8%, and 69.6% for the no-delay, within-chains delay, and between-chains delay conditions, respectively. Statistical analysis revealed a significant effect of condition, $F(2, 142) = 16.58$, $p < .001$, but not of the other factors or their interaction ($p > .05$) on percentage of accuracy retained. Planned comparisons revealed that differences between all condition means were significant ($p < .05$).

Mean rates of responding during the training component were 0.48, 0.23, and 0.22 responses per second for the rate-building, within-chains delay, and between-chains delay conditions, respectively. Mean reinforcement rates (food deliveries per hour) during the rate-building, rate-controlled, and between-chains rate-controlled conditions were 65.0, 72.5, and 74.4, respectively. Analysis of variance revealed no significant differences in mean reinforcement rates across conditions, $F(2,142) = 1.53$, $p = .219$. Regression analyses revealed that response rates during training were significantly related to training accuracy and retention accuracy (ps $= .001$ and $.01$, respectively), although reinforcement rates were not (ps $= .397$ and $.641$, respectively).

Mean response latencies were 1.44, 2.08, and 1.27 s for the no-delay, within-chains delay, and between-chains delay conditions, respectively. Repeated measures analysis of variance indicated a significant overall effect of condition, $F(2, 142) = 45.64$, $p < .001$, but not of the other factors or their interaction, on response latency. Planned comparison tests revealed that all means differed significantly from one another ($p < .05$).

In general, accuracy increased as subjects progressed through components under all conditions. Response rates increased across completed components during the no-delay condition (mean increase from the first five chains to the last five was 0.155 responses per second), but decreased under the within-chains and between-chains delay conditions (changes were -0.045 and $-0.0.25$ responses per second, respectively). Mean response latencies decreased from the first to the last five chains during the no-delay condition (mean decrease was 0.278 s per response), changed very little during the between-chains delay condition (mean decrease was 0.008 s per response), and increased during the within-chains delay condition (mean change was -0.232 s per response). It is important to note, however, that overall mean latencies during the between-chains delay condition may be artificially reduced because the imposed delay may have diminished the effects of postreinforcement pausing on that measure.

Each pigeon's accuracy data for each training and retention component under all conditions are displayed in Figures 2 and 3, respectively. In general, patterns that are evident in group means also are evident in the performance of individual subjects. That is, accuracy during the training component typically was highest during the no-delay condition, somewhat lower during the within-chains delay condition, and lowest during the between-chains delay condition. During the retention component, accuracy for individual birds usually was similar during the no-delay and between-chains delay conditions and was substantially lower during the within-chains delay condition. It is important to point out that in some cases (e.g., Figure 3, Subject 12104, Sessions 6 and 7) retention accuracy was higher than acquisition accuracy. This pattern of results indicates that the discrimination was not always mastered during the acquisition component and that further learning could occur during the retention component.

DISCUSSION

As reported by Doughty et al. (2004), the results of all but three of the 48 studies that have examined the effects of rate-building procedures are confounded by at least one of two variables, reinforcement rate or number of trials. The presence of these confounding effects and the mixed results of the adequately controlled studies (Evans & Evans, 1985; Evans et al., 1983; Shirley & Pennypacker, 1994) raise questions regarding the extent to which establishing high response rates per se contributes to the enhanced performance typically seen with such procedures. The current study controlled for the effects of reinforcement rate and trials across conditions that generated different rates of responding. It also held motivation for the reinforcer and the difficulty of the conditional discrimination being acquired relatively constant across conditions in which higher and lower response rates were generated.

Comparison of performance between the no-delay and within-chains delay conditions of the present study indicates that the condition that engendered faster responding produced greater accuracy during training. It also produced better retention, regardless of whether absolute or relative measures of retention were considered. These data are consistent with the applied literature and are of significance in that conditions that generated faster responding also generated greater accuracy when we held potentially extraneous variables constant.

In addition, accuracy during training was higher during the no-delay condition than during the between-chains delay condition. Interestingly, however, absolute accuracy during retention components was similar in the no-delay and between-chains delay conditions; retained accuracy, which takes into account differences in performance during training, was higher under the latter condition. This finding indicates that the way the environment is arranged to manipulate response rates significantly influences resulting effects on conditional discriminations. It is noteworthy that the between-chains rate-controlled condition engendered the lowest response latencies during acquisition; hence, in one sense the pigeons responded faster under this condition than under either of the others.

In applied studies that have demonstrated the beneficial effects of training to a fluency criterion, accurate responding typically is established under conditions in which rate is not constrained, and then the task is practiced under conditions that substantially increase the rate of responding (Doughty et al., 2004). For example, a student learning to add 2 to single-digit numbers might begin by having his or her

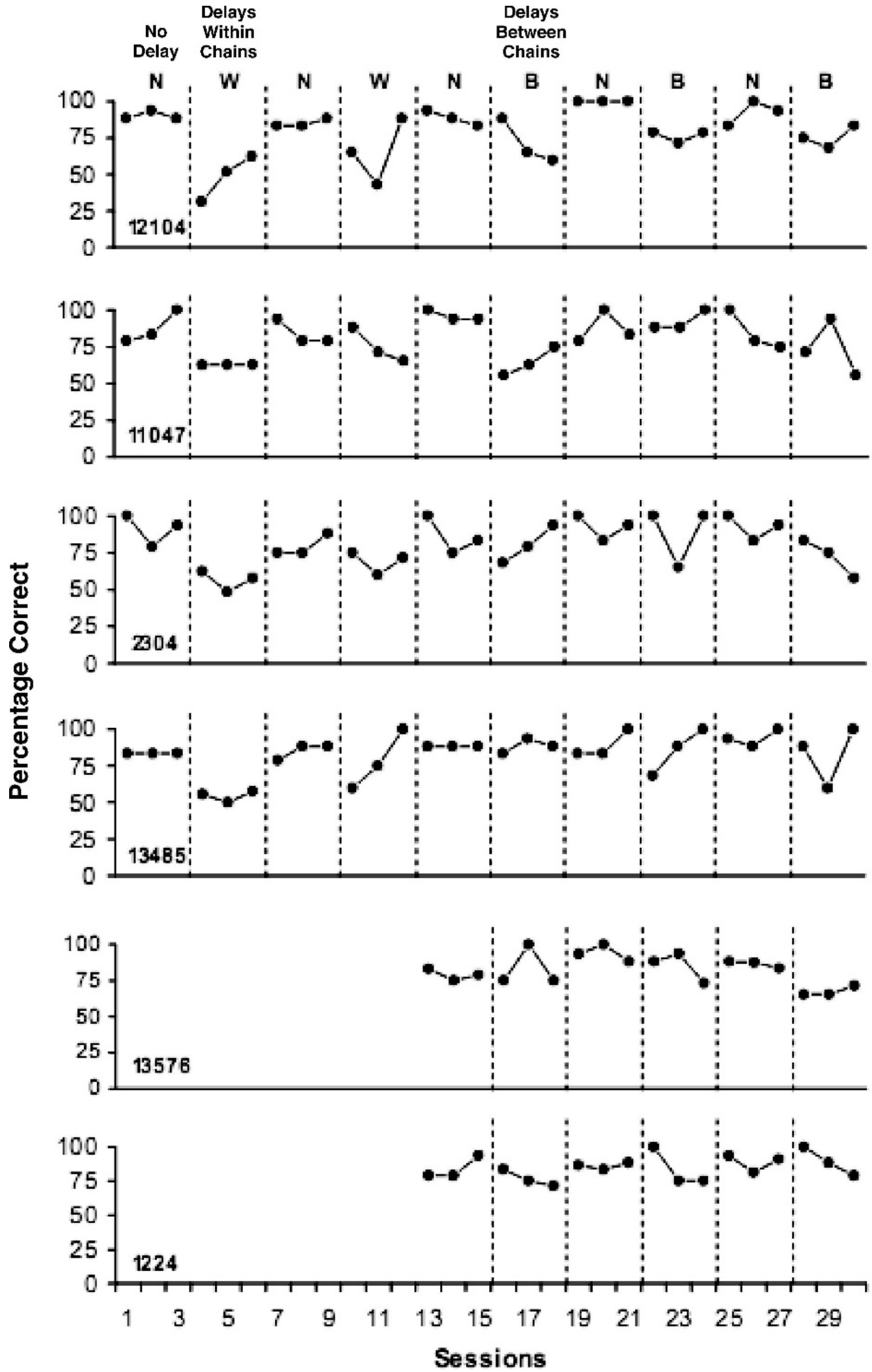

Figure 2. Percentage of correct responses each session by individual pigeons during the last five chains of the training components under each of the three experimental conditions. N, W, and B designate the no-delay, within-chains delay, and between-chains delay conditions, respectively.

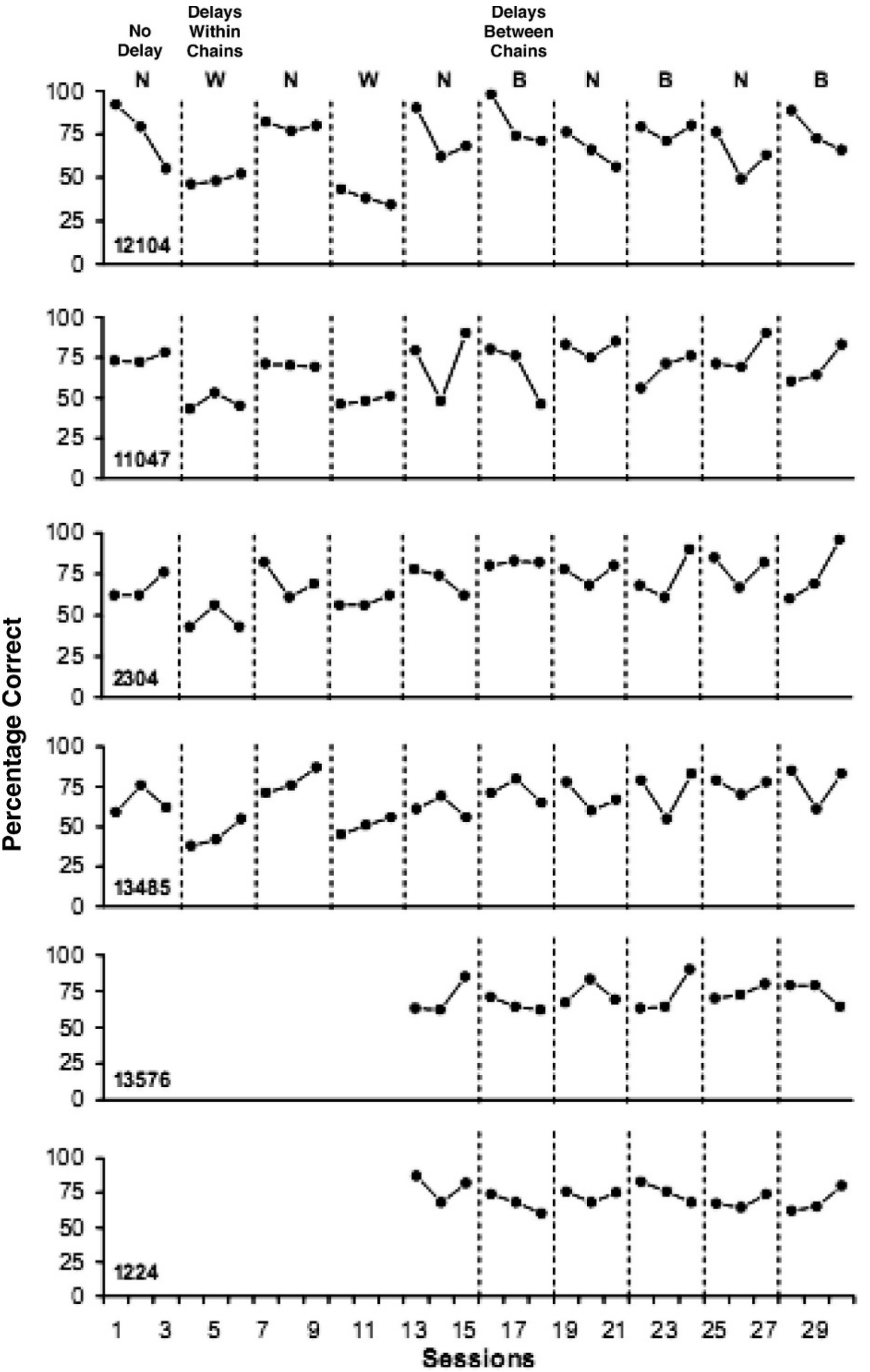

Figure 3. Percentage of correct responses each session by individual pigeons during the first five chains of the retention components under each of the three experimental conditions. N, W, and B designate the no-delay, within-chains delay, and between-chains delay conditions, respectively.

teacher present individual flash cards from a deck of 10, each depicting an addition problem (e.g., 0 + 2 =, 9 + 2 =). Each card would constitute the discriminative stimulus (S^D), and the student would be allowed a substantial period of time (e.g., 10 s) to respond. If necessary, prompting might be used to engender a response, and an appropriate consequence would be arranged following the response (e.g., praise, a putative reinforcer, would follow a correct response). Delivery of the consequence would be the final component of a learning trial. Learning trials would be arranged until the student had answered all of the problems a specified number of times, at which time the training session would end. Training sessions would continue as described until an accuracy criterion, perhaps 100% correct for two consecutive sessions, was met. At that time, the student would begin to move through the deck more rapidly, working to complete all problems correctly within a specified period of time. The time criterion would be determined empirically for each student and would be reduced over sessions until a terminal value, perhaps completing all 10 problems in less than 30 s, was achieved. At that time, performance would be deemed fluent and training would end.

The repeated acquisition procedure allows the repeated establishment of conditional discriminations and is sensitive to the effects of a wide range of variables (Poling & Byrne, 2000), but the procedures used in the present study differ from those just described in two obvious ways. First, response chaining was not involved in the applied example, but it was required in the present study. Chained responses can, of course, be trained to a fluency criterion, as when a beginning driver is taught to start a car quickly and correctly, but the chained responses taught in applied settings typically are heterogeneous, in that different response topographies are required across the course of the chain. The response chain in the present study was homogeneous; that is, the same response topography (pecking a response key) was required throughout the chain. Although there is no reason to believe that stimulus control processes differ with homogeneous and heterogeneous response chains, the repeated acquisition procedure as we arranged it does not have great face validity as a procedure for studying conditional discriminations as they are typically taught to children and adults through precision teaching.

Second, accurate but relatively slow responding, followed by fast and accurate responding, was not established in the present study. Instead, responding was first established at a rate observed to be associated with accurate responding when rate was not constrained, and then the rate of responding was reduced by increasing the time between trials (i.e., the intertrial interval, ITI), either within or between chains. Previous applied studies not involving chained schedules have shown that reducing the ITI increased accuracy in students learning to read and perform other discrimination tasks (e.g., Carnine, 1976, 1981; Darch & Gersten, 1985; Koegel, Dunlap, & Dyer, 1980). In consideration of such results, rapid trial presentation (short ITIs) is a hallmark of direct instruction, a widely used and effective instructional technique (e.g., Becker, Englemann, Carnine, & Rhine, 1981; Engelmann, Becker, Carnine, & Gersten, 1988). Interestingly, applied studies that have demonstrated beneficial effects of faster trial presentations do not characteristically control for reinforcement rate or number of trials presented, and the extent to which these variables may contribute to the observed effects is unclear. In the present study, reinforcement rate and number of trials were controlled, and increasing the ITI nonetheless reduced accuracy during acquisition.

In the applied studies that have examined the effects of ITI length cited in the previous paragraph, delays were arranged between successive trials, and the length of the delay determined the ITI and, in consequence, the rate of responding. In other applied studies, response rate under discrete-trials procedures was manipulated within trials by varying the wait time allowed after presentation of an S^D (e.g., Riley, 1986; Rowe, 2003; Tobin, 1980). For example, Rowe compared the performance of students in elementary science programs under conditions in which mean wait times following teachers' queries were approximately 1 s and under conditions in which they were approximately 3 to 5 s. Performance was consistently better when the wait time was longer and the response rate was necessarily lower. These results suggest that it is essential that participants be given sufficient time to formulate and emit complex verbal responses, which appear to have been required in Rowe's study. Subjects were given unlimited time to respond following presentation of the S^D in the present experiment, and the required response was nonverbal and topographically simple. Therefore, our findings are not closely related to those that involve manipulations of wait time.

Another strategy to manipulate response rate was used in an applied study by Van Houten and Thomas (1976), who found that second-grade students completed more math problems during a 30-min period when they were explicitly timed every minute than when they were not timed. Although the rate of responding (problems solved per minute) was roughly twice as high during the latter condition, the percentage of problems solved correctly did not vary. In a subsequent study by Van Houten and Little (1982), reducing the time available to students to complete math problems from 20 to 5 min substantially increased the rate of responding and slightly increased accuracy. Both of these studies used a free-operant rather than discrete-trials arrangement, which may have influenced results.

From the early days of applied behavior analysis (e.g., Lee, 1978) to the present era (e.g., Gutierrez et al., 2007), applied behavior analysts have endeavored to develop effective procedures for establishing discriminated operant responding. In general, the present findings suggest that there are some benefits to using procedures under which conditional discriminations are performed relatively rapidly, although how response rates are manipulated, as well as the rates obtained, are important determinants of performance. In addition, manipulations that influence rate may affect accuracy when reinforcement rate and number of trials are held constant. These findings provide basic-research support for the rapid presentation of trials in Direct Instruction and for rate building in precision teaching and suggest that these procedures do not produce their effects by simply increasing the rate of reinforcement or number of learning trials presented. Of course, there is debate about whether discrimination learning in verbal humans, especially as it relates to equivalence class formation, is fundamentally different from discrimination learning in other animals. More generally, there is also debate about the extent to which findings with nonhumans are relevant to human behavior (for an overview of these issues, see *The Behavior Analyst*, 1991, Vol. 14). These issues are beyond our scope. Certainly our findings do not suggest specific strategies for improving direct instruction or precision teaching, both of which are empirically validated educational methods (e.g., Moran & Malott, 2004). They do, however, provide evidence that environmental manipulations that affect response rate in and of themselves influence discrimination learning, at least in pigeons.

Although response rates were manipulated successfully, it is important to emphasize that studies of fluency training in applied settings typically involve comparing performance under conditions in which a task is mastered to an accuracy criterion alone to performance under conditions in which the same task is mastered to a high-rate as well as an accuracy criterion

(Doughty et al., 2004). This tack was not taken in the present study; as discussed earlier, its procedures more closely resemble those used in applied studies that have manipulated rates of responding within (e.g., Riley, 1986; Rowe, 2003) and between (e.g., Carnine, 1976; Darch & Gersten, 1985) learning trials than those used in the fluency literature.

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Received May 18, 2007
Final acceptance January 23, 2008
Action Editor, Timothy Vollmer