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Delayed reinforcement of vocalization rate in young infants

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DELAYED REINFORCEMENT OF VOCALIZATION

RATE IN YOUNG INFANTS

by

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Abstract

DELAYED REINFORCEMENT OF VOCALIZATION RATE IN INFANTS

by

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The current study is an exploration of the parameters of delayed reinforcement with six 2- to 6-month-old infants in two experiments with single-subject repeated-reversal designs. In Experiment 1, unsignaled, 3-s delayed reinforcement was used to increase infant vocalization rate when compared to a differential-reinforcement-of-other-than-vocalization (DRO) condition and a yoked noncontingent comparison condition. In Experiment 2, unsignaled 5-s delayed reinforcement was used to increase infant vocalization rate when compared to an alternating-treatment comparison condition. The alternating-treatment comparison condition consisted of 3-min components of DRO and 3-min components of a nontreatment baseline. Successful conditioning was obtained in both Experiments of the current study. These results are in contrast to those of previous infant researchers who did not obtain conditioning with delays as long as 3 s with infants and who attributed their findings to the limitations of the infant's memory capacity. We present an alternative conceptual framework and methodology for the analysis of delayed reinforcement in infants.

Acknowledgements

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Delayed Reinforcement of Vocalization Rate in Young Infants

The use of delayed reinforcement to produce behavior change has been demonstrated across several species and a variety of responses in the animal literature including maze-learning in rats (Grice, 1948; Wolfe, 1934), key-pecking in pigeons (Dews, 1960; Ferster, 1953; Gleeson & Lattal, 1987; Sizemore & Lattal, 1977; Williams, 1976), and key-pressing in monkeys (Ferster & Hammer, 1965). There are inherent problems, however, with the implementation of delayed reinforcement schedules. It may be more difficult to obtain conditioning with delayed rather than immediate reinforcement because of the possibility of adventitious reinforcement. Specifically, during the delay interval, nontarget responses may be emitted. Occasionally, these responses may be followed immediately by the delivery of the reinforcer. Most reinforcement schedules are programmed such that the target response will produce the reinforcer with a far greater probability than will the variety of superstitiously conditioned responses. Therefore, to produce an association between the target response and the reinforcer, many more trials may be required under delayed reinforcement. To the extent that these issues are not sufficiently addressed by experimental procedures, researchers may not be able to obtain conditioning with delayed reinforcement.

Delayed reinforcement schedules, when used with infants, have sometimes been unsuccessful in producing conditioning (Millar & Watson, 1979; Ramey & Ourth, 1971) or limited by the age of the infant or the length of the delay (Millar, 1972). The failure to demonstrate conditioning may be due to interspecies differences between human infants, and the other animals studied in the research mentioned above. In fact, only one study has demonstrated that infants as young as 4 months can learn with delays of reinforcement as long as 3 s. It would not be surprising, however, to find that longer conditioning phases might be important to the acquisition of responding under delayed reinforcement. In the early developmental studies, each infant received only a single exposure to the contingency schedule. Further, the contingency exposure in these experiments was either 3 min (Millar, 1972; Millar and Watson, 1979) or 6 min (Millar, 1972; Ramey and Ourth, 1971) in length. The length of the contingency segment in studies of delayed reinforcement, or any reinforcement schedule, may be best determined by the response acquisition patterns of the infant, rather than by an a priori time schedule.

In addition to the possibility that the experimental phase may be too short to produce conditioning with delayed reinforcement, the baseline phase can be too short to adequately sample behavior. Short baselines may produce spuriously inflated or deflated response rates because the infant may need time to habituate to the laboratory surroundings. The early developmental studies often used 60-s baselines, in which the experimenter was present only for the final 30 s (Millar & Watson, 1979; Ramey & Ourth, 1971) or 3-min baselines (Millar, 1979.) Because these baselines were quite short, response rates may not have stabilized. The comparison between response rates under delayed reinforcement and an inflated baseline may lead to the inaccurate conclusion that conditioning did not occur. Conversely, the conclusion that conditioning did occur during delayed reinforcement following a deflated baseline may also be spurious.

Baseline procedures, in addition to baseline length, determine whether any change in behavior can be attributed to reinforcement. In many of the early developmental studies of delayed reinforcement, an observation-only baseline was used as the comparison condition (Millar, 1972; Millar & Watson, 1979; Ramey & Ourth). Observation-only baselines, in which the target response is measured, but the nominal reinforcer is not delivered, do not control for the possibility of elicitation of the response by the mere presentation of the reinforcer in subsequent phases. As a result, in Millar's (1972) experiment, when response rate increases did occur during 1- and 2- s delays of reinforcement, it is difficult to determine whether such increases were the result of delayed reinforcement rather than elicitation by the nominal reinforcers.

To control for elicitation, another baseline measure used in the early infant literature on delayed reinforcement was noncontingent reinforcement (Millar, 1972). Noncontingent reinforcement consists of the delivery of reinforcers independently of the occurrence of the target response. Nominally noncontingent schedules, however, may produce adventitious reinforcement of the target response, resulting in an increase in response rate during baseline. In fact, in his research with pigeons, Lattal (1974) found that when as few as 30% of the reinforcers were delivered following the target response, response rates increased. It is therefore important to determine the proportion of target responses followed by reinforcer delivery during the noncontingent schedule, compared to during the delayed reinforcement schedule, prior to interpreting the results. High response rates resulting from adventitious reinforcement during nominally noncontingent schedules may account for the failure to demonstrate conditioning with 3-s delays. Conversely, low response rates during both noncontingent and delayed reinforcement may be accounted for by a low rate of reinforcer delivery following the target response in both conditions. Although Millar (1972) reported conditioning with 1- and 2-s, but not 3-s, delays with a nominally noncontingent baseline, without a separate analysis of the presentation of the reinforcer in all conditions of the experiment, it is difficult to evaluate whether operant conditioning occurred. Thus, the selection and implementation of the experimental condition is crucial to the interpretation of the results.

A procedure that may facilitate conditioning with delayed reinforcement is the explicit signaling of the delay interval immediately following the target response. Although such signals were not used in the early infant literature, which focused on delays of 1 to 10 s, a review of the animal literature shows that the use of discriminative stimuli (S^Ds) can result in learning with signaled delays of reinforcement extending up to 24 hrs. In particular, Ferster and Hammer (1965) trained a monkey to key-press with 24-hr delayed reinforcement using a white light to signal the delay period. Also, Wolfe (1934) trained rats in a discrimination box to perform a choice task with 30-s delays of reinforcement using colors to distinguish the alleyways. Grice (1948) found that when the discrimination box did not contain these colors, rats performed the task with 5-s, but not 10-s delays to reinforcement. Azzi, Fix, Keller, and E. Silva (1961) demonstrated that delay periods in which the experimental chamber was darkened resulted in higher response rates than delay periods unsignaled by illumination changes. Discriminative stimuli may thus prove important in establishing the parameters of learning under delayed reinforcement, in infants and in other species.

An additional consideration in designing delayed reinforcement research is the delay procedure itself. In contrast to the early developmental literature, learning under schedules of delayed reinforcement with signaled delays of 3 s in infants has been demonstrated in one recent study (Reeve, et al., 1992). This experiment consisted of a repeated-reversal experimental design comparing delayed reinforcement with a differential-reinforcement-of-other schedule (DRO). This research design was embedded in an across-subjects multiple-baseline design to evaluate the effects of DRO on an observation-only baseline. The DRO comparison condition was chosen to avoid the possible adventitious reinforcement associated with noncontingent schedules, and to provide stimulation during baseline such that conclusions about reinforcement might be drawn. The dependent measure was the vocalization rate of each of three infants in the study. The delivery of reinforcement was signaled immediately following infant vocalization by the illumination of a small, red light visible to the infant. Experimental sessions were 12 min in duration, and were conducted over many daily sessions. Condition changes for individual infants occurred when the response rate in the given condition stabilized (in the case of observation-only) or when it was apparent that response acquisition had occurred (in the case of DRO and delayed reinforcement). The results show that response rates during delayed reinforcement were systematically higher than rates obtained during DRO for all 3 infants. During DRO, response rates systematically decreased from levels obtained during the observation-only condition across 2 of the 3 infants. Thus, signaled delayed reinforcement contingencies with delays of 3 s are sufficient to produce conditioning of vocalization rate in infants as young as 4 months of age. Also, it was demonstrated that the DRO schedule caused the lower-than-observation-only rate of responding in the infants. Given that there were negligible differences in stimulation rates between DRO and delayed reinforcement conditions, and given that response rates during DRO were lower than observation-only, and response rates during delayed reinforcement were higher than DRO, there is strong evidence that the systematic response rate increases under the delayed reinforcement condition were produced by the contingencies of reinforcement.

Although signaled 3-s delayed reinforcement seems to have produced the behavior change demonstrated in the Reeve, et. al study, it is not known whether conditioning would have occurred if the length of the delay had been increased or if the signal had been removed. Thus, the major purpose of the present study is three-fold. First, this study will extend the delay of reinforcement explored with young infants from the 3-second delay used in the Reeve, et al. (1992) study to a 5-second delay. Second, it will investigate the use of delayed reinforcement without the use of a signal for the onset of the delay period. Third, these experiments will explore the use of observation-only, DRO, and non-contingent reinforcement as control conditions through a separate analysis of the delivery of reinforcers.

Experiment 1

Method

Subjects. Three normally developing infants, Mark, Jason, and Adam, participated as subjects. Their parents were contacted through flyers posted in local small businesses in the borough of Queens. At the beginning of the experiment the infants were 119, 108, and 98 days old respectively. The study was completed within 1 1/2 months.

The Mental Scale of the Bayley Scales of Infant Development (Bayley, 1969) was given to each infant within one week prior to experimentation. Each infant scored within the normal range (mean = 100). Mark's Bayley score was 98, Jason's was 127, and Adam's was 100. Each infant was accompanied by the same parent during all experimental sessions.

Setting and apparatus. The study took place in the Infant Laboratory located in the New Science Building at Queens College of the City University of New York. The laboratory was fully carpeted and was furnished with a couch and some toys to provide a home-like atmosphere. It also contained a 61 x 152 cm three-panel plywoood screen with a 30 x 43 cm window opening in the center panel. An infant carseat was placed behind the screen. The parent sat on the other side of the window opening on the carpet. The window was at eye level for both parent and infant. The window was covered with a 76 x 43 cm beige Venetian blind (Achim "Sunshine" blind) with 2.5 cm slats. The slats remained closed throughout the experiment. When the blind was down, both parent and infant were unable to see each other. When the blind was raised, the parent could touch and play with the infant through the window opening.

Three 28-volt incandescent bulbs with colored crystals served as signal lights. A yellow signal light was positioned on the upper left side of the window facing the parent 11 cm from the window opening. A corresponding red signal light was positioned on the upper right corner of the window facing the infant 11 cm from the window opening. The signal lights were activated by foot switches pressed by observers according to the schedule that was in effect. A green light was located below the signal light on the parents' side of the screen. The red light on the infant's side of the screen was only used during the DRO schedule.

Two observers sat behind the infant and scored infant vocalizations on S & K portable event recorders. Venetian blind operation and activation of the signal lights were automatically recorded on the event recorder with solenoid switches that depressed keys on the event recorder. Noise from the foot switches was not discernable to the observers.

General procedure. Infants and parents attended between three and four 12-min sessions per week over a period of 1 to 1 1/2 months. The parent brought the infant to the laboratory, put the infant in the carseat behind the screen, and then sat outside the screen facing the infant through the open window. An experimental session began when the parent lowered the blind and closed the microswitch.

The independent variable was the schedule of social reinforcement. The purpose was to demonstrate that an unsignaled 3-s delay of social reinforcement could increase an infant's vocalization rate.

Social reinforcement was defined as the raising of the window blind. Social reinforcement occurred as follows during the delay schedule: Two observers turned on the yellow signal light on the parent's side of the screen using foot switches. The light illuminated only if both foot switches were pressed simultaneously. This indicated the onset of the delay schedule to the parent. A green light, also located on the parent's side of the screen, was timed from the onset of the yellow light, and indicated the end of the delay schedule. When the green light was illuminated, the parent raised the blind for 5 s. The parent was asked to make eye contact with the infant and then to play with the infant while the window blind was raised. An 80 decibel buzzer automatically signaled the parent to lower the blind 5 s after its opening. The timing of the blind raising and lowering was measured automatically by a microswitch on the window blind.

During the differential-reinforcement-of-other-than-vocalization (DRO) condition, in which infants were reinforced for not vocalizing, and during the noncontingent reinforcement condition, the two lights on the parent's side of the screen were illuminated simultaneously. As soon as the lights were turned on, social reinforcement occurred as described above.

The rate of infant vocalization served as the dependent variable. A vocalization was defined as a discrete, voiced sound that occurred within a respiratory unit and was not followed by another voiced sound for a minimum of 1 s. The onset of infant vocalizations was recorded by two independent observers on event recorders during experimental sessions.

Sessions were terminated if the infant fussed or cried for longer than 1 min. Crying occurring for under 1 min was treated procedurally as a vocalization. In the data analysis, however, crying was not considered to be vocalizing.

Experimental design and conditions. Experiment 1 was conducted as a single-subject ABACBC reversal experimental designs. Three experimental conditions were used in the following order: 1) a differential-reinforcement-of-other-than-vocalization (DRO) schedule, 2) a delayed reinforcement schedule for vocalizations, and 3) noncontingent reinforcement. Condition changes occurred when the graphed data were judged to be stable (Baer, Wolf, & Risley, 1968). The CBC comparison was run to focus on the effects of delayed reinforcement. We did not conduct an ACA comparison because of time constraints.

During the DRO condition, as long as the infant did not vocalize, the window blind was raised every 2 s for a 5-s period of social reinforcement by the parent, as described under the General Procedure. If the infant did vocalize during DRO, the window-blind opening was delayed until no vocalization occurred for 4 s.

The delayed-reinforcement condition was automated as described above such that there was a delay between the infant's initial vocalization after the window blind was closed and the onset of the green light to signal the parent to open the window blind. Infant vocalizations made within the delay interval or during the window-blind open period did not have any programmed consequences.

In the noncontingent reinforcement condition, the schedule of window-blind opening was determined by yoking each noncontingent session to one of the delay sessions. The delay sessions chosen for yoking were those with the three median frequencies of window-blind openings.

Data analysis. Data on infant vocalization and window-blind opening were analyzed in 3-min intervals. Intervals that were terminated prior to 120 s to meet the infants' needs were discarded. Data on infant crying were analyzed using 5-s interval sampling.

Because the duration of the Venetian blind-open reinforcement episodes was not held constant, the measure of the infants' vocalization rate was adjusted in the following manner: The number of vocalizations and the number of seconds that the window blind was open was subtracted from the data prior to the calculation of the rate of vocalizations during each 3-min interval.

To determine the functional outcome of the programmed reinforcement procedures in the present study, we calculated the percentage of window-blind openings not preceded by infant vocalization and the percentage of vocalizations followed by window-blind opening within 5 s. A 5-s time frame was selected for window-blind opening because the delay interval was 3 s and we allowed 2 s for the parent to pull the blind open.

Interobserver agreement. Interobserver agreement for infant vocalization was obtained during 80% of the 169 3-min intervals used in the data analysis.

For each part of this experiment, the interobserver agreement for the onset of infant vocalizations was calculated on a point-by-point basis by dividing the number of agreements by the sum of the number of agreements and disagreements multiplied by 100. Vocalizations recorded by both observers within 1 s's time were counted as an agreement. Interobserver agreement during DRO was 83% overall for 49 intervals. During delayed reinforcement, it was 83% overall for 46 intervals. During noncontingent reinforcement, overall interobserver agreement was 82% for 40 intervals.

Interobserver agreement for the occurrence of fussing/crying was calculated by dividing the number of 5-s intervals in which both observers reported fussing/crying by the number of 5-s intervals in which both observers agreed and disagreed about the occurrence of fussing/crying. Interobserver agreement was 85% for 155 intervals containing fussing/crying during DRO, 86% for 73 intervals during delayed reinforcement, and 83% for 121 intervals during noncontingent reinforcement.

Results

The initial focus of the results section will be the comparison of the unsignaled delay condition with its control conditions. Subsequently, the results section will focus on the control conditions themselves and the manner in which the independent variable functioned.

Figure 1 presents the number of vocalizations/min for each 3-min interval during the control and delayed-reinforcement conditions for each of 3 infants in Experiment 1. Two types of control conditions are shown: DRO (closed circles) and noncontingent reinforcement (open triangles). The delayed reinforcement condition is shown with open circles. The mean rate of window opening per experimental condition is shown with a horizontal line.

(See Figure 1)

As can be seen in Figure 1, the infants systematically demonstrated an increased rate of vocalization during the unsignaled 3-s delayed-reinforcement condition (open circles), as compared to either type of control conditions, DRO (closed circles) or noncontingent reinforcement (open triangles), in a single-subject reversal ABACBC design. Specifically, Mark's vocalization rate increased from 3.5 vocalizations/min in the first DRO condition (closed circles) to between 9 and 16 vocalizations/min during the first delayed-reinforcement condition (open circles). When DRO was reintroduced, Mark's vocalization rate gradually decreased from 8 to about 2.5 vocalizations/min. Mark's parent chose not to continue the experiment beyond this point.

Jason's vocalization rate followed a pattern similar to Mark's. Specifically, Jason's vocalization rate was systematically higher during delayed reinforcement (open circles) than during the control conditions, either DRO (closed circles) or noncontingent reinforcement (open triangles).

The pattern of Adam's vocalization rate was similar to Jason's and Mark's. That is, the vocalization rate was systematically higher during delayed reinforcement than during either the DRO or noncontingent control condition. Note that during the first noncontingent control condition, with the exception of one outlying point, the trend was flat. During the subsequent reintroduction of the delay condition (open circles), the trend was increasing.

The horizontal lines in the figure illustrate the mean rate of social reinforcement per experimental condition for each infant. The mean window-opening rate was systematically higher during DRO than during the delay condition for all three infants for 5 of 6 comparisons. The one exception was Mark's final DRO phase, in which the mean rate of window opening was lower than either of the prior conditions. The mean window-opening rate was systematically lower during the noncontingent condition than during delayed reinforcement for Jason and Adam. During DRO, an overall mean of about 4.63 window openings occurred over about fifty-three 3-min intervals. During delayed reinforcement, an overall mean of 3.69 window openings occurred for sixty-six 3-min intervals. Although the window-opening rate was programmed to be equal in the noncontingent and delayed-reinforcement conditions, mean window opening was slightly lower during the noncontingent condition. An overall mean window-opening of 3.46 occurred over 49 components during noncontingent reinforcement. The level of mean window openings was similar across all infants and conditions.

Table 1 presents the number of 3-min components contained in each session for each infant. (See Table 1)

Across all 3 infants, the number of components per condition did not vary systematically across conditions.

Figure 2 focuses on the control conditions and examines the functional outcome of the reinforcement procedure. (See Figure 2)

The left-hand side of Figure 2 presents the percentage of vocalizations followed by reinforcement within 5 s for Mark, Adam, and Jason for each consecutive 3-min interval during the DRO (closed circles), and delayed reinforcement conditions (open circles). For Adam and Jason, the percentage of vocalizations followed by reinforcement during the noncontingent-reinforcement condition (open triangles) is also shown. For each infant, the percentage of vocalizations followed by reinforcement within 5 s was lowest during the DRO conditions (closed circles) and highest during the delayed-reinforcement conditions (open circles). The percentage of vocalizations followed by reinforcement within 5 s during the noncontingent reinforcement condition (open triangles) for Adam and Jason reached an intermediate level, overlapping with the high range of points during DRO (closed circles), but not with the low points of the delayed-reinforcement condition (open circles).

The right-hand side of Figure 2 presents the percentage of window openings that were not preceded by vocalizations, for each consecutive 3-min interval during DRO (closed circles) and delayed reinforcement (open circles) for Mark, and during DRO, delayed reinforcement, and noncontingent reinforcement (open triangles) for Mark, Adam, and Jason.

For each infant, the percentage of window openings that were not preceded by vocalizations was highest during the DRO condition (closed circles), and lowest during the delayed-reinforcement condition (open circles). Intermediate percentages of window openings not preceded by vocalizations occurred during the noncontingent- reinforcement conditions (open triangles) for both Adam and Jason.

Table 2 shows the percentage of 5-s intervals containing fussing/crying for each condition.

(See Table 2)

The percentage of 5-s intervals that contained fussing/crying was systematically higher during DRO than delayed reinforcement for Mark, but not for Jason and Adam. There was no systematic difference in the percentage of 5-s intervals containing crying that occurred during noncontingent reinforcement and DRO conditions, or the percentage that occurred during noncontingent reinforcement and delayed reinforcement conditions.

Discussion

Three-second, unsignaled delayed reinforcement effectively and systematically increased the vocalization rate of the three infants in this study compared to both DRO and noncontingent reinforcement control conditions. Because social stimulation rates (window opening) were, in most cases, systematically higher during DRO than delayed reinforcement, and because social stimulation rates were nearly equivalent during noncontingent and delayed reinforcement, elicitation effects resulting from the presentation of delayed reinforcement are unlikely. The analysis of the presentation of reinforcers indicated that the reinforcement schedules programmed were functionally implemented because the percentage of vocalizations followed by window-opening was systematically higher during delayed reinforcement than during the DRO and noncontingent reinforcement control conditions, and the percentage of window-openings not preceded by a vocalization was systematically higher during the two control conditions than during delayed reinforcement. Thus, it can be concluded that the change in vocalization rate observed in Mark, Jason, and Adam can be attributed specifically to the changes in reinforcement schedules.

In Experiment 2, the length of the unsignaled delay of reinforcement will be extended from 3 to 5 s, and a multielement control condition, containing both DRO and observation-only components will be used.

Experiment 2

Method

Subjects. Three infants, Stacey, Chris, and Arlene, participated in this experiment. They were 180, 86, and 88 days old, respectively, at the beginning of the study. Each infant was given the Mental Scale of the Bayley Scales of Infant Development within 2 days prior to the first session.

Each infant scored within the normal range (mean = 100). Stacey scored 150, Arlene scored 100, and Chris scored 127.

Setting and apparatus. The setting and apparatus were identical to those in Experiment 1.

Experimental design and procedure. Experiment 2 was conducted in an ABAB single-subject repeated-reversal experimental design comparing 5-s, as opposed to 3-s, delayed social reinforcement with a control condition. Within the control condition, an alternating treatments design was used to compare an observation-only baseline and a DRO schedule in 3-min intervals. During the observation-only baseline, the window blind remained open throughout the 3-min interval. The parent was asked to touch and play with the infant through the window opening. Otherwise, the procedures used in Experiment 2 were the same as those used in Experiment 1.

Data analysis. The data were analyzed in the same manner as those in Experiment 1, with one exception. The functional outcome of the programmed reinforcement procedures was measured by calculating the percentage of vocalizations followed by window-blind opening within 7, instead of 5, s. A 7-s time frame was selected for window-blind opening because the delay interval was 5 s, instead of 3 s as in Experiment 1, and we allowed 2 s for the parent to pull the blind open.

Interobserver agreement. Interobserver agreement for infant vocalizations was obtained as described in Experiment

1 for 88% of the one-hundred twenty-three 3-min intervals used in the data analysis. During the observation-only baselines, interobserver agreement was 89% for thirty-five 3-min intervals. Interobserver agreement during DRO was also 89% for thirty-five 3-min intervals. Interobserver agreement during delayed reinforcement was 86% for thirty-eight 3-min intervals.

Interobserver agreement for fussing/crying was obtained for each 5-s interval as described in Experiment 1. Interobserver agreement was 91% for eighty-seven 5-s intervals containing fussing/crying during DRO, and 91% for forty-seven 5-s intervals during Observation-Only. Interobserver agreement was 86% for eighty-three 5-s intervals during delayed reinforcement.

Results

As in Experiment 1, the initial focus of the results section for Experiment 2 will be the comparison of the unsignaled 5-s delay condition with the control conditions. Subsequently, the results section will focus on the manner in which the independent variable functioned.

Figure 3 presents the rate of infant vocalizations for each of 3 infants for each consecutive 3-min interval during the multielement control condition (alternating 3-min of DRO and observation-only) and delayed reinforcement during Experiment 2. (See Figure 3)

As can be seen in Figure 3, each infant systematically increased in vocalization rate during the unsignaled 5-s delayed reinforcement condition (open circles), as compared to the DRO condition (closed circles) and the observation-only condition (open squares).

Across all three infants, the DRO and the observation-only multielement condition were associated with similar levels of responding during 4 of the 6 multielement phases. The vocalization rate for all three infants was similar during these control conditions with the following two exceptions: 1) During Stacey's initial multielement phase, her vocalization rate was highest during observation only, and 2) for Arlene, during the second implementation of the multielement phase, her vocalization rate was consistently higher during DRO than during observation-only.

The horizontal lines in the figure represent the mean window openings for each condition. For 6 out of 6 comparisons, the mean window opening rate was higher during DRO than during delayed reinforcement. The overall mean-window opening rate during DRO was 5.79 for 37 intervals, and during delayed reinforcement, it was 3.39 for 48 intervals.

Table 3 presents the number of 3-min components in each session during each condition for each infant.

(See Table 3)

There were no systematic differences in the number of components presented during the sessions of the multielement and delayed reinforcement schedules.

The manner in which the independent variable was implemented is presented in Figure 4. (See Figure 4)

On the left-hand side of the graph, the percentage of vocalizations followed by window-blind opening within 7 s is presented for each of the three infants during the DRO condition of the multielement design (closed circles), and during delayed reinforcement (open circles). For Stacey, Chris, and Arlene, consistently higher percentages of vocalizations were followed by window-blind openings within 7 s during the delayed-reinforcement condition (open circles). In general, during the DRO condition (closed circles), when vocalizations occurred infrequently, systematically lower percentages of vocalizations were followed by window-blind opening within 7 s than during the delayed-r einforcement condition (open circles). The DRO condition in Figure 4 was part of the multielement design shown in Figure 3. Of course, there are no comparable data for the observation-only condition of the multielement design because the window blind remained open during observation-only intervals. Furthermore, the variability of the percentage of vocalizations reinforced within 7 s was very high (0-100%) during DRO (closed circles) when the vocalization rate was very low, as shown in Figure 3.

The right-hand side of Figure 4 presents the percentage of window-blind openings that were not preceded by vocalizations. For each of the three infants, a systematically higher percentage of window-blind openings were not preceded by vocalizations during the DRO components of the multielement baseline (closed circles) than during the delayed-reinforcement phase (open circles).

The percentage of 5-s intervals containing fussing/crying in each condition is presented in Table 4.

(See Table 4)

The percentage of 5-s intervals that contained fussing/crying did not change systematically with experimental conditions.

General Discussion

In both experiments in the present study, it was demonstrated that delayed reinforcement resulted in an increase in the vocalization rate of young infants. These results are consistent with those of Reeve, et al. (1992), but not with some of the earlier infant literature (Millar & Watson, 1979; Ramey & Ourth, 1981). In both experiments in the present study, infants experienced extended exposure to the experimental conditions. As in the Reeve, et al. (1992) experiment, each infant in the present studies was exposed to each experimental condition over many daily 12-min sessions, and conditioning with delayed reinforcement was obtained for delays of 3 s and longer. In contrast, in the earlier studies, 3 or 6 min of exposure to the contingency within a single session was used, and behavioral control was not demonstrated for delays greater than 2 s. The demonstration of delayed reinforcement may require exposure to the experimental conditions longer than 6 min repeated across many daily sessions. The length of time and number of sessions required will probably vary with individual infants and the target response chosen. In addition, in the present study, it was found that the use of an S^D to signal the onset of the delay period was unnecessary with delays as long as 5 s.

Differences in measurement and procedure between the present study and most of the earlier research may account for the results and contribute to the plausibility of the explanations presented here. These differences include the choice of control condition, and the measurement of the presentation of the independent variable relative to target responding. Specifically, in the first experiment of this study, two control conditions, DRO and noncontingent reinforcement, were used. In the second experiment, we used an alternating treatment comparison condition, consisting of components of DRO and observation-only. Both experiments contained an analysis of the manner in which the reinforcer was presented. These analyses lead to the conclusion that because the percentage of vocalizations followed by window-opening was systematically higher during delayed reinforcement than during DRO or noncontingent reinforcement conditions, and because the percentage of window openings not preceded by a vocalization was systematically higher during DRO and noncontingent reinforcement than during delayed reinforcement conditions, the schedules we programmed for vocalizing were, in fact, functionally implemented. Thus, we can attribute the changes in rate of vocalization in both of the above experiments to the differences between the reinforcement schedules themselves. Previous studies within the earlier infant literature investigating delayed reinforcement have used either observation-only (Millar, 1972; Millar & Watson, 1979; Ramey & Ourth, 1971), or immediate reinforcement and noncontingent reinforcement as comparison conditions (Millar, 1972). No information on the functioning of the reinforcer was presented in any of the earlier studies.

The use of the DRO schedule as a comparison condition in the present study may have contributed to the clarity of the results. The advantage of the DRO schedule over the noncontingent schedule may be that DRO is less likely to produce adventitious reinforcement of target responding. Thus, the rate of target responding under DRO should be lower than that of noncontingent reinforcement, and the comparison between responding under DRO and delayed reinforcement should produce a stronger contrast than the comparison between noncontingent and delayed reinforcement. In fact, when the actual reinforcement rate for target responding was measured in this study, the rate was systematically higher during noncontingent reinforcement than during DRO. Conversely, the actual reinforcement rate following the absence of the target response was systematically lower during noncontingent reinforcement than during DRO. Consequently, the rate of vocalization during noncontingent reinforcement was also systematically higher than during DRO. Because the rate of reinforcement of the target response was systematically higher during delayed reinforcement than either DRO or noncontingent reinforcement, and because the rate of reinforcement following the absence of the target response was systematically lower during delayed reinforcement than during either control condition, the vocalization rate during delayed reinforcement was also highest. The difference between the vocalization rate during DRO and during delayed reinforcement is more apparent because the change in the level of vocalization rate is large and the trends are opposite. The vocalization rate during DRO was low and generally decreasing, but, during delayed reinforcement it was high and increasing. The same comparison during noncontingent reinforcement and delayed reinforcement yields the same conclusions, but the difference in the level of vocalization rate was smaller and there was no trend during noncontingent reinforcement.

Despite its theoretical advantage over noncontingent reinforcement schedules in predicting a behavioral outcome, the use of DRO as a control condition against which to compare delayed reinforcement has produced inconsistent results in the animal literature. One study demonstrated an increase in responding during delayed reinforcement (Dews, 1960) and another showed no difference between DRO and delayed reinforcement (Pierce, 1972). In the infant literature, DRO was used in one recent study as a control condition (Reeve, et al., 1992) and conditioning was demonstrated with delayed reinforcement. Although a programmed DRO schedule should produce little adventitious reinforcement of the target response, analysis of reinforcement rates may nevertheless clarify the reason for the contradictory data of Pierce (1972) and other researchers using DRO schedules.

The analysis described above concerning the presentation of the reinforcer following the target response in each condition in the present study helps to explain the pattern of responding that occurred under each schedule. This analysis is particularly relevant to the interpretation of the results of the noncontingent reinforcement schedule, because this schedule is not necessarily associated with a given proportion of reinforcers delivered following target responding and following the absence of target responding. Without knowing how the behavior interacts with those schedules, we cannot predict the level of responding one will obtain under a noncontingent schedule. The one previous infant study that used noncontingent reinforcement as a control condition consisted of several experiments in which the researcher was able to demonstrate the conditioning of infants with delays of reinforcement of 1 and 2, but not 3 s (Millar, 1972). Because Millar did not present an analysis of the presentation of reinforcers during delayed reinforcement and the noncontingent control, it is not clear why the 3-s delay did not produce an increase in responding. There may have been a difference in reinforcement rate for the target response between the 3-s delayed reinforcement and noncontingent control conditions, but the rate of target responding did not change accordingly, or the 3-s delayed and noncontingent reinforcement conditions may have both produced similar reinforcement rates and thus similar rates of target responding occurred. Alternatively, there may have been no difference in the reinforcement rate following the absence of the target response during delayed reinforcement and noncontingent reinforcement. If reinforcers were presented when the target response was not emitted during both the delayed reinforcement and noncontingent schedules, the rate of target responding should be low under both conditions. The use of noncontingent reinforcement as a control condition produced inconsistent results in the animal literature as well. Although the majority of animal studies did demonstrate conditioning (Gleeson & Lattal, 1987; Sizemore & Lattal, 1977; Williams, 1976), at least one did not (Williams, 1976). Again, an analysis of the presentation of the independent variable might have explained the seemingly contradictory results.

In both of the experiments in the current study, the rate of reinforcement (window opening) provided information not only on the contingencies, but also on the likelihood of elicitation effects. Specifically, if the rate of window opening in the control condition was systematically lower than that of the delayed reinforcement condition, the result could be attributed to elicitation by the window opening, rather than to the conditioning of infant vocalizations under a delayed schedule. In fact, in most cases, the mean rate of reinforcement during DRO was generally lower than during delayed reinforcement in both parts of the present study. Thus, it is more likely that conditioning, rather than elicitation, accounted for the increase in vocalization rate. Further, the mean rates of window opening during noncontingent and delayed reinforcement schedules in Experiment 2 were nearly equal, again suggesting that elicitation is not a plausible explanation of the results. Without the measurement of the rate of reinforcer delivery in all conditions, it would not be possible to determine the likelihood of elicitation effects. Comparison conditions in which there is no stimulation are inappropriate for use with schedules of reinforcement because one is merely comparing stimulation and no stimulation, rather than comparing noncontingent and contingent reinforcement, or two different contingencies (Poulson & Nunes, 1984). In addition, with the exception of the Reeve, et al. (1992) study, the infant literature on delayed reinforcement does not present information on the amount of reinforcement delivered in the various experimental conditions in these studies, and therefore, one cannot rule out elicitation effects when delayed reinforcement is demonstrated.

Another procedural issue concerns the response measure. The definition of the target response must be fully operationalized. In the present study, vocalization, exclusive of crying, was the target response. Because it is possible for an infant to cry more in one condition than another, and to do so systematically, it was necessary to measure crying as well as vocalization to make sure that crying was not counted as vocalization in one condition and not in another. In the present study, with the exception of 1 infant in Experiment 1, crying did not vary systematically by experimental condition. In most of the infant literature on delayed reinforcement, measures of non-target responses that may effect the obtained frequency of target responding are not reported.

Although discriminative stimuli (S^Ds) were not used in the present experiment to signal the delay period, the animal literature suggests that longer delays may warrant the use of such signals for effective conditioning, at least during initial training (Ferster & Hammer, 1953; Richards, 1981; Schall & Branch, 1988; Schall & Branch, 1990). As in the experiments conducted by Schall and Branch (1988; 1990), an S^D may be used during the entire delay period initially, and then the researcher may choose to gradually fade the amount of time signaled during the delay.

As a minor point, it might be noted that the comparison between observation-only and DRO schedules in an alternating treatment design yielded no systematic differences in response rate. We believe this is due to a floor effect because response rates during observation-only were low.

It seems clear that conditioning in infants under a range of delayed contingencies can occur. To facilitate this phenomenon, however, a control condition must be carefully chosen and analyzed, the contingencies must be presented repeatedly over time, and discriminative stimuli, such as signal lights, may be needed initially during a delay period exceeding 5 s.

Table 1

Number of 3-min Components per Session for Each Infant in Experiment 1.

Session	Condition	No. of Components
Infant: Mark		
1	DRO	3
2	DRO	2
3	DRO	2
4	DELAY	4
5	DELAY	3
6	DRO	2
7	DRO	2
Infant: Jason		
1	DRO	1
2	DRO	3
3	DRO	4
4	DRO	4
5	DRO	4
6	DELAY	3
7	DELAY	4
8	DELAY	4
9	DELAY	3
10	DELAY	3

(Table 1 continued)

11	DRO	4
12	DRO	2
13	DRO	3
14	NONCONTINGENT	3
15	NONCONTINGENT	4
16	NONCONTINGENT	2
17	NONCONTINGENT	4
18	DELAY	3
19	DELAY	4
20	DELAY	4
21	DELAY	4
22	NONCONTINGENT	4
23	NONCONTINGENT	4
24	NONCONTINGENT	4
25	NONCONTINGENT	2

Infant: Adam

1	DRO	4
2	DRO	3
3	DELAY	4
4	DELAY	2
5	DELAY	4
6	DELAY	2
7	DRO	4
8	DRO	2

(Table 1 continued)

9	DRO	2
10	NONCONTINGENT	3
11	NONCONTINGENT	4
12	NONCONTINGENT	3
13	DELAY	2
14	DELAY	4
15	DELAY	4
16	DELAY	4
17	NONCONTINGENT	4
18	NONCONTINGENT	4
19	NONCONTINGENT	4

Table 2

Percentage of 5-s Intervals Containing Crying in Each Condition for All Infants in Experiment 1.

	Condition					
Infant	DRO1	Delay1	DRO2	Noncont1	Delay2	Noncont2
Mark	15	7	21	--	--	--
Jason	3	2	12	7	2	12
Adam	14	6	4	0	9	12

Table 3

Number of 3-min Components per Session for Each Infant in Experiment 2.

Session	Condition	No. of Components
Infant: Stacey		
1	MULTIELEMENT	4
2	MULTIELEMENT	4
3	MULTIELEMENT	1
4	DELAY	3
5	DELAY	4
6	MULTIELEMENT	2
7	MULTIELEMENT	4
8	MULTIELEMENT	3
9	DELAY	4
10	DELAY	3
Infant: Chris		
1	MULTIELEMENT	3
2	MULTIELEMENT	2
3	MULTIELEMENT	2
4	MULTIELEMENT	4
5	MULTIELEMENT	3
6	DELAY	4
7	DELAY	4

(Table 3 continued)

8	DELAY	4
9	MULTIELEMENT	4
10	MULTIELEMENT	4
11	DELAY	3
12	DELAY	4

Infant: Arlene

1	MULTIELEMENT	4
2	MULTIELEMENT	4
3	MULTIELEMENT	4
4	MULTIELEMENT	4
5	MULTIELEMENT	4
6	DELAY	4
7	DELAY	3
8	DELAY	3
9	MULTIELEMENT	4
10	MULTIELEMENT	4
11	MULTIELEMENT	4
12	MULTIELEMENT	4
13	DELAY	2
14	DELAY	3
15	DELAY	2

Table 4

Percentage of 7-s Intervals Containing Crying in Each Condition for All Infants in Experiment 2.

	Condition					
Infant	DRO1	Obs1	Delay1	DRO2	Obs2	Delay2
Stacey	2	0	8	0	4	0
Chris	3	6	3	0	0	6
Arlene	13	3	3	9	1	14

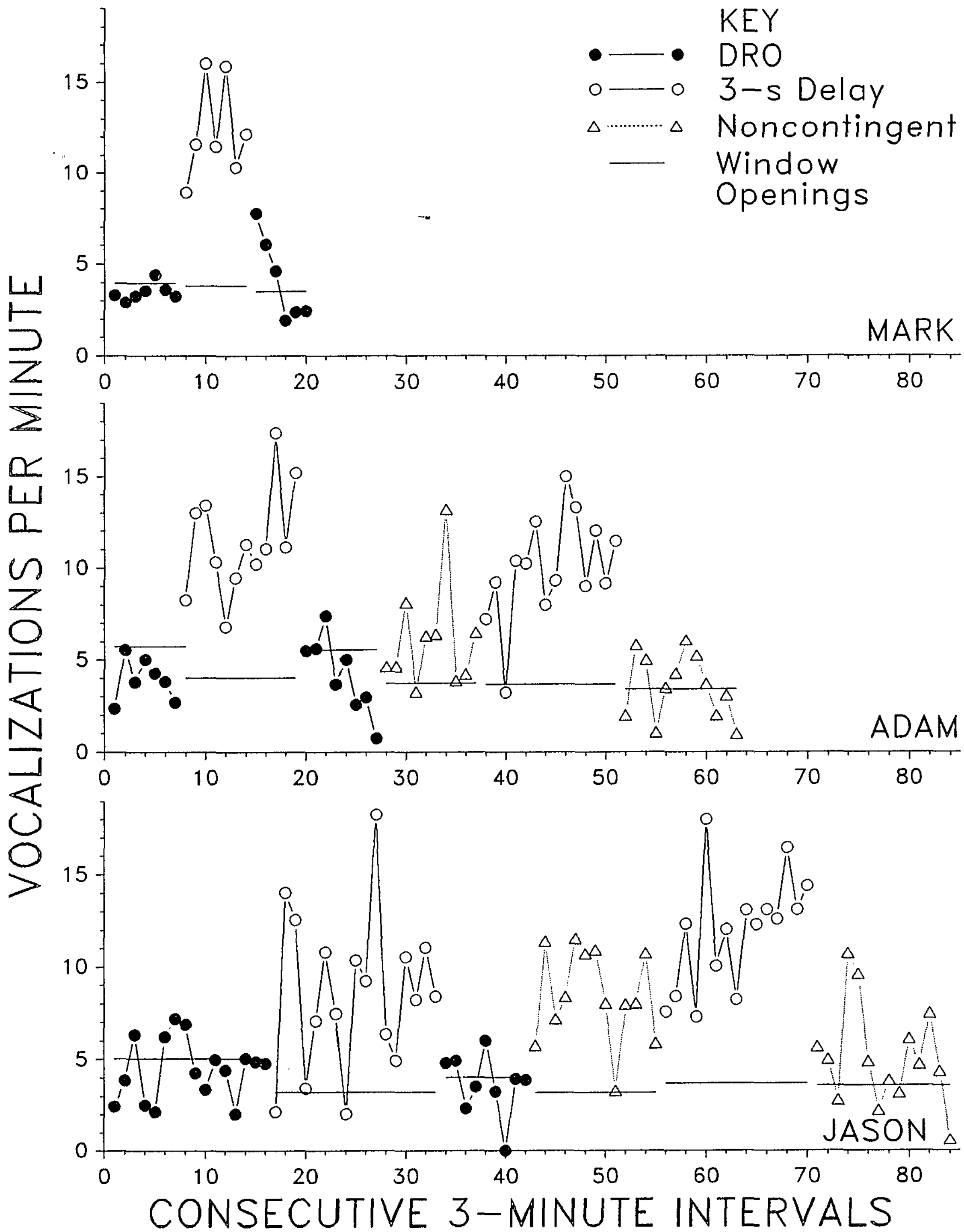
Figure Captions

Figure 1. Rate of vocalization in Experiment 1 by Mark, Jason, and Adam and the mean rate of window-blind opening for consecutive 3-min intervals in the differential-reinforcement-of-other-than-vocalizations (DRO) condition, the unsignaled 3-s delayed-reinforcement condition, and the noncontingent reinforcement condition in a single-subject reversal design.

Figure 2. This is an analysis of the obtained reinforcement patterns in Experiment 1. Percentage of window-blind openings following infant vocalization within 5 s and percentage of window-blind openings not preceded by infant vocalization for Mark, Jason, and Adam for consecutive 3-min intervals in the differential-reinforcement-of-other-than-vocalizations (DRO) condition, the noncontingent reinforcement condition, and the unsignaled 3-sec delayed-reinforcement condition in a single-subject reversal design.

Figure 3. Rate of vocalizations in Experiment 2 by Stacey, Chris, and Arlene, and the mean rate of window-blind opening for consecutive 3-min intervals during the multielement baseline and the unsignaled 5-s delayed reinforcement condition in a single-subject reversal design. The multielement baseline consisted of alternating 3-min components of differential-reinforcement-of-other-than-vocalizations (DRO) and observation-only.

Figure 4. This is an analysis of the obtained reinforcement patterns in Experiment 2. Percentage of window-blind openings following infant vocalization within 7 s of window-blind openings not preceded by infant vocalization for Stacey, Chris, and Arlene for consecutive 3-min intervals in the differential-reinforcement-of-other-than-vocalizations (DRO) components of the multielement baseline, and the unsignaled 3-s delayed-reinforcement condition in a single-subject reversal design.


KEY
DRO
3-s Delay
Noncontingent
Window Openings
VOCALIZATIONS PER MINUTE
MARK
ADAM
JASON
CONSECUTIVE 3-MINUTE INTERVALS
0
5
10
15
20
30
40
50
60
70
80

<u>**Figure 1**</u>

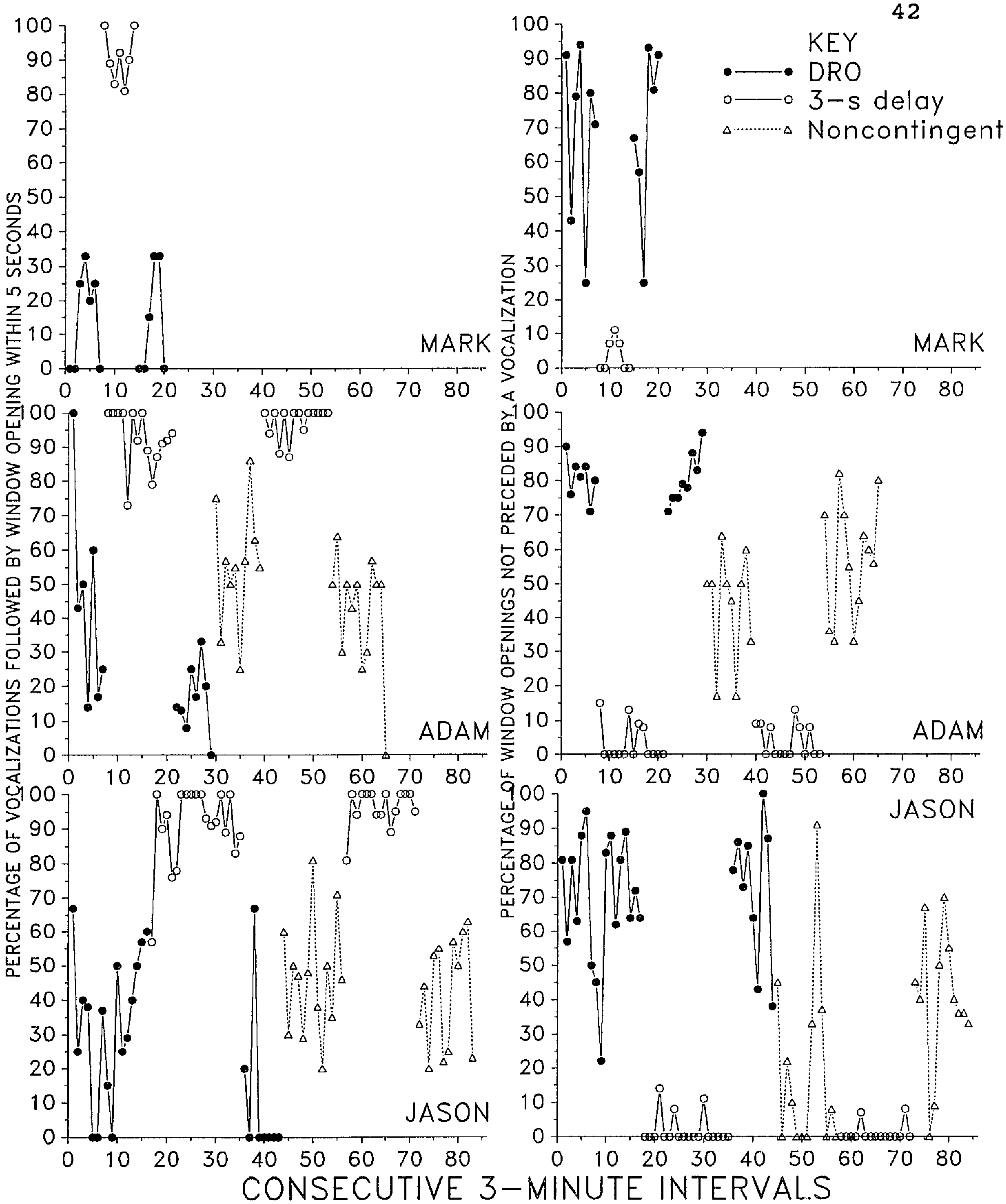

PERCENTAGE OF VOCALIZATIONS FOLLOWED BY WINDOW OPENING WITHIN 5 SECONDS
PERCENTAGE OF WINDOW OPENINGS NOT PRECEDED BY A VOCALIZATION
KEY
DRO
3-s delay
Noncontingent
MARK
ADAM
JASON
CONSECUTIVE 3-MINUTE INTERVALS

Figure 2

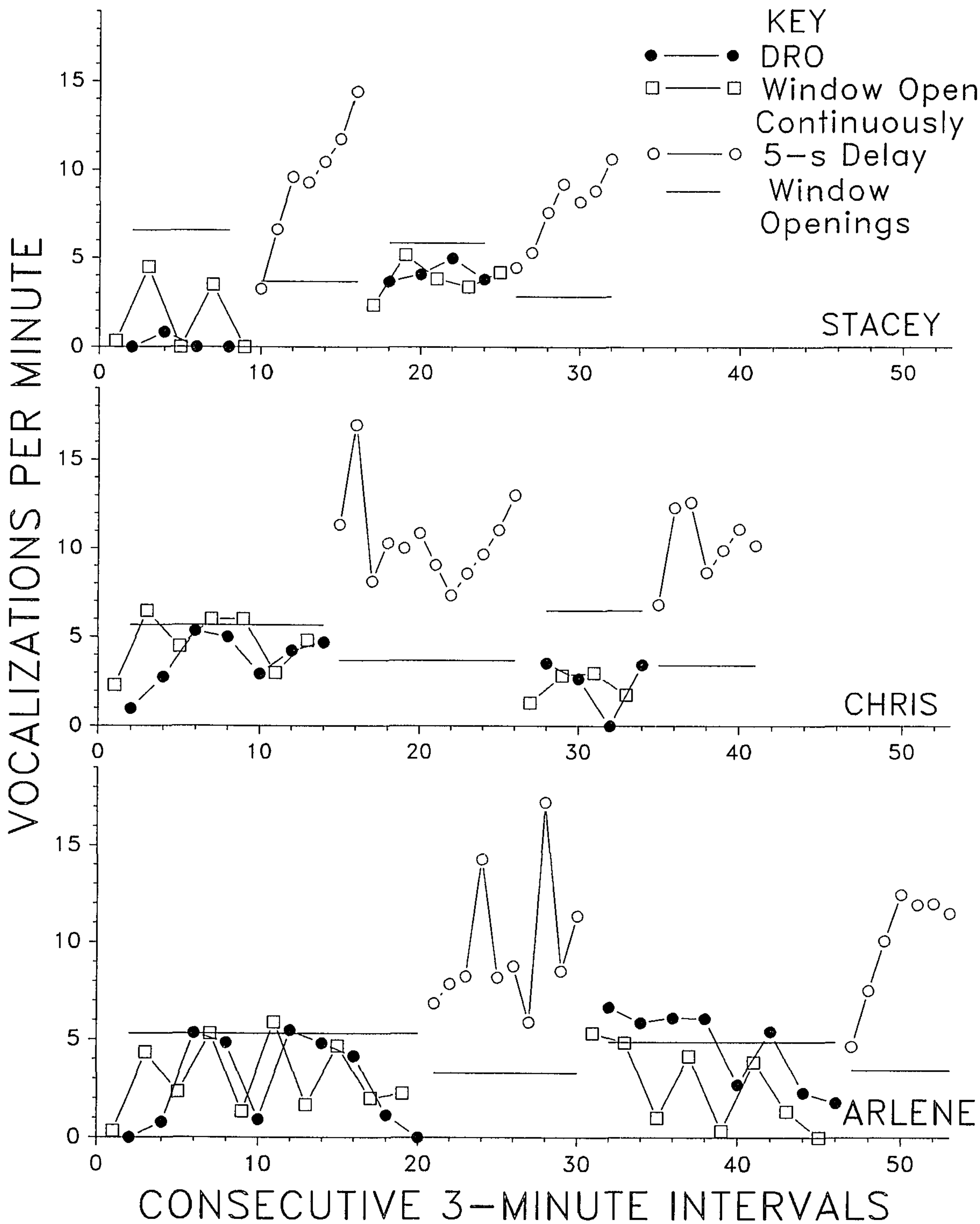

KEY
DRO
Window Open Continuously
5-s Delay
Window Openings
STACEY
CHRIS
ARLENE
VOCALIZATIONS PER MINUTE
CONSECUTIVE 3-MINUTE INTERVALS
0
5
10
15
20
30
40
50

Figure 3

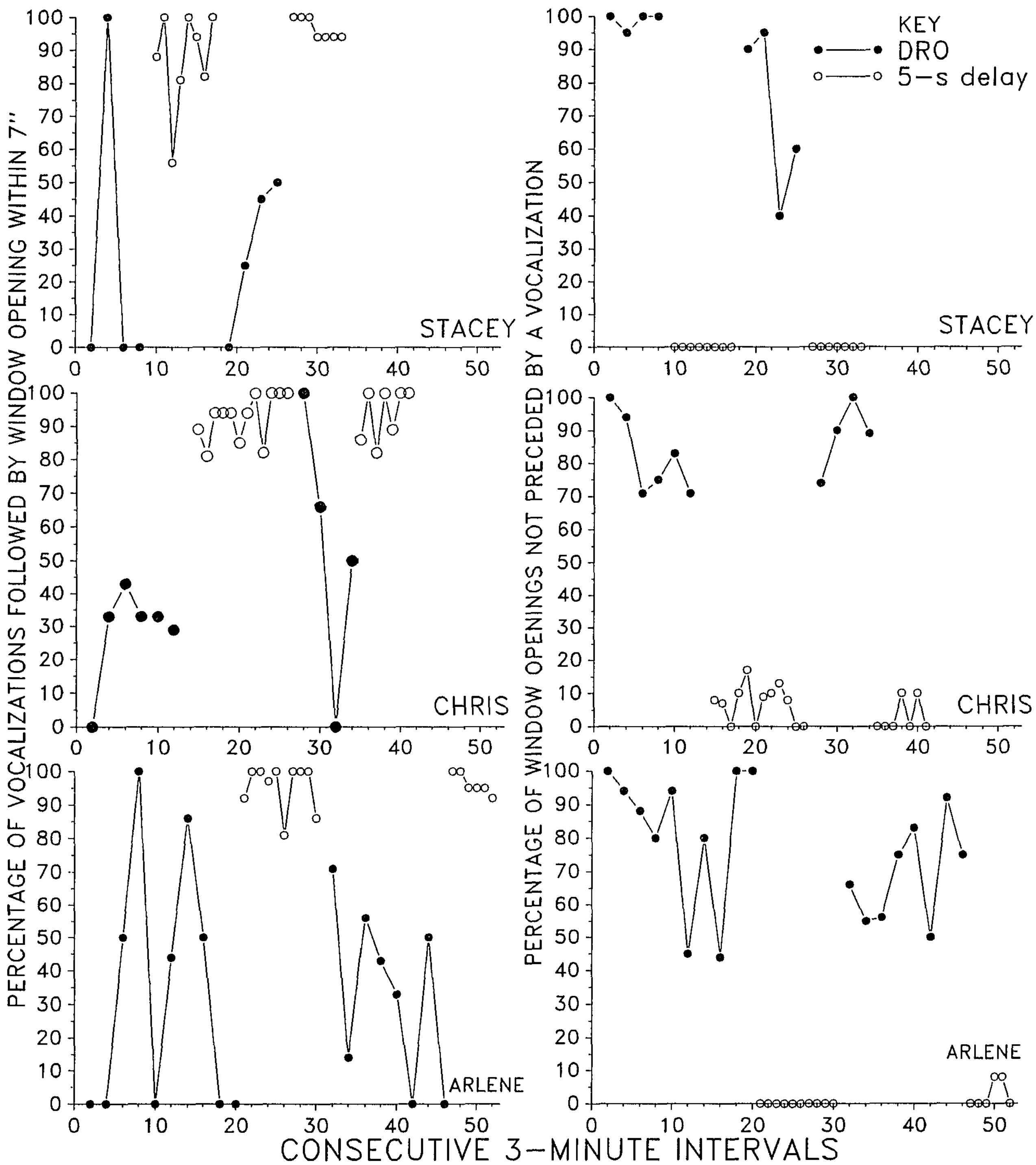

PERCENTAGE OF VOCALIZATIONS FOLLOWED BY WINDOW OPENING WITHIN 7"
PERCENTAGE OF WINDOW OPENINGS NOT PRECEDED BY A VOCALIZATION
KEY
DRO
5-s delay
STACEY
CHRIS
ARLENE
CONSECUTIVE 3-MINUTE INTERVALS

Figure 4

References

Azzi, R., Fix, D. S., Keller, F. S., & E Silva, M. I. (1961). Exterioceptive control of response under delayed reinforcement. Journal of the Experimental Analysis of Behavior, 7, 159-162.

Baer, R. A, Williams, J. A., Osnes, P. G., & Stokes, T. F. (1984). Delayed reinforcement as an indiscriminable contingency in verbal/nonverbal correspondence training. Journal of Applied Behavior Analysis, 17, 429-440.

Catania, A. C. (1984). Learning, Second Edition, NJ: Prentice Hall.

Dews, P. B. (1960). Free-operant behavior under conditions of delayed reinforcement. I. CRF-type schedules. Journal of the Experimental Analysis of Behavior, 3, 221-234.

Ferster, C. B. (1953). Sustained behavior under delayed reinforcement. Journal of Experimental Psychology, 45, 218-224.

Ferster, C. B., & Hammer, C. (1965). Variables determining the effects of delay in reinforcement. Journal of the Experimental Analysis of Behavior, 8, 243-254.

Fowler, S. A., & Baer, D. M. (1981). "Do I have to be good all day?" The timing of delayed reinforcement as a factor in generalization. Journal of Applied Behavior Analysis, 14, 13-24.

Gleeson, S., & Lattal, K. A. (1987). Response-reinforcer relations and the maintenance of behavior. Journal of the Experimental Analysis of Behavior, 48, 383-393.

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

Lattal, K. A. (1974). Combinations of response-reinforcer dependence and independence. Journal of the Experimental Analysis of Behavior, 22, 357-362.

Millar, W. S. (1972). A study of operant conditioning under delayed reinforcement in early infancy. Monographs of the Society for Research in Child Development, 32, (2, Serial No. 147).

Millar, W. S., & Watson, J. S. (1979). The effect of delayed feedback on infant learning re-examined. Child Development, 50, 747-751.

Pierce, C. H., Hanford, P. V., & Zimmerman, J. (1972). Effects of different delay of reinforcement procedures on variable-interval responding. Journal of the Experimental Analysis of Behavior, 18, 141-146.

Poulson, C. L. (1983). Differential reinforcement of other-than-vocalization as a control procedure in the conditioning of infant vocalization rate. Journal of Experimental Child Psychology, 36, 471-479.

Poulson, C. L., & Nunes, L. R. P. (1988). The infant vocal conditioning literature: A theoretical and methodological critique. Journal of Experimental Child Psychology, 46, 438-450.

Ramey, C. T., & Ourth, L. L. (1971). Delayed reinforcement and vocalization rates of infants. Child Development, 42, 291-297.

Reeve, L., Reeve, K. F., Brown. A. K., Brown, J. L., & Poulson, C. L. (1992). Effects of delayed reinforcement on infant vocalization rate. Journal of the Experimental Analysis of Behavior, 58, 1-8.

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

Richards, R. W. (1981). A comparison of signaled and unsignaled delay of reinforcement. Journal of the Experimental Analysis of Behavior, 35, 145-152.

Schaal, D. W., & Branch, M. N. (1988). Responding of pigeons under variable-interval schedules of unsignaled, briefly signaled, and completely signaled delays to reinforcement. Journal of the Experimental Analysis of Behavior, 50, 33-54.

Schaal, D. W., & Branch, M. N. (1990). Responding of pigeons under variable-interval schedules of signaled delayed reinforcement: Effects of delay-signal duration. Journal of the Experimental Analysis of Behavior, 53, 103-121.

Sizemore, O. J., & Lattal, K. A. (1977). Dependency, temporal contiguity, and response-independent reinforcement. Journal of the Experimental Analysis of Behavior, 25, 119-125.

Tarpy, R. M., & Sawabini, F. L. (1974). Reinforcement delay: A selective review of the last decade. Psychological Bulletin, 81, 984-997.

Williams, B. A. (1976). The effects of unsignaled delayed reinforcement. Journal of the Experimental Analysis of Behavior, 26, 441-449.

Wolfe, J. B. (1934). The effect of delayed reward upon learning in the white rat. Comparative Psychology, 17, 1-21.