# EVALUATIONS OF DELAYED REINFORCEMENT IN CHILDREN WITH DEVELOPMENTAL DISABILITIES

By

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To my parents, who taught me to value education and enjoy life

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LIST OF ABBREVIATIONS

| | |
|---|---|
| DD | Developmental Disability; Characterized by below-average scores on tests of mental ability and limited daily living skills (e.g., communication) |
| DRO | Differential Reinforcement of Other Behavior; Reinforcement provided contingent on the absence of problem behavior for a pre-specified interval |
| FI | Fixed Interval; Reinforcement provided for the first response following a constant period of time |
| FR | Fixed Ratio; Reinforcement provided following the last of a constant number of responses |
| IRI | Interreinforcement Interval; Time between successive reinforcer deliveries |
| ITI | Intertrial Interval; Time between the consumption of the reinforcer and the start of the next trial |
| $S^D$ | Discriminative Stimulus; Stimulus that signals that a particular response will produce reinforcement |
| $S^\Delta$ | S-Delta; Stimulus that signals that a particular response will not produce reinforcement |
| PT | Progressive Time; Schedule of reinforcement in which reinforcers are delivered following progressively increasing delays |
| VI | Variable Interval; Schedule of reinforcement in which reinforcement is provided for the first response following an average period of time |
| VT | Variable Time; Schedule of reinforcement in which reinforcement is provided, independent of responding, following an average interval of time |

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It is commonly recommended that reinforcers be provided immediately after behavior to establish or maintain responding (e.g., Miltenberger, 2008). These recommendations are usually provided in the absence of supporting empirical work, which is unfortunate because several laboratory experiments have found that delayed reinforcement can produce response acquisition and maintenance (e.g., Lattal & Gleeson, 1990). Relatively fewer studies with humans have isolated the effects of unsignaled, delayed reinforcement. Fewer still have evaluated unsignaled, delayed reinforcement in children with developmental disabilities (DD). Thus, the general purpose of the following experiments was to (a) examine whether delayed reinforcement could produce response maintenance in children with DD during an operant arrangement, (b) examine whether delayed reinforcement could produce discrimination acquisition in children with DD, (c) examine some of the variables that may affect the efficacy of delayed reinforcement in children with DD, and (d) examine one variable that may account for situations in which delayed reinforcement prevents acquisition. We found that delayed reinforcement produced response maintenance during three human operant arrangements. In addition, we found that 20-, 30-, and 40-s

delays to reinforcement lead to discrimination acquisition for the majority of subjects. The availability of identical responses during the delay did not prevent response maintenance for 2 out of 3 subjects or discrimination acquisition for 2 out of 3 subjects. For 1 out of 2 subjects, discrimination acquisition was hindered when the number of responses targeted during each session was increased. These results suggest that delayed reinforcement can produce acquisition and maintenance under specific conditions. In addition, we found that longer intertrial intervals (time between delivery of a reinforcer and the presentation of the next trial) most likely do not account for cases in which discrimination acquisition fails to occur under conditions of delayed reinforcement.

# CHAPTER 1
# INTRODUCTION

## Recommendations About the Necessity of Reinforcement Immediacy

Several notable textbooks recommend that reinforcers be provided immediately following a response to establish or maintain behavior (e.g., Miltenberger, 2008; Skinner, 1953). Skinner noted, “The reinforcement which develops skills must be *immediate*. Otherwise, the precision of the differential effect is lost.” (p.96) Likewise, Catania (2007) noted, “with both positive and negative reinforcement, immediate reinforcement is more effective than delayed reinforcement.” (p.99) Given these types of recommendations, it is not surprising that the temporal proximity between a response and a reinforcing event has been considered to be one of the most important parameters of reinforcer efficacy (Williams, 1976). Nevertheless, results from several experiments suggest that delayed reinforcement can produce response acquisition and maintenance under some conditions.

## Laboratory Studies of Delayed Reinforcement

### A Summary of Laboratory Studies

Researchers have evaluated both signaled delays to reinforcement, which program a stimulus change immediately following a response, and unsignaled delays to reinforcement, which do not program a stimulus change following a response. Due to their pairing with delayed reinforcement, stimulus changes may begin to function as conditioned reinforcers and supplement the effects of delayed reinforcement with immediate reinforcement. Laboratory studies have found that both signaled and unsignaled delays to reinforcement can produce response acquisition (e.g., Critchfield & Lattal, 1993; Lattal & Gleeson, 1990) and maintenance (e.g., Gleeson & Lattal, 1987;

Schaal & Branch, 1988). Some of these studies program resetting delays, in which every response that occurs during the delay resets the delay interval, ensuring that obtained delays to reinforcement match programmed delays. Resetting contingencies do not allow experimenters to isolate the effects of delayed reinforcement independent of a differential reinforcement of other behavior (DRO) contingency, which requires that a given amount of time elapse since the last response before a reinforcer can be delivered. Thus, many researchers program nonresetting delays in which responses that occur during the delay do not have programmed consequences. Lattal and Gleeson found that unsignaled, nonresetting 30-s and resetting 10-s delays produced response acquisition in pigeons, and that unsignaled, resetting 10-s or 30-s delays produced response acquisition in rats.

**Innovative Methods Used to Evaluate Delayed Reinforcement**

Given the wealth of basic research on delayed reinforcement, it is not surprising that several procedural advances have been made. These advances allow researchers to isolate the effects of delayed reinforcement. Although concurrent arrangements, in which two or more responses are available and proportional responding is measured, can be used to study *relative* preference for immediate reinforcement over delayed reinforcement (e.g., Dixon, Horner, & Guercio, 2003), single-operant arrangements, in which only one response is available, provide information about the *absolute* effects of delayed reinforcement, and several laboratory experiments have used such arrangements (e.g., Critchfield & Lattal, 1993).

Basic researchers have also created procedures that rule out the effects of (a) reinforcement rate, (b) immediate conditioned reinforcement, and (c) adventitious reinforcement. When delayed reinforcement conditions are compared with immediate reinforcement conditions, it is often the case that at least two variables differ between conditions: (a) the time between a response and a reinforcer, and (b) reinforcement rate (with delayed reinforcement sessions associated with lower rates of reinforcement). To rule out decreases in reinforcement rate as a confounding variable, reinforcement rate must be equated across delayed reinforcement and immediate reinforcement conditions. Researchers have done this by yoking interreinforcement intervals (IRI; intervals of time between successive reinforcer deliveries) in each immediate reinforcement session to IRI obtained during each preceding delayed reinforcement session (e.g., Reilly & Lattal, 2004). Researchers have also eliminated the effects of immediate, conditioned reinforcement by programming *unsignaled* delays to reinforcement that do not include a stimulus change following a response (e.g., Lattal & Gleeson, 1990). Finally, the effects of adventitious reinforcement can be ruled out by imposing a resetting, or DRO, contingency so that responses cannot occur in temporal proximity to reinforcement (e.g., Lattal & Gleeson).

In addition to these advances, a procedure used by Reilly and Lattal (2004) allows researchers to examine the effects of multiple delays within a single session. Reilly and Lattal programmed chained schedules, in which a reinforcer was delivered following the successive completion of two component schedules, each of which operated in the presence of a different stimulus, and tandem schedules, in which a reinforcer was delivered following the successive completion of two components schedules, each of which operated in the presence of the same stimulus. These schedules incorporated variable interval (VI) components, in which the first response after an average interval of time elapsed resulted in reinforcement or the presentation of the next component schedule, fixed interval (FI) components, in which the first response after a fixed interval of time elapsed resulted in reinforcement or the presentation of the next component schedule, and progressive time (PT) components, in which reinforcers were delivered following progressively increasing intervals of time, regardless of behavior occurring during that time. Progressive time intervals increased by 2 s following each reinforcer delivery. More specifically, Reilly and Lattal programmed a tandem VI 30-s – PT 2-s schedule of reinforcement, a tandem FI 30-s – PT 2-s schedule of reinforcement, and a chained VI 30-s – PT 2-s schedule of reinforcement. These arrangement allowed the researchers to examine response rates as a function of several different delays within a single session.

Finally, laboratory studies have evaluated the effects of delayed reinforcement on discriminated responding (i.e., differential responding that is the result of different contingencies in place for different response alternatives) by comparing response rates on both reinforcement and no-consequence operandi (e.g., Escobar & Bruner, 2007; Keely, Feola, & Lattal, 2007; Sutphin, Byrne, & Poling, 1998). For example, Sutphin et al. examined the effects of unsignaled 8-, 16-, 32-, and 64-s delays to reinforcement on the response distribution of eight rats when reinforcers were delivered on a fixed ratio (FR) 1 schedule following every response. They found that all subjects were more likely to respond on the reinforcement lever relative to the no-consequence lever when the delay to reinforcement was small (i.e., 0 or 8 s). However, rates of responding on each lever became more similar (i.e., discriminated responding was lost) as delays to reinforcement increased.

In summary, basic research has isolated the effects of delayed reinforcement and developed methods to control for a range of potentially confounding variables. Unfortunately, there have been relatively fewer studies with humans that isolate the effects of unsignaled, delayed reinforcement.

## The Effects of Delayed Reinforcement on Human Behavior

Applied studies of delayed reinforcement typically do not isolate delay to reinforcement as an independent variable. Instead, applied studies generally focus on identifying methods that can be used to shift response allocation to those responses that produce delayed reinforcement (e.g., Vollmer, Borrero, Lalli, & Daniel, 1999), or on methods that can be used to bridge the delay to reinforcement (e.g., Schwarz & Hawkins, 1970; Terrell, 1958). Schwarz and Hawkins used delayed reinforcement during a DRO procedure to reduce problematic behavior exhibited by a 12-year-old girl. In this procedure, the subject viewed a video recording of her behavior during a mathematics period that had taken place 1 to 5 hr beforehand. During this time, tokens, exchangeable for larger items, were delivered contingent on the absence of target responses. The researchers found that this procedure produced long-lasting decreases in three target responses. Although these results suggest that delayed reinforcement is effective, it is unclear whether delayed reinforcement would have been effective had the subject not been allowed to view the video recording of her previous behavior. In addition, in studies in which delayed reinforcement is combined with instructions about the contingencies (e.g., Erickson & Lipsitt, 1960; Okouchi, 2009; Rieber, 1961), it is unclear whether delayed reinforcement would be effective in the absence of instructions.

In addition, it is difficult to interpret the results of many applied studies of delayed reinforcement, as these studies have several potential flaws. These potential flaws have included the lack of single subject data, making it difficult to evaluate the effects of delayed reinforcement on individual behavior (e.g., Brackbill & Kappy, 1962; Erickson & Lipsitt, 1960; Millar & Watson, 1979), the absence of any raw data (e.g., Terrell & Ware, 1961; Ware & Terrell, 1961), the inclusion of dependent variables that were not clearly defined (e.g., Brackbill & Kappy), brief analyses (e.g., Hockman & Lipsitt, 1961; Millar & Watson) that may not have allowed response rates to stabilize (Reeve, Reeve, & Poulson, 1993), the use of group comparisons with small groups that may not be similar prior to the introduction of the independent variable (e.g., Okouchi, 2009), the absence of a baseline condition (e.g., Rieber, 1961), and the inclusion of DRO contingencies (e.g., Millar, 1972; Okouchi), which can sometimes create conditions of partial reinforcement only in the delayed reinforcement condition (Millar & Watson).

## Variables that May Influence Delayed Reinforcement

Evaluating the effects of delayed reinforcement on the behavior of individuals with developmental disabilities (DD) is difficult, as the effects of delayed reinforcement may depend on several variables, including (a) the duration of the delay, (b) the schedule of reinforcement, (c) whether responses occur during the delay, and (d) the number of alternatives targeted at one time. In addition, it is possible that any disruption in responding associated with delayed reinforcement is due to increases in the duration of the intertrial interval (ITI; time between consumption of a reinforcer and the presentation of the next trial), rather than the delay.

### Delay Duration

Response rate, speed of acquisition, and whether acquisition occurs at all can all depend on the duration of the delay to reinforcement. Several studies with non-human animals have found a decreasing, negatively accelerating relationship between response rate and increases in the delay to reinforcement (e.g., Fowler & Trapold, 1962; Reilly & Lattal, 2004). In addition, speed of acquisition by non-humans has been found to vary as a function of delay duration (e.g., Williams, 1998). Finally, some researchers have found that larger (e.g., 64-s) delays impede response acquisition, while smaller (e.g., 32-s) delays do not (e.g., Dickinson, Watt, & Griffiths, 1992). Collectively, these results suggest that delay duration is an important variable to consider when evaluating the effects of delayed reinforcement on response acquisition and maintenance. Little is known about the effects of different delay durations on responding of children with DD.

### Reinforcement Schedule

Reinforcement schedules have well documented effects on behavior (Ferster & Skinner, 1957). In addition, the delay to reinforcement has been found to interact with the reinforcement schedule. In studies with rats, Skinner (1938) found that delayed reinforcement interfered with response acquisition when a FI schedule of reinforcement was in place, but not when a continuous schedule of reinforcement was in place. Similar evaluations have yet to be conducted with children with DD.

### Responses During the Delay

Responses that occur during the delay may influence the efficacy of delayed reinforcement. Sidman (1960) noted, "Whenever a delay occurs between the recorded behavior and its programmed consequence, we can be sure that the period of delay is not empty. Some behavior is taking place all the time, and even though such behavior is unrecorded it may still play a vital role in mediating the effects of the delay." (p. 371) Watson (1917) noted that behavior that occurs during the delay might become adventitiously reinforced by reinforcer delivery (i.e., the level of a response temporally contiguous with reinforcer delivery may increase even though a reinforcement contingency is not arranged for that response). Adventitious reinforcement of non-target responses may interfere with the acquisition or maintenance of target responses. Alternatively, Catania (1971) noted that, if a response is followed by a different response that is reinforced, the reinforcer might affect both responses even though its delivery is only dependent on the second one. This possibility has practical implications: Namely, "teachers must be alert for sequences in which a student's errors are followed by corrections, so that they don't strengthen incorrect responses along with the correct ones that they reinforce." (Catania, 2007, p.177). Thus, responses that occur either before or after responses for which a reinforcement contingency is arranged may become adventitiously reinforced. However, the extent to which adventitious reinforcement of nontarget responses interferes with the acquisition of the target response may depend on the length of the analysis, with longer analyses offsetting the effects of any adventitious reinforcement contingencies (Reeve, Reeve, Brown, Brown, & Poulson, 1992).

Indeed, researchers have found that the effects of adventitious reinforcement are not necessarily stable over long periods of time because other responses may become adventitiously reinforced or the response that was previously adventitiously reinforced may no longer contact reinforcement (e.g., Morse & Skinner, 1957; Williams & Lattal, 1999). Likewise, researchers (e.g., Lattal & Gleeson, 1990) have found that adventitious reinforcement of target responses that occur during the delay cannot account for response acquisition and maintenance under delayed reinforcement, as responses can be acquired when DRO contingencies ensure that the target response does not occur in close temporal proximity to reinforcer delivery. Despite the wealth of basic research on this phenomenon, less applied work has been done. Thus, more research on the effects of adventitious reinforcement of nontarget responses on the rate of target responses exhibited by individuals with DD is needed.

In addition, it is possible that the occurrence of intervening responses could weaken the contingency between the target response and the delayed consequence, regardless of whether intervening responses become adventitiously reinforced.

**Number of Alternatives Targeted at One Time**

Delayed reinforcement may be associated with different outcomes, depending on the number of alternatives targeted within a single evaluation (e.g., Hockman & Lipsitt, 1961). Hockman and Lipsitt examined the effects of unsignaled 0-, 10-, and 30-s delays to reinforcement on rate of discrimination acquisition (i.e., engagement in a particular response in the presence of one stimulus and a different response in the presence of a different stimulus, such that percent correct meets or exceeds a pre-established criterion) of school-aged children during conditional discrimination training (i.e., reinforcement is provided contingent on engagement in one response in the presence of a particular stimulus, and engagement in a different response in the presence of a different stimulus) when either two or three alternatives were targeted. Hockman and Lipsitt taught subjects to press a particular button in the presence of an orange light and to press a different button in the presence of a green light. The researchers did not find significant differences in either the rate of learning or the mean number of correct responses over learning trials when two alternatives were targeted and 0-, 10-, or 30-s delays to reinforcement were programmed. However, when the number of alternatives was increased from two to three, conditions in which reinforcers were delivered following 10- or 30-s delays were associated with lower mean numbers of correct responses over learning trials and no acquisition. This study had several limitations: (a) data were averaged across subjects, (b) a maximum of 36 trials were conducted per subject, so it is unclear if additional trials would have facilitated acquisition, (c) "acquisition" was poorly defined, and (d) data were presented as the mean number of correct responses, even though the total number of responses may have varied across subjects. Thus, further evaluations of the effects of the number of response alternatives on the efficacy of delayed reinforcement are warranted.

**Intertrial Intervals**

Some research suggests that increases in ITI are responsible for decreases in response rate associated with conditions in which reinforcement is delivered following a delay (e.g., Bilodeau & Bilodeau, 1958). This finding, however, is not robust. Although Saltzman, Kanfer, and Greenspoon (1955) found that a delayed reinforcement condition that involved increases in the duration of the ITI relative to the immediate reinforcement condition did not produce differences in the accuracy in which undergraduate students drew a 3-in line, Denny, Allard, Hall, and Rokeach (1960) hypothesized that increases in ITI duration may hinder acquisition if subjects do not know what the target response is. In summary, the finding that longer ITI are associated with decreases in response rate is not robust, and more research is needed in this area.

## General Purpose

This series of experiments will determine whether the findings from basic research translate to the behavior of children with DD during an operant arrangement and during conditional discrimination training. In addition, this series of studies will examine some factors that may affect the efficacy of delayed reinforcement during these arrangements. Both arrangements employed trial-based procedures that allowed us to control and measure the types of responses that could occur during the delay (i.e., subjects could only make a single correct response or a single incorrect response).

# CHAPTER 2
# HUMAN OPERANT EVALUATIONS OF DELAYED REINFORCEMENT

## Purpose

The purpose of the following experiments was to evaluate whether the findings from basic research translated to the behavior of school-aged individuals with DD during an operant arrangement. With individuals with DD as subjects, we sought to evaluate whether (a) progressively-increasing delays to reinforcement (i.e., delays that increased by a fixed amount following successive reinforcer deliveries) would produce response maintenance, (b) response rates would decrease as delays to reinforcement increased, and (c) delayed reinforcement would maintain discriminated responding. In addition, we sought to evaluate whether the availability of "correct" and "incorrect" responses during the delay would disrupt responding.

## General Methods

### Subjects and Setting

Subjects were 3 preschool-aged children who were diagnosed with DD and who had limited verbal repertoires. These subjects were recruited from a local elementary school. Vlade was a 4-year-old boy diagnosed with Autism Spectrum Disorder (ASD). Alice was a 4-year-old girl diagnosed as developmentally delayed, specifically in the area of language. Walden was a 4-year-old boy diagnosed with ASD. All subjects fell below the normal range of functioning in the areas of receptive and expressive communication on the Battelle Developmental Inventory, which was administered by the pre-Kindergarten school psychologist.

All sessions were conducted in a common area at the subjects' school. The subjects sat in a chair in front of a touch screen monitor that was placed on a table approximately 6 in in front of them.

**Target Responses**

The target responses consisted of contact between part of the subject's body (usually his or her hand) and one of two squares depicted on the touch screen monitor. During each session, responses on one square (the discriminative stimulus, or $S^D$; stimulus in the presence of which responses could be reinforced) were considered to be "correct" and responses on the opposite square (the s-delta, or $S^\Delta$; stimulus in the presence of which responses were never reinforced) were considered to be "incorrect." A computer program designed using VB.NET automatically recorded each subjects' responses in real time.

**Procedure**

During each experiment, a delayed reinforcement condition was alternated with an immediate reinforcement condition. During both conditions, subjects sat in front of a touch screen monitor that depicted two different squares. The color of the squares (Vlade and Alice) or the pictures displayed in the squares (Walden) varied from session to session and, at the start of each session, one color or picture was randomly designated as the $S^D$ while the other color or picture was randomly designated as the $S^\Delta$. Stimuli changed from session to session to eliminate the effects of history on responding. During each session, the location of the $S^D$ and $S^\Delta$ was randomized across trials. "Correct" responses could result in the delivery of small edible items (e.g., half a fruit snack) or 30 s of access to an iPod, whereas "incorrect" responses never resulted in reinforcement. The experimenter sat next to the touch screen, and did not interact with the subject, unless an auditory sound from the touchscreen prompted the experimenter to deliver a reinforcer. The experimenter attempted to remain neutral throughout each session, minimizing cues that might have indicated whether a response was "correct." Vlade and Alice received edible items, whereas Walden, due to severe food allergies, received access to an iPod. These items were identified as reinforcers during a previous reinforcer test in which a reversal design was used to evaluate the reinforcing efficacy of the iPod or the edible items when a concurrent schedule of reinforcement was in place (i.e., two schedules of reinforcement operated simultaneously, but independently, for two different responses). During each session of the evaluation, a blue square and a white square were depicted on the monitor, and the position of the squares was randomized across trials. During one condition (A), every response to the blue square resulted in the immediate delivery of either the iPod or a small edible item on a fixed ratio (FR) 1 schedule, whereas responses to the white square did not result in differential consequences. During the second condition (B), every response to the white square resulted in the immediate delivery of either the iPod or a small edible item on a FR 1 schedule, whereas responses to the blue square did not result in differential consequences. Conditions were alternated in a ABAB reversal design. A reinforcement effect occurred when subjects allocated more responding to the stimulus that produced reinforcement during a given condition.

At the very beginning of Experiment 1A, the experimenter prompted subjects to touch both squares to ensure they contacted the contingencies associated with either response. From that point on, additional prompting was not provided. However, at the start of every session, subjects contacted ten forced-exposure trials in which reinforcers were delivered immediately on a FR 1 schedule contingent on responses to the $S^D$. Responses to the $S^\Delta$ during these trials did not result in reinforcement. Forced exposure trials were programmed to ensure that subjects would acquire the discrimination prior to an assessment of response maintenance under either immediate or delayed reinforcement. Within-session analyses (i.e., comparisons of percent “correct” during the first five and last five trials) suggested that subjects generally acquired the discrimination during this period.

Sessions in which reinforcers were delivered following progressively increasing delays were alternated with yoked control sessions that controlled for reinforcement rate by delivering reinforcers immediately on either a ratio schedule (Experiment 1A) or an interval schedule (Experiments 1B and 1C) yoked to the obtained IRI of each previous delayed reinforcement session. Although the goal was to compare the effects of immediate reinforcement with delayed reinforcement while controlling reinforcement rate, obtained reinforcement rates were generally lower in the immediate reinforcement condition relative to the delayed reinforcement condition.

Delayed reinforcement sessions continued until a maximum delay of 120 s was reached or until subjects did not respond for three times the maximum pause in responding observed during the previously described reinforcer test. This amounted to 84 s, 150 s, and 51 s for Vlade, Alice, and Walden, respectively. The duration of each immediate reinforcement session was yoked to the duration of each preceding delayed reinforcement session.

One session was conducted per day, three to five days per week, depending on subject availability.

## Experiment 1A: Procedure

During the delayed reinforcement condition of Experiment 1A, a chained FR 1 – PT 5- or 10-s schedule of reinforcement was in effect. Each response to the $S^D$ initiated the PT terminal link, during which stimuli were removed from the screen. The duration of the terminal link increased by a 5 s (Vlade) or 10 s (Alice and Walden) following successive reinforcer deliveries, and reinforcers were delivered once the terminal link ended. A PT 5-s schedule was programmed for Vlade, the first subject in the Experiment. However, this schedule resulted in lengthy session durations of around 50 min, so a PT 10-s schedule was programmed for Alice and Walden to decrease total session time. Each response to the $S^\Delta$ also initiated the terminal link, the duration of which was equal to the duration of the terminal link during the previous trial. However, a reinforcer was not presented at the end of the interval. Following the terminal link, stimuli appeared on the screen following a brief ITI.

During the immediate reinforcement condition of Experiment 1A, a chained variable time (VT) - FR 1 schedule of reinforcement was programmed. A VT schedule is a schedule in which reinforcers (or, in this case, access to the terminal link) are delivered following an interval of time that varies from one reinforcer delivery to the next, irrespective of behavior. This schedule was programmed to keep the response requirement constant (FR 1) while making it more likely that reinforcement rate matched rates of reinforcement obtained during each preceding delayed reinforcement session. The intervals in the initial link were yoked to the IRI of the previous delayed reinforcement session. Stimuli were only present during the terminal link. During the terminal link, a “correct” response resulted in the immediate delivery of a small edible item or 30 s of access to an iPod and removal of the stimuli from the screen. An “incorrect” response only resulted in the removal of stimuli from the screen.

**Experiment 1A: Results and Discussion**

At the start of each session, subjects’ responses during the first 10 trials generally suggested that discriminations were acquired. Vlade selected the “correct” response 100% of the time during the last five trials prior to each delayed reinforcement session and 92.73% of the time (range, 80% - 100%) during the last five trials prior to each immediate reinforcement session. Alice selected the “correct” response 74.29% of the time (range, 20% - 100%) during the last five trials prior to each delayed reinforcement session and 77.14% of the time (range, 20% - 100%) during the last five trials prior to each immediate reinforcement session. Although Alice’s level of percent “correct” was low during some of these first 10 trials, there was not a relationship between levels of percent “correct” during the last five trials and levels of percent “correct” during subsequent delayed reinforcement ($R^2$ = .06) sessions. However, there was somewhat of a positive relationship between levels of percent “correct” during the last five trials and levels of percent “correct” during subsequent immediate reinforcement sessions ($R^2$ = .66). Walden selected the “correct” response 90.77% of the time (range, 60% - 100%) during the last five trials prior to each delayed reinforcement session and 93.85% of the time (range, 40% - 100%) prior to each immediate reinforcement session. Once again, although percent “correct” was low during some of these first 10 trials, there was not a relationship between percent “correct” during the last 5 trials and during subsequent delayed reinforcement ($R^2 < .01$) and immediate reinforcement sessions ($R^2$ = .03).

Response rates were calculated for each delayed reinforcement and immediate reinforcement session. Given that the arrangement used in both conditions was trial based, subjects could not respond freely and responding might have been better categorized in terms of latency (time between the presentation of stimuli and the first response). However, this would have made it difficult to analyze delay gradients, which are generated by analyzing the relationship between response rates and delays to reinforcement. In addition, this would have made it difficult to compare the results from Experiment 1A to the results of Experiments 1B and 1C, in which subjects were able to make multiple responses during each trial. Thus, we chose to examine response rates, which, in Experiment 1A, were the reciprocals of response latencies. Response rates obtained during Experiment 1A are depicted in Figure 2-1. During Experiment 1A, delayed reinforcement maintained lower response rates relative to immediate reinforcement. Response rates were only calculated for the period of time following the first 10 forced exposure trials. Response rate was calculated by dividing the number of “correct” responses by the total time in which it was possible to make a response. Thus, time in which stimuli were removed from the screen was not included in the calculations. Vlade engaged in an average of 12.57 responses per min during the immediate reinforcement condition (range, 10.60 – 15.29 responses per min) and an average of 4.58 responses per min in the delayed reinforcement condition (range, 3.62 – 5.89 responses per min). Alice engaged in an average of 10.29 responses per min during the immediate reinforcement condition (range, 3.50 – 21.80 responses per min) and an average of 3.04 responses per min in the delayed reinforcement condition (range, 1.57 – 6.15 responses per min). Walden engaged in an average of 26.10 responses per min in the immediate reinforcement condition (range, 14.04 – 33.00 responses per min) and an average of 14.26 responses per min in the delayed reinforcement condition (range, 2.86 – 24.83 responses per min).

Figure 2-2 displays mean response rates and predicted curves for each subject as a function of each delay to reinforcement. During Experiment 1A, mean response rates decreased as delays to reinforcement increased. Mean response rates for each delay were calculated by first computing the response rate during the time since the last trial. This was done by dividing the number of “correct” responses (either zero or one in Experiment 1A) by the total duration in which stimuli were available (i.e., time between the presentation of the stimuli and their subsequent removal following a response). Thus, if stimuli were present on the screen for 5 s prior to a “correct” response, then response rate for that particular delay was considered to be 12 responses per min (one response divided by 5 s, multiplied by 60 s). Within each session, response rates for each delay were averaged, even if reinforcers were not delivered at the end of the delay. Thus, if a “correct’ response was followed by an “incorrect” response, the delay would be equal for these responses, even though a reinforcer would only be delivered following the “correct” response. In these cases, response rates were calculated separately and then averaged. Response rates were then averaged across sessions as a function of each delay. It should be noted that more response rates were averaged into mean response rates during the smaller delays. This is because subjects did not contact high delays during sessions with low breakpoints. Thus, for Vlade, 11 sessions of data were averaged into each mean response rate for delays between 5 s and 60 s, 6 sessions of data were averaged into each mean response rate for delays between 65 s and 80 s, and 5 or fewer sessions of data were averaged into each mean response rate for delays between 90 s and 120 s. For Alice, 14 sessions of data were averaged into each mean response rate for delays between 10 s and 100 s, and 12 sessions of data were averaged into each mean response rate for 110-s and 120-s delays. For Walden, 25 sessions of data were averaged into each mean response rate for delays between 10 s and 60 s, 24 sessions of data were averaged into each mean response rate for delays between 70 s and 80 s, 23 sessions of data were averaged into each mean response rate for 90- to 110-s delays, and 21 sessions of data were averaged into the mean response rate for the 120-s delay. The relationship between mean response rate and delay to reinforcement was quantified using a modified version of Mazur's (1987) hyperbolic delay discounting equation:

$$B = B_I / (1 + kD)$$

Reilly and Lattal (2004) used this equation to predict response rate ($B$) as a function of each delay ($D$). The equation contains two free parameters, $B_I$ and $k$, which represent estimated rate of responding under immediate reinforcement and estimated degree of discounting due to increasing delays to reinforcement, respectively. $B_I$ and $k$ were estimated using Microsoft® Excel, which minimized the sum of squared deviations between the obtained values and the predicted curve.

Percent "correct" data for all 3 subjects are presented in Figure 2-3. Percentage of "correct" responses was calculated by dividing the number of "correct" responses by the total number of responses. Responses from the first 10 forced-exposure trials were not included in these calculations. Vlade selected the "correct" response an average of 94.38% during the delayed reinforcement condition (range, 91% - 100%) and an average of 92.29% during the immediate reinforcement condition (range, 78% - 100%). Alice selected the “correct” response 89.57% (range, 54.5% - 100%) and 81.98% (range, 18.2% - 100%) during the delayed reinforcement and immediate reinforcement conditions, respectively. Walden was initially more likely to select the “correct” response during the immediate reinforcement condition. However, he eventually selected the “correct” response almost exclusively during both delayed reinforcement (89.85%; range, 53.33% - 100%) and immediate reinforcement (98.66%; range, 90.9% - 100%) conditions. Figure 2-4 presents mean percent “correct” data as a function of each delay to reinforcement. For all 3 subjects, percent “correct” remained fairly stable across increasing delays to reinforcement.

Figure 2-5 presents breakpoints obtained during the chained FR 1 – PT schedule in Experiment 1A. Breakpoints were defined as the last delay contacted prior to meeting the session termination criteria. The maximum possible delay that subjects could contact was 120 s. In general, breakpoints varied from session to session. Vlade’s mean breakpoint was 85.7 s (range, 60 - 120 s), Alice’s mean breakpoint was 117.14 s (range, 110 – 120 s), and Walden’s mean breakpoint was 110.77 s (range, 60 - 120 s). For Alice and Walden, there was a negative relationship between the *k* value estimated using the modified version of Mazur’s hyperbolic delay discounting equation and mean breakpoint. In other words greater degrees of discounting due to the delay were associated with lower breakpoints, which suggests that *k* was an accurate representation of discounting due to the delay for these subjects.

In summary, Experiment 1A evaluated the effects of delayed reinforcement on the behavior of children with DD using a chained schedule of reinforcement. The removal of stimuli in the terminal component of the chained schedule ensured that programmed delays matched obtained delays because subjects could not emit the target response during the terminal component. Additionally, the removal of stimuli was programmed following both “correct” and “incorrect” responses, thus degrading the relationship between the removal of stimuli and reinforcement. The results from Experiment 1A suggests that signaled, delayed reinforcement can maintain responding by individuals with DD, even when the signal is degraded. In addition, results suggest that adding a delay between a response and a reinforcer will not produce decreases the percent of “correct” responses made by the subjects. Results also suggest that individuals with DD will continue to respond, even as delays to reinforcement increase. However, these findings might be specific to the reinforcement schedule programmed (FR 1 schedule). Thus, the purpose of Experiment 1B was to examine the effects of delayed reinforcement using a VI schedule.

## Experiment 1B: Procedure

During Experiment 1B, subjects were again exposed to two experimental conditions. During the delayed reinforcement condition, a chained VI 15- or 30-s – PT schedule of reinforcement was in effect. Relative to the FR 1 schedule programmed in Experiment 1A, this schedule was programmed to allow for greater response variability in the initial component. The VI 15-s schedule consisted of 20 intervals (range, 0.38 to 59.94 s) generated using a Fleshler and Hoffman (1962) progression, while the VI 30-s schedule consisted of 20 intervals (range, 0.76 to 119.87 s) generated using the same progression. All subjects were initially exposed to the chained VI 30-s – PT schedule of reinforcement. However, Walden’s low percent “correct” appeared to be the result of interval strain, so for him the initial component was switched to a VI 15-s schedule for

Experiments 1B and 1C. During the delayed reinforcement condition, the position of stimuli was randomized following each response that occurred before the interval had elapsed. Stimuli were removed from the screen contingent on the first response after the interval had elapsed and remained absent for the duration of the PT component, which increased by a fixed amount (i.e., 5 or 10 s) following successive reinforcer deliveries. At the end of the terminal component, a tone was sounded and reinforcers were delivered if the response that initiated the terminal component had been “correct.” If this response had been “incorrect,” a tone was not sounded and reinforcers were not delivered. Following the completion of each terminal link, stimuli were represented on the screen following a 3-s or 30-s ITI. This ITI was programmed to allow subjects to consume the reinforcer.

During the immediate reinforcement condition, a yoked VI schedule of reinforcement was in effect. Again, this schedule was chosen to keep the response requirement relatively similar to that programmed in the delayed reinforcement condition, while at the same time equating reinforcement rate to that obtained during each previous delayed reinforcement session. In the yoked VI schedule, the intervals were yoked to the obtained IRI of each previous delay session. The duration of each immediate reinforcement session was yoked to the duration of each previous delayed reinforcement session. During each session in the immediate reinforcement condition, responses that occurred prior to the end of the interval resulted in the randomized repositioning of stimuli on the screen, and the first response after the interval requirement elapsed either resulted in the immediate presentation of a tone and a reinforcer (if the response had been “correct”) or an absence of differential consequences (if the response had been “incorrect”).

### Experiment 1B: Results and Discussion

At the start of each session, subjects’ responses during the first 10 trials generally suggested that discriminations were acquired. Vlade selected the “correct” response 95.21% (range, 60% - 100%) of the time during the last five trials prior to each delayed reinforcement session and 94.78% of the time (range, 40% - 100%) during the last five trials prior to each immediate reinforcement session. Alice selected the “correct” responses 88% of the time (range, 20% - 100%) during the last five trials prior to each delayed reinforcement session and 91% of the time (range, 60% - 100%) during the last five trials prior to each immediate reinforcement session. Although Alice’s level of percent “correct” was low during some of these sets of trials, there was not a relationship between levels of percent “correct” during the last five trials and levels of percent “correct” during subsequent delayed reinforcement ($R^2$ = .02) or immediate reinforcement ($R^2$ = .03) sessions. Walden selected the “correct” response 87.14% of the time (range, 40% - 100%) during the last five trials prior to each delayed reinforcement session and 92.86% of the time (range, 60% - 100%) prior to each immediate reinforcement session. For Walden, there was not a relationship between levels of percent “correct” during the last five trials and levels of percent “correct” during subsequent delayed reinforcement ($R^2$ = .02) or immediate reinforcement ($R^2$ = .01) sessions.

Figure 2-6 displays response rate data from Experiment 1B. Response rates were calculated in a manner similar to Experiment 1A, with the total number of “correct” responses following the first 10 forced-exposure trials divided by the total amount of time in which it was possible to make a response. Response rates were again slightly elevated during immediate reinforcement condition relative to the delayed reinforcement condition. Vlade engaged in an average of 4.38 responses per min during the immediate reinforcement condition (range, 1.22 – 13.41 responses per min) and an average of 3.27 responses per min in the delayed reinforcement condition (range, 0.75 – 12.43 responses per min). Alice engaged in an average of 4.48 responses per min during the immediate reinforcement condition (range, 2.62 – 6.60 responses per min) and an average of 3.06 responses per min in the delayed reinforcement condition (range, 1.15 – 5.98 responses per min). Walden engaged in an average of 3.08 responses per min in the immediate reinforcement condition (range, 1.25 – 8.64 responses per min) and an average of 3.92 responses per min during the VI 30-s component of the delayed reinforcement condition (range, 1.65 – 8.57 responses per min) and 1.56 responses per min during the VI 15-s component of the delayed reinforcement condition (range, 1.00 – 2.62 responses per min).

Figure 2-7 depicts mean response rates as a function of each delay and curves predicted by the modified version of Mazur’s (1987) hyperbolic delay discounting equation. Calculations of mean response rates were similar to those computed during Experiment 1A: The number of “correct” responses made prior to each delay were divided by the total amount of time in which it was possible to make a response since the last trial. Once again, more response rates were averaged into mean response rates during the smaller delays. For Vlade, at least 20 sessions of data were averaged into each mean response rate for delays between 5 s and 40 s, at least 10 sessions of data were averaged into each mean response rate for delays between 45 s and 60 s, and 7 or fewer sessions of data were averaged into each mean response rate for delays between 65 s and 120 s. For Alice, at least 10 sessions of data were averaged into each mean response rate for delays between 10 s and 60 s, but 8 or fewer sessions of data were averaged into each mean response rate for delays between 70 s and 90 s. For Walden, 7 sessions of data were averaged into each mean response rate for delays between 10 s and 30 s, but only 5 or fewer sessions of data were averaged into each mean response rate for delays between 40 s and 70 s. Walden's data only include data from the VI 15-s component. For Vlade and Alice, mean response rates decreased as delays to reinforcement increased. For Walden, mean response rates remained fairly stable as delays to reinforcement increased.

In general, percent "correct" did not differ across conditions. Percent "correct" was again calculated by dividing the number of "correct" responses made after the first 10 forced-exposure trials by the total number of "correct" and "incorrect" responses made after the first 10 forced-exposure trials. These data are depicted in Figure 2-8. Vlade selected the "correct" response an average of 82.45% during the delayed reinforcement condition (range, 40% - 100%) and an average of 80.27% during the immediate reinforcement condition (range, 55.55% - 100%). Alice selected the "correct" response an average of 71.15% during the delayed reinforcement condition (range, 50% - 91.18%) and an average of 67.81% during the immediate reinforcement condition (range, 41% - 91.67%). Walden selected the "correct" response an average of 64.72% during the VI 30-s component of the delayed reinforcement condition (range, 51.32% - 88.24%), an average of 61.45% during the VI 15-s component of the delayed reinforcement condition (range, 48.57% - 75%), and an average of 67.55% during the immediate reinforcement condition (range, 49.21% - 82.76%). Figure 2-9 presents mean percent “correct” data as a function of each delay to reinforcement. For all 3 subjects, percent “correct” remained fairly stable across increasing delays to reinforcement.

Figure 2-10 displays breakpoints obtained when a chained VI - PT schedule of reinforcement was programmed. Mean breakpoints were 39.89 s (range, 10 s – 85 s), 58.75 s (range, 20 s – 80 s), and 38.57 s (range, 10 s – 70 s) for Vlade, Alice, and Walden, respectively. Walden’s data can be further broken down into breakpoints obtained during the VI 30-s component (31.43 s) and the VI 15-s component (45.71 s). Once again, for Alice and Walden, there was a negative relationship between mean breakpoints and the *k* value estimated using the modified version of Mazur’s hyperbolic delay discounting equation and data obtained during Experiment 2. Thus, greater degrees of discounting due to the delay were associated with lower breakpoints.

In summary, the results of Experiment 1B suggest that delayed reinforcement will maintain responding, even when not all “correct” responses are reinforced. In addition, the percentage of “correct” responses was again comparable across delayed reinforcement and immediate reinforcement conditions, albeit low in both conditions. The fact that low levels of percent “correct” occurred in both conditions suggests that the VI schedule may have been unable to maintain discriminated responding, independent of the delay. In addition, it appeared the change in the schedule of reinforcement in the initial component of the chained schedule (from FR 1 to VI 15 or 30 s) resulted in lower overall breakpoints, suggesting that, to some extent, the effects of delayed reinforcement may be influenced by the schedule of reinforcement.

One potential limitation of both Experiments 1A and 1B was that subjects could not engage in topographically similar responses during the delay. The trial-based arrangement used in these experiments therefore differed from typical free operant situations in which subjects may engage in a variety of responses during the delay. It is possible that the occurrence of responses during the delay would disrupt responding maintained by delayed reinforcement. Therefore, the purpose of Experiment 1C was to evaluate whether delayed reinforcement would still maintain responding when subjects were free to engage in topographically similar responses during the delay.

## Experiment 1C: Procedure

During the delayed reinforcement condition of Experiment 1C, a tandem VI – PT schedule of reinforcement was in effect. During the terminal link, stimuli continued to be presented on the screen and subjects could respond to these stimuli. During both the initial and terminal links, stimulus placement on the screen was randomized following each response. Reinforcement contingencies were only arranged for the last response in the initial link (i.e., the first response after the interval requirement elapsed). If this response had been “correct,” the duration of the terminal link increased by 5 or 10 s across trials. If this response had been “incorrect,” the duration of the terminal link was equal to the duration of the terminal link during the preceding trial. After the terminal link elapsed, a tone was sounded and reinforcers were delivered if the previous response had been “correct.” Following all trials, stimuli were represented on the screen following a 3-s or 30-s ITI.

The immediate reinforcement condition was identical to that programmed in Experiment 1B; a yoked VI schedule of reinforcement was in effect.

## Experiment 1C: Results and Discussion

At the start of each session, subjects' responses during the first 10 trials generally suggested that discriminations were acquired. Vlade selected the "correct" response 97.65% (range, 80% - 100%) of the time during the last five trials prior to each delayed reinforcement session and 96.47% of the time (range, 80% - 100%) during the last five trials prior to each immediate reinforcement session. Alice selected the "correct" responses 93% of the time (range, 40% - 100%) during the last five trials prior to each delayed reinforcement session and 93% of the time (range, 80% - 100%) during the last five trials prior to each immediate reinforcement session. Although Alice's level of percent "correct" was low during some sets of trials prior to delayed reinforcement sessions, there was only a minimal relationship between levels of percent "correct" during the last five trials and levels of percent "correct" during subsequent delayed reinforcement ($R^2$ = .27) sessions. Walden selected the "correct" response 94% of the time (range, 60% - 100%) during the last five trials prior to each delayed reinforcement session and 98% of the time (range, 80% - 100%) prior to each immediate reinforcement session. For Walden, although percent "correct" was low prior to some delayed reinforcement sessions, there was only a minimal positive relationship between levels of percent "correct" during the last five trials and levels of percent "correct" during subsequent delayed reinforcement ($R^2$ = .29) sessions.

Response rate data obtained during Experiment 1 C are depicted in Figure 2-11. We compared response rates across both components of a tandem VI - PT schedule of reinforcement with response rates during the immediate reinforcement condition. During both conditions, response rates were calculated by dividing the number of "correct" responses made following the first 10 forced-exposure trials by the total amount of time in which it was possible to make a response. Vlade engaged in an average of 3.82 responses per min during the immediate reinforcement condition (range, 1.56 – 7.68 responses per min) and an average of 2.70 responses per min in the delayed reinforcement condition (range, 1.00 – 5.07 responses per min). Alice engaged in an average of 4.64 responses per min during the immediate reinforcement condition (range, 1.32 – 8.21 responses per min) and an average of 2.55 responses per min in the delayed reinforcement condition (range, 1.18 – 6.91 responses per min). Walden engaged in an average of 3.00 responses per min in the immediate reinforcement condition (range, 1.44 – 5.77 responses per min) and an average of 3.93 responses per min in the delayed reinforcement condition (range, 2.19 – 6.50 responses per min).

Figure 2-12 displays mean response rates as a function of each programmed delay. Unlike Experiments 1A and 1B, mean response rates were calculated across both initial and terminal components of the tandem VI - PT schedule as a function of each programmed delay. Thus, the total number of “correct” responses made across both initial and terminal links was divided by the total duration of the initial and terminal link, for each delay. Again, within each session, response rates for identical delays were calculated separately and then averaged. Response rates were then averaged across sessions as a function of each delay. Once again, more values were averaged into mean response rates for smaller delays because subjects did not contact high delays during sessions with low breakpoints. For Vlade, at least eight values were averaged into mean response rates for delays between 5 s and 30 s. However, only three or fewer values were averaged into mean response rates for delays between 35 and 55 s. For Alice, at least 17 values were averaged into mean response rates for 10- and 20-s delays, whereas nine or fewer values were averaged into mean response rates for 30- and 40-s delays. For Walden, at least nine values were averaged into mean response rates for 10- and 20-s delays, but only six or fewer values were averaged into mean response rates for 30-, 40-, 50-, and 60-s delays. For Vlade and Alice, mean response rates decreased as delays to reinforcement increased. For Walden, response rates remained relatively stable across increasing delays. We fit the modified version of Mazur's (1987) hyperbolic delay discounting equation to Vlade and Walden's data, but did not do so for Alice because we obtained so few measures of response rates under different delays.

Figure 2-13 displays mean response rates as a function of obtained delays to reinforcement, when obtained delays were defined as the time between the last response (regardless of whether it was "correct" or "incorrect") and reinforcer delivery. Response rates were calculated for each obtained delay, and then averaged (both within and across sessions) for each identical delay (in bins of 1 s). In general, response rates decreased as obtained delays to reinforcement increased. We fit the data to the modified version of Mazur's (1987) hyperbolic delay discounting equation. It should be noted that mean response rates and obtained delays were not completely independent because lower rates of responding could produce longer obtained delays to reinforcement. Figure 2-14 displays mean response rates as a function of obtained delays to reinforcement, when obtained delays were defined as the time between the last "correct" response and reinforcer delivery, regardless of whether "incorrect" responses occurred between the last "correct" response and reinforcer delivery. Again, response rates were calculated for each obtained delay, and then averaged across identical delays. Mean response rates decreased as obtained delays to reinforcement increased. Once again, it should be noted that mean response rates and obtained delays were not completely independent of one another.

Figure 2-15 displays percent “correct” data for all subjects. Again, percent “correct” was calculated using data obtained following the first 10 forced-exposure trials of each session. Overall, percent “correct” generally did not differ between immediate reinforcement and delayed reinforcement conditions. An average of 71.92% of Vlade’s responses during the delayed reinforcement condition were “correct” (range, 53.85% - 83.87%) and an average of 71.75% of his responses during the immediate reinforcement condition were “correct” (range, 55.81% - 100%). Alice selected the “correct” response an average of 57.23% during the delayed reinforcement condition (range, 35.7% - 85.19%) and an average of 59.17% during the immediate reinforcement condition (45.71% - 81.81%). Walden selected the “correct” response an average of 61.49% during the delayed reinforcement condition (range, 42.86% - 79.17%) and an average of 60.26% (range, 45.71% - 75%) during the immediate reinforcement condition. These results suggest that each subject’s ability to discriminate between stimuli deteriorated during both conditions of this evaluation. There was no noticeable effect of the delay on percent “correct.” Figure 2-16 presents mean percent “correct” data as a function of each delay to reinforcement. For all 3 subjects, percent “correct” remained fairly stable across increasing delays to reinforcement, with only a slight decreasing trend for Vlade.

Figure 2-17 displays breakpoints obtained during the tandem VI - PT schedule of reinforcement. Breakpoints were lowest during this evaluation, and varied across sessions. Vlade's average breakpoint was 20.59 s (range, 5 – 55 s), Alice's average breakpoint was 23.5 s (range, 0 – 40 s), and Walden's average breakpoint was 32 s (range, 10 - 60 s). For Vlade and Walden, there was a negative relationship between the *k* value estimated in the modified version of Mazur's hyperbolic delay discounting equation and breakpoints, such that greater degrees of discounting due to the delay were associated with lower breakpoints.

As noted by Lattal (2010), "the delay is not a period of behavioral emptiness through which time passes…responding invariably occurs during the delay" (p. 135). The methods used in the third evaluation allowed us to measure the effects of at least two possible intervening responses (responses to the $S^D$ and responses to the $S^\Delta$). Results from Experiment 1C suggest that delayed reinforcement will maintain responding when subjects can engage in topographically similar responses during the delay. Responses that occur during the delay may increase the efficacy of delayed reinforcement by making obtained delays (i.e., the delay between the last "correct" response and reinforcer delivery) shorter than programmed delays (i.e., the delay between the "correct" response that initiated the delay and reinforcer delivery). However, this arrangement may instead decrease the efficacy of delayed reinforcement if "incorrect" responses occur closer in time to reinforcer delivery than "correct" responses. Indeed, for Vlade, 42% (range, 0% - 100%) of reinforcer deliveries were preceded by an "incorrect" response. For Alice, 44% (range, 0% - 100%) of reinforcer deliveries were preceded by an "incorrect" response. For Walden, 25.3% (range, 0% - 100%) of reinforcer deliveries were preceded by an "incorrect" response. Nevertheless, this arrangement still resulted in maintenance of the target response. However, this arrangement was less likely to maintain discriminated responding, relative to Experiment 1A.

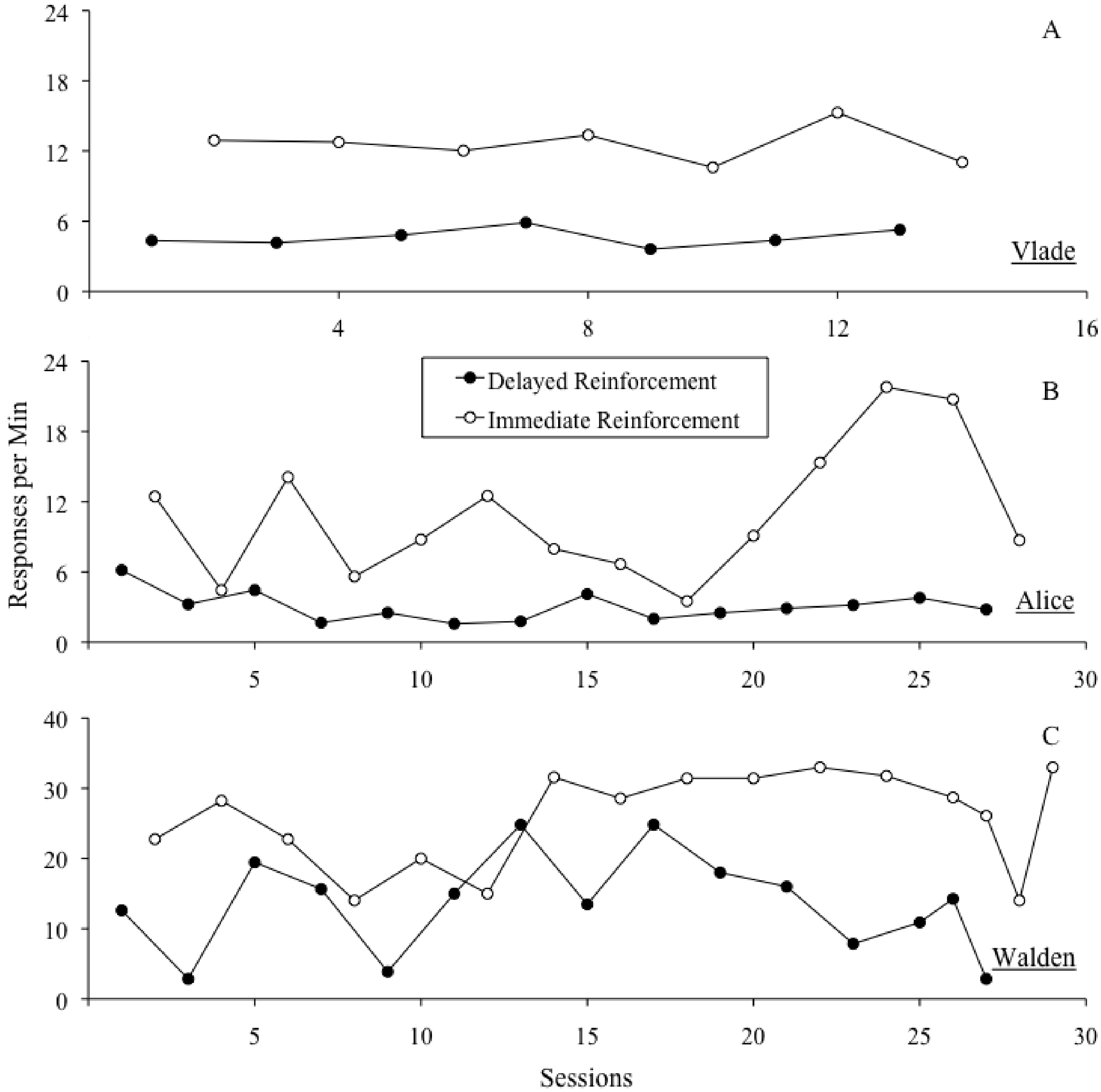


Figure 2-1. Rate of “correct” responses during the first component of the chained FR 1 - PT schedule of reinforcement in the delayed reinforcement condition (closed circles) and the second component of the chained VT - FR 1 schedule of reinforcement in the immediate reinforcement condition (open circles) during Experiment 1A. A) Data for Vlade. A chained FR 1 - PT 5-s schedule of reinforcement was in place during the delayed reinforcement condition. B) Data for Alice. A chained FR 1 - PT 10-s schedule of reinforcement was in place in the delayed reinforcement condition. C) Data for Walden. A chained FR 1- PT 10-s schedule of reinforcement was in place in the delayed reinforcement condition.

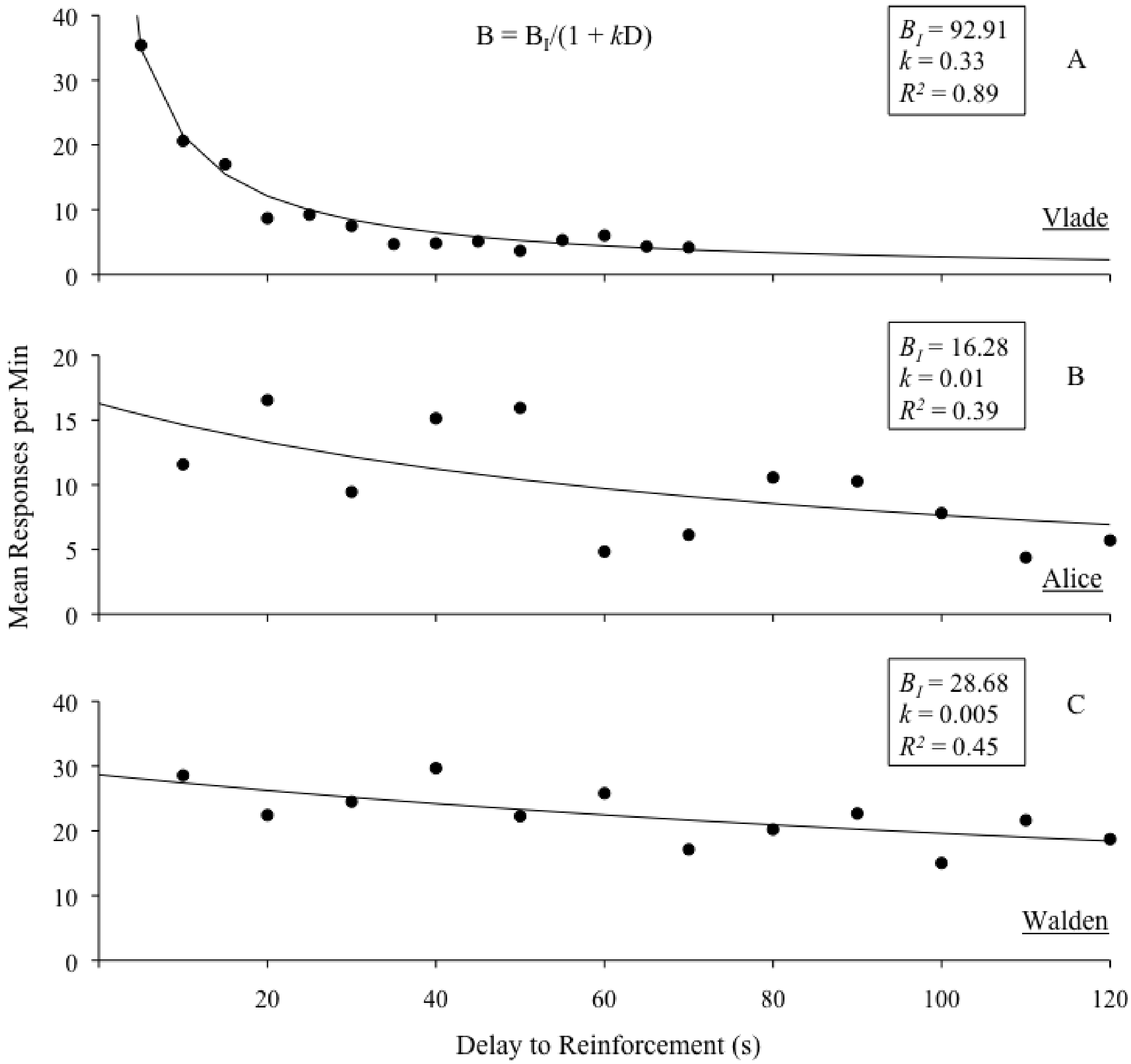


Figure 2-2. Mean rate of "correct" responses as a function of each delay, during the first component of the chained FR 1 - PT schedule of reinforcement in the delayed reinforcement condition of Experiment 1A, and a hyperbola depicting the estimated relationship between mean response rate and delay to reinforcement. $B_I$ and $k$ are fitted parameters that represent estimated response rate under immediate reinforcement and estimated degree of discounting, respectively. A) Data for Vlade. A chained FR 1 - PT 5-s schedule of reinforcement was in place. B) Data for Alice. A chained FR 1 - PT 10-s schedule of reinforcement was in place. C) Data for Walden. A chained FR 1 - PT 10-s schedule of reinforcement was in place.

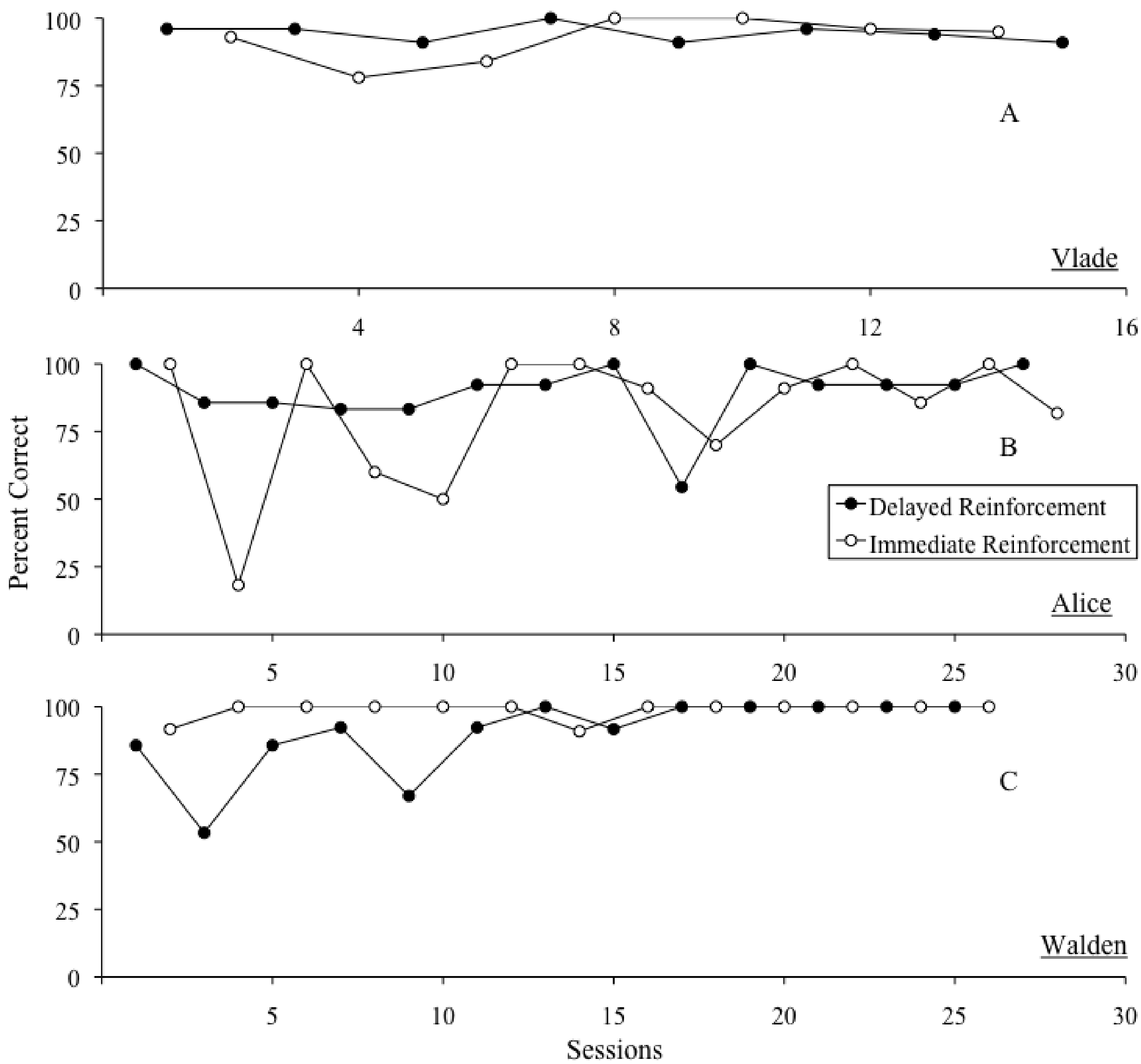


Figure 2-3. Percentage of "correct" responses across consecutive delayed reinforcement (closed circles) and immediate reinforcement (open circles) sessions during Experiment 1A. A) Data for Vlade. A chained FR 1 - PT 5-s schedule of reinforcement was in place during the delayed reinforcement condition. B) Data for Alice. A chained FR 1 - PT 10-s schedule of reinforcement was in place during the delayed reinforcement condition. C) Data for Walden. A chained FR 1- PT 10-s schedule of reinforcement was in place during the delayed reinforcement condition.

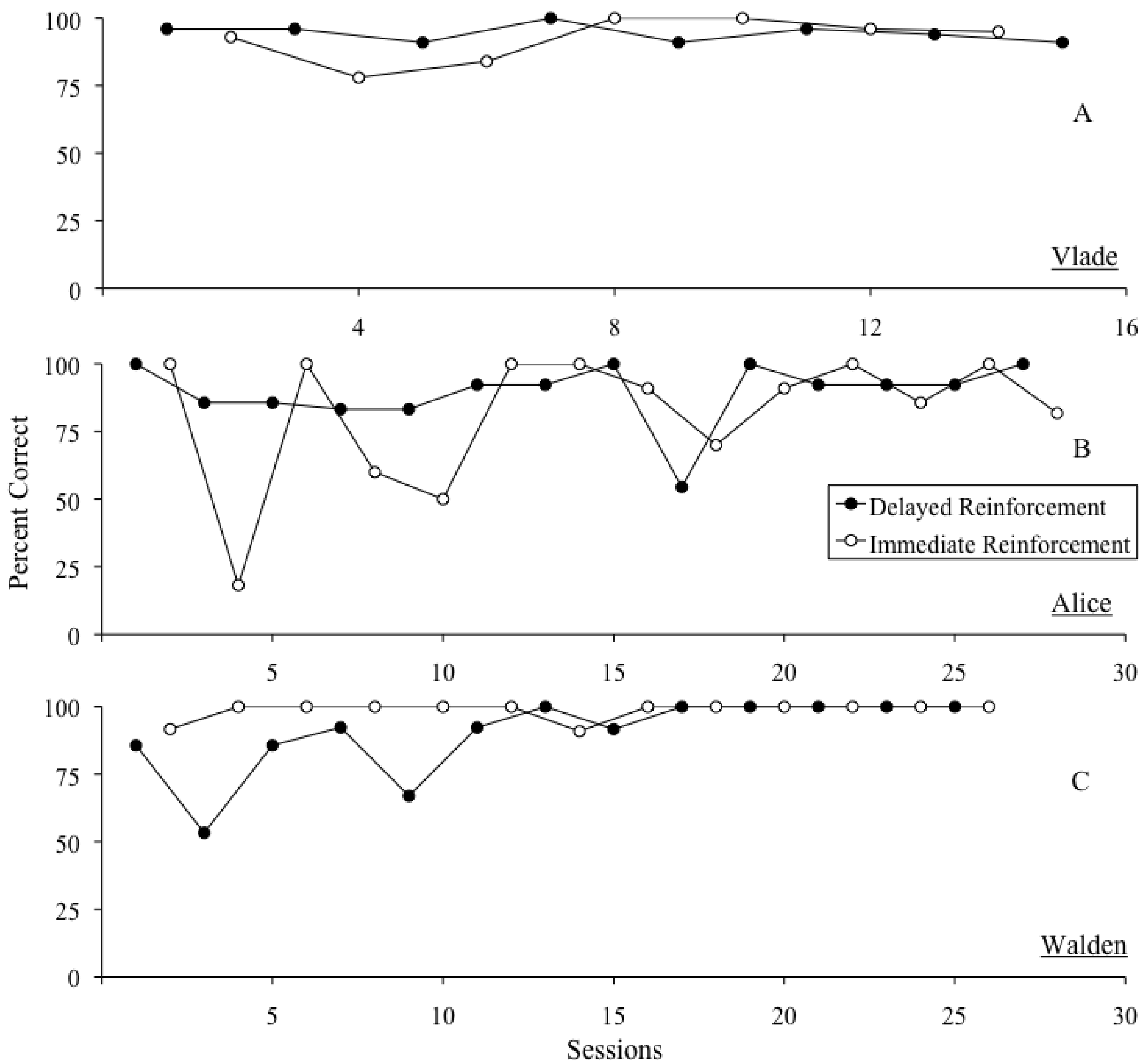


Figure 2-4. Mean percentage of "correct" responses across consecutive delays to reinforcement during Experiment 1A. A) Data for Vlade. A chained FR 1 - PT 5-s schedule of reinforcement was in place. B) Data for Alice. A chained FR 1 - PT 10-s schedule of reinforcement was in place. C) Data for Walden. A chained FR 1- PT 10-s schedule of reinforcement was in place.

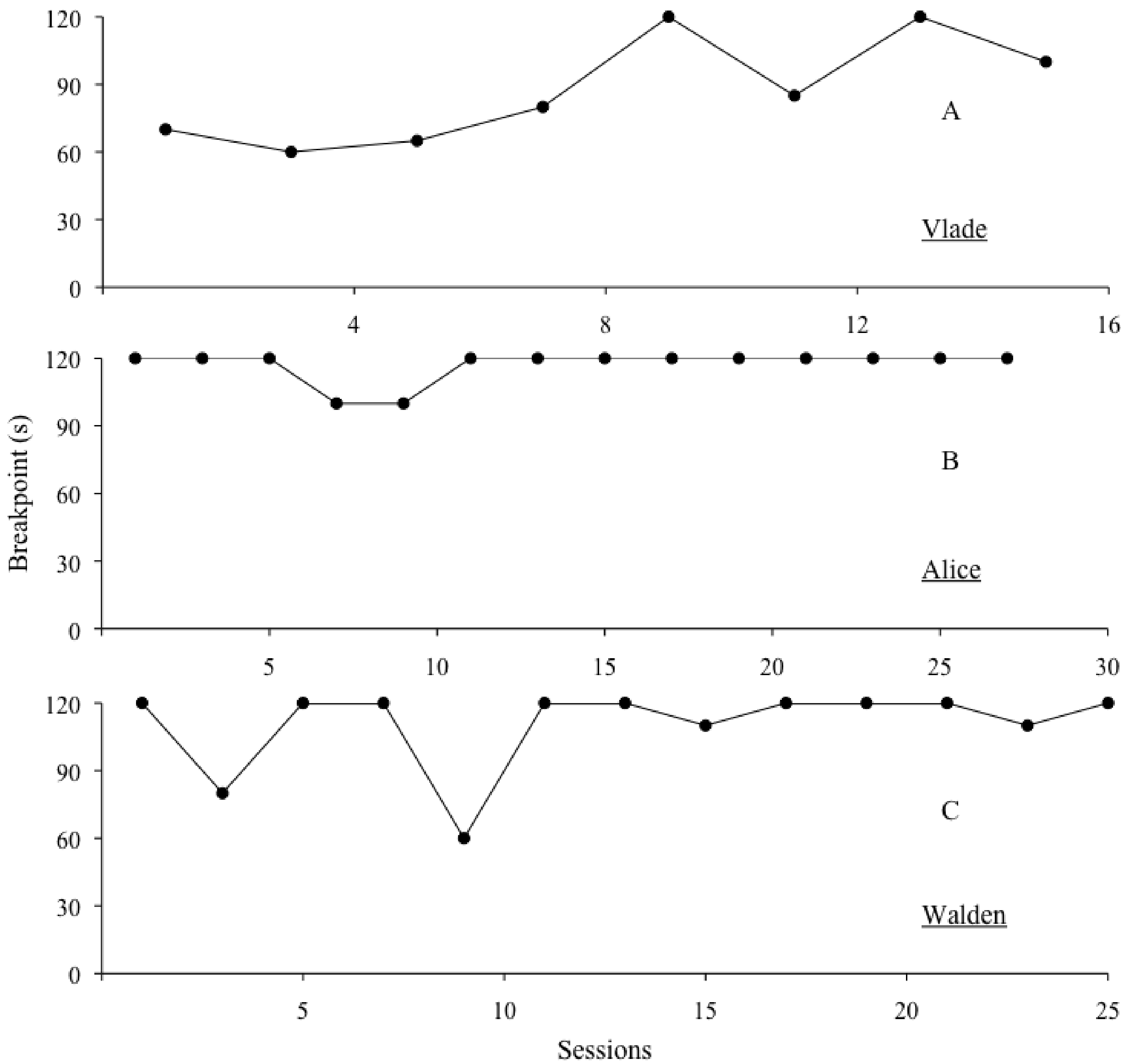


Figure 2-5. Breakpoints obtained during the chained FR 1 - PT schedule of reinforcement in the delayed reinforcement condition of Experiment 1A. A) Data for Vlade. A chained FR 1 - PT 5-s schedule of reinforcement was in place. B) Data for Alice. A chained FR 1 - PT 10-s schedule of reinforcement was in place. C) Data for Walden. A chained FR 1 - PT 10-s schedule of reinforcement was in place.

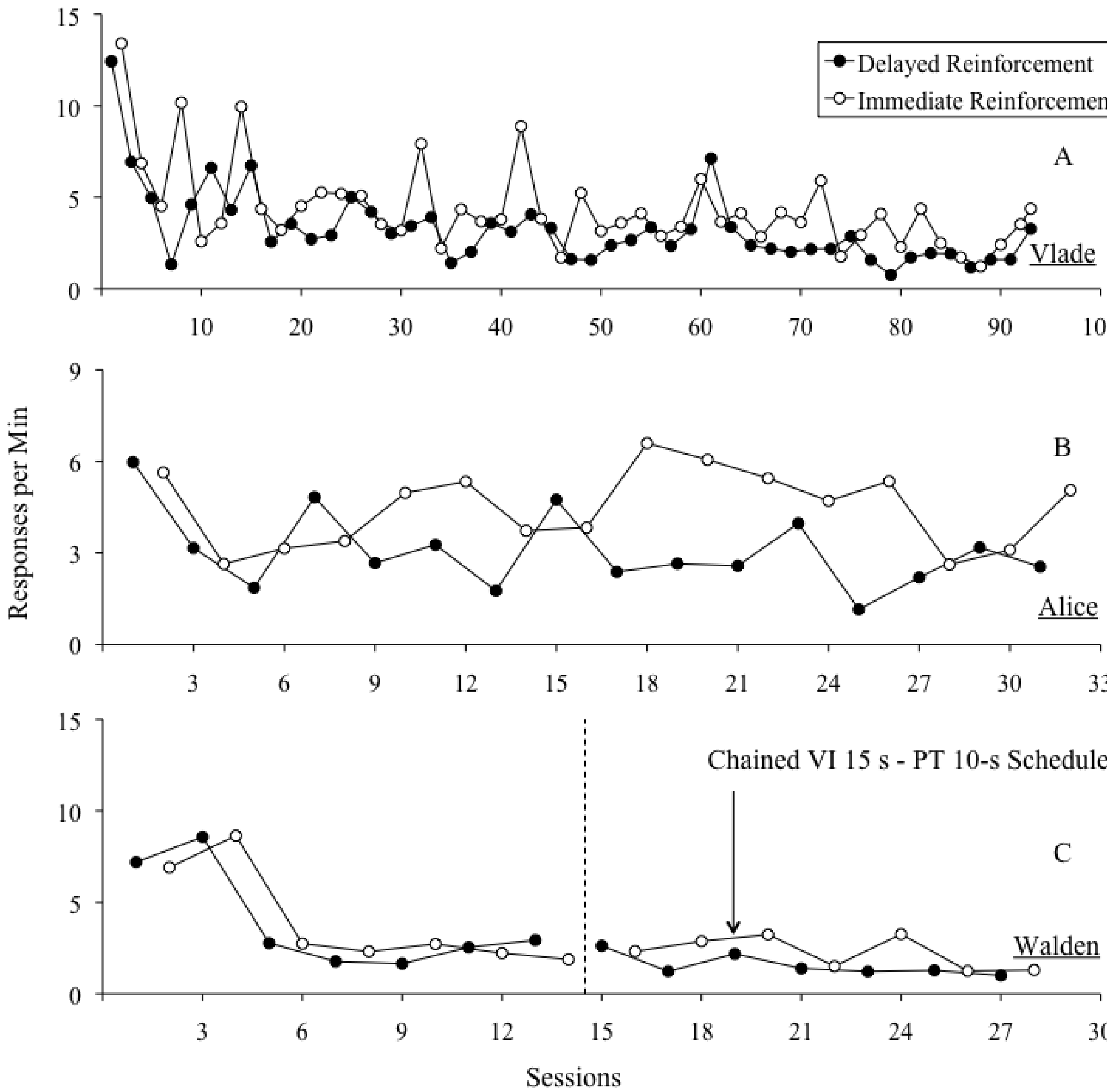


Figure 2-6. Rate of “correct” responses during the first component of the chained VI – PT schedule of reinforcement in the delayed reinforcement condition (closed circles) and during the yoked VI schedule of reinforcement in the immediate reinforcement condition (open circles) of Experiment 1B. A) Data for Vlade. A chained VI 30 - PT 5-s schedule of reinforcement was in place during the delayed reinforcement condition. B) Data for Alice. A chained VI 30 - PT 10-s schedule of reinforcement was in place during the delayed reinforcement condition. C) Data for Walden. Prior to the phase change line, a chained VI 30 - PT 10-s schedule of reinforcement was in place during the delayed reinforcement condition. After the phase change line, a chained VI 15- PT 10-s schedule of reinforcement was in place during this condition.

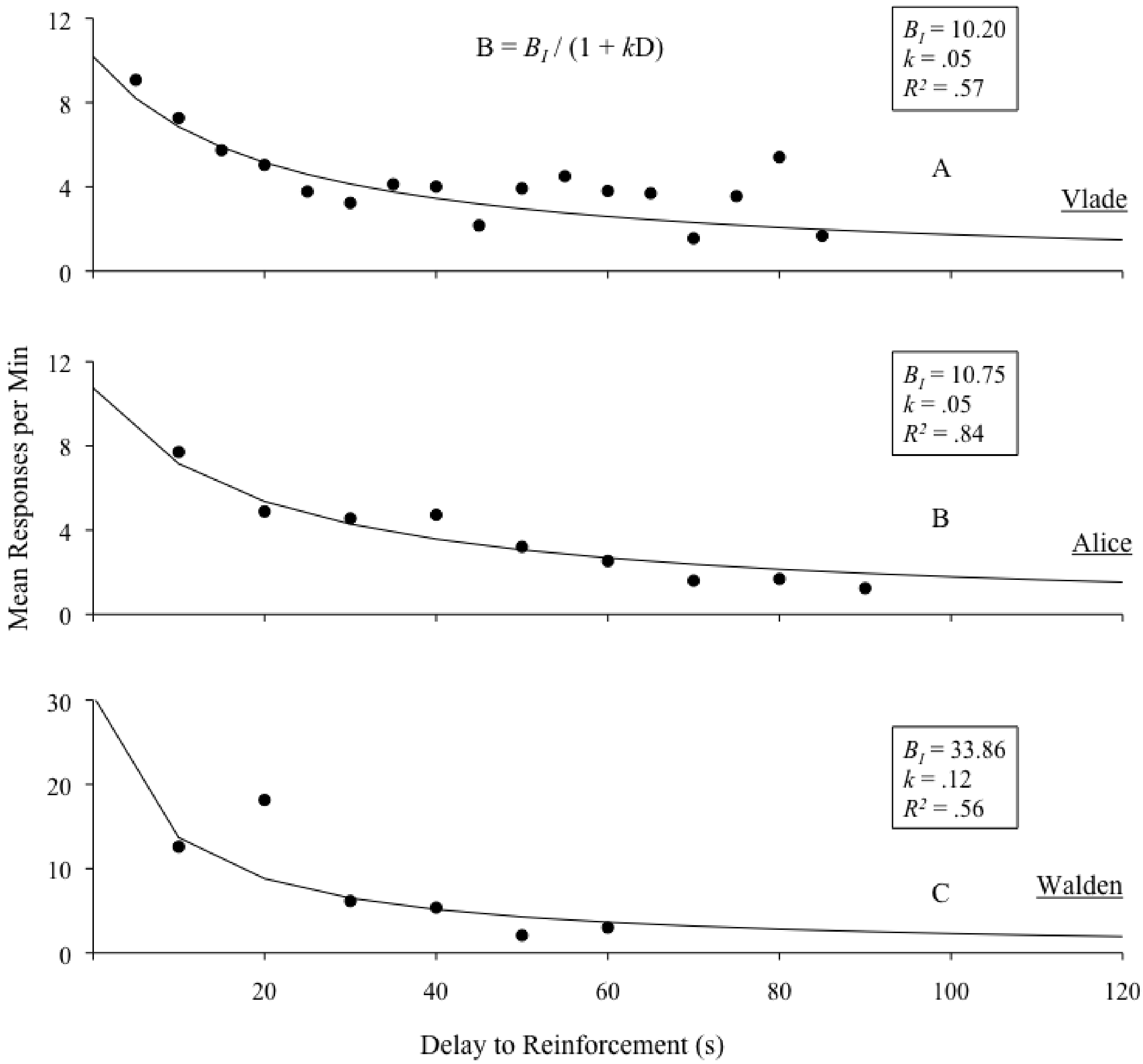


Figure 2-7. Mean rate of "correct" responses as a function of each delay, during the first component of the chained VI - PT schedule of reinforcement in Experiment 1B, and a hyperbola depicting the estimated relationship between mean response rate and delay to reinforcement. $B_I$ and $k$ are fitted parameters that represent estimated response rate under immediate reinforcement and estimated degree of discounting, respectively. A) Data for Vlade. A chained VI 30 - PT 5-s schedule of reinforcement was in place. B) Data for Alice. A chained VI 30 - PT 10-s schedule of reinforcement was in place. C) Data for Walden. A chained VI 15- PT 10-s schedule of reinforcement was in place.

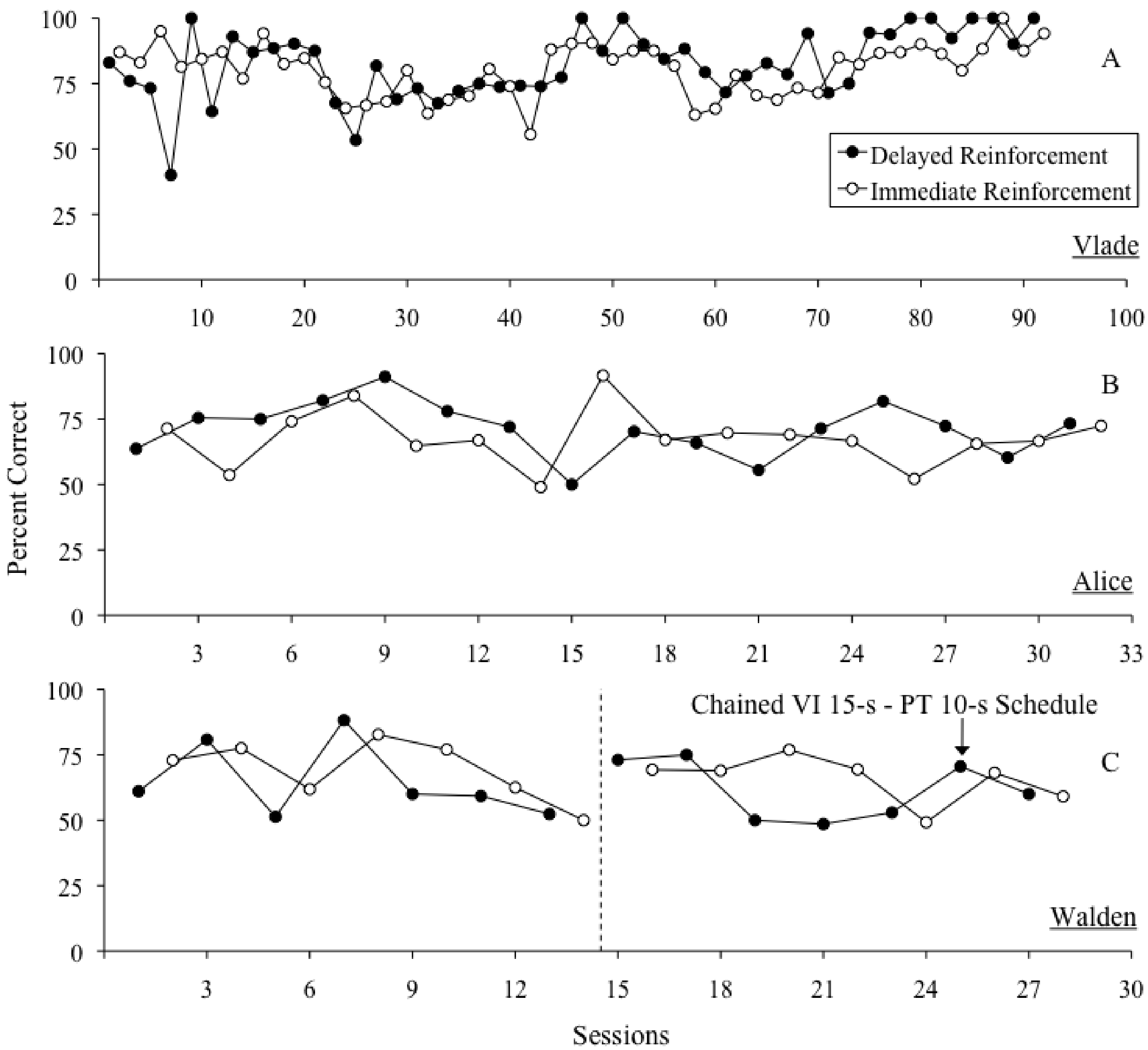


Figure 2-8. Percentage of “correct” responses across consecutive delayed reinforcement (closed circles) and immediate reinforcement (open circles) sessions during Experiment 1B. A) Data for Vlade. A chained VI 30 - PT 5-s schedule of reinforcement was in place in the delayed reinforcement condition. B) Data for Alice. A chained VI 30 - PT 10-s schedule of reinforcement was in place in the delayed reinforcement condition. C) Data for Walden. Prior to the phase change line, a chained VI 30 - PT 10-s schedule of reinforcement was in place in the delayed reinforcement condition.

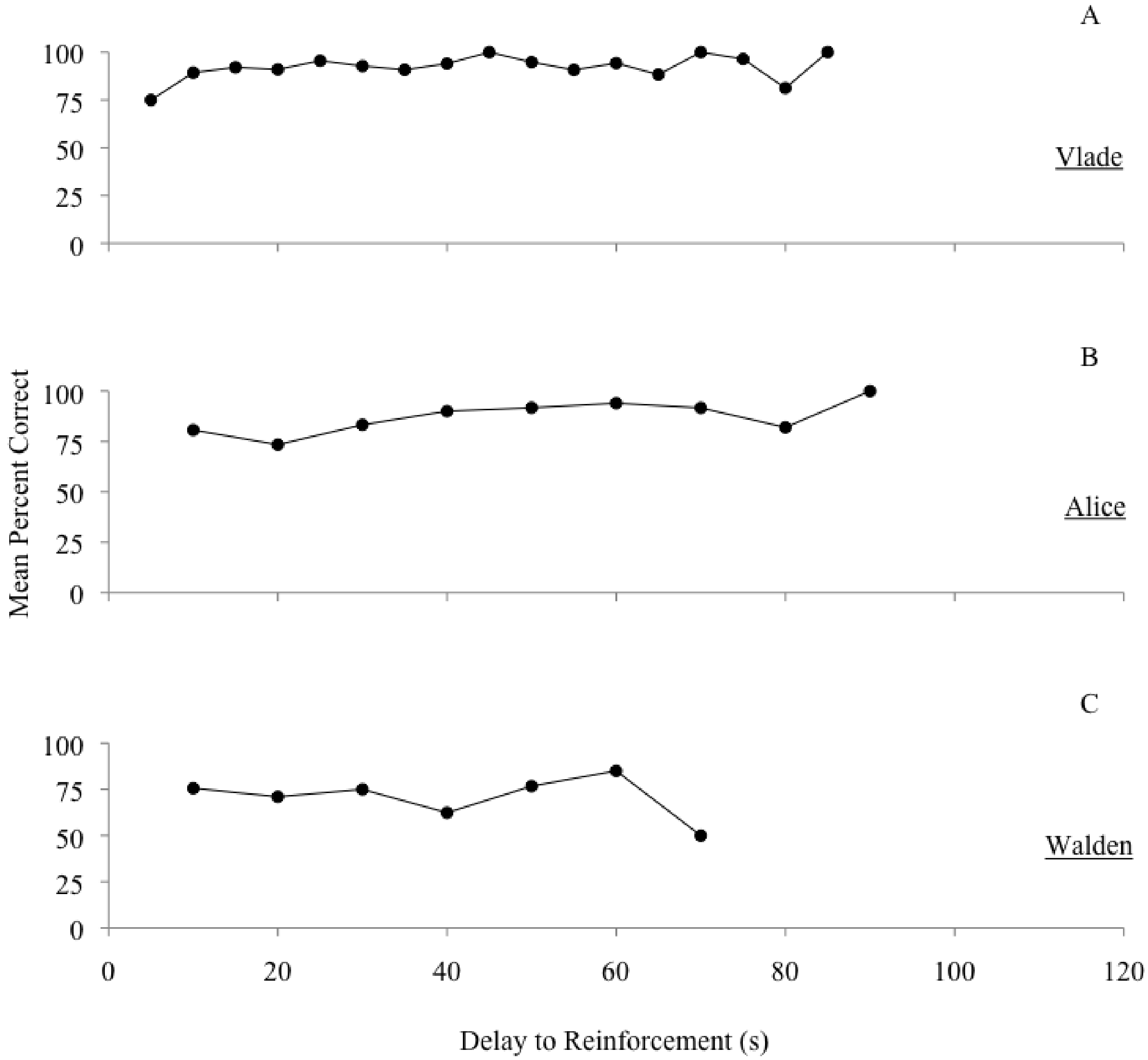


Figure 2-9. Mean percentage of “correct” responses across consecutive delays to reinforcement during Experiment 1B. A) Data for Vlade. A chained VI 30 - PT 5-s schedule of reinforcement was in place. B) Data for Alice. A chained VI 30 - PT 10-s schedule of reinforcement was in place. C) Data for Walden. A chained VI 15 - PT 10-s schedule of reinforcement was in place.

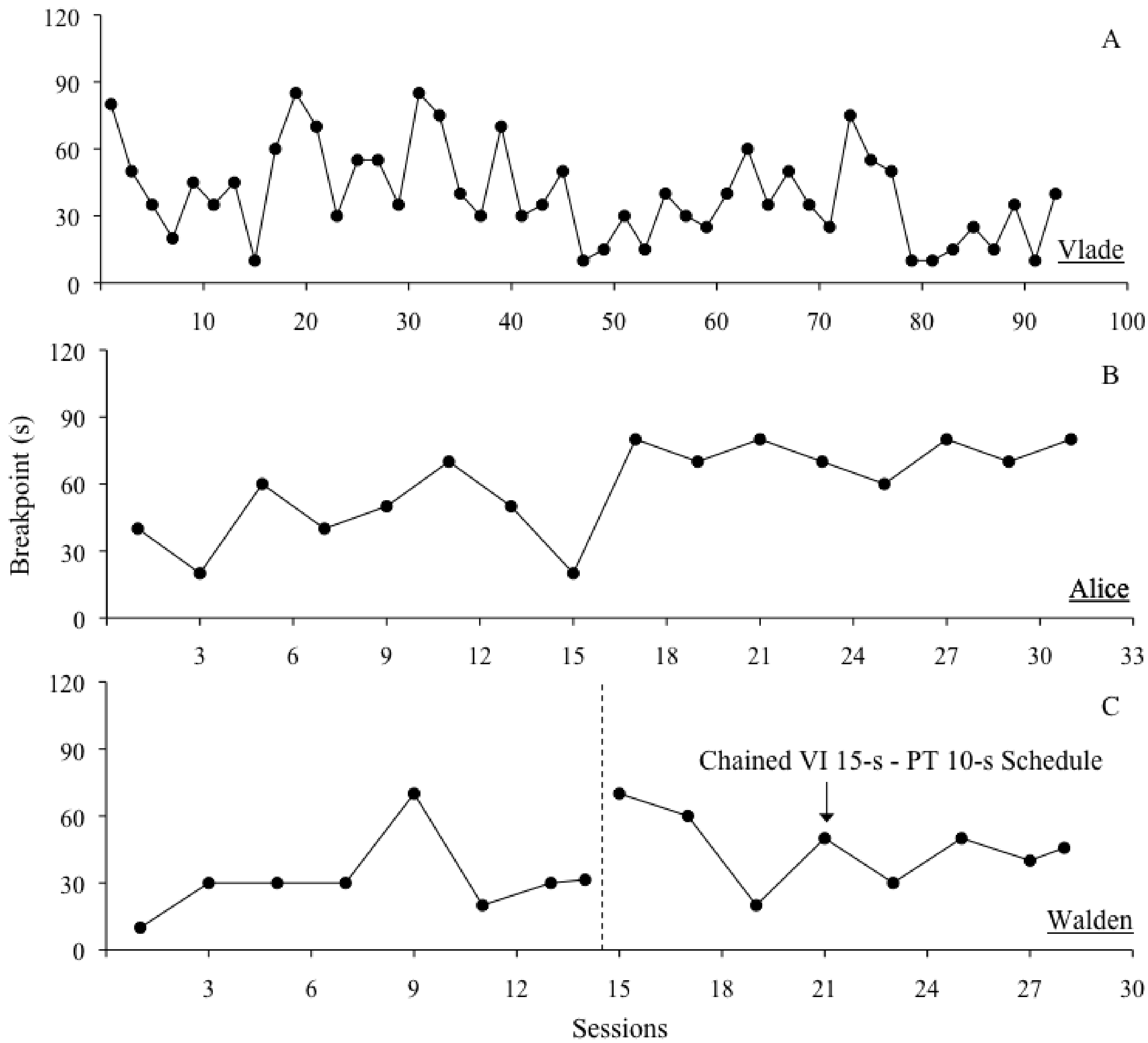


Figure 2-10. Breakpoints obtained during the delayed reinforcement condition of Experiment 1B. A) Data for Vlade. A chained VI 30 - PT 5-s schedule of reinforcement was in place. B) Data for Alice. A chained VI 30 - PT 10-s schedule of reinforcement was in place. C) Data for Walden. Prior to the phase change line, a chained VI 30 - PT 10-s schedule of reinforcement was in place.

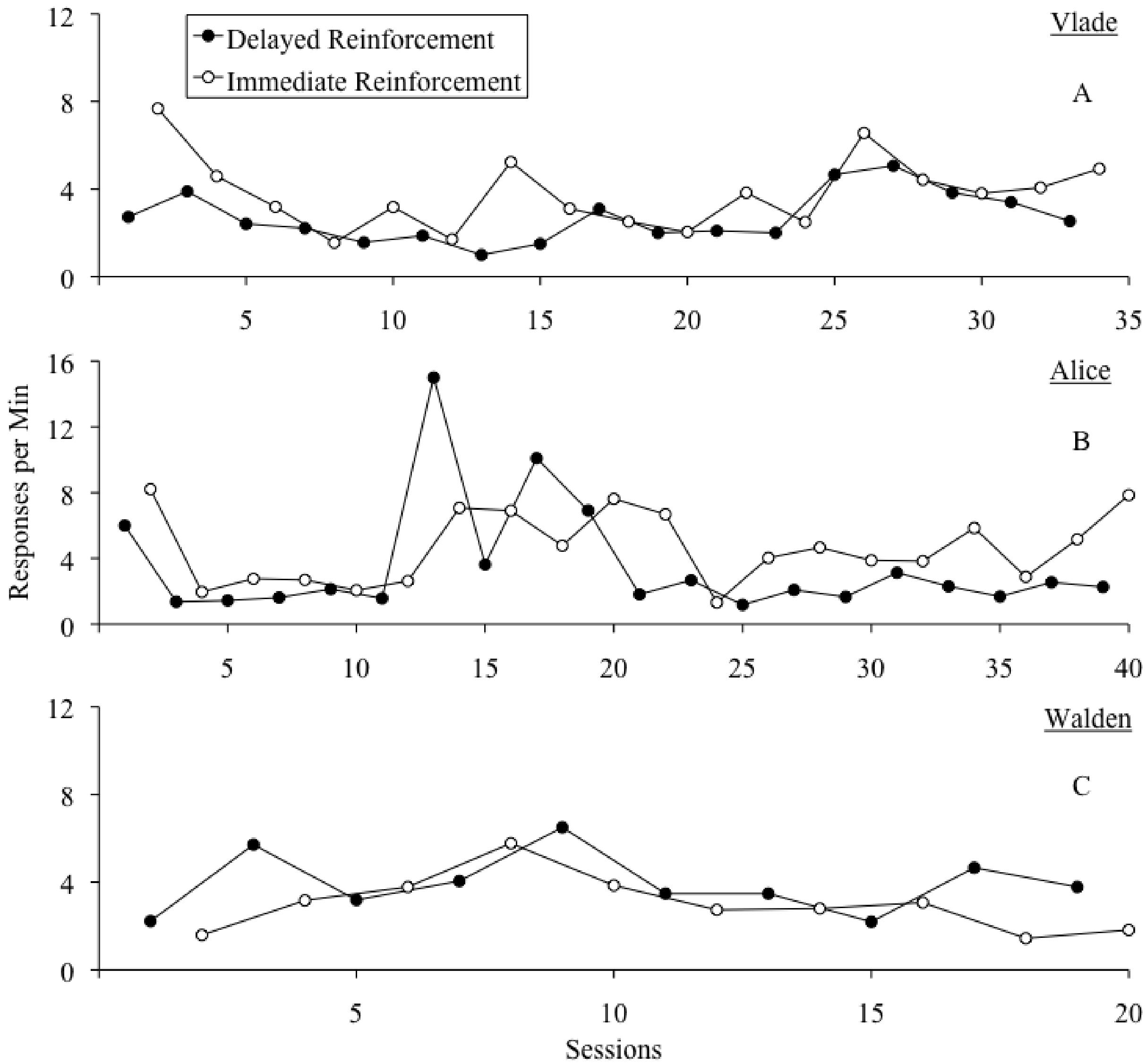


Figure 2-11. Rate of "correct" responses during both components of the tandem VI – PT schedule of reinforcement in the delayed reinforcement condition (closed circles) and during the yoked VI schedule of reinforcement in the immediate reinforcement condition (open circles) of Experiment 1C. A) Data for Vlade. A tandem VI 30 - PT 5-s schedule of reinforcement was in place in the delayed reinforcement condition. B) Data for Alice. A tandem VI 30 - PT 10-s schedule of reinforcement was in place in the delayed reinforcement condition. C) Data for Walden. A tandem VI 15 - PT 10-s schedule of reinforcement was in place in the delayed reinforcement condition.

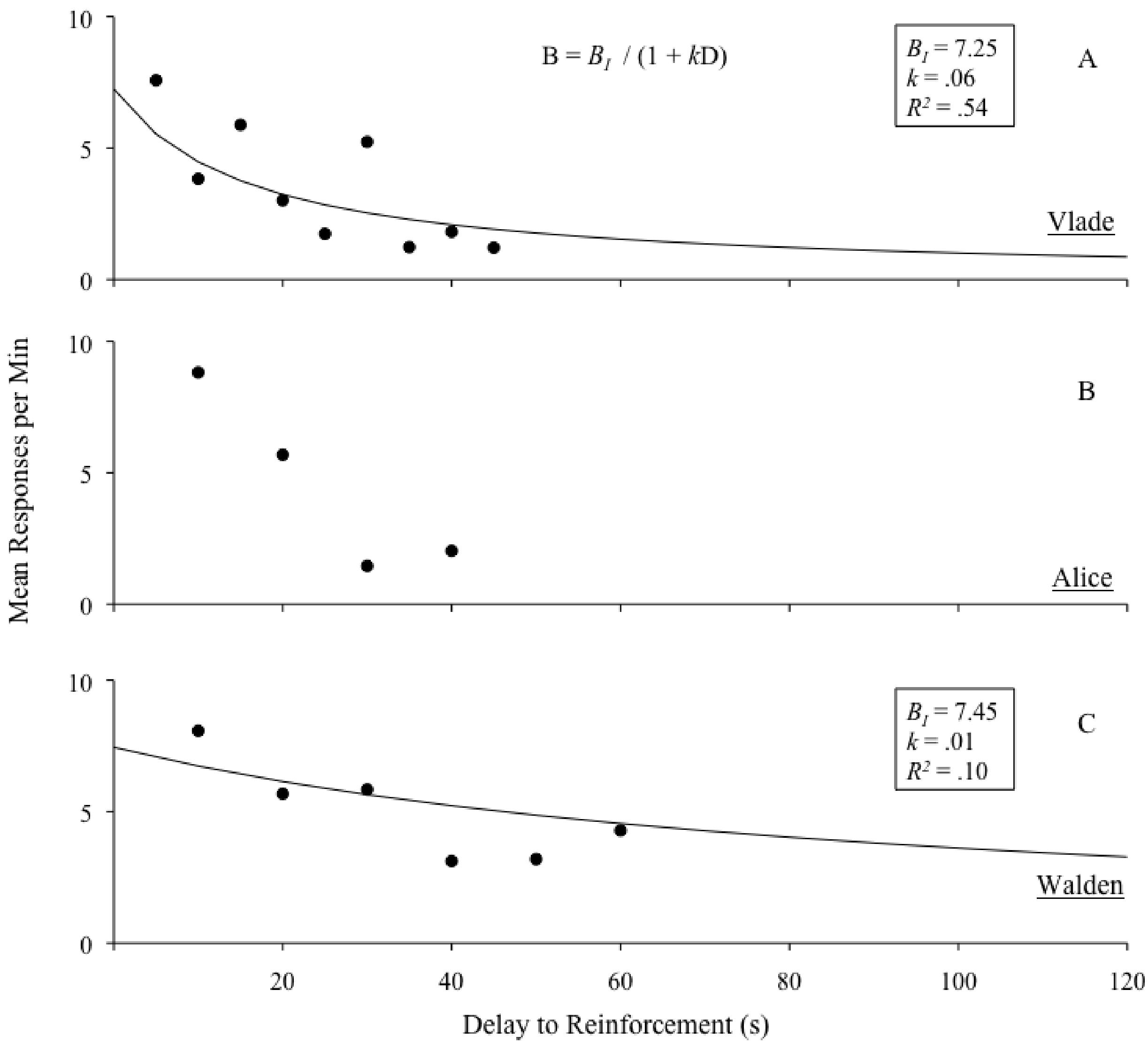


Figure 2-12. Mean rates of "correct" responses as a function of each delay, during both components of the tandem VI - PT schedule of reinforcement in Experiment 1C, and hyperbolas depicting the estimated relationship between these variables. $B_I$ and $k$ are fitted parameters that represent estimated response rate under immediate reinforcement and estimated degree of discounting, respectively. A) Data for Vlade. A tandem VI 30 - PT 5-s schedule of reinforcement was in place. B) Data for Alice. A tandem VI 30 - PT 10-s schedule of reinforcement was in place. C) Data for Walden. A tandem VI 15 – PT 10-s schedule of reinforcement was in place.

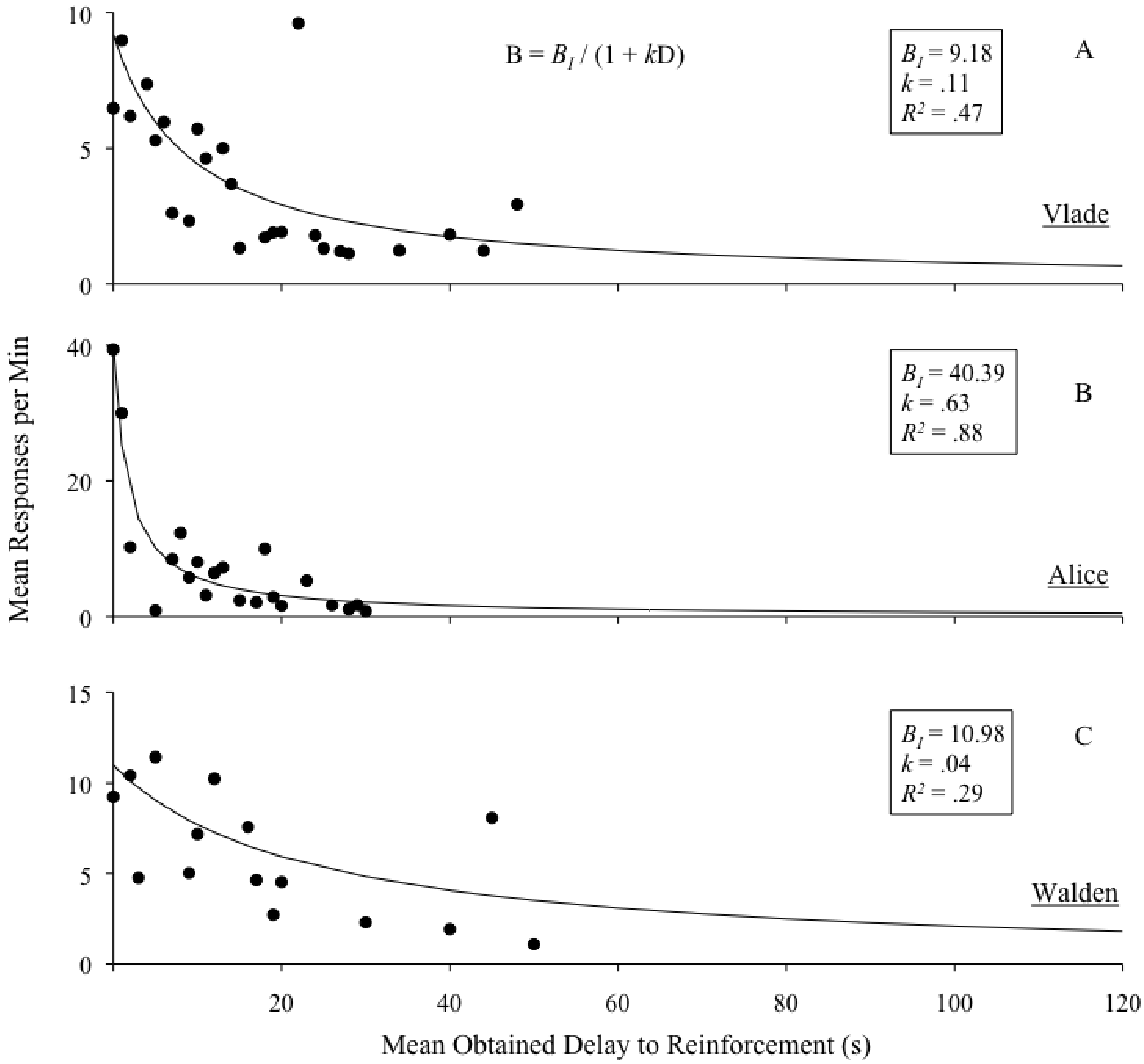


Figure 2-13. Mean rates of "correct" responses as a function of each obtained delay, during both components of the tandem VI - PT schedule of reinforcement in Experiment 1C, and hyperbolas depicting the estimated relationship between these variables. Obtained delays defined as time between the last response (either "correct" or "incorrect") and reinforcer delivery. $B_I$ and $k$ are fitted parameters that represent estimated response rate under immediate reinforcement and estimated degree of discounting, respectively. A) Data for Vlade. A tandem VI 30 - PT 5-s schedule of reinforcement was in place. B) Data for Alice. A tandem VI 30 - PT 10-s schedule of reinforcement was in place. C) Data for Walden. A tandem VI 15 – PT 10-s schedule of reinforcement was in place.

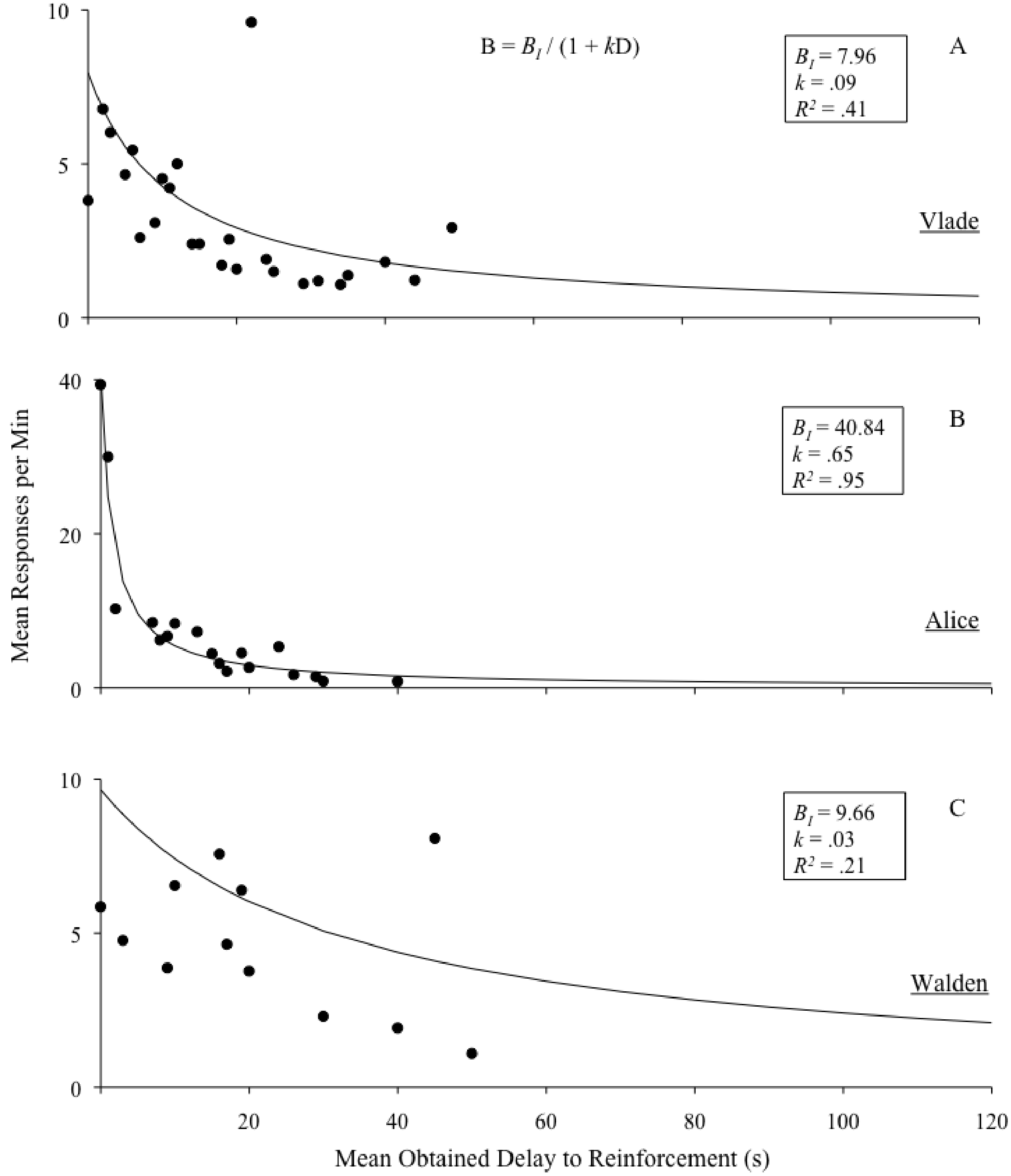


Figure 2-14. Mean rates of “correct” responses as a function of each obtained delay, during both components of the tandem VI - PT schedule of reinforcement in Experiment 1C, and hyperbolic curve depicting the estimated relationship between these variables. Obtained delays defined as time between the last “correct” response and reinforcer delivery. $B_I$ and $k$ are fitted parameters that represent estimated response rate under immediate reinforcement and estimated degree of discounting, respectively. A) Data for Vlade. A tandem VI 30 - PT 5-s schedule of reinforcement was in place. B) Data for Alice. A tandem VI 30 - PT 10-s schedule of reinforcement was in place. C) Data for Walden. A tandem VI 15 – PT 10-s schedule of reinforcement was in place.

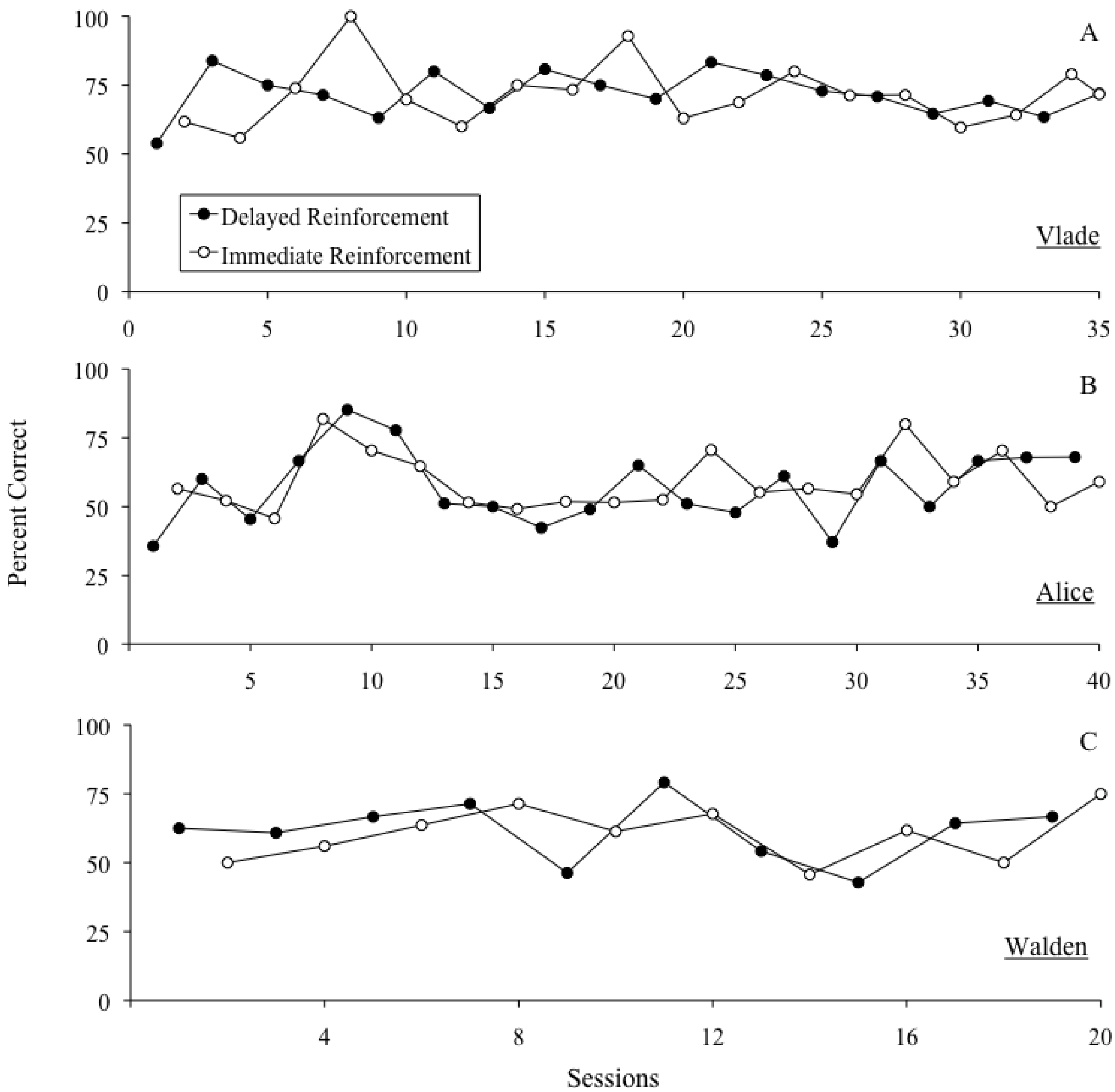


Figure 2-15. Percentage of “correct” responses across consecutive delayed reinforcement (closed circles) and immediate reinforcement (open circles) sessions during Experiment 1C. A) Data for Vlade. A tandem VI 30 - PT 5-s schedule of reinforcement was in place in the delayed reinforcement condition. B) Data for Alice. A tandem VI 30 - PT 10-s schedule of reinforcement was in place in the delayed reinforcement condition. C) Data for Walden. A tandem VI 15 - PT 10-s schedule of reinforcement was in place in the delayed reinforcement condition.

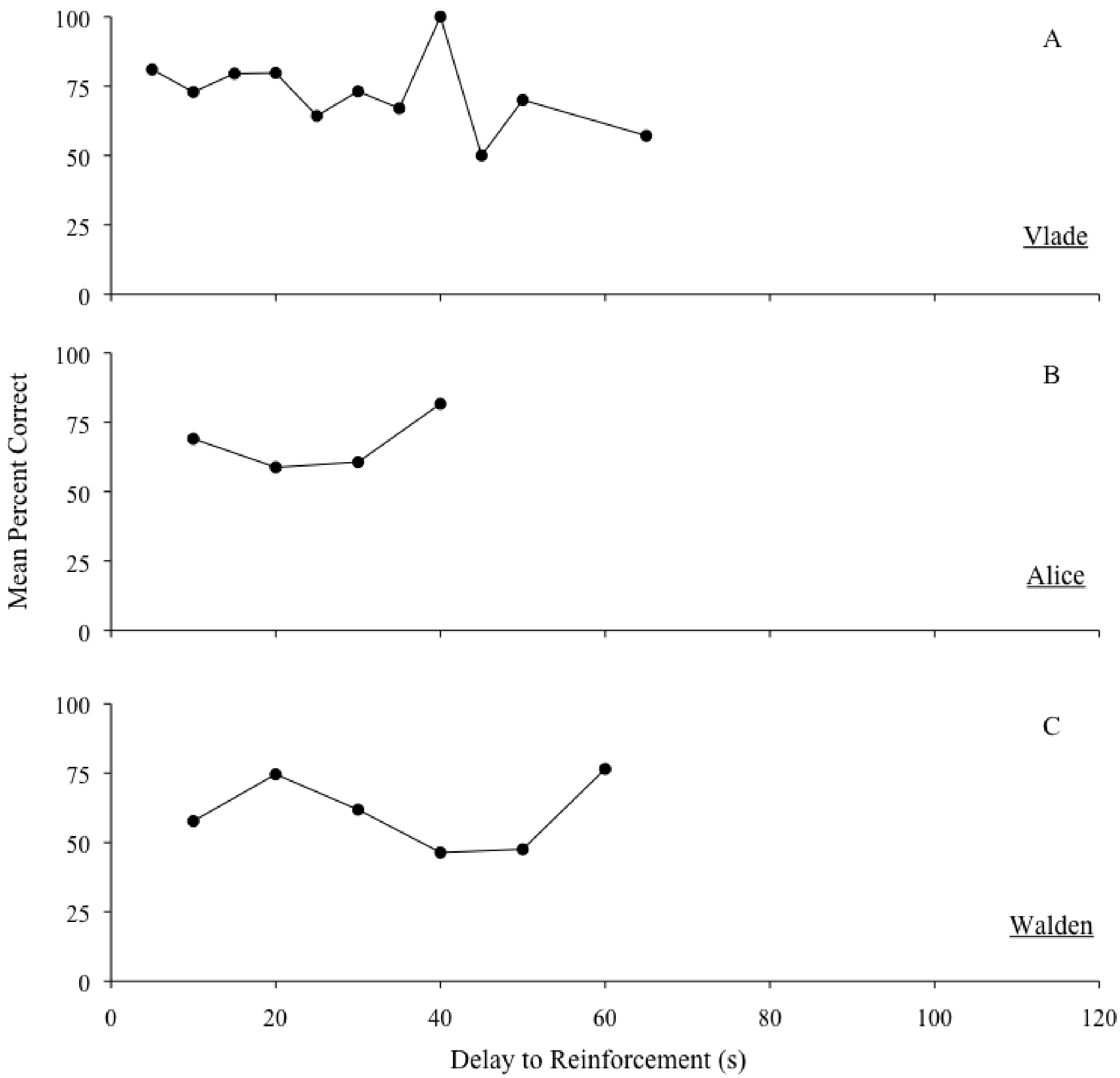


Figure 2-16. Mean percentage of “correct” responses across consecutive delays to reinforcement in Experiment 1C. A) Data for Vlade. A tandem VI 30 - PT 5-s schedule of reinforcement was in place in the delayed reinforcement condition. B) Data for Alice. A tandem VI 30 - PT 10-s schedule of reinforcement was in place in the delayed reinforcement condition. C) Data for Walden. A tandem VI 15 - PT 10-s schedule of reinforcement was in place in the delayed reinforcement condition.

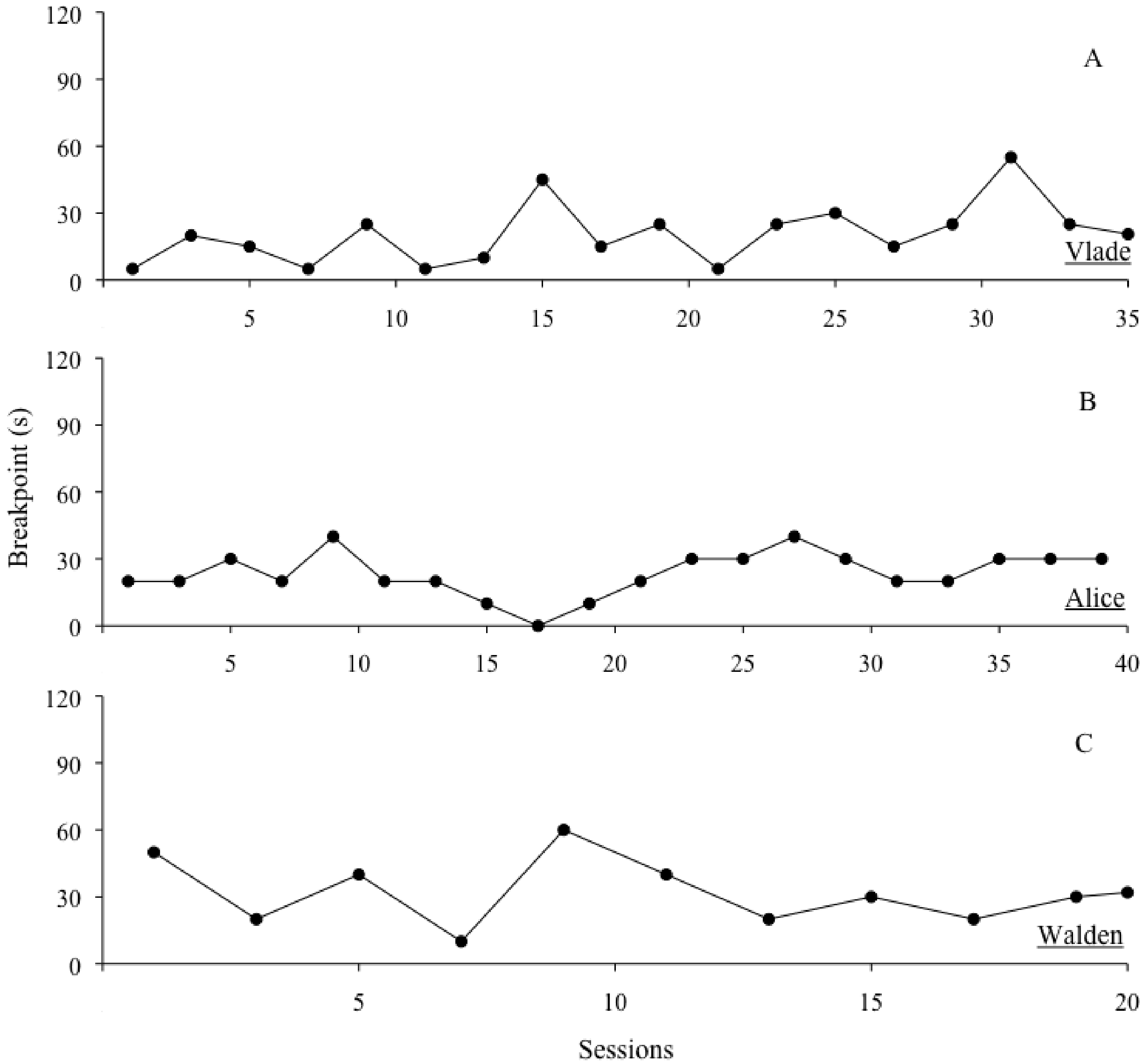


Figure 2-17. Breakpoints obtained during the tandem VI - PT schedule of reinforcement in the delayed reinforcement condition of Experiment 1C. A) Data for Vlade. A tandem VI 30 - PT 5-s schedule of reinforcement was in place. B) Data for Alice. A tandem VI 30 - PT 10-s schedule of reinforcement was in place. C) Data for Walden. A tandem VI 15 – PT 10-s schedule of reinforcement was in place.

# CHAPTER 3
# THE EFFECTS OF DELAYED REINFORCEMENT ON DISCRIMINATION ACQUISITION DURING CONDITIONAL DISCRIMINATION TRAINING

## Conditional Discrimination Training

To date, no research has evaluated whether unsignaled delayed reinforcement alone can lead to discrimination acquisition by individuals with DD. Grindle and Remington (2002) conducted an initial evaluation of the effects of reinforcement delay on discrimination training and found that 3 children diagnosed with ASD could be taught to receptively identify one new picture at a time when reinforcement followed a signaled 5-s delay and an error correction procedure was implemented following incorrect responses. As noted by the authors, it might be important to evaluate delayed reinforcement when a signal is not provided following the response. Additionally, it may be useful to evaluate the effects of longer delays, and to evaluate whether delayed reinforcement can lead to conditional discrimination acquisition when more than one alternative is targeted at a time and an error correction procedure is not implemented. Finally, it is important to identify the conditions under which delayed reinforcement will produce conditional discrimination acquisition.

## Purpose

The purpose of Experiment 2A was to examine whether conditional discriminations could be acquired by children with DD during conditional discrimination training when reinforcers were delivered following unsignaled delays to reinforcement. The purpose of Experiment 2B was to evaluate how the availability of responses during the delay affected discrimination acquisition. The purpose of Experiment 2C was to evaluate the effects of delayed reinforcement when the number of alternatives targeted during each condition was increased from two to four. The purpose of Experiment 2D was to evaluate whether immediate reinforcement would produce discrimination acquisition when ITI were matched to ITI programmed during one of the delayed reinforcement conditions.

## General Methods

### Subjects and Setting

Subjects were preschool-age and school-aged individuals diagnosed with DD. All subjects had limited verbal repertoires, as indexed by their below-average performance on the expressive and receptive communication components of the Battelle Developmental Inventory, administered by the pre-Kindergarten school psychologist. Jorma was a 4-year-old boy diagnosed with ASD. Alice was a 5-year-old girl diagnosed as developmentally delayed. Victor was a 4-year-old boy diagnosed with ASD. Vlade was a 5-year-old boy diagnosed with ASD. Jade was a 3-year-old girl diagnosed as developmentally delayed. Morgan was a 7-year-old girl diagnosed with Down Syndrome. Amira was an 8-year-old girl diagnosed with an Intellectual disability. Mara was a 4-year-old girl diagnosed as developmentally delayed. All subjects scored in the below average range in the areas of receptive and expressive communication on the Battelle Developmental Inventory. Alice and Vlade had previously served as subjects in Experiments 1A, 1B, and 1C. Alice, Amira, Jade, Jorma, Mara, Morgan, Victor, and Vlade, served as subjects in Experiment 2A. Jade, Mara, and Victor served as subjects in Experiment 2B. Jade and Jorma served as subjects in Experiment 2C. Amira, Jade, and Morgan served as subjects in Experiment 2D.

All sessions were conducted in a common area of the subjects' school.

## Target Responses and Data Collection

The target responses differed for each subject, but generally consisted of academic discrimination tasks (e.g., receptive identification of a numeral from a field of stimuli following a verbal prompt).

Independent observers collected data on correct responses, incorrect responses, and the absence of responding using handheld computers. Responses made within 5 s of the instruction that corresponded with the instruction were counted as correct. Responses that did not correspond with the instruction were counted as incorrect. Responses were counted as incorrect if the subject picked both response options (i.e., if the subject placed both stimuli in the experimenters hand) or if the subject did something with the stimuli other than place them in the experimenter’s hand. A “no response” key was scored if the subject did not respond for 5 s following the instruction. Interobserver agreement (IOA) data were collected during 29.40% of all sessions during Experiment 2A, 20.91% of all sessions during Experiment 2B, 53.85% of all sessions during Experiment 2C, and 32.55% of all sessions during Experiment 2D. IOA was calculated by dividing each session into 10-s intervals, calculating agreement for each interval, and averaging across intervals. Across subjects, IOA averaged 95.53% (range, 78.13% to 100%) for Experiment 2A, 96.66% (range, 80.15% to 100%) for Experiment 2B, 97.87% (range, 89.17%% to 100%) for Experiment 2C, and 96.96% (range, 80% to 100%) for Experiment 2D.

## General Procedure

### Preference assessment

Prior to each discrimination training session, subjects were allowed to choose from an array of edible items and toys. The item chosen first was subsequently used as a reinforcer during the remainder of the session, unless the subject indicated that a new item became more preferred.

**Baseline assessment**

During baseline, consequences were never provided for correct or incorrect responses. Throughout all evaluations, either two or four alternatives were targeted per condition. During each session, a fixed number of trials of each instruction was delivered. The order in which each instruction was presented was randomized across trials. For example, the experimenter might have placed the numerals “50” and “70” in front of the subject, and then randomly alternated both the position of the stimuli and the order of the instructions (i.e., “Give me 50” or “Give me 70”) delivered. Thus, the experimenter sometimes said, “Give me 50” when the numeral 50 was in the right side of the field, sometimes said, “Give me 50” when the numeral 50 was on the left side of the field, sometimes said, “Give me 70” when the numeral 70 was in the right side of the field, and sometimes said, “Give me 70” when the numeral 70 was in the left side of the field. Instructions associated with low percentages of correct responses were targeted during conditional discrimination training.

**Conditional discrimination training**

During conditional discrimination training, sessions were identical to baseline, except that reinforcers were delivered following correct responses. Incorrect responses did not result in differential consequences. During the immediate reinforcement condition, a correct response resulted in the immediate delivery of a small edible item or 30 s of access to a preferred toy on a FR 1 schedule. During the delayed reinforcement condition, either a chained (Experiments 2A and 2C) or tandem (Experiment 2B) FR 1 – FT schedule of reinforcement was in effect. During the chained schedule, stimuli were removed during the delay. During the tandem schedule, stimuli remained in front of the subject during the delay. Preferred items were delivered following the completion of the FT component.

## Experiment 2A: Procedure

In Experiment 2A, a combined nonconcurrent multiple baseline - multielement design was used to evaluate whether the delivery of a preferred item (a) immediately or (b) following an unsignaled delay, could produce discrimination acquisition. Two alternatives were targeted during each condition. The duration of the unsignaled delay varied across evaluations and ranged from 20 to 40 s. For all subjects except for Amira, a 20-s delay was initially programmed in the delayed reinforcement condition. If this delay led to discrimination acquisition, a 30-s delay to reinforcement was subsequently evaluated. If the 30-s delay to reinforcement led to discrimination acquisition, a 40-s delay to reinforcement was subsequently evaluated. Immediate reinforcement sessions were alternated with delayed reinforcement sessions. For all subjects except Jade, a total of 20 trials (10 trials of each alternative) were administered per session. For Jade, with the exception of the 20-s delayed reinforcement versus immediate reinforcement comparison and the first 24 sessions of the 30-s delayed reinforcement versus immediate reinforcement comparison, a total of 10 trials (5 trials of each alternative) were administered per session. This was done because within-session analyses revealed that Jade performed better during the first 10 trials.

## Experiment 2A: Results and Discussion

Results from Experiment 2A are depicted in Figures 3-1, 3-2, and 3-3. During the baseline conditions of all evaluations of Experiment 2A, all subjects' percent correct was at or below levels expected by chance. Discrimination acquisition was defined as percent correct equal to or greater than 85% across three consecutive sessions. During the first reinforcement condition, immediate reinforcement led to discrimination acquisition for 6 out of 7 subjects and 20-s delays to reinforcement led to discrimination acquisition for 4 out of 7 subjects. Results were replicated with new sets of stimuli for Jorma and Alice. For the 4 subjects who acquired discriminations under delayed reinforcement, rates of discrimination acquisition were comparable across immediate reinforcement and 20-s delayed reinforcement conditions. For Mara, the subject who did not acquire discriminations under either immediate reinforcement or delayed reinforcement, we subsequently increased response effort by having the subject stand up and walk 3 ft to select a card following each instruction. This manipulation resulted in further separation between the delayed reinforcement and immediate reinforcement condition during most sessions, but did not lead to discrimination acquisition in either condition. These results are depicted in Figure 3-1. We subsequently found that 30-s delays to reinforcement led to discrimination acquisition for 4 out of 4 subjects. However, for Jade, discriminations were acquired slower under the 30-s delayed reinforcement condition relative to the immediate reinforcement condition. Jade only acquired discriminations under 30-s delays to reinforcement when the total number of trials was reduced from 20 to 10. These data are displayed in Figure 3-2. We also found that 40-s delays to reinforcement led to discrimination acquisition for 3 out of 3 subjects. These data are displayed in Figure 3-3. For Jorma, we replicated the effect with a new set of stimuli. During this evaluation, rates of discrimination acquisition were comparable across immediate reinforcement and 40-s delayed reinforcement conditions for Jorma and Victor. However, Amira’s rate of discrimination acquisition was slower under the 40-s delayed reinforcement condition relative to the immediate reinforcement condition.

In summary, these results suggest that brief (i.e., 20- to 40-s) delays to reinforcement can produce conditional discrimination acquisition for some children with DD. These findings extend the results of previous research (Grindle & Remington, 2002) by demonstrating that delayed reinforcement can produce discrimination acquisition (a) in the absence of a prompting procedure, (b) when a signal is not programmed between a response and a reinforcer, (c) when larger delays are programmed, and (d) when more than one response alternative is targeted in each condition.

One limitation of the current study was that the subject was unable to make either correct or incorrect responses during the delay. The efficacy of delayed reinforcement may depend on the type of responses that occur during the delay. In addition, the removal of stimuli following a response, even though not directly correlated with reinforcement, may have functioned as a signal and made the preceding response more salient. Thus, the purpose of Experiment 2B was to examine whether procedures used in Experiment 2A would produce discrimination acquisition when stimuli were available during the delay, and the subject was free to make either correct or incorrect responses during the delay. A trial-based procedure was programmed to limit the number and type of responses that could occur during the delay (i.e., subjects were limited to making only correct or incorrect responses during the delay).

## Experiment 2B: Procedure

In Experiment 2B, a combined nonconcurrent multiple baseline - multielement design was used to evaluate whether the delivery of a preferred item (a) immediately or

(b) following an unsignaled delay in which response alternatives were available during the delay, would produce discrimination acquisition. Two alternatives were targeted during each condition. The duration of the unsignaled delay was 20 s (Mara), 30 s (Jade), or 40 s (Victor). Immediate reinforcement sessions were alternated with delayed reinforcement sessions. For Mara and Victor, a total of 20 trials (10 trials of each alternative) were administered per session. For Jade, a total of 10 trials (5 trials of each alternative) were administered per session. During each session, the experimenter randomly alternated between two instructions.

During the delayed reinforcement condition, a tandem FR 1 - FT schedule of reinforcement was in effect. During both components of the tandem schedule, stimuli were left out in front of the subject. Thus, the subject could continue to make either correct or incorrect responses during the delay. Following any of these responses, the experimenter simply replaced the cards back in front of the subject. Ten trials of each of two instructions were delivered per session.

**Experiment 2B: Results and Discussion**

Figure 3-4 displays percent correct as a function of consecutive sessions during both delayed reinforcement and immediate reinforcement conditions of Experiment 2B. The availability of stimuli during the delay did not interfere with discrimination acquisition for Jade or Victor. In addition, for Victor, discriminations were acquired rapidly across delayed reinforcement and immediate reinforcement conditions. For Jade, the rate of discrimination acquisition was initially slower under the delayed reinforcement condition relative to the immediate reinforcement condition. However, when a replication was ran with new sets of stimuli, rates of discrimination acquisition were comparable across conditions. For Mara, the availability of stimuli during the delay interfered with discrimination acquisition.

Differences between subjects may have been due to the fact that Victor did not respond during the delay, Jade generally made correct responses during the delay, and Mara made both correct and incorrect responses during the delay. Thus, for Victor, reinforcers were never preceded by incorrect responses during the delay. On average, 81.37% of Jade's responses during the delay were correct (range, 53.33% - 100%). In addition, for Jade, only 17.27% (range, 0% - 71.43%) of reinforcers were preceded by an incorrect response and 47.17% (range, 0% - 100%) of final correct responses were not followed by reinforcement. On the other hand, on average, only 45.82% (range, 31.82% - 65.53%) of Mara's responses during the delay were correct. In addition, for Mara, 52.71% (range, 28.57% - 70%) of reinforcers were preceded by an incorrect response and 43.49% (range, 7.69% - 85.71%) of final correct responses were not followed by reinforcement. Final responses were defined as the last response made before a trial ended. These responses could have consisted of the initial response (the response for which a reinforcement contingency was programmed) or a response that occurred during the delay (a response for which reinforcement contingencies were not programmed).

These results suggest that the ability to respond during the delay may prevent discrimination acquisition if subjects often make incorrect responses during the delay and if reinforcers are often preceded by incorrect responses. Less is known about whether discrimination acquisition will occur when reinforcement is delayed and more than two alternatives are targeted at one time. Although Hockman and Lipsitt (1961) found that increasing the number of alternatives targeted at one time made it less likely that typically functioning school-age children would acquire discriminations under delayed reinforcement, the study had several limitations (noted previously). In addition, to date, no study has examined the combined effects of delayed reinforcement and an increase in the number of alternatives targeted on discrimination acquisition by school-aged individuals with DD. Thus, the purpose of Experiment 2C was to evaluate whether discrimination acquisition would still occur when the number of alternatives was increased from two to four.

### Experiment 2C: Procedure

In Experiment 2C, a combined nonconcurrent multiple baseline - multielement design was used to evaluate whether the delivery of a preferred item (a) immediately or (b) following an unsignaled delay, could produce discrimination acquisition. Unlike Experiments 2A and 2B in which two alternatives were targeted during each condition, four alternatives were targeted during each condition. The duration of the unsignaled delay varied across subjects and evaluations, and ranged from 10 to 40 s. Immediate reinforcement sessions were alternated with delayed reinforcement sessions. The experimenter randomly selected one of the four instructions during each trial, until 5 trials of each instruction had been delivered.

### Experiment 2C: Results and Discussion

Figure 3-5 displays results from Experiment 2C. For Jade, a child for whom 30-s delays to reinforcement had previously produced discrimination acquisition when two alternatives were targeted, 30-s delays to reinforcement produced discrimination acquisition when four alternatives were targeted. In addition, discrimination acquisition occurred in the immediate reinforcement condition when four alternatives were targeted.

The rate of discrimination acquisition was comparable across conditions. For Jorma, a child for whom 40-s delays to reinforcement had previously produced discrimination acquisition when two alternatives were targeted, 40-s delays to reinforcement did not produce discrimination acquisition when four alternatives were targeted. In addition, Jorma began to protest when he observed the stimuli associated with the delayed reinforcement condition on the table. However, immediate reinforcement produced discrimination acquisition when four alternatives were targeted. We then replicated the evaluation using different stimuli and briefer (i.e., 10-s) delay to reinforcement (third and fourth conditions). Again, immediate reinforcement produced discrimination acquisition when four alternatives were targeted. Although 10-s delays to reinforcement started to produce discrimination acquisition, discrimination acquisition was not conclusively demonstrated because Jorma left the school before the evaluation could be completed.

In summary, these results suggest that, for some subjects, the efficacy of delayed reinforcement may depend on the number of alternatives targeted at one time, with a negative relationship between the number of responses targeted and the length of the delay associated with discrimination acquisition.

In cases in which discrimination acquisition does not occur under delayed reinforcement, it is difficult to evaluate whether the delay to reinforcement, or the longer ITI associated with delayed reinforcement relative to immediate reinforcement, are responsible for the lack of discrimination acquisition. Thus, the purpose of Experiment 2D was to compare the effects of different ITI lengths on discrimination acquisition.

**Experiment 2D: Procedure**

In Experiment 2D, a combined nonconcurrent multiple baseline – multielement design was used to compare the occurrence and speed of discrimination acquisition during conditions in which either 0-s or 30-s ITI were programmed. In both conditions, reinforcers were delivered immediately on a FR 1 schedule contingent on correct responses. Two response alternatives were targeted during each condition. Either five (Jade) or ten (all other subjects) trials of each of two instructions were delivered per session. The experimenter randomly alternated between the instructions.

### Experiment 2D: Results and Discussion

The percentage of correct responses made during both 0-s ITI and 30-s ITI conditions in Experiment 2D are depicted in Figure 3-6. For all 3 subjects, discrimination acquisition occurred in the 30-s ITI condition. For Jade (top panel), discrimination acquisition initially failed under the 0-s ITI condition. However, for Jade, discrimination acquisition had previously occurred under immediate reinforcement and 0-s ITI (see bottom panels of Figures 3-1 and 3-2, middle panel of Figure 3-4, and top panel of Figure 3-5). Thus, we hypothesized that something about the alternatives targeted (the numerals 13 and 14) hindered discrimination acquisition independent of ITI length, and we compared 0-s and 30-s ITI conditions with two new sets of stimuli. During the second and third evaluations, discrimination acquisition occurred in both 0-s and 30-s ITI conditions. For Amira, discrimination acquisition occurred slightly more rapidly in the 30-s ITI condition relative to the 0-s ITI condition. For Morgan, the rate of discrimination acquisition was comparable across conditions. In addition, discrimination acquisition occurred rapidly in each condition. These results are contrary to those of previous researchers (e.g., Bilodeau & Bilodeau, 1959) and suggest that longer ITI may not always have detrimental effects on behavior. In addition, these results suggest that cases in which delayed reinforcement fails to produce discrimination acquisition likely cannot be accounted for by longer ITI typically associated with the delayed reinforcement condition.

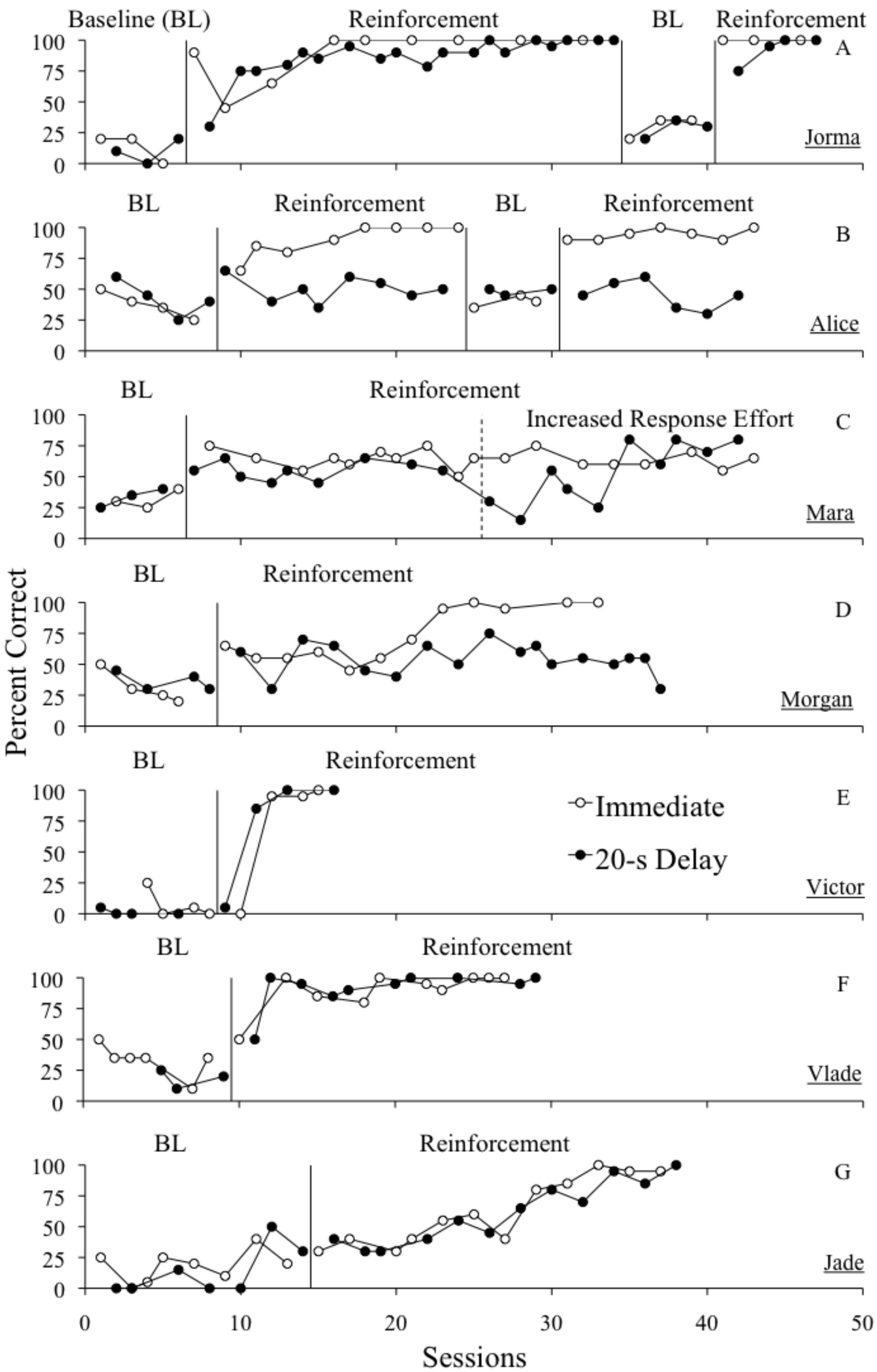


Figure 3-1. Percent correct across 20-s delayed reinforcement (closed circles) and immediate reinforcement (open circles) conditions in Experiment 2A. A) Data for Jorma. Findings were replicated with a new set of stimuli. B) Data for Alice. Findings were replicated with a new set of stimuli. C) Data for Mara. Response effort was increased following the phase change line by requiring Mara to walk 3 ft to select a response. D) Data for Morgan. E) Data for Victor. F) Data for Vlade. G) Data for Jade.

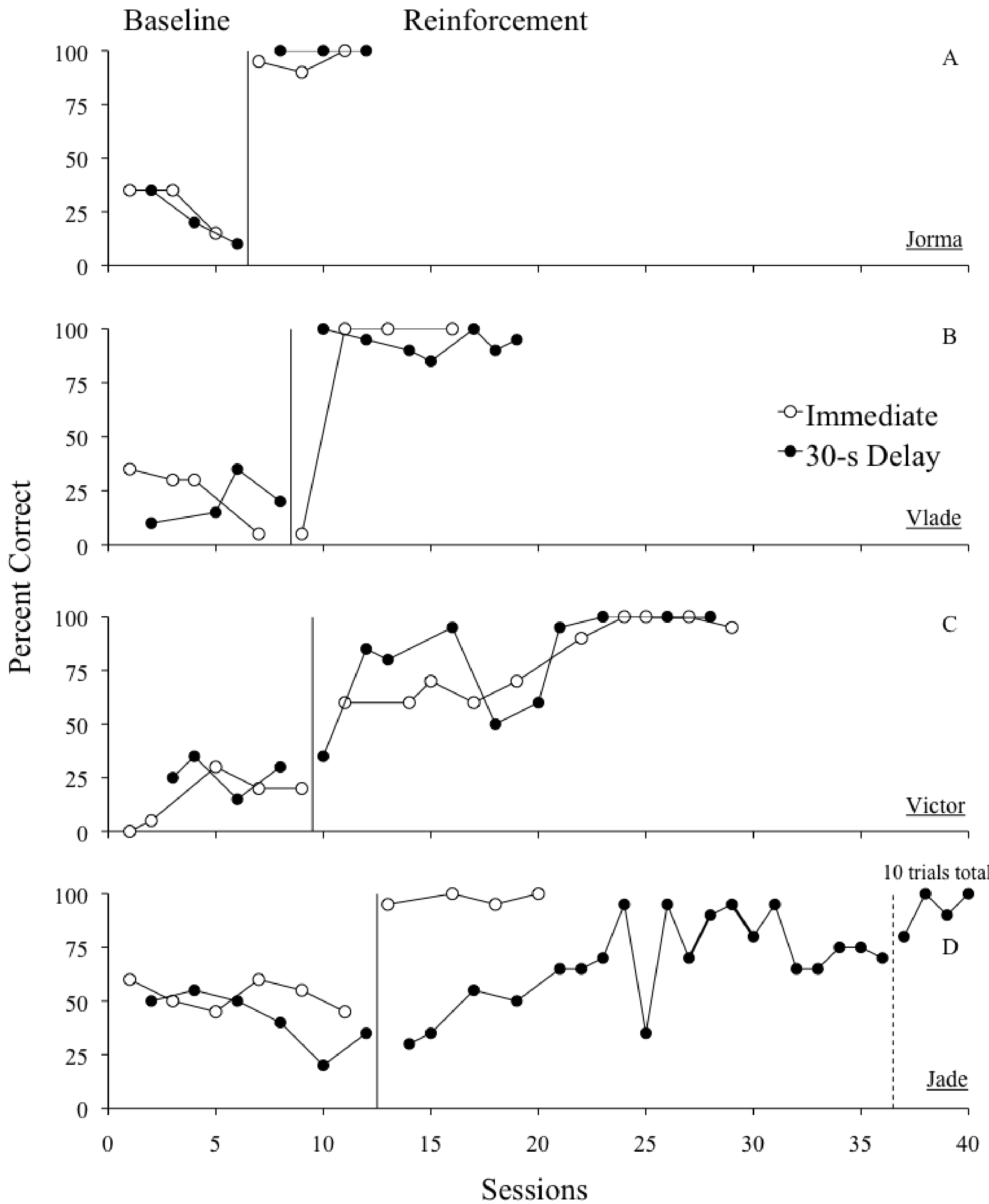


Figure 3-2. Percent correct across 30-s delayed reinforcement (closed circles) and immediate reinforcement (open circles) conditions during Experiment 2A. Unless otherwise noted, 20 trials were completed per session. A) Data for Jorma. B) Data for Vlade. C) Data for Victor. D) Data for Jade. Following the second phase change line, 10 trials were completed per session.

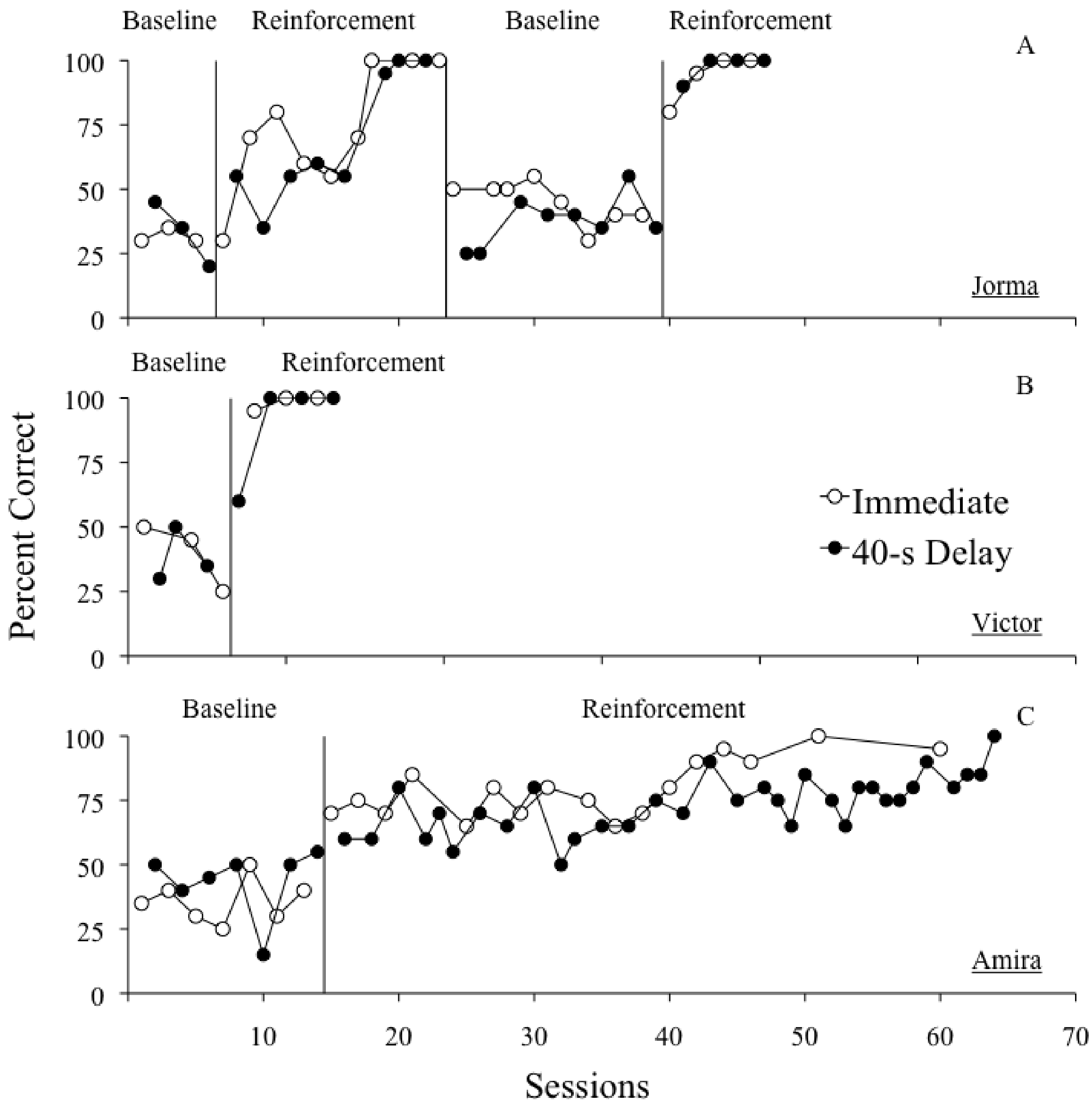


Figure 3-3. Percent correct across 40-s delayed reinforcement (closed circles) and immediate reinforcement (open circles) conditions during Experiment 2A. A) Results for Jorma. Findings were replicated with a new set of stimuli. B) Results for Victor. C) Results for Amira.

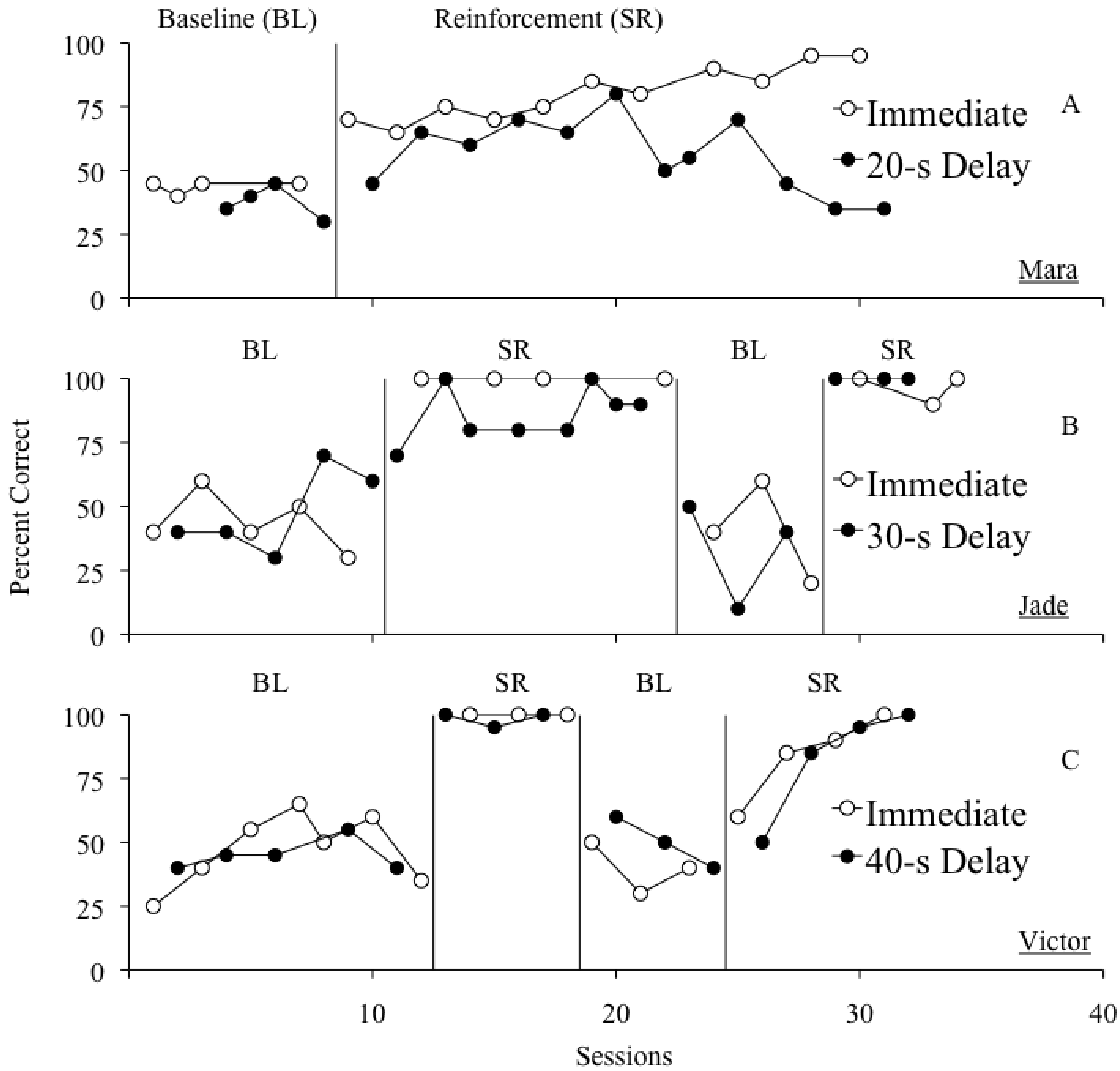


Figure 3-4. Percent correct across delayed reinforcement (closed circles) and immediate reinforcement (open circles) conditions of Experiment 2B. A) Data for Mara. A 20-s delay was programmed in the delayed reinforcement condition. B) Data for Jade. A 30-s delay was programmed in the delayed reinforcement condition. Findings were replicated with a new set of stimuli. C) Data for Victor. A 40-s delay was programmed in the delayed reinforcement condition. Findings were replicated with a new set of stimuli.

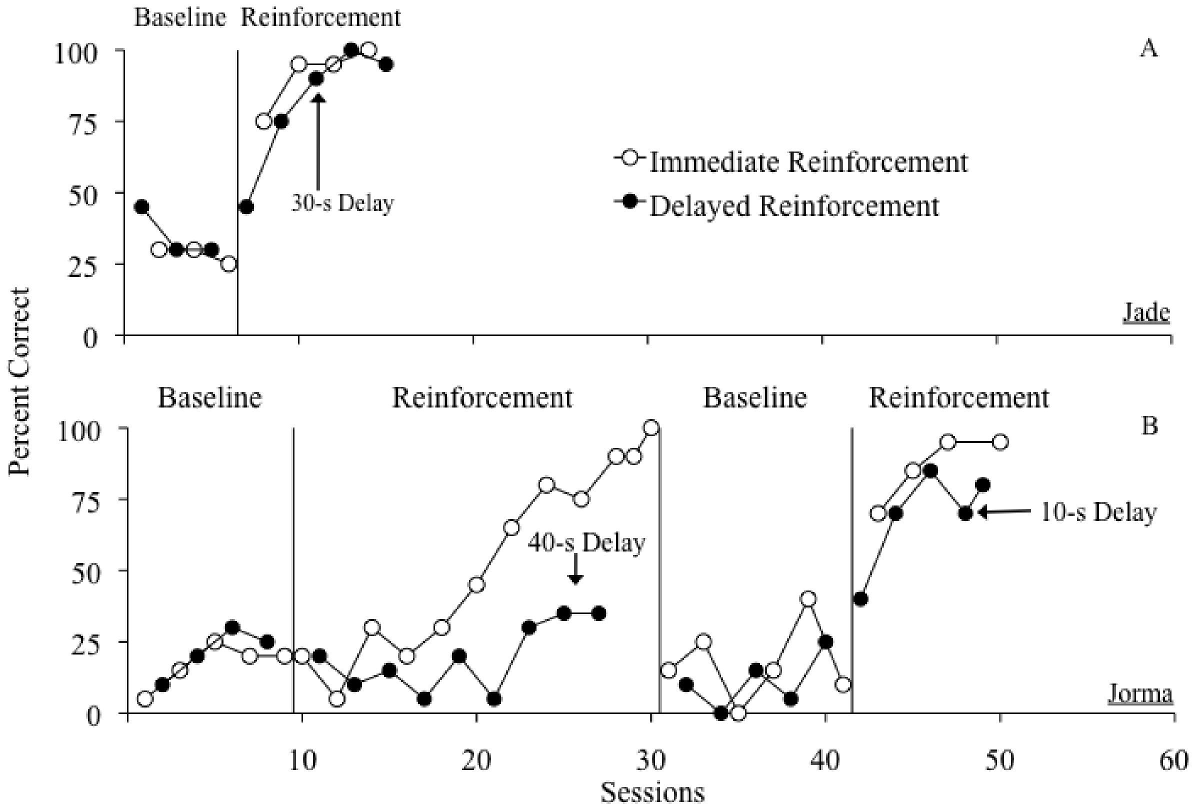


Figure 3-5. Percent correct across delayed reinforcement (closed circles) and immediate reinforcement (open circles) conditions of Experiment 2C when 4 alternatives were targeted per condition. A) Data for Jade. A 30-s delay was programmed in the delayed reinforcement condition. B) Data for Jorma. In the first delayed reinforcement condition, a 40-s delay was programmed. In the second delayed reinforcement condition, a 10-s delay was programmed.

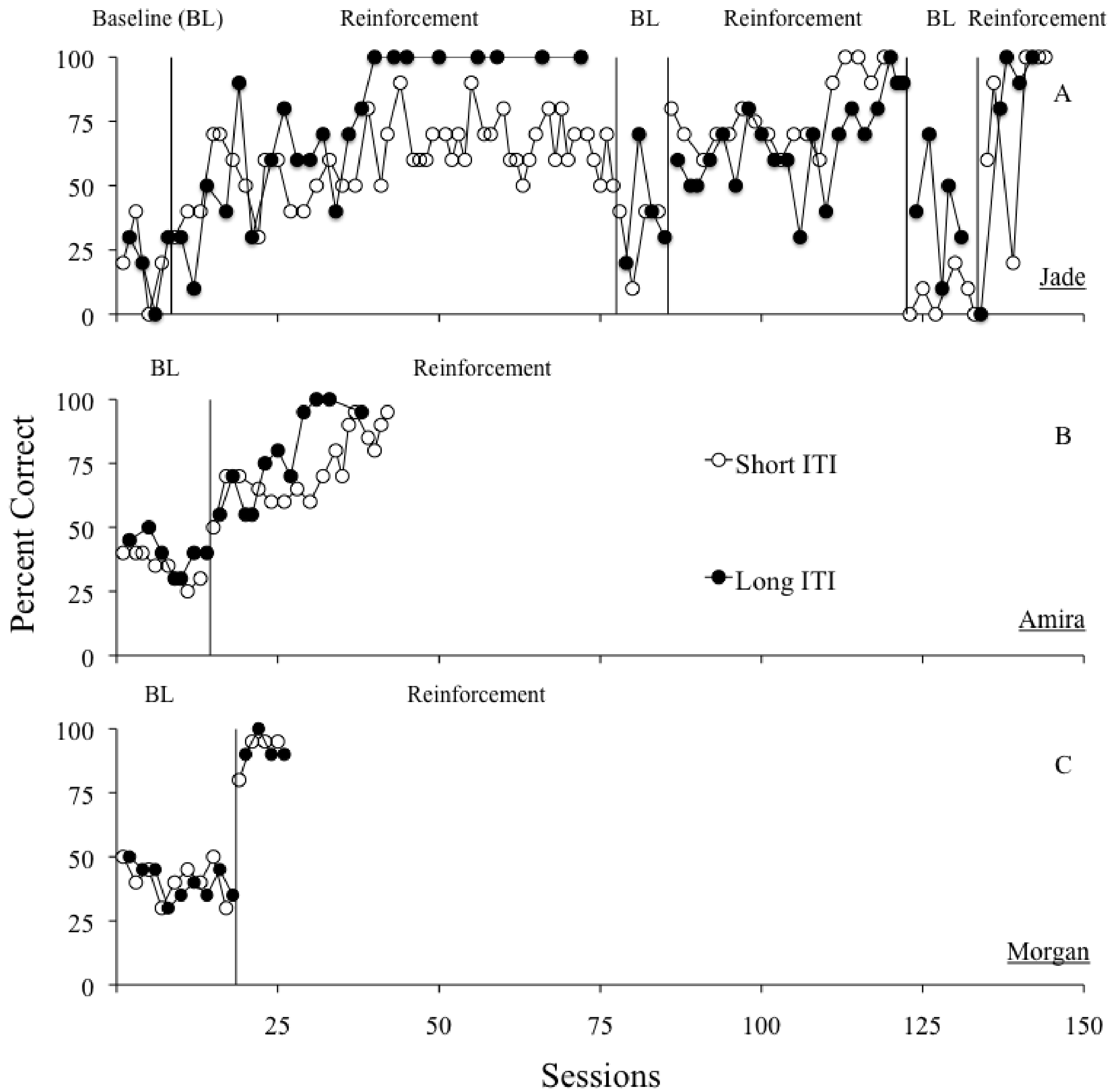


Figure 3-6. Percent correct across conditions in which either 0-s (open circles) or 30-s (closed circles) ITI were programmed during Experiment 2D. During baseline, reinforcers were not delivered. In the reinforcement phase, reinforcers were delivered immediately contingent on correct responses. A) Data for Jade. Two replications were conducted with new sets of stimuli. B) Data for Amira. C) Data for Morgan.

CHAPTER 4
GENERAL DISCUSSION

## Overall Summary

Experiment 1 evaluated whether arrangements similar to those used in the laboratory could be used to evaluate the behavior of children with DD under conditions of delayed reinforcement, and whether the findings from nonhuman laboratories would translate to this population. Experiment 2 evaluated (a) whether delayed reinforcement could produce discrimination acquisition in children with DD, (b) some of the variables that might affect the efficacy of delayed reinforcement, and (c) whether longer ITI prevented discrimination acquisition.

### Experiment 1

Overall, the results of Experiment 1 suggest that reinforcement immediacy may not be essential under some teaching arrangements when delays to reinforcement are progressively increased following successive reinforcer deliveries and the goal is simply to maintain already-established responding. The results also suggest that delayed reinforcement may be more likely to maintain responding when a stimulus change (e.g., the removal of squares depicted on a touch screen) follows a response, even if the stimulus change is not exclusively paired with reinforcement. This was indexed by higher response rates during Experiments 1A and 1B (which programmed stimulus removal during the terminal component) relative to Experiment 1C (which did not program stimulus removal during the terminal component). This finding is contrary to that of previous research (i.e., Ferster, 1953). Ferster found that a VI schedule of reinforcement with response-contingent blackouts not correlated with reinforcement did not produce differences in responding relative to a VI schedule that did not include blackouts and a VI schedule that included response-independent blackouts. However, these discrepancies may be due to the fact that Ferster did not compare conditions in which blackouts were and were not correlated with later reinforcer delivery.

The overall percentage of “correct” responses (evidence of discrimination) was lower during Experiments 1B and 1C relative to the Experiment 1A. One interpretation of these results is that delayed reinforcement may be less likely to maintain discriminated responding under an intermittent schedule of reinforcement (i.e., a VI 30-s schedule relative to a FR 1 schedule). Alternatively, lower percentages of “correct” responses may simply have been due to interval strain, independent of the delay. Previous evaluations of delayed reinforcement typically establish steady state responding under an interval schedule prior to introducing a delay to reinforcement (e.g., Gleeson & Lattal, 1987). In the present experiments, this was not done. Instead, responding was briefly established at the start of each session by exposing subjects to 10 trials in which reinforcers were delivered immediately on a FR 1 schedule contingent on “correct” responses. Although discriminations were typically established during this initial exposure period, they quickly deteriorated once the chained or tandem VI – PT schedule was introduced. Thus, although these procedures were specifically designed to increase the speed in which we could evaluate response rates under various delays to reinforcement, they may not have been sufficient to examine the effects of delayed reinforcement on the maintenance of discriminated responding. However, this arrangement may be analogous to classroom situations in which a teacher demonstrates how to complete a problem, reinforces the correct completion of a few problems, and then moves away to assist other students, only to come back at a later time to evaluate a student’s progress. Thus, the methods used in Experiments 1B and 1C in some way resembles how delayed reinforcement contingencies operate in the natural environment.

Mean levels of percentage “correct” generally did not decrease as delays to reinforcement increased, which is contrary to the results of some experiments (e.g., Escobar & Bruner, 2007; LeSage, Byrne, & Poling, 1996). Escobar and Bruner compared responding on both an operative lever and six nonoperative levers across seven groups of three rats exposed to 0-, 1-, 2-, 4-, 8-, 16-, or 32-s delays to reinforcement. The researchers found that rats exposed to 16- or 32-s delays to reinforcement allocated more of their responses to the nonoperative levers relative to rats exposed to 0- or 2-s delays to reinforcement. The responses to the nonoperative levers competed with the target responses, decreasing the percentage of “correct” responses. Differences between Escobar and Bruner’s findings and the findings of the present experiments may be due to several procedural differences between the two studies (e.g., within subjects versus between subjects comparisons). Lattal (2010) noted that delayed reinforcement is associated with a variety of outcomes, depending on the circumstances in which it is evaluated.

**Experiment 2**

The purpose of Experiment 2 was to examine the effects of delayed reinforcement on discrimination acquisition in children with DD, and to evaluate some of the variables that may affect the efficacy of delayed reinforcement. The results of Experiment 2A demonstrated that, for some subjects, discriminations could be acquired when reinforcers were delivered following a 20- to 40-s unsignaled delay. The results of Experiment 2B demonstrated that delayed reinforcement could produce discrimination acquisition when responses occur during the delay, as long as incorrect responses do not occur often. The results of Experiment 2C demonstrated that, for some individuals, the efficacy of delayed reinforcement was dependent on the number of response alternatives targeted per condition. ITI length (which was longer in all previous delayed reinforcement conditions in Experiment 2 relative to immediate reinforcement conditions) was not found to produce an effect on the rapidity or occurrence of discrimination acquisition.

Findings from Experiment 2 have several implications for practitioners who use discrimination training to teach individuals with DD new skills. First, findings suggest that, in many cases, practitioners can complete other necessary tasks (e.g., data recording, blocking of dangerous behavior) prior to delivering a reinforcer as long as the reinforcer is delivered within a reasonable amount of time and as long as there is a contingency arranged between a correct response and reinforcement. Second, results suggest that, in cases in which practical limitations necessitate the delay of reinforcement, it may be necessary to limit the number of alternatives targeted at one time for some individuals. Third, results suggest that it may not be necessary to remove stimuli immediately following a response. Although these implications may seem minor in isolation, collectively, they may help practitioners better manage their time, and they may make procedures appear less daunting to new practitioners in the field. It should be noted, however, that evaluations similar to those conducted in Experiments 1 and 2 should be conducted for each individual to determine the effects of delayed reinforcement on an individual basis. In addition, results do not suggest that reinforcement *should* be *intentionally* delayed. Instead, results simply suggest that there may be more leeway in the extent to which reinforcers must be provided immediately under some controlled circumstances.

## Conclusions

The methods used in Experiments 1 and 2 extend the methods used in basic research (e.g., Reilly & Lattal, 2004) to children with DD. As noted by Mace and Critchfield (2010), more translational research is needed to bridge the gap between basic and applied research. Replications of effects seen with nonhumans provide important empirical support for the notion of interspecies generality of operant principles and suggest that the questions asked by basic researchers have some applied value (Mace & Critchfield). Skinner was a proponent of translational research, arguing that the reader is not "expected to be interested in the behavior of the rat for its own sake. The importance of a science of behavior derives largely from the possibility of an eventual extension to human affairs" (Skinner, 1938, p. 441).

Experiment 1 replicated the results of basic, laboratory experiments, in that increases in the delay to reinforcement were associated with decreases in response rate (e.g., Reilly & Lattal, 2004). This relationship was nicely described by the modified version of Mazur's (1987) hyperbolic delay discounting equation. The across-subjects ranking of the parameter $k$, which represents estimated degree of discounting due to the delay, did not remain consistent across Experiments 1A, 1B, and 1C. For example, Vlade's $k$ value was higher than Walden's $k$ value in Experiments 1A and 1B, but lower than Walden's $k$ value in Experiment 1C. These results suggest that relative ranking of $k$ values may not remain consistent across time. Experiment 2 extended the results of basic, laboratory experiments to an arrangement commonly used to teach children with DD new skills. It is unknown whether delays to reinforcement are likely to occur under this arrangement in the natural environment. However, this arrangement was designed as one way to carefully control the number and type of responses that could occur during the delay. Future evaluations will first examine the effects of delayed reinforcement on free operant responding under controlled, laboratory conditions, next examine the effects of delayed reinforcement on both problem behavior and appropriate behavior in analogue settings, and finally examine the effects of delayed reinforcement on both problem behavior and appropriate behavior in the natural environment.

There has been some debate about the mechanisms responsible for response acquisition and maintenance under delayed reinforcement (see Lattal, 2010, for a review). For example, it has been suggested that responding can be maintained when reinforcement is delayed due to “superstitious” responses that bridge the delay to reinforcement (Keller & Schoenfeld, 1950). Indeed, Ferster (1953) found that each subject consistently engaged in a particular response (e.g., turning in a circle with the head stretched high) during a 60-s delay interval. These responses then continued to occur throughout an approximately 100-hr experimental period. In the present investigation, all subjects engaged in alternative responses during the delay interval. These responses varied over time and across subjects, ranging from stereotypy (Walden) to drinking water (Vlade and Amira). The lack of consistency suggests that the efficacy of delayed reinforcement was not mitigated by “superstitious” responses occurring during the delay. Instead, these responses could have either been adjunctive responses induced by the reinforcement schedule (e.g., water consumption, Falk, 1961) or responses that were briefly adventitiously reinforced. Reeve et al. (1993) noted that responses that are adventitiously reinforced by temporally contiguous reinforcement may vary and fade over time as the overall contingency (reinforcement for the target response) begins to control behavior.

Assuming that the procedures used in the current investigation accurately estimate response rates under delayed reinforcement, the results of this investigation may have implications for skill acquisition and maintenance of problem behavior. It may be the case that teachers need not provide reinforcers immediately to maintain an appropriate response, even if problem behavior occurs following those appropriate responses. However, it may also be the case that the delivery of reinforcers for appropriate responses that occur some time after problem behavior may actually serve to maintain problem behavior. However, it is difficult to make a jump from the systematic controlled arrangement set up in the current experiments to the more complex contingencies operating in the natural environment. It is hoped that the current series of studies will set the stage for more research on delayed reinforcement in complex environments.

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# BIOGRAPHICAL SKETCH

Jolene Rachel Sy was born in Sacramento, CA in 1981 and was raised in the Sacramento area. In 1998, Jolene moved to Santa Cruz, CA to attend the University of California, Santa Cruz. After earning a Bachelor of Arts in language studies, Jolene began work as a behavior analyst working with children with ASD. It was at this time that she became interested in behavior analysis. In 2005, Jolene moved to Stockton, CA to attend the University of the Pacific (UOP). At UOP, Jolene served as a research assistant in Dr. John Borrero's laboratory and earned a master's degree under his supervision. In 2007, Jolene entered the doctoral program in behavior analysis under the supervision of Dr. Tim Vollmer. Jolene earned a doctor of philosophy in 2011, and will relocate to Saint Louis to begin an assistant professor position at Saint Louis University.