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REINFORCEMENT DELAY FADING DURING DIFFERENTIAL REINFORCEMENT OF COMMUNICATION: THE EFFECTS OF SIGNALS ON RESPONSE MAINTENANCE

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Signals during delays to reinforcement may lessen reductions in responding that typically occur when there is a delay between a response and its reinforcer. Sparse applied research has been devoted to understanding the conditions under which responding may be maintained when delays to reinforcement are introduced. We evaluated the extent to which providing signals during delay fading affected responding in the context of differential reinforcement of communication responses. Three individuals were exposed to gradually increasing signaled and unsignaled reinforcement delays in multiple-schedule and/or withdrawal designs. Results for 2 of 3 participants suggested that (a) the presence of signals facilitated response maintenance under delayed reinforcement and (b) coordinated basic and applied research may advance both conceptual understanding and clinical outcomes of delayed reinforcement.

Key words: translational research, delay fading, delayed reinforcement, functional communication training, communication, signaled delays, stimulus control

Delayed reinforcement is an area of research that has drawn considerable attention from both basic and applied researchers. Azzi, Fix, Keller, and Rocha e Silva (1964) conducted a preliminary study on the effects of exteroceptive stimuli on responding during delays to reinforcement. Responding was more regular and occurred at higher rates during conditions in which a change in the lighting in the operant chamber was correlated with the delay interval. This effect has been replicated across several studies, despite significant procedural variation (e.g., Lattal, 1984; Richards, 1981). For example, Lattal showed that, in general, signaled delays maintained response rates close to baseline levels, and that unsignaled delays produced large decrements in responding compared to an immediate-reinforcement baseline. In a follow-up experiment, Lattal also showed an important relation between the percentage of delay intervals that were signaled and response maintenance. Response rates were positively correlated with the percentage of delay intervals that included a signal.

Schaal and Branch (1988) compared response rates under conditions of unsignaled, briefly signaled, and completely signaled delays to reinforcement. A 1-s reinforcement delay decreased responding relative to a variable-interval (VI) 60-s schedule with immediate reinforcement. Response rates returned to immediate-reinforcement levels when a signal (i.e., a change in the color of the key light) was introduced during the first 0.5 s of the delay. Response rates comparable with immediate reinforcement were maintained with this brief signal at 1-s, 3-s, and 9-s delays, but not at 27-s delays. Results of a subsequent experiment showed that a signal lasting the entire delay was necessary to maintain responding under the 27-s delay condition. Schaal and Branch suggested that signals may function as conditioned reinforcers, and thus, help to ''bridge the gap'' between the occurrence of the response and reinforcer delivery.

Although basic research on the efficacy of providing signals suggests a rather robust effect for response maintenance during rein-

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forcement delays, the generality of this effect has not been systematically evaluated in applied or translational research. The potential clinical value of translational research on delayed reinforcement is unlikely to be realized without a direct understanding of the problem that delayed reinforcement presents to applied researchers. For example, clinicians often use functional communication training (Carr & Durand, 1985), a type of differential-reinforcement intervention, for reducing problem behavior and increasing adaptive behavior. A common posttreatment problem for clinicians may include the inadvertent introduction of a delay between the occurrence of the trained communication response and the delivery of the reinforcer, which may lead to treatment failure. Often, this delay may be unsignaled (e.g., a caregiver simply ignores the individual's request for an unspecified period of time), resulting in the reemergence of previously reinforced problem behavior. Alternatively, information about upcoming reinforcement delivery in the form of signals may reduce the likelihood of this occurring. In one of the few studies that evaluated the efficacy of signals, Vollmer, Borrero, Lalli, and Daniel (1999) showed that impulsive responding (e.g., allocating behavior to a response option correlated with a smaller, sooner reward) could be reduced by signaling the delay to reinforcement for a concurrently available alternative response (i.e., the larger, delayed reward option).

In the current study, we evaluated the extent to which signals introduced during delays to reinforcement for a communication response would maintain levels of responding comparable to immediate reinforcement. This comparison was conducted in the context of delay fading, a procedure that is commonly used in applied studies to increase the practicality of differential-reinforcement procedures. Delay fading in this manner has rarely, if ever, been studied in basic-research investigations. The purposes of the current study were to (a) establish conditions under which signaled delays may support levels of responding comparable to immediate reinforcement (an applied concern) and (b) compare the current results to results from conceptually similar basic research (to assess the generality of basic research on delayed reinforcement).

METHOD

Participants and Settings

Participants were 3 individuals diagnosed with developmental disabilities who were referred to a facility specializing in the assessment and treatment of severe behavior disorders. These individuals were selected for participation because communication training with delay fading was identified as a treatment goal by their therapy teams.

Brian was a 14-year-old boy diagnosed with severe mental retardation and autism. He was nonverbal and did not consistently follow spoken requests. His individual-education-plan (IEP) goals included increasing communication and better tolerance of delays to reinforcement because caregivers reported that Brian was likely to engage in self-injury and aggression when access to preferred items was delayed or denied. Chuck was an 8-year-old boy diagnosed with severe mental retardation, cerebral palsy, and autism. Chuck sometimes followed rudimentary directions and communicated mainly by way of gestures (e.g., pointing). Michele was an 8-year-old girl diagnosed with moderate mental retardation, cerebral palsy, and autism. Michele spoke in four- to six-word sentences and sometimes followed simple directions. She was initially referred for assessment and treatment of destructive behavior, which included aggression and property destruction. Results of previous assessments indicated that these behaviors were maintained by negative reinforcement in the form of escape from demands.

The study took place in classrooms and therapy rooms that contained tables, desks, chairs, and relevant session materials. During all sessions, Brian was seated at a table facing a wall in a classroom that measured 6.1 m × 9.2 m. Other students, teachers, and therapists were periodically present in the classroom but did not interact with Brian or the therapists. The therapist and observers sat next to Brian at the table but did not interact with him except to conduct session-related activities. Chuck's sessions were conducted in a therapy room that measured 3.1 m × 6.1 m. Only Chuck and a therapist were present in the therapy room during sessions. Observers collected data from behind a one-way mirror. Michele's sessions were conducted in a therapy room that measured 2.5 m × 3.1 m. Michele, the therapist, and observers were present in the therapy room during sessions.

Response Measurement, Selected Reinforcers, and Interobserver Agreement

Communication responses were selected based on each individual's communication goals and caregiver preference. Brian's target communication response was a card touch that produced small edible items; a card touch was defined as contact between any part of Brian's palm and a ''snack please'' card (15 cm × 20 cm), which was located 45 cm in front of him on a table. Chuck's communication response was handing a remote control to a therapist. Occurrences of the communication response produced 30-s access to a video. This response was selected because Chuck often attempted to operate televisions and remote controls when he came into contact with them, and his mother wanted him to appropriately request assistance at such times. The television/videocassette recorder (TV/VCR), the therapist, and the table on which the remote control was located were always in the same locations in the therapy room. The therapist sat next to the TV/VCR, and the table with the remote control was approximately 3 m from the therapist. Michele's communication response was a card exchange, which was defined as picking up a ''break please'' card (15 cm × 20 cm) and placing it into the therapist's hand. Occurrences of the communication response produced 20-s escape from demands. This response was selected because a prior assessment suggested that Michele's destructive behavior was reinforced by escape from demands. This communication was selected as a replacement for destructive behavior.

Response rate data were collected on laptop computers. For sessions during which a delay to reinforcement occurred, the delay intervals were subtracted from the total session duration prior to calculating response rate because the participants could not engage in the communication responses during the delay interval (i.e., the therapist retained the cards or remote control during the delay interval). Interobserver agreement (IOA) was collected on 40.9%, 38.9%, and 49.7% of sessions for Brian, Chuck, and Michele, respectively. Mean IOA for the dependent variable was calculated by dividing each session into consecutive 10-s bins and comparing the number of responses recorded in each interval by each observer. An exact agreement was defined as both observers recording the same number of responses in a given 10-s interval. Agreement percentages were calculated by dividing the number of intervals with exact agreement by the total number of intervals in a session and converting the resulting quotient into a percentage. Mean exact agreement across sessions for communication responses was 95.3% (range, 77.2% to 100%) for Brian, 94.2% (range, 65.0% to 100%) for Chuck, and 96.2% (range, 70.5% to 100%) for Michele.

Procedures and Experimental Conditions

A graduated prompting sequence similar to that described by Shirley, Iwata, Kahng, Mazaleski, and Lerman (1997) was used to teach the communication responses to the participants prior to the study. During these training trials (defined as 10 opportunities to engage in a response and contact reinforcement), the therapist used a 3-step prompting sequence (i.e., successive verbal, model, and physical prompts) if the participant did not engage in the response within 5 s of the start of a trial. That is, a trial began with a 5-s period during which the therapist waited for the participant to emit the response independently. Contingent on no response, the therapist vocally instructed the participant to engage in the response (e.g., ''touch the card''). Contingent on another 5 s without a response, the therapist modeled the correct response by picking up the card or remote and demonstrating a communication response while saying, ''hand me the___.'' If another 5 s passed without the response, the therapist put the card or remote in the participant's hand and then guided the participant to complete the communication response. Training was terminated when the participants communicated independently on at least 80% of trials.

All participants were exposed to four conditions: immediate reinforcement, signaled delay fading (i.e., gradually increasing delays), unsignaled delay fading, and extinction. Two to eight 10-min sessions per day were conducted 2 to 5 days per week. Session length was increased to 15 min when the delay reached 120 s and to 20 min when the delay reached 450 s so that each participant's behavior would have more opportunities to contact the con-

Table 1

Experimental sequence and fading progressions in seconds (highest delay value reached for each participant in each exposure to delay fading).

Experimental sequence				
Multiple-schedule designs		Withdrawal designs		
Brian	Chuck	Brian	Chuck	Michele
Imm. Rein.	Imm. Rein.	Imm. Rein.	Imm. Rein.	Imm. Rein.
Sig v. Uns DF	Sig v. Uns DF	Sig DF	Uns DF	Uns DF
Extinction	Imm. Rein.	Extinction	Imm. Rein.	Imm. Rein.
Sig v. Uns DF	Sig v. Uns DF	Imm. Rein.	Sig DF	Sig DF
	Imm. Rein.	Uns DF	Imm. Rein.	Extinction
	Sig v. Uns DF	Imm. Rein.	Uns DF	Imm. Rein.
	Imm. Rein.	Sig DF	Imm. Rein.	Sig DF
	Sig v. Uns DF		Sig DF	Extinction
				Imm. Rein.
				Uns DF

Fading progression				
Multiple-schedule designs		Withdrawal designs		
Brian	Chuck	Brian	Chuck	Michele
2	2	2	20	2
5	5	5	40	5
7	7	7	60	7
9	9	9	80	9
11	11	11	100	11
14	14	14	120	14
19	19	19		19
24	24	24		24
31	31	31		31
40	40	40		40
60	50	60		60
90	60	75		90
120	75	90		120
300	90	120		300
450	120	300		
600	300			
750	450			
	600			

Sig = Signaled; Uns = Unsignaled; DF = Delay Fading; Imm. Rein. = Immediate Reinforcement

tingencies (i.e., the participants had fewer opportunities to respond within each session as the delay interval increased).

The target terminal reinforcement delay (300 s) was based on caregiver/teacher preference. The actual terminal delay was shorter or longer than 300 s in some phases of the study depending on each participant's response patterns under delay fading. Table 1 shows the experimental sequence and fading progression used with each participant.

When signaled and unsignaled delay conditions were compared in a multiple-schedule design, delay fading was terminated before reaching 300 s if responding decreased and remained below previous levels of responding in that condition for several consecutive sessions. Conversely, the terminal delay value was lengthened in some conditions if responding was maintained under the 300-s delay but was undifferentiated across conditions. When signaled and unsignaled delay conditions were compared in a withdrawal design, delay fading was terminated prior to 300 s whenever responding remained below immediate reinforcement levels for four consecutive sessions. Communications were exposed to a series of extinction sessions whenever responding was maintained under the terminal delay in a given condition (e.g., signaled delay) to provide a similar recent history prior to the next delay-fading condition (e.g., unsignaled delay).

Brian and Chuck were provided with 1- to 2-min access to the reinforcer prior to each session. The reinforcer was then restricted and 20-s access to the reinforcer was provided contingent on each communication response [i.e., a fixed-ratio (FR)-1 schedule] in all conditions except extinction. For Michele, continuous demand trials involving a towel-folding task were presented using a 3-step prompting sequence (i.e., verbal, model, and physical prompts) in all conditions. A 20-s break from demand trials was provided contingent on each communication response in all conditions except extinction.

Immediate reinforcement. Access to food (Brian), the video (Chuck), or escape from demands (Michele) was available contingent on communication. Reinforcement was delivered immediately following each communication (i.e., 0-s delay). The participants did not have the opportunity to emit the response while the reinforcer was available (20-s access to food, video, or escape) because the therapist retained the communication card or remote control during this time.

Extinction. No programmed consequences were provided for communication. The participant could not engage in the communication response for 20 s following each response (i.e., the therapist retained the communication card or remote control for 20 s). This procedure ensured that response rates would be comparable across all conditions.

Signaled delay fading. Procedures were identical to those in the immediate reinforcement condition with one exception: the introduction of gradually increasing signaled delays. Contingent on each occurrence of communication, the therapist presented the signal during the specified delay interval and removed it when the reinforcer was delivered. The delay to reinforcement was increased by a predetermined interval every two sessions. The first two delays were 2 s and 5 s. For each subsequent fading step, the reinforcement delay was increased by 30% (rounded up to the nearest whole number) of the previous delay. When the delay reached 40 s, the reinforcement delay was increased by a fixed amount of time rather than as a percentage of the previous delay to prevent large changes in the delay interval. Each delay increase ranged from 15 s to 180 s (see Table 1 for specific delay fading progressions). The fading schedule was altered for Chuck when the conditions were compared in a withdrawal design (the delay increased by 20 s every eight sessions). Delay fading continued until either (a) the target terminal delay value was reached or (b) communication decreased and remained below previous levels in that condition for at least four consecutive sessions. In latter conditions of the study, participants were abruptly exposed to large delays if responding was maintained under both signaled and unsignaled delay conditions.

The signals were chosen individually for each participant via collaboration between the therapists and parents/caregivers. For Brian, the signal consisted of a closed container that contained coins. Contingent on a communication response, the therapist placed the container in front of Brian and shook it for the duration of the delay interval so that the signal provided both auditory and visual stimulation. At the end of the delay interval, the therapist removed the container and delivered 20-s access to preferred food. For Chuck, the signal consisted of the therapist holding the videotape halfway in the VCR for the duration of the delay interval contingent on the communication response. At the end of the delay interval, the therapist placed the video into the VCR and provided 20-s access to the video. For Michele, the therapist set and placed a digital timer on the table while continuing to present instructional trials during the delay immediately following communication. Arranging the timer took approximately 1–2 s, and did not interfere with the delivery of the instructional sequence. At the end of the delay interval, the timer sounded a beeping tone, and all instructions, instructional materials, and the timer were removed for the 20-s reinforcement interval.

Unsignaled delay fading. Procedures were identical to those in the signaled-delay fading condition except the therapist did not deliver the signal during the delays to reinforcement. That is, contingent on each communication, the therapist waited the specified time period before delivering the reinforcer to Brian and Chuck; the therapist did not alter his or her behavior subsequent to the communication response and the delivery of the reinforcer. For Michele, the therapist continued to present demand trials until the delay expired. As in immediate reinforcement, the participants did not have the opportunity to emit the response during the delay interval or while the reinforcer was available because the therapist retained the communication card or remote control.

Experimental Arrangements and Sequence

Participants were presented with the sequence of conditions in Table 1. Brian and Chuck were exposed to the multiple-schedule design first. For both participants, the first phase of this design involved a baseline of immediate reinforcement. In the next phase, the signaled and unsignaled delay fading conditions were alternated in a quasirandom fashion within a multiple-schedule design. The third phase was extinction, and the comparison of signaled and unsignaled reinforcement conditions was reintroduced in the fourth phase. For Chuck, two more exposures to immediate reinforcement occurred in the fifth and seventh phases and the multiple-schedule comparison of signaled and unsignaled reinforcement occurred in the sixth and eighth phases. A multiple-schedule design was not used to compare the signaled and unsignaled conditions with Michele because she showed similar rates of responding under immediate reinforcement and extinction when these two conditions were alternated within a multiple-schedule design (see top panel of Figure 3).

Because Brian and Chuck showed similar rates of responding under the signaled and unsignaled reinforcement conditions with the multiple-schedule design, we compared the experimental conditions using a withdrawal design (in an attempt to establish experimental control). The withdrawal designs for all 3 participants began with an immediate reinforcement baseline in Phase 1. In the second phase, participants received the signaled or unsignaled delay fading condition in a random order. If rates of communication were maintained at levels comparable to the immediate reinforcement baseline, extinction was implemented prior to the next immediate reinforcement baseline (see third phase for Brian and fifth and eighth phases for Michele). Otherwise, the next phase was the immediate reinforcement baseline before introducing or reintroducing one of the delay-fading conditions. In the withdrawal design, Brian was exposed to two phases of signaled delay fading and one phase of unsignaled delay fading. Chuck and Michele were exposed to two phases of signaled delay fading and two phases of unsignaled delay fading (see Table 1). A different stimulus was paired with each delay-fading condition to facilitate discrimination of the conditions. The stimuli for Chuck and Michele consisted of colored pieces of cardboard (55 cm × 70 cm) that were attached to the wall directly in front of the participants. For Brian, different therapists were paired with each condition.

RESULTS

Results of Brian's multiple-schedule delay-fading comparison are depicted in the top panel of Figure 1. In the immediate reinforcement condition, Brian engaged in stable rates of communication ($M = 2.6$ rpm). Beginning with Session 11, Brian's communication was exposed to gradually increasing delays to reinforcement in both the signaled and the unsignaled delay-fading conditions. Rates of the communication were somewhat variable, but were maintained at similar levels in both the signaled condition ($M = 2.1$ rpm) and the unsignaled condition ($M = 2.2$ rpm) until the terminal delay value (300 s) was reached. When communication was exposed to a series of extinction sessions, response rates gradually decreased. Signaled and unsignaled delayed reinforcement was reintroduced before communication completely extinguished. Because responding was maintained when it was exposed to a 300-s delay, reinforcement was reintroduced at this delay value following extinction. The delay was subsequently increased to 450 s and 600 s. Rates of communication were more variable in the unsignaled delay-fading condition than in the signaled condition at the 300-s and 450-s delays. However, levels were similar in both conditions when the delay reached 600 s.

Results of Brian's comparison in the withdrawal design are shown in the bottom panel of Figure 1. Rates of communication were high and stable in the immediate reinforcement condition ($M = 2.4$ rpm). Responding decreased somewhat relative to immediate reinforcement but was maintained until the terminal delay value of 300 s was reached. Communication was then exposed to extinction, and responding decreased to lower levels. High levels of communication were reestab-

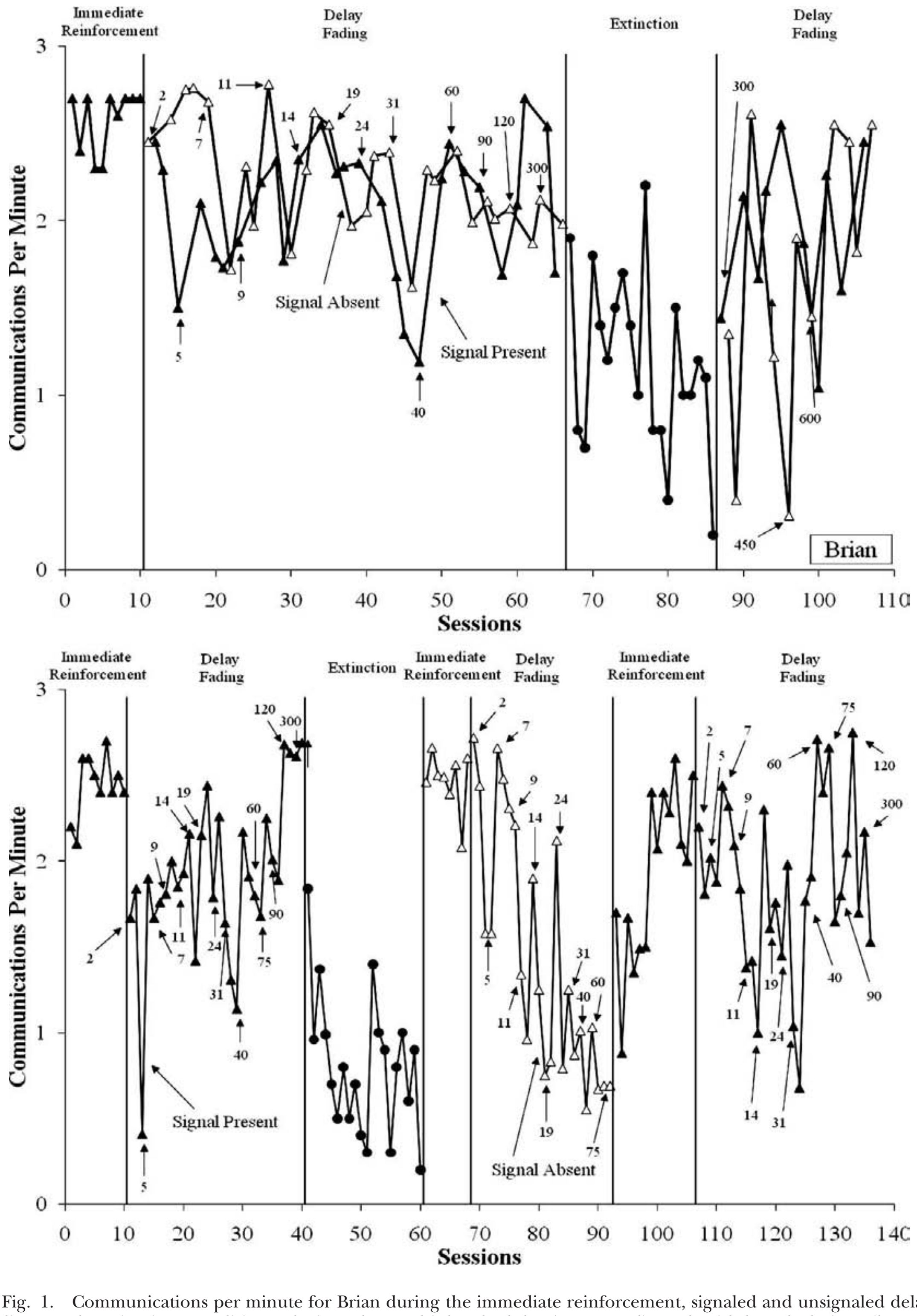

Fig. 1. Communications per minute for Brian during the immediate reinforcement, signaled and unsignaled delay-fading, and extinction conditions during the multiple-schedule (top panel) and withdrawal design (bottom panel) comparisons.

lished when food was delivered immediately following each occurrence of the response during the return to the immediate reinforcement condition (M = 2.5). During the unsignaled-delay-fading condition, levels of communication gradually decreased and remained low as the delay increased, so the condition was terminated at the 75-s delay value. Responding was low and variable during the return to the immediate reinforcement condition, but response rates returned to previous levels during the final eight sessions of this condition (M = 2.3 rpm). During the second exposure to signaled-delay fading, rates of communication were variable but were maintained at relatively high levels until the terminal delay value was reached.

The results of Chuck's multiple-schedule comparison are depicted in the top panel of Figure 2. In the first phase, Chuck displayed high rates of communication in the immediate reinforcement condition (M = 1.3 rpm for both therapists 1 and 2) than under extinction (M = 0.3 rpm), and remained low throughout that phase. Beginning with Session 13, Chuck's rates of responding were similar in both delay-fading conditions until the delay value reached 300 s. The delay was then increased to 450 s, 600 s, and 750 s to determine whether different rates of responding would be evident at larger delays during the delay fading conditions. Response rates were highly variable but similar under the 450-s and 600-s delays and decreased to 0 in both conditions at the 750-s delay.

The immediate reinforcement condition was then reintroduced. To further evaluate the effects of the signals in the absence of the gradual delay fading, the 105-s delay was introduced. This value was selected because it was the largest delay under which communication was stable in the signaled condition but variable in the unsignaled condition during the previous multiple-schedule comparison. Response rates generally were maintained at the 105-s delay, but extinguished when the delay was increased to 300 s. This effect was replicated after reinstating immediate reinforcement and reintroducing the 105-s and 300-s delays. After a final immediate reinforcement condition, communication was maintained at similar levels in the signaled and unsignaled conditions under a 105-s delay.

Results of Chuck's comparison in the withdrawal design are shown in the bottom panel of Figure 2. During immediate reinforcement, communication was stable across eight sessions (M = 1.4 rpm). Responding in the unsignaled condition remained generally stable as the delay interval was increased to 80 s, whereupon rates became variable and were much lower for five consecutive sessions. Delay fading was terminated, and responding was reestablished during the return to the immediate reinforcement (M = 1.5 rpm). During the signaled-delay condition, rates of communication were maintained near immediate-reinforcement levels until the 100-s delay. Responding abruptly decreased to low levels during the last three sessions of the 100-s signaled delay and remained low under the 120-s delay. Previous response rates (M = 1.5 rpm) were reestablished with reintroduction of immediate reinforcement prior to replicating the unsignaled-delay condition. In the second phase of unsignaled-delay fading, responding was variable but generally was maintained until the delay was increased to 80 s. Finally, following a return to the immediate reinforcement condition, signaled delay fading was reintroduced and response rates were highly variable and decreased to low levels after the delay interval reached 60 s.

Results of Michele's initial multiple-schedule comparison are depicted in the top panel of Figure 3. In the first phase, Michele was exposed to a series of extinction sessions (which occurred after she was trained to emit the communication response; training data not shown). In the second phase, Michele displayed relatively high rates of communication in the extinction condition and the immediate reinforcement conditions conducted by therapists 1 and 2. In the third phase, when communication was exposed to a series of extinction sessions, responding decreased. Because Michele failed to show differential rates of responding between the extinction and immediate reinforcement conditions when those conditions were alternated in a multiple-schedule design, the comparison of signaled and unsignaled delayed reinforcement was conducted in a withdrawal design.

Results of Michele's comparison in the withdrawal design are presented in the bottom panel of Figure 3. Response rates were low during the initial immediate reinforcement condition but increased and stabilized across the last seven sessions (M = 1.9 rpm for last

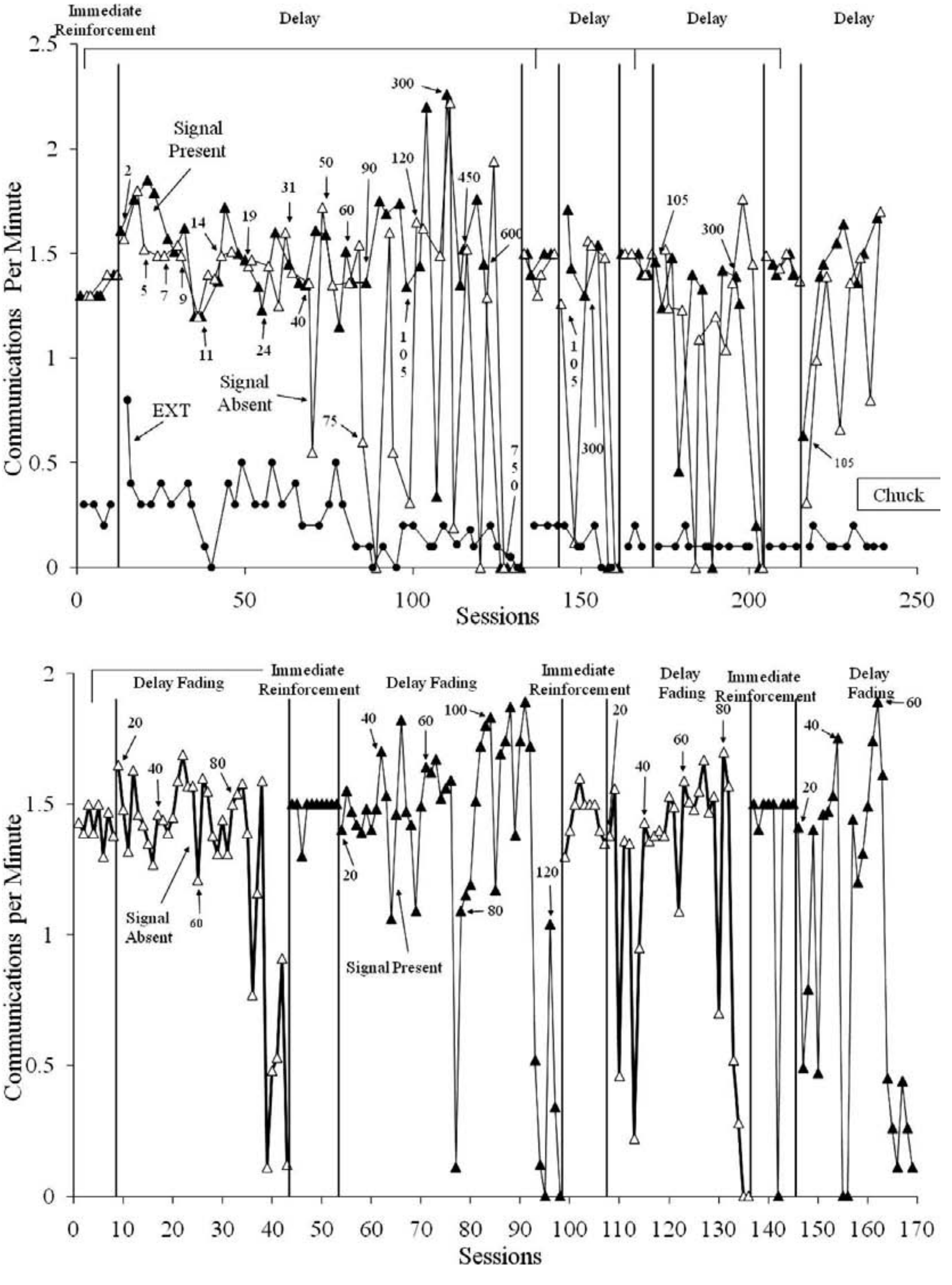

Fig. 2. Communications per minute for Chuck during the immediate reinforcement, signaled and unsignaled delay-fading, and extinction conditions during the multiple-schedule (top panel) and withdrawal design (bottom panel) comparisons.

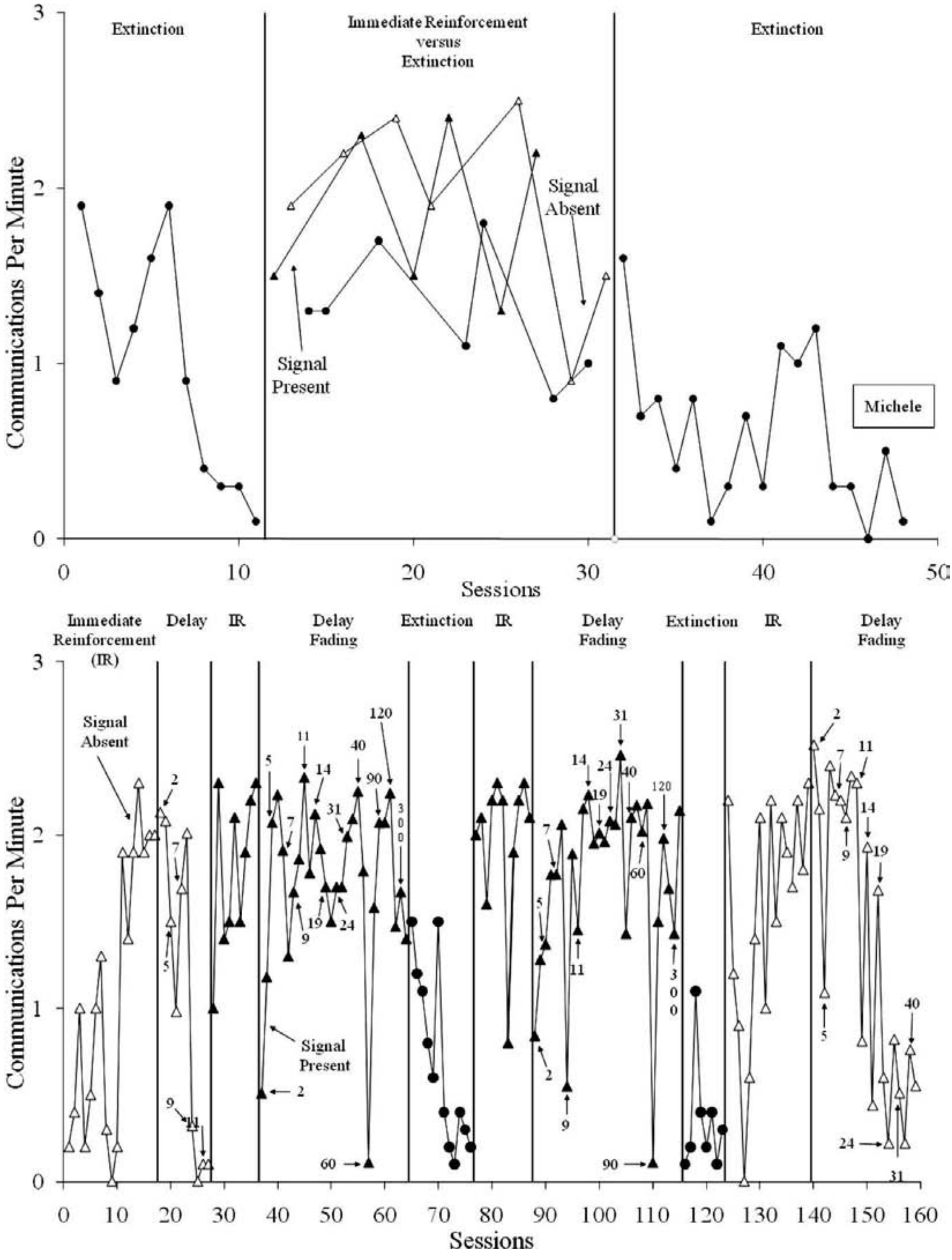

Fig. 3. Communications per minute for Michele during the immediate reinforcement and extinction conditions (top panel) and immediate reinforcement, signaled and unsignaled delay-fading, and extinction conditions during the withdrawal design (bottom panel) comparisons.

seven sessions). When communication was exposed to unsignaled delay fading in the second phase, rates decreased to low levels under the 9-s and 11-s delays. Rates of communication increased when escape was delivered immediately following the occurrence of the response during the return to immediate reinforcement (M = 1.8 rpm). Throughout the next phase, when signaled delay fading was in effect, responding generally was maintained at levels similar to the immediate reinforcement baseline until the terminal delay-fading value of 300 s was reached. In the subsequent extinction condition, rates of responding gradually decreased to low levels. In the sixth phase, when the immediate reinforcement baseline was reintroduced, rates of communication increased and stabilized (M = 2.0 rpm). During the second exposure to signaled delay fading, responding again generally was maintained at levels observed in the immediate reinforcement baseline until the terminal delay-fading value of 300 s was reached, thus replicating the effects observed in the initial signaled delay fading phase. During the second exposure to extinction, Michele's rates of communication again decreased to low levels. In the ninth phase, when immediate reinforcement was reintroduced, rates of communication again increased and stabilized (M = 2.0 rpm for the last eight sessions). Finally, in the last phase, when communication was again exposed to unsignaled delay fading, rates of responding remained somewhat stable until the 11-s delay was reintroduced. Responding then began to decrease and remained low for seven consecutive sessions when the delay intervals ranged between 9 s and 40 s. Michele was not exposed to the complete fading schedule because responding was not maintained at levels comparable to those with smaller delay values in this condition.

In Figure 4, we re-graphed and summarized the data for Brian (top panel) and Chuck (bottom panel) from the multiple-schedule design in a format similar to Richards (1981; Figure 2; reprinted in this article as Figure 6). Figure 4 depicts Brian's (top panel) and Chuck's (bottom panel) multiple-schedule design exposure to signaled and unsignaled delays depicted as average communications per minute at each delay value. For Brian, average levels of responding in the immediate reinforcement condition (i.e., 0-s delay to reinforcement) were similar in both conditions (Ms = 2.6 rpm for both). Average rates of responding at each delay interval (2 s through 600 s) were similar in both the signaled and unsignaled delay-fading conditions. For Chuck, average levels of responding in immediate reinforcement (i.e., 0-s delay to reinforcement) were similar in both conditions (Ms = 1.4 rpm, for both). Like Brian's responding, average rates of responding at each delay interval (2 s through 600 s) were similar in both the signaled and unsignaled conditions. Responding decreased to low levels in both conditions at the 750-s delay.

Figure 5 depicts Brian's (top panel), Chuck's (middle panel), and Michele's (bottom panel) withdrawal design exposure to signaled and unsignaled delays depicted similar to Richards (1981). For Brian, average levels of responding during the immediate reinforcement condition (i.e., 0-s delay to reinforcement) were similar in both conditions (Ms = 2.5 rpm and 2.1 rpm, respectively). Average rates of responding at each delay interval (2 s through 9 s) were similar in both the signaled and unsignaled conditions. However, beginning at the 11-s delay value, average response rates in the unsignaled condition were lower and showed a downward trend, relative to the signaled condition, in which responding was maintained until the 600-s delay. For Chuck, average levels of responding in the immediate reinforcement condition (i.e., 0-s delay to reinforcement) were similar in both conditions (Ms = 1.4 rpm). Average response rates at each delay interval were similar in both the signaled and unsignaled conditions until the delay value reached 80 s, when the response rates under the unsignaled condition met the termination criteria. Responding was maintained in the signaled condition up to the 100-s delay to reinforcement, and met the termination criterion at 120-s delay. For Michele, average levels of responding in the immediate reinforcement condition (i.e., 0-s delay to reinforcement) were similar in both conditions (Ms = 1.9 rpm and 1.6 rpm, respectively). Average rates of responding at each delay interval (2 s through 9 s) were similar in both the signaled and unsignaled conditions. However, beginning at the 11-s delay value,

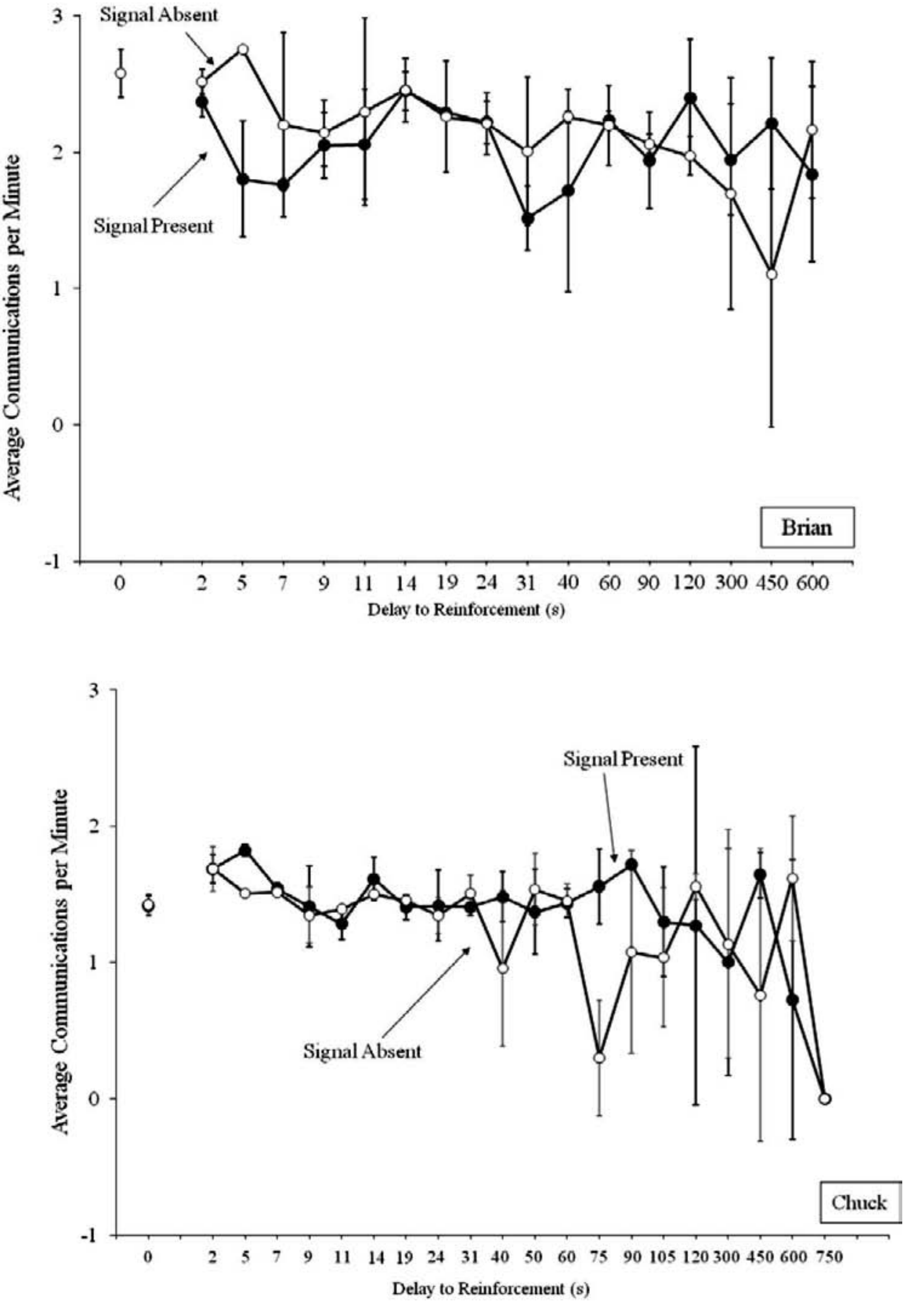

Fig. 4. Average communication responses per minute for Brian (top panel) and Chuck (bottom panel) during immediate reinforcement conditions and exposure to each of the delay values in the signaled and unsignaled conditions during the reversal design. Error bars indicate one standard deviation above and below the means.

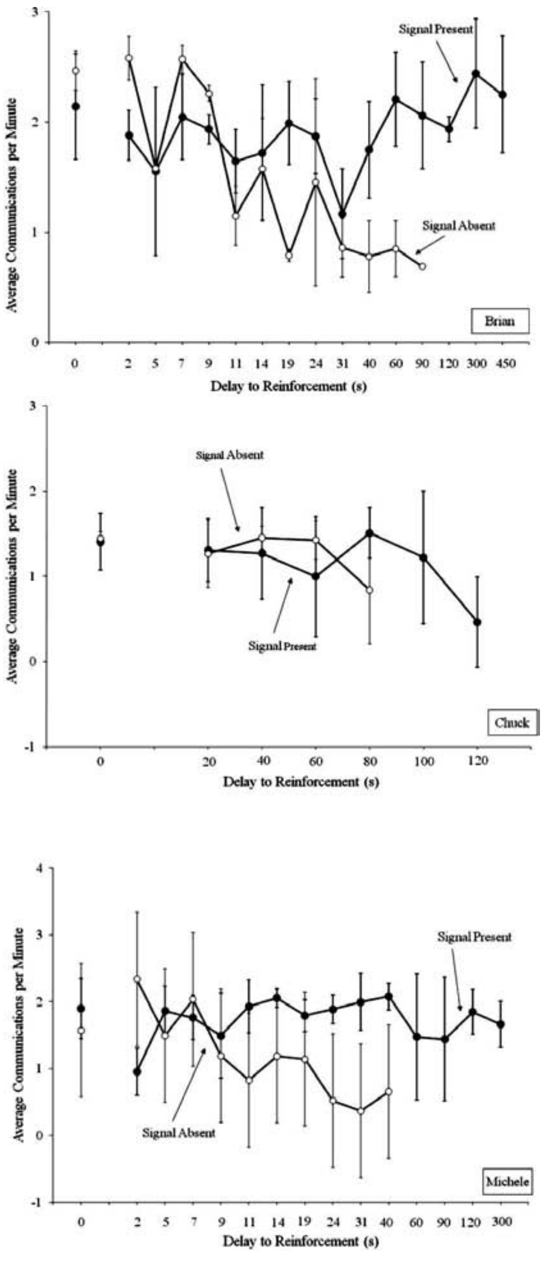

Fig. 5. Average communications per minute for Brian (top panel), Chuck (middle panel), and Michele (bottom panel) during immediate reinforcement and exposure to each of the delay values in signaled and unsignaled conditions in the multiple-schedule design. Error bars indicate one standard deviation above and below the means.

average response rates in the unsignaled condition were lower and showed a downward trend, relative to the signaled condition, in which response rates were maintained until the 300-s delay.

DISCUSSION

The effects of signals on communication maintained by delayed reinforcement were evaluated in both multiple-schedule and withdrawal designs. When signaled and unsignaled delay-fading conditions were compared in a multiple-schedule design, the presence of a signal did not produce higher response rates or greater response persistence than when a signal was not present. This comparison was terminated for the third participant (Michele) because responding was undifferentiated across the immediate reinforcement and extinction conditions, suggesting that this failure to establish stimulus control would have similarly occurred if the signaled and unsignaled conditions were also compared in a multiple-schedule design. When the signaled and unsignaled delay-fading conditions were compared in a withdrawal design, responding for all 3 participants persisted at longer reinforcement-delay values when signals were used (although the effect was more robust for Brian and Michele than for Chuck). That is, responding persisted at or close to immediate reinforcement baseline levels up to 300 s for Michele and 450 s for Brian, but only 100 s for Chuck.

These findings extend the current literature on differential reinforcement of alternative behavior, such as functional communication training (FCT; Carr & Durand, 1985). FCT is a commonly used procedure to establish communication as an alternative to problem behavior. Communication is often developed under well-controlled settings, and subsequently may fail in more naturalistic environments due to treatment challenges that are not accounted for in treatment development (Vollmer et al., 1999). For example, caregivers may be unable or unwilling to provide immediate reinforcement when the treatment is implemented in more naturalistic environments. Results of this study and previous research indicate that responding may fail to be maintained under relatively short delays to reinforcement and that treatment effects may be compromised (e.g., Fisher, Thompson, Hagopian, Bowman, & Krug, 2000; Hagopian, Fisher, Sullivan, Acquisto, & LeBlanc, 1998; Hanley, Iwata, & Thompson, 2001).

As noted, a number of basic research studies have demonstrated that providing signals during delays to reinforcement increases the likelihood of response maintenance (e.g., Azzi et al., 1964; Lattal, 1984; Richards, 1981; Schaal & Branch, 1988). Nonetheless, few studies have attempted to establish the generality of this basic relation with clinical populations and problems. The purpose of the current study was to provide an initial bridge between basic and applied work by replicating basic research findings on signaled delayed reinforcement. As such, the effects of signals were evaluated in the context of communication training with a delay-fading procedure similar to those used in previous applied studies evaluating FCT (e.g., Fisher et al., 2000; Hagopian et al., 1998).

One goal of the current study was to determine whether signals could improve typical fading methods, which generally have failed to produce response maintenance at delay intervals exceeding 30 s. A secondary goal was to evaluate the extent to which using an atypical graphing technique (for applied behavioral research) would reveal a common relation between basic and applied research on responding under signaled and unsignaled delays. As shown in Figure 6, the results of the current study were similar to those reported by Richards (1981), in which pigeons' key-pecking was exposed to either a variable-interval (VI) 60-s or a differential reinforcement of low response rates (DRL) 20-s schedules of immediate reinforcement. Response rates decreased in the unsignaled delay conditions relative to the signaled delays at several delay values (1, 2.5, 5 and 10-s delays) for both schedules. Although the species (human vs. pigeons), the method by which the participants/subjects were exposed to delays (fading across sessions vs. abrupt changes in delays across sessions), the actual delay values (1 to 10 s vs. 2 to 750 s), and the reinforcement schedules differed across the studies, the relation between the independent variable (signaled vs. unsignaled delays) and the dependent variable (response rate) were similar.

Based on basic research, we hypothesized that communication would persist at longer delay intervals when delays were signaled, regardless of the experimental design employed. This basic relation was not demonstrated for any participant when a multiple-schedule design was used. A failure to establish stimulus control may have obscured any differences in responding across conditions. The rapid alternation of the signaled and unsignaled delay conditions may have contributed to the undifferentiated results. Michele's response patterns during both of the exposures to extinction alone and when extinction was alternated with reinforcement suggested a failure to establish stimulus control. Collectively, results for the 3 participants indicated that an alternative experimental design was warranted for further evaluation of signals. Because Brian's and Michele's responding was maintained in the signaled condition and extinguished in the unsignaled condition, it seems reasonable to conclude that the failure to establish stimulus control was at least partially responsible for the undifferentiated outcomes found with the multiple-schedule design. For Chuck, though, signals did not strongly influence response persistence under either design. This finding is in contrast to basic studies, in which conditions and correlated stimuli rapidly alternate (multiple-schedule arrangement).

It is also possible that the therapist's behavior during the unsignaled delay-fading condition may have inadvertently provided information about the upcoming delivery of reinforcement after the programmed delay. For example, when Chuck handed the remote control to the experimenter, he or she held the remote until the delay expired, and then played the video. Holding the remote could have served as a signal that a delay was in effect. The functional difference between conditions may not have been whether there was a signal, but rather the nature of the signals. Specifically, the therapist's behavior during the signaled condition may have functioned as a more salient signal for delayed reinforcement. Thus, sensitivity to schedule-correlated stimuli (including analyses of differential salience of stimuli) may be an area for future research when evaluating basic methodologies with clinical populations and problems. Future researchers may also wish to evaluate methods for selecting stimuli for use as signals. The signals did appear to improve treatment efficacy by producing response maintenance at higher delay values. The signals that were selected for Brian and Chuck required continuous action by the therapists throughout the delay interval. Although it is unlikely that this feature of the signals

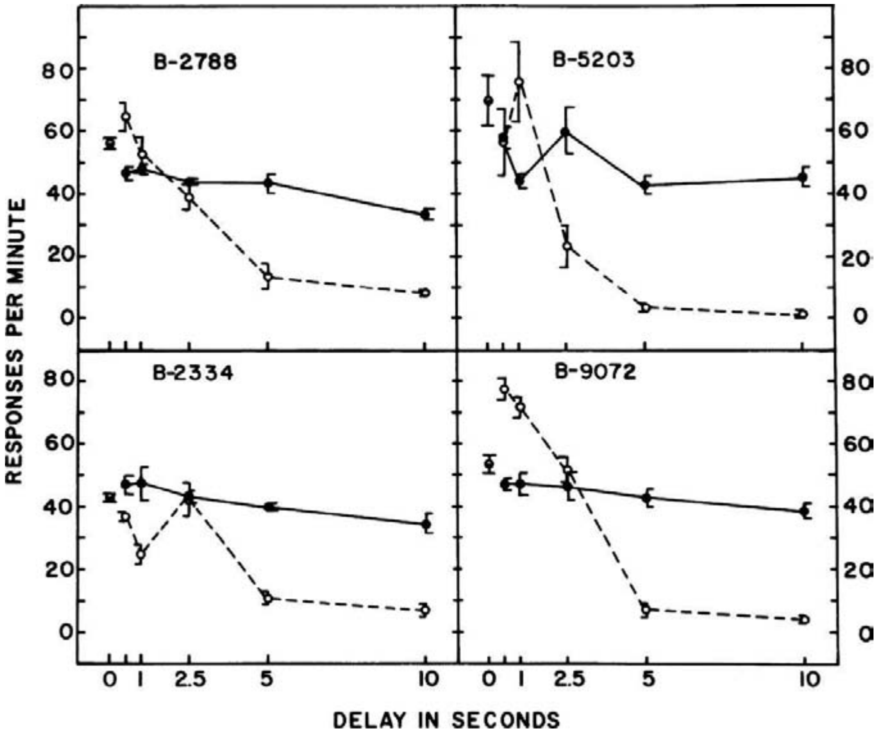

Fig. 6. Figure reprinted from Richards (1981; Figure 1). The figure depicts mean response rate during the last six sessions at each duration of signaled (filled circles) and unsignaled (open circles) delay of reinforcement with a VI 60-sec schedule.

contributed to differential response maintenance in the signaled and unsignaled conditions, the applied value of the findings would be enhanced by including signals that did not require continuous behavior by caregivers.

Finally, basic research findings were useful for producing an efficacious clinical outcome. The results of the current study also have the potential to stimulate additional basic research on signaled and unsignaled reinforcement delays. Questions remain about the influence of the rapid alternation of stimulus conditions for a small number of delay values compared to systematically fading the delay value from 0 s to some large terminal delay. For example, pigeons' key-pecking behavior was maintained at immediate reinforcement levels at 1-, 3-, and 9-s briefly signaled delays, but not briefly signaled 27-s delays (Schaal & Branch, 1988). Fading the delay from 9 s to 27 s, instead of abruptly exposing the pigeons' responding to large delays, could potentially maintain responding at immediate reinforcement levels. Thus, additional reciprocal basic and applied research appears warranted for advancing both conceptual understanding of basic behavioral principles and effective clinical interventions.

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