An Evaluation of the Effects of Fixed-Time Schedules on Response Maintenance

By

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Abstract

Response-independent schedules of reinforcement (e.g., fixed-time schedules) have typically been shown to decrease the rate of responding. However, researchers have suggested that responses may maintain under response-independent schedules, although it is currently unclear as to what mechanisms are responsible for this maintenance. The purposes of the current study were to (a) replicate previous research showing that responding will maintain under fixed-time (FT) schedules after a history of response-dependent reinforcement, (b) evaluate a simple procedure for promoting response maintenance under FT schedules if this pattern of responding is not observed, and (c) determine possible mechanisms by which response maintenance under FT schedules occurs. We found for several children that responding maintained under FT schedules, both with and without a history of contingent reinforcement. In addition, for those children whose responding did not maintain under FT schedules, a single within-session dependent reinforcer promoted maintenance under FT schedules. Finally, for some children for whom mechanisms were evaluated, stimulus control was likely the factor that was responsible for response maintenance. Implications and considerations for future research are discussed.

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Response-independent schedules of reinforcer delivery, as opposed to response-dependent schedules (e.g., ratio or interval schedules), involve the delivery of reinforcers based on time without regard to responding. These schedules (most commonly known as time-based schedules [e.g., Zeiler, 1968] or noncontingent reinforcement [NCR; Carr & Severtson, 2005]) occur when reinforcers are delivered on a schedule independent of responding and based solely on the passage of time. With time-based schedules, there is no programmed temporal contiguity between responding and reinforcer delivery (Skinner, 1938). There are two types of time-based schedules that have been described in the literature: fixed-time (FT) schedules and variable-time (VT) schedules (Zeiler).

FT schedules of reinforcement involve the delivery of a reinforcer following a fixed period of time without regard to responding (Alleman & Zeiler, 1974). For example, under an FT 5-min schedule of reinforcement, a reinforcer is delivered every 5 minutes to the subject. Any responses made by the subject have no effect on the delivery of the reinforcer. On the other hand, VT schedules of reinforcement involve the delivery of a reinforcer following a varied amount of time around a specified average (Marr & Zeiler, 1971). For example, under a VT 5-min schedule of reinforcement, a reinforcer might be delivered to the subject following the first minute, then following 7 minutes, then following 5 minutes, and so on. Like FT schedules, any responses made by the subject have no effect on the delivery of the reinforcer.

Response-independent schedules have been shown to decrease responding in most cases (e.g., Ecott & Critchfield, 2004; Edwards & West, 1968; Skinner, 1938; Skinner, 1948) and are commonly used in clinical settings as a treatment for problem behavior (e.g., Fischer, Iwata, & Mazaleski, 1997, Hagopian, Fisher, & Legacy, 1994; Mace & Lalli, 1991; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993; Vollmer, Marcus, & Ringdahl, 1995). However, a growing number of studies have shown that response-independent schedules will maintain responding, particularly if that responding has been previously maintained under response-dependent schedules. In addition, several mechanisms have been proposed to account for the maintenance effects of response-independent schedules.

Behavior Maintenance

Response maintenance under conditions of time-based schedules has been shown in basic research studies across a variety of species (e.g., Appel & Hiss, 1962; Hernstein & Morse, 1957; Skinner, 1948). For example, Skinner (1938) conducted a study in which he compared lever pressing in rats under response-dependent and response-independent schedules. First, Skinner evaluated responding under a fixed-interval (FI) 6-min schedule. After 3 days of responding under the FI schedule, the schedule of reinforcement was changed to an FT 6-min schedule for nine days. Following this, the FI 6-min schedule was re-implemented. The results of the study showed that for all rats, the average number of responses under the FT schedule decreased to approximately one-fourth the rate of responding under the preceding FI schedule. Although the results showed that responding decreased under the FT schedule, responding did not decrease to zero rates, and in fact maintained (albeit at a lower rate than under the FI schedule) for the duration of the nine days. Skinner suggested that due to a history of reinforcement for responding under the FI schedule, responding was likely to occur under the FT schedule at a rate sufficient to be adventitiously (or accidentally) reinforced. That is, responding may have occurred immediately prior to reinforcer delivery in some cases. The response pattern produced is referred to as superstitious responding. In Skinner's (1948) article, "Superstition in the pigeon", he describes how during experiments in which reinforcers were delivered on time-based schedules, pigeons in the experiments would develop well-defined response patterns that could be measured, such as orienting to a part of the cage, a stepping response, or a counterclockwise turn, even though the delivery of reinforcers was independent of any responding. With respect to response maintenance of responding under FT schedules, it is possible that similar superstitious responding (in the case of the target response) may occur.

Herrnstein & Morse (1957) evaluated the effects of time-based reinforcers for maintenance of a key-peck response in six homing pigeons. First, each pigeon experienced a preliminary training phase with a differential reinforcement of low rates (DRL) 5-min schedule. A blue stimulus light was in place for most of the session. In addition, on a VT 6-min schedule, the blue stimulus light was changed to a yellow stimulus light. The stimulus change was not associated with any change in the reinforcement schedule. Following maintenance of responding in the preliminary-training phase, the experimental phase was implemented. During this phase, the procedures were identical to the preliminary-training phase, with the exception that following one minute after the yellow stimulus light came on, a response-independent food delivery occurred. During this phase, the rate of responding increased dramatically when the time-based reinforcer delivery was in place, but only during the period of the session in which the yellow-stimulus light was on. These data suggest that responding maintained under the time-based reinforcer delivery, and that the yellow light exerted some stimulus control over responding.

Appel and Hiss (1962) compared the effects of FI and FT schedules for response maintenance with four white Carneaux pigeons. The authors used a discrimination procedure, in which discriminative stimuli were alternated between equivalent FI and FT schedules. These schedules ranged from 1-min to 4-min schedules. The results showed that responding maintained at a higher rate under the FI schedules; however, responding never decreased to lower than 3 responses per minute under the FT schedule, thus showing response maintenance.

Some researchers have specifically evaluated the necessity of a history of response-dependent reinforcement in order to show maintenance under time-based schedules. Neuringer (1970) conducted a series of studies evaluating whether time-based schedules could be used to maintain key-peck responses in pigeons. In Study 1 specifically, the experimenter evaluated whether responding could be maintained under time-based schedules following only a few response-dependent reinforcement deliveries. Three groups of pigeons (i.e., experimental group, control group, and response-independent group) were included. The pigeons in both the experimental group and the control group began the study by first contacting three response-dependent reinforcer deliveries on a fixed-ratio (FR)1 schedule. Following these response-dependent reinforcer deliveries, the experimental group experienced a VT 30-s schedule for 20 sessions, whereas the control group experienced extinction for 20 sessions. The response-independent group did not receive any response-dependent reinforcers but received reinforcers on a VT 30-s schedule for 20 sessions. The results of this study showed that responding by the experimental group maintained for the duration of the 20 sessions. Over time, responding in this group decreased but never fully extinguished. Responding in both the control group and the response-independent group quickly decreased to zero levels. Overall, the results from Study 1 suggest that responding maintained under time-based schedules following only a few response-dependent reinforcers; however, responding did not maintain under time-based schedules when no history of response-dependent reinforcement was programmed. Overall, the study suggested that responding can be maintained under time-based schedules, even after a history of only a few response-dependent deliveries of reinforcement.

Some researchers have evaluated maintenance of responding under both FT and VT schedules (e.g., Brinker & Treadway, 1975). Brinker and Treadway conducted a study using four Asian quail. The purposes of the study were twofold. First, the authors wanted to determine if there was a preference between response-dependent and response-independent schedules. Second, the authors wanted to determine if responding would maintain under response-independent schedules. The authors used a concurrent chains procedure to determine preference between schedules. For all of the quail, the response was key pecking a disk. The initial link was a VI 30-s schedule of reinforcement. For two quail, the terminal links were either an FI 30-s schedule or an FT 30-s schedule of reinforcement. For the remaining two quail, the terminal links were a VI 30-s schedule or a VT 30-s schedule of reinforcement. The results of the study showed that the quail responded indifferently to the response-independent or response-dependent schedules. That is, the quail responded approximately equally during the initial link for each of the different terminal-link schedules, suggesting that the quail did not show a clear preference for response-dependent or response-independent schedules. The results also showed that responding maintained during the terminal links for all schedules; however, rates of responding during the response-dependent schedules (FI and VI) were higher than the rates of responding for the response-independent schedules (FT and VT).

Overall, the basic research in this area suggests that in some situations, responding will maintain under time-based schedules. In addition, FT and VT schedules have similar effects with respect to response maintenance. In many cases, response maintenance has been shown to occur when the schedules of time-based delivery were equivalent to response-dependent schedules (although there are some exceptions; Neuringer, 1970). Finally, in most cases, response maintenance under time-based schedules occurs following response-dependent schedules of reinforcement.

Applied researchers have recently become interested in evaluating the effects of time-based schedules on the maintenance of behavior for several reasons. First, when using time-based schedules for the treatment of problem behavior, it is possible that in some cases problem behavior might maintain. Knowing the conditions under which response maintenance might occur under time-based schedules would be advantageous so applied researchers could manipulate these conditions to create more effective treatments. Second, time-based schedules may be useful for maintaining behaviors of applied importance (e.g., appropriate classroom behavior) and may be easier to implement than other procedures (e.g., differential reinforcement of alternative behavior [DRA]).

Several studies that have been conducted to evaluate the effects of time-based schedules on the reduction of behavior have shown that these schedules are ineffective for reducing behavior for some individuals under some conditions (e.g., Thompson et al., 2003; Vollmer, Ringdahl, Roane, & Marcus, 1997). Vollmer et al. (1997) evaluated the effects of time-based schedules for reducing aggression maintained by access to magazines. During the initial treatment condition, continuous access to magazines resulted in a decrease in aggression to zero levels. However, in the next treatment condition in which the schedule of magazine delivery was thinned to an FT 1-min schedule, aggression reemerged. These data suggest that the dense reinforcement schedule was effective for reducing problem behavior but the thinner FT schedule resulted in maintained levels of problem behavior. In addition, Thompson et al. (2003) compared the effects of differential reinforcement of other behavior (DRO), FT, and extinction in reducing responding. The authors showed that for several subjects, responding maintained under FT schedules but decreased under conditions of extinction and DRO.

Given the results of studies that showed that time-based schedules were sometimes ineffective for reducing problem behavior, researchers started evaluating the conditions under which these schedules might maintain responding. One variable that has been evaluated is the effect of the magnitude of the stimulus delivered under time-based schedules. Carr et al. (1998) compared responding under three time-based schedules with various magnitudes of reinforcement after a history of contingent reinforcement. All three FT schedules were based on the mean interresponse time of the previous baseline phase. The three conditions that were compared were FT (high magnitude), FT (medium magnitude), and FT (low magnitude). The conditions differed in the amount of food that was delivered during the scheduled delivery times of the FT schedules. The results showed that the FT (high magnitude) condition suppressed responding the most, the FT (medium magnitude) condition suppressed responding less, and the FT (low magnitude) condition maintained responding at levels similar to baseline. The authors suggested that the reductions in responding under the FT (high magnitude) phase were likely due to satiation effects. As for the maintenance of responding under the FT (low magnitude) condition, the authors suggested that responding may have continued due to either instructional control of the situation (i.e., discriminative stimulus effects) or adventitious reinforcement.

In addition to magnitude of stimulus delivery, several researchers have compared the effects of different time-based schedules on responding (e.g., Dozier et al., 2001; Ringdahl et al., 2001). Ringdahl et al. compared the effects of different FT schedules on responding that was previously maintained by response-dependent schedules. First, the authors reinforced an arbitrary response on either an FR 1 or FI 30-s schedule. Following this condition, the authors compared the effects of similar and dissimilar FT schedules and extinction on response maintenance. During the FT (similar) condition, the reinforcer rate of the FT schedule was yoked to the previous response-dependent schedule (FR1 or FI 30s). During the FT (dissimilar) condition, the reinforcer rate of the FT schedule was either the response-dependent rate of reinforcement divided by six or the response-dependent rate of reinforcement multiplied by six. The results showed that although there was a reduction in responding during both of the FT conditions and the extinction condition as compared to the contingent reinforcement condition, responding maintained at a higher rate under the FT (similar) condition. These data suggest that FT conditions may maintain responding that was previously maintained by contingent reinforcement. They also suggest that FT schedules that are similar to previous response-dependent schedules may be more effective at a maintaining responding than those that are dissimilar. However, because the schedule during the FT (dissimilar) condition varied between denser or leaner schedules than the contingent reinforcement condition, it is unclear as to the separate effects of leaner or denser schedules on responding.

In a similar study, Dozier et al. (2001) compared the effects of three different FT schedules on the maintenance of responding. The authors first conducted baseline, in which no reinforcers were delivered. Next, they conducted a phase in which responding was initially reinforced on an FR 1 schedule that was gradually thinned to a VR-3 schedule of reinforcement. In order to test the effects of different FT schedules on responding, three conditions were compared in a multi-element design. During the FT (yoked) condition, the FT schedule was based on the mean inter-reinforcement interval from the VR-3 phase. During the FT (dense) condition, the schedule of reinforcer delivery was half the mean inter-reinforcement interval from the VR-3 phase. In the FT (thin) schedule, the FT schedule was twice the mean inter-reinforcement interval from the VR-3 phase. The results of the study showed that after a history of contingent reinforcement, responding maintained under both yoked and thin fixed-time schedules of reinforcement. It is possible that responding maintained under the FT (thin) and FT (yoked) conditions, but not the FT (dense) condition, due to the discriminability between the FT schedules and the VR-3 schedule. For example, under the FT (yoked) and FT (thin) schedules, assuming the subject was responding at the same rate as in the VR-3 schedule, it is likely that some responses will occur around the time that reinforcers are delivered. However, in the FT (dense) schedule, it is likely that more reinforcers are delivered in the absence of responding. This may have made the noncontingent delivery of the reinforcers easier to discriminate as compared to the FT (yoked) and FT (thin) conditions.

In a recent study, Borrero, Bartels-Meints, Sy, and Francisco (2011) evaluated the effects of an FT schedule and a modified FT schedule for maintenance of a work task (punching holes in paper) with three adults with schizophrenia. The authors also extended previous research by using tokens as conditioned reinforcers that could be traded for nickels following session. The tokens varied in color depending on which schedule was in place. In order to attempt to equate the number of tokens earned across sessions of different conditions, sessions lasted for 20 min or until 14 tokens were earned, whichever occurred first. The authors compared the effects of three different schedules: FI 60-s, FT 60-s, and conjoint FI 60-s FT 60-s schedules. Under the conjoint schedule, both schedule components (FI and FT schedule) operated simultaneously and independently from one another. That is, under the FT component, a token was delivered every 60 s regardless of responding. In addition, under the FI component, a token was delivered following the first response after 60 s had elapsed in session. The authors implemented this conjoint schedule as an analogue for conditions in which responses under FT schedules result in intermittent reinforcement. Because previous research had shown that FT schedules may in some cases be useful for maintaining responding, the authors wanted to evaluate the use of conjoint schedules to determine if they might also be useful in maintaining responding. The results showed that for two subjects, responding maintained under FI, FT, and conjoint FI FT schedules of reinforcement. However, for one of those subjects, responding maintained at higher rates under the conjoint schedule. For one subject, responding only maintained under the FI schedule. The authors concluded that FT schedules, as well as conjoint response-dependent and response-independent schedules may be useful in maintaining responding in applied settings.

Overall, research has shown that time-based schedules can maintain responding. First, response maintenance has, in most cases, been demonstrated under time-based schedules following a history of contingent reinforcement (e.g., Appel & Hiss, 1962; Neuringer, 1970). In addition, response maintenance has been shown to be more likely to occur when the time-based schedule is similar or leaner than the response-dependent schedule it follows (e.g., Dozier et al.; Ringdahl et al., 2001). Little difference has been shown between the effects of FT and VT (e.g., Brinker & Treadway, 1975) schedules in maintaining responding, although VT schedules have been studied much less than FT schedules.

Behavioral Maintenance Mechanisms

Response maintenance under time-based schedules is somewhat counterintuitive, due to the lack of any specific contingency between the target behavior and the delivery of reinforcers. However, several possible mechanisms have been proposed to account for maintenance under these schedules. Responding may maintain due to an accidental temporal contiguity between a response and a reinforcer, leading to adventitious reinforcement of the target response. Under conditions of adventitious reinforcement, responding may be intermittently reinforced due to this accidental pairing (Skinner, 1948; Iwata & Kahng, 2005). Additionally responding may maintain under time-based schedules due to discriminative stimulus effects (Uhl & Garcia, 1969; Iwata & Kahng). That is, when a subject has a history of the delivery of reinforcers contingent on responding, the presence and delivery of reinforcers may exert stimulus control and evoke responding when delivered on a time-based schedule. Several methodologies have been used in order to determine the specific mechanisms that may influence the maintenance of responding under time-based schedules.

Methodology for Determining Mechanisms

Adventitious Reinforcement. Several researchers have conducted additional analyses to determine whether adventitious reinforcement may be the mechanism by which time-based schedules result in response maintenance. Several methodologies (both correlational and experimental) have been used in order to attempt to determine whether responding maintains due to adventitious reinforcement. The two most commonly used methodologies have been the use of within-session data analyses (e.g., Dozier et al., 2001; Ringdahl et al., 2001) and the use of experimental manipulations of the delivery of reinforcers (e.g., Thompson et al., 2003; Vollmer et al., 1997).

In order to further clarify the mechanism of action for the maintenance under FT schedules, Dozier et al. (2001) used within-session analyses of the cumulative responding during these sessions (also referred to as a contiguity analysis) to assess why responding may have maintained under FT schedules. That is, sessions were divided into 10-s bins, and the cumulative number of responses was graphed. The authors determined whether a response occurred in the 10-s bin immediately prior to the reinforcer delivery (suggesting the reinforcer delivery occurred closely following responding) and whether a response occurred in the 10-s bin immediately following reinforcer delivery (suggesting that the reinforcer delivery occurred prior to responding). The authors then determined the percentage of responses that occurred under each situation. Results showed that the percentage of responses that occurred within the 10-s bin before the delivery of a reinforcer was low, suggesting that adventitious reinforcement was unlikely to be the variable responsible for maintained responding. The authors suggested that the presence or delivery of reinforcers might have functioned as a discriminative stimulus for engaging in the target response. That is, due to the pairing of the presence and delivery of reinforcers with response-contingent reinforcement in the VR-3 condition, it is possible that the presence or delivery of those reinforcers became discriminative stimuli for the availability of reinforcement for responding.

Ringdahl et al. (2001) found that responding maintained under FT schedules that were similar (or yoked) to previous response-dependent schedules. The authors suggested that the mechanisms behind response maintenance might have been either adventitious reinforcement or stimulus control. The authors attempted to clarify this distinction by conducting within-session analyses of the data in the FT (similar) phase. Specifically, they compared the conditional probabilities of responding prior to and after the delivery of reinforcement as compared to the unconditional probability of responding. The authors calculated the probabilities that a response occurred prior to a reinforcer delivery (i.e., within 9 s before a reinforcer delivery) and compared those results to when no response occurred prior to a reinforcer delivery (i.e., there was no response within 9 s before a reinforcer delivery). The authors found that as the FT (similar) condition continued, there was a higher probability of responding prior to reinforcement as compared to the probability of responding not occurring prior to reinforcement. These data suggest that adventitious reinforcement may have been responsible for maintained responding in the FT (similar) phase.

Vollmer et al. (1997) found that after fading the FT schedule used to decrease problem behavior, aggression reemerged and maintained with one subject. The authors used a contiguity analysis to assess why problem behavior may have reemerged. Results of the analysis showed that aggressive responses occurred in 76% of the 10-s bins immediately prior to reinforcer delivery. In addition, aggression only occurred during 16% of the 10-s bins that immediately followed the reinforcer delivery. These data suggest that problem behavior may have been adventitiously reinforced. Because reinforcer delivery commonly followed instances of aggressive responses, it is possible that the pairing of these responses and reinforcers may have inadvertently reinforced aggression. The authors then conducted an additional experimental evaluation using a momentary differential reinforcement of other behavior (MDRO) procedure. This procedure was identical to the FT schedule procedure, with the exception that the delivery of reinforcement only occurred if no problem behavior was exhibited during the 10 s prior to the scheduled delivery time. The purpose of this procedure was to remove the possibility that a reinforcer delivery immediately followed an aggressive response. This procedure effectively decreased the aggressive responding, and the schedule was thinned to an MDRO 5-min schedule. The results of this study suggest that time-based schedules may result in adventitious reinforcement that maintains problem behavior, and other procedures can be used to prevent this adventitious maintenance. However, one potential confound is that under the MDRO procedure, the frequency of reinforcer delivery decreased if responding occurred prior to the scheduled reinforcer delivery, which may have also been responsible for the decrease in responding.

In addition, Thompson et al. (2003) found that for some subjects, responding maintained under FT schedules following a history of an FR1 schedule. In order to determine if adventitious reinforcement might have played a role in this maintenance, the authors conducted a DRO condition with one subject, in which reinforcers were delivered for the absence of responding. The authors found that responding continued to maintain under the DRO schedule. These data suggest that response maintenance was not likely due to adventitious reinforcement (as there was no adventitious reinforcement possible during the DRO condition). The authors suggested that, more likely, responding continued due to the stimulus control exerted by the presence of and delivery of reinforcers.

Overall, there are two general methodologies for determining if adventitious reinforcement may be responsible for response maintenance under FT schedules. First, within-session contiguity analyses can be used to determine if reinforcer delivery commonly follows responding under FT conditions. Second, the removal of the possibility of adventitious reinforcement (e.g., MDRO; Vollmer et al., 1997) can be used to determine if adventitious reinforcement is necessary for the maintenance of responding.

Stimulus Control. Several studies have conducted additional manipulations to determine whether response maintenance under time-based schedules may be due to stimulus control (i.e., discriminative stimulus effects). Specifically, studies have manipulated stimulus conditions in order to determine how programmed or unprogrammed discriminative stimuli might influence responding. For example, Gamzu & Schwartz (1973) conducted a study using three Silver King pigeons to determine the effects of VT schedules on a pecking response. Throughout the entire study, no response-dependent reinforcers were delivered. The purpose of the study was to determine the effect of the response key as a discriminative stimulus for the delivery of food on responding. All subjects were exposed to nondifferential or differential multiple schedules with VT or extinction components. Nondifferential multiple schedules consisted of two identical schedules of time-based reinforcement (e.g., mult VT 100 s VT 100 s). Differential multiple schedules consisted of two non-identical schedules (e.g., mult VT 100 s EXT). Each component of the multiple schedule had a different discriminative stimulus associated with that component. The authors collected data on the subjects' responding during each component of the multiple schedule. The results of the study showed that when the discriminative stimulus signaled food delivery (i.e., during the differential multiple schedules), rates of responding increased during the VT component of the multiple schedules. When the discriminative stimulus did not signal food delivery (i.e., during the nondifferential multiple schedules), rates of responding decreased across both components. The authors suggested that the response key served as a discriminative stimulus for responding during the time-based schedules, and that these discriminative-stimulus effects are important in the maintenance of responding under time-based schedules, especially given that responding did not maintain when the stimuli were not discriminative for food delivery. These data support the possibility that stimulus control may be the mechanism of action for maintenance under time-based schedules.

As discussed above, Thompson et al. (2003) showed that responding during an FT schedule was unlikely to due adventitious reinforcement because responding also maintained under conditions of DRO. The experimenters suggested that maintained responding under both FT and DRO schedules may be due to stimulus control. To further test this, the authors conducted an extinction condition during which the reinforcers were present but not delivered. Responding under this condition decreased to zero rates. These results suggested that the presence of the reinforcers may have not exerted stimulus control over responding, but the delivery of reinforcers (such as in the FT and DRO conditions) may have exerted stimulus control. Overall, these data suggest that response maintenance was due to the stimulus control exerted by the delivery of reinforcers.

Although research with respect to the experimental manipulation of multiple discriminative stimuli has yet to be conducted in the context of response maintenance under time-based schedules, Halle (1989) conducted a study demonstrating the control exerted by discriminative stimuli on verbal behavior, and suggested a methodology (as well as specific controlling stimuli) that may be useful for testing the control exerted by potential discriminative stimuli. Two children with intellectual and developmental disabilities participated. The authors specifically targeted coin labeling. Following baseline probes in which no reinforcers were available for correct coin labeling, the experimenters conducted training under very specific stimulus conditions. Each session was conducted in the morning, in the classroom, with a specific teacher sitting 1 ft away from the child, facing the child, and using the prompt “What’s this?” Modeling, delay prompts, and reinforcement were used to teach the coin labeling responses. Once the responses were acquired, no-reinforcement probes were conducted in which specific discriminative stimuli (e.g., teacher, setting, time, location of the teacher) were systematically changed. For example, a probe may have been conducted in which the teacher, teacher location, and time were identical to the training phase, but the probe was conducted in a different setting. The authors found that no one stimulus condition removal decreased the correct coin-label response. The authors next conducted a manipulation in which two stimulus conditions (e.g., teacher and setting) were changed simultaneously. During this phase, one of the two subjects ceased correct responding to the coin-labeling task when both the setting and the therapist changed, even though correct responding maintained in the previous single-stimulus probes. Overall, the authors showed for one participant that specific stimulus conditions were necessary to evoke previously maintained responding.

Halle and Holt (1991) conducted a similar study in which the word “please” was taught under specific stimulus conditions. Four children with developmental disabilities participated, and the specific response was the use of the word “please” to make requests when teachers sent the children on errands to retrieve certain items, which they would then deliver back to the teacher. During baseline probes, the response was tested under several stimulus conditions in the absence of reinforcement, including with different requesters, different items that were to be requested, different receivers of those requests, and different settings. Following baseline probes the training phase was initiated. During the training phase, very specific stimulus conditions were used (one requester, one item to be requested, one recipient of the request, and one setting). During this phase, if the child made a request without the word "please", the recipient of the request prompted the child to say please, followed by a model if the response was not emitted. Descriptive praise was provided, as well as the item requested, when the response "please" was emitted. Following the training phase, the authors assessed each potential discriminative stimulus in isolation (i.e., one training stimulus [e.g., requester] and three non-training stimuli [e.g., item to be requested, recipient of request, and setting]). If none of these conditions evoked the appropriate use of the word please, then two stimulus conditions were combined (i.e., two training stimuli [e.g., requester and setting] and two non-training stimuli [e.g., item to be requested and recipient of request]). The overall results showed that the single-stimulus probes only evoked correct responding in one child (when the training request recipient was present). For two other children, the dual-stimuli probes were necessary to evoke responding (although which stimuli evoked responding varied within and across these children). The fourth child acquired the response under baseline conditions. Overall, the authors showed that responding came under the control of specific discriminative stimuli, and that changing some of those stimuli resulted in a reduction of correct responding.

Overall, researchers have used a variety of methods in order to determine the effects of discriminative stimuli on responding. Most commonly, researchers manipulate the presence or absence of potential discriminative stimuli in order to determine if those stimuli are necessary or sufficient to maintain responding. If responding decreases when a particular discriminative stimulus or discriminative stimuli are removed or changed, then it could be said that stimulus control was, at least in part, a mechanism for the maintenance of responding. Research on the mechanisms of response maintenance under time-based schedules has overall shown mixed results. Several studies suggest that either adventitious reinforcement (e.g., Ringdahl et al., 2001; Vollmer et al., 1997) or stimulus control (Dozier et al., 2001; Thompson et al., 2003) are likely mechanisms for response maintenance. It is also possible that a combination of both adventitious reinforcement and stimulus control may influence the maintenance of responding under FT schedules. Both correlational (e.g., contiguity analyses) and experimental (e.g., MDRO; removal of potential discriminative stimuli) analyses have been used to further clarify the mechanisms by which responding maintains under time-based schedules. However, there are several limitations to the current literature that have not been addressed. First, although applied research has been conducted showing response maintenance under FT schedules following a history of contingent reinforcement, studies have not assessed whether the history of reinforcement is necessary for response maintenance. Second, extensive research has not been conducted looking at how to promote response maintenance under FT schedules when responding does not maintain following a history of contingent reinforcement. Third, when experimental analyses have been conducted to determine if adventitious reinforcement is the mechanism for response maintenance, procedures did not necessarily take into account that the frequency of reinforcers delivered during session also decreased (e.g., Vollmer et al.), which may have confounded the results. Finally, very little research has been conducted looking at the influence of specific discriminative stimuli on the maintenance of responding.

Purpose

Given the current limitations of the literature, there were several purposes of the current study. First, we attempted to replicate previous research that demonstrated responding would maintain under FT schedules (Phase 1). Second, for those participants for whom responding did not maintain under FT schedules, we evaluated a simple procedure for maintaining responding under FT schedules (Phase 1). Third, we evaluated the possible mechanisms by which maintenance under FT schedules occurred (Phase 2 and Phase 3). Specifically, we wished to assess the removal of adventitious reinforcement without decreasing the frequency of reinforcer deliveries. In addition, we wished to evaluate the effects of discriminative stimuli, and for one child, assess the role of specific discriminative stimuli on response maintenance.

General Methods

Participants and Setting

Six preschool-age children (ages 3-5 years) who attended the Edna A. Hill Child Development Center at the University of Kansas participated in this study (see Table 1 for specific information on each of the participants). None of our participants had a diagnosed disability, and all participants appeared to be typically developing based on classroom curriculum assessments demonstrating that they were able to follow simple and complex directions and had good receptive language skills. However, we did not conduct a formal battery of assessments to determine this. Children were selected for participation in the current study based on several criteria. Children were only selected if they were over the age of three, as previous research studies conducted by our research lab suggested that children under the age of three had difficulty responding to tokens as generalized-conditioned reinforcers, especially given the very brief token training used in this study. For the same reason, children were only included if they did not have a diagnosed disability and based on curriculum assessments could follow complex rules. Because the purpose of the study was to evaluate response maintenance under FT schedules, and not to determine the efficacy of contingent reinforcement using tokens, children whose responding did not maintain under contingent reinforcement were excluded from the study. Sessions were conducted in either a sectioned-off portion of an empty classroom or a large therapy room. Both rooms were equipped with a one-way mirror and sound system for observation. Chairs, tables, and task materials appropriate to each condition were present. Sessions were conducted 1 to 4 times per day, 3 to 5 days per week.

Materials

During all sessions, a variety of age appropriate toys (e.g., action figures, dolls, and building blocks) were available during both presession and session. In addition, a large, green, plastic container (toy bin) was present. The toy bin was covered with a laminated piece of paper that covered the entire top of the bin with the exception of a 12.7 cm X 12.7 cm square hole cut in the center.

For sessions in which tokens were present and delivered, a small transparent plastic container was used to deposit tokens (i.e., token bin). This container was placed in an area next to the toy bin, which was easily visible to the child. For sessions in which tokens were delivered but not present (i.e., stimulus probes, fixed-time with neutral stimuli condition), the container was hidden from view and only presented following the session. Small plastic poker chips of varying colors (white, blue, and red) were used as tokens. There was no association between poker-chip color and specific conditions (i.e., all colors of poker chips were delivered across all conditions). Tokens could be traded for a variety of edible items (e.g., gummy worms, gummy bears, Cheetos ®, Sour Patch Kids ®, animal crackers, Twizzlers ®, M&M's ®, Skittles ®, Cheez-its ®, and Mike & Ike ®) and small toys (e.g., bracelets, plastic rings, temporary tattoos, stickers).

Response Measurement and Interobserver Agreement

Trained observers collected data in real time on participant behavior using Palm Pilots™ or Apple iPods ™ . Data collection software collected data on a second-by-second basis such that every response was time stamped to allow for the analysis of when each event was scored in relation to each other event. The dependent variable was the number of items children placed in the toy bin (during a session) after toy play (presession). We used a frequency measure, as opposed to a duration or interval measure, because a frequency measure allowed us to better determine when tokens were delivered in relation to correct responses given the discrete nature of the responses. If a duration or interval measure were used, it would have been more difficult to determine exactly when in relation to a response tokens were delivered. A correct response was scored when a child released a single toy into the opening of bin. If the child released multiple toys into the bin at once, a correct response was not scored. We chose this particular response because it was a response that the children engaged in daily in their preschool classroom. However, the response may not be socially valid due to the restrictions of the response (i.e., requiring only one toy at a time), which may have been different than what was typically required in their classrooms. In addition, observers collected data on therapist token delivery. Token delivery was scored when the therapist placed a token into the token container. Therapists in the study were doctoral candidates in the Department of Applied Behavioral Science at the University of Kansas. Each therapist was given verbal instruction, as well as a written protocol, for the conducting of sessions. In addition, the author provided feedback on an ongoing basis related to the therapists' procedural integrity.

To determine procedural integrity, the percentage of correct token deliveries was calculated for each phase. Procedural integrity coefficients were determined by looking at the data streams of the appropriate sessions and determining whether tokens were delivered at the appropriate times. For example, during the CR condition, a correct token delivery was scored if a token was delivered within 2 s of a correct response (e.g., under the FR 2 schedule, a correct delivery would be scored if a token was delivered within 2 s of two consecutive responses). During the FT condition, a correct token delivery was scored if a token was delivered within 2 s of the time the token was scheduled to be delivered. During the FT + 3-s and FT + 6-s delay conditions, a correct token delivery was scored if a token was delivered within 2 s of the time the token was scheduled to be delivered, unless responding occurred within 3-s or 6-s of that scheduled delivery, in which case a correct token delivery was scored if a token was delivered after the specified delay period. Procedural integrity coefficients were calculated by dividing the number of correct token deliveries by the total number of deliveries and multiplied by 100%. Because the correct number of token deliveries during the baseline and FT with neutral stimuli conditions was zero, a score of 100% was given for those sessions if zero tokens were delivered. A score of 0% was given if any tokens were delivered during these sessions. Procedural integrity data were collected during at least 30% of sessions from each phase across participants. Procedural integrity data for Bradley were calculated for 32% of sessions, and the procedural integrity coefficient was 99% (range, 86%-100%). Procedural integrity data for Sanford were calculated for 32% of sessions, and the procedural integrity coefficient was 97% (range, 83%-100%). Procedural integrity data for Edward were calculated for 33% of sessions, and the procedural integrity coefficient was 99% (range, 89%-100%). Procedural integrity data for Carrie were calculated for 35% of sessions, and the procedural integrity coefficient was 97%

(range, 78%-100%). Procedural integrity data for Gladice were calculated for 35% of sessions, and the procedural integrity coefficient was 99% (range, 83%-100%). Procedural integrity data for Midas were calculated for 32% of sessions, and the procedural integrity coefficient was 99% (range, 77.8%-100%).

To determine interobserver agreement, a second independent observer simultaneously collected data during at least 50% of sessions across participants. Interobserver agreement coefficients were calculated by dividing the session time into 10-s intervals and comparing observer data on an interval-by-interval basis. If exact agreement occurred (i.e., both observers scored the same number within a 10-s interval), a score of 1 was given for that interval. For any disagreements, the smaller score in each interval was divided by the larger. The interval scores were summed, divided by the total number of observation intervals, and multiplied by 100%. Interobserver agreement data for Bradley were collected during 60.8% of sessions. Mean interobsever agreement scores were 94% (range, 59%-100%) and 94% (range, 66%-100%) for correct responding and token delivery, respectively for Bradley. Interobserver agreement data for Sanford were collected during 50.6% of sessions. Mean interobsever agreement scores were 97% (range, 63%-100%) and 97% (range, 79%-100%) for correct responding and token delivery, respectively for Sanford. Interobserver agreement data for Edward were collected during 66% of sessions. Mean interobsever agreement scores were 91% (range, 77%-100%) and 94% (range, 89%-100%) for correct responding and token delivery, respectively for Edward. Interobserver agreement data for Carrie were collected during 54.3% of sessions. Mean interobsever agreement scores were 89% (range, 65%-100%) and 98% (range, 80%-100%) for correct responding and token delivery respectively, for Carrie. Interobserver agreement data for Gladice were collected during 54.7% of sessions. Mean interobsever agreement scores were

94% (range, 91%-100%) and 96% (range, 65%-100%) for correct responding and token delivery, respectively for Gladice. Interobserver agreement data for Midas were collected during 59.1% of sessions. Mean interobsever agreement scores were 97% (range, 79%-100%) and 96% (range, 89%-100%) for correct responding and token delivery, respectively for Midas. For some participants, the few sessions with low agreement percentages seemed to be correlated with errors in the observers starting the data collection devices simultaneously, which may have altered the intervals in which each observer scored a particular response. In each of the sessions with low interobserver agreement (below 80%), the exact same frequency of responses was scored, but on an interval-by-interval basis the data streams produced lower interobserver agreement coefficients.

Procedure

All sessions contained two portions, the presession and session. During *presession*, the child was given 5 min to play with various toys that are typically found in a preschool classroom (e.g., dolls, toy trucks, books, and puzzles). In addition, the therapist played with the child and interacted with the toys, providing continuous attention for the duration of presession. Immediately after the presession play period, the session began. All sessions were 3 min in length unless otherwise specified. At the start of each *session*, a brief vocal prompt was delivered instructing the child to engage in correct responding (i.e., "It's time to clean up. You can keep playing, or you can clean up. Remember, clean up only one toy at a time"). In conditions in which tokens were present and delivered, a brief rule regarding token delivery was delivered (see below). The child was reminded two more times during the session to clean up only one toy at a time (at the end of minutes 1 and 2). No further prompts were delivered during sessions; however, brief interactions were provided if the child initiated those interactions (e.g., if the child said, “look at this”, the therapist said, “that’s pretty cool”). After all sessions in which tokens were delivered, the child was allowed to exchange the tokens for edible items or small toys. The therapist handed the child the token container with all of the tokens that he or she earned during session. The therapist then showed the child the bin of available items for which he or she could trade the tokens and prompted the child to trade the tokens. A variety of edible items (e.g., gummy worms, gummy bears, Cheetos ®, Sour Patch Kids ®, animal crackers, Twizzlers ®, M&M’s ®, Skittles ®, Cheez-its ®, and Mike & Ike ®) and small toys (e.g., bracelets, plastic rings, temporary tattoos, stickers) were available from which to choose. The value of each token was one small piece of edible item or one small toy.

Token Training. Token training occurred prior to the first contingent reinforcement session (see below). No data were collected during this procedure. During token training, the child was given five tokens and told, “These are tokens. You can trade these for snacks or toys in research.” The therapist had the bin of edibles and toys available and prompted the child to pick an item. The therapist then prompted the child to trade one token for that item. This procedure was repeated until all five tokens were traded. This procedure was only conducted once. The purpose of this procedure was to expose the child to the token exchange and to establish the value of the token as a generalized conditioned reinforcer.

Phase 1: Maintenance Evaluation

The purpose of this phase was to replicate the results of previous studies (e.g., Dozier et al., 2001), showing that responding would maintain under fixed-time schedules. Specifically, we evaluated whether responding would maintain under FT schedules given a history of contingent reinforcement. If responding did not maintain under FT schedules, we evaluated the effects of programming a brief, within-session history of response-dependent reinforcers on response maintenance under FT schedules (similar to Neuringer, 1970 discussed above).

Baseline (BL). During baseline sessions, tokens were not present, and no programmed consequences were provided for correct responding. At the end of the session, the child was told that the session was complete and was escorted back to his or her classroom. The purpose of this condition was to determine if the child would engage in the correct response in the absence of reinforcer delivery.

Contingent reinforcement (CR). During CR sessions, a token container (described above) was placed in a visible area. Additionally, a rule was delivered regarding the delivery of tokens at the start of the session (i.e., "If you clean up, you will sometimes get tokens"). The therapist delivered tokens + brief praise (e.g., "you got a token") on an FR 1 schedule for correct responses (placing toys in the bin), which was gradually thinned to an FI 20-s schedule of reinforcement across sessions. The criteria for thinning was as follows: (1) After the first session in a CR phase, the schedule was thinned from an FR 1 to and FR 2 schedule of reinforcement if responding was higher than the average of the *preceding phase*; (2) during each subsequent session in a CR phase, the schedule was thinned if the response rate was higher than or within the range of the previous two sessions without any apparent decreasing trend in responding across sessions within the *CR phase*. The schedule of reinforcement was thinned in the following manner: FR 1, FR 2, FR 3, FR 5, FI 20s. The purpose of this condition was to provide a history of contingent reinforcement for responding prior to determining whether responding would maintain under FT schedules.

Fixed-time schedule (FT). During FT sessions, a token container was placed in a visible area. Additionally, a rule was delivered regarding the delivery of tokens at the start of the session (i.e., "Sometimes you will get tokens"). The therapist delivered tokens + brief praise to the child on an FT 20-s schedule throughout the session. Because the session was 3-minutes in length, a total of 9 tokens were delivered, with the session ending immediately after the delivery of the ninth token. An FT 20-s schedule was chosen because prior research (e.g., Dozier et al., 2001, Ringdahl et al, 2001) has suggested that response maintenance is more likely under FT schedules when the schedule is similar to the preceding contingent reinforcement schedule. The purpose of this condition was twofold. First, the condition was conducted after baseline and prior to the CR condition to determine if responding would occur, maintain, or both under FT schedules without a history of contingent reinforcement. Second, the condition was conducted following the CR condition for some children to determine if, given a history of contingent reinforcement, responding would maintain under FT schedules.

Fixed-time schedule with contingent reinforcement (CR + FT). The CR + FT condition was conducted with children for whom responding did not maintain under the FT condition. During the CR + FT phase, a token container was placed in a visible area. Additionally, a rule was delivered regarding the delivery of tokens at the start of the session (i.e., "If you clean up, you will sometimes get tokens"). During CR + FT sessions, the therapist delivered tokens + praise on a mixed FR1 FT 20-s schedule. Specifically, a token + praise was delivered contingent upon the first correct response of the session. Following this initial token delivery, tokens + praise were delivered on an FT 20-s schedule for the remainder of the session. Sessions were continued until nine tokens were delivered or until 9 min elapsed, whichever occurred first. If 9 min elapsed, the remaining tokens would have been delivered. However, this did not occur with any children (i.e., all children who participated in this phase always received 9 tokens before 9 min elapsed). This ensured that the number of tokens was equated to the previous FT conditions to control for the possibility of response maintenance due to a different number of reinforcers delivered. The purpose of this condition was to determine if a brief, within-session history of response-dependent reinforcer delivery would evoke responding, which could then be maintained under an FT schedule.

Phase 2: Mechanism Evaluation (Adventitious Reinforcement)

The purpose of Phase 2 was to determine whether maintained responding under FT schedules was due to the adventitious reinforcement of responding. In order to test this, we conducted two separate evaluations. The first evaluation was a contiguity analysis of within-session responding and reinforcer delivery. The purpose of this evaluation was to determine whether token delivery frequently preceded or followed responding, which may suggest that the temporal contiguity necessary for adventitious reinforcement was present in the FT conditions. The second evaluation was an experimental evaluation, similar to that used by Thompson et al. (2003,) including two conditions that parametrically evaluated delays to reinforcement when responding occurred prior to the scheduled delivery of a reinforcer. The purpose of this evaluation was to determine if removing the temporal contiguity between responding and token delivery (i.e., the possibility of adventitious reinforcement) would lead to a decrease in responding, suggesting that adventitious reinforcement may have been responsible for the maintenance of responding under the FT condition. In addition, the purpose of the evaluation was to determine if differing delays to reinforcement (3-s delay and 6-s delays) would disrupt responding. These delays were chosen due to precedence in the literature and based on mean inter-response times during FT conditions for pilot participants.

Contiguity Analysis. Contiguity analyses were conducted during FT and CR + FT conditions to determine the conditional probability of token deliveries immediately preceding or immediately following responding. The data streams of each session were used to determine these conditional probabilities. During this analysis, a token delivery was scored as an antecedent or consequence. Token deliveries not meeting the definition of an antecedent or consequence were not scored. We determined the conditional probabilities for each of these conditions using both 3-s and 6-s bins. If a token was delivered either during the same second, or within the bin following a response, the token was scored as a consequence. If a token was delivered either during the same second, or within the bin preceding a response, it was scored as an antecedent. In this way, it is possible that a token could be scored as both an antecedent and a consequence. The conditional probability of a token serving as a consequence was calculated by dividing the number of consequences by the total number of tokens delivered for that condition. The conditional probability of a token serving as an antecedent was calculated by dividing the number of antecedents by the total number of tokens delivered for that condition. Because each session ended in a token delivery, it was impossible for the final token in each session to be scored as an antecedent, so this final token was not part of the calculations for the antecedent conditional probability. In addition, because the first token delivery in the CR + FT condition was programmed to be a consequence, it was not included in calculations. The purpose of these analyses was to determine if reinforcer delivery occurred more frequently as a consequence as compared to an antecedent, which might suggest that adventitious reinforcement may be responsible for the maintenance of responding under the FT or CR + FT conditions.

Fixed-time + 3-s delay (FT + 3-s delay). During FT + 3-s delay sessions, rules were delivered during presession (i.e., “Sometimes you will get tokens”). The therapist delivered tokens + praise on an FT 20-s schedule (e.g., at 20 s, 40 s, 60 s, 80 s, etc.). However, a 3-s delay to token + praise delivery was implemented if a correct response occurred within 3 s prior to the scheduled delivery of the token. If the child responded correctly during the delay period or at the end of the delay period, the delivery of the token was delayed a further 3 s from that response. If responding continued to occur, the delay was reset, and no token was delivered until 3 s elapsed with no responding. The programmed delay did not affect the schedule of delivery of the subsequent token deliveries (they were delivered at the time scheduled). For example, if a response occurred at the 20-s mark during session, the token was not delivered until the 23-s mark. However, the next token was still delivered at the 40-s mark of the session. If responding continued to occur such that tokens could not be delivered at the scheduled times, all tokens that were earned were delivered once responding stopped for 3 s. For example, if a child started responding at the 20-s mark and responded continuously until the 40-s mark, then 2 tokens would be delivered at the 43-s mark. In addition, sessions continued until all 9 available tokens were delivered or until 9 min elapsed, whichever came first. If 9 min elapsed, the remaining tokens (up to 9) would have been delivered at the end of session. However, this never occurred. This ensured that the number of tokens was equated to the previous FT conditions to control for decreased levels of responding due to the reduced number of tokens earned. The purpose of this condition was to evaluate levels of responding when the potential for adventitious reinforcement was removed.

Fixed-time + 6-s delay (FT + 6-s delay). The FT + 6-s delay condition was identical to the FT + 3-s delay condition with a few exceptions. During the FT + 6-s delay condition, rules were delivered during presession (i.e., “Sometimes you will get tokens”). The therapist delivered tokens + praise on an FT 20-s schedule (e.g., 20 s, 40 s, 60 s, 80 s, etc.). However, a 6-s delay to token + praise delivery was implemented if a correct response occurred within 6 s prior to the scheduled delivery of the token. If the child responded correctly during the delay period or at the end of the delay period, the delivery of the token was delayed a further 6-s from that response. The programmed delay did not affect the schedule of delivery of the subsequent token deliveries (they were delivered at the time scheduled). For example, if a response occurred at the 20-s mark during session, the token was not delivered until the 26-s mark. However, the next token was still delivered at the 40-s mark of the session. If responding continued to occur such that tokens could not be delivered at the scheduled times, all tokens that were earned were delivered once responding stopped for 6 s. For example, if a child started responding at the 20-s mark and responded continuously until the 40-s mark, then 2 tokens would be delivered at the 46-s mark. In addition, sessions continued until all 9 available tokens were delivered or until 9 min elapsed, whichever came first. If 9 min elapsed, the remaining tokens (up to 9) would have been delivered at the end of session. However, this never occurred. This ensured that the number of tokens was equated to the previous FT conditions to control for decreased levels of responding due to the reduced number of tokens earned. The purpose of this condition was to evaluate levels of responding when the potential for adventitious reinforcement was further removed.

Phase 3: Mechanism Evaluation (Stimulus Control)

The purpose of Phase 3 was to determine whether maintained responding under FT schedules was due to the stimulus control exerted by various stimuli in the environment that were shared between the CR and FT conditions. In order to test this, we conducted several possible conditions that evaluated the effects of removing one or several potential discriminative stimuli (similar to those used in Halle [1989] and Halle and Holt [1991]).

Fixed-time w/ neutral stimuli (FT w/o S^D). Sessions in the FT w/o S^D condition were identical to the FT condition described above, except that potential discriminative stimuli present in the FT condition were changed (similar to those manipulated in Halle, 1989). The session was conducted in a different session room from Phases 1 and 2, which was located in a different building and had different dimensions and features (e.g., different colored walls, windows, one-way mirrors). In addition, a different therapist (the same therapist conducted all Phase 3 sessions) implemented the procedures. The therapist delivered rules similar to those during baseline (i.e., "It's time to clean up. You can keep playing, or you can clean up. Remember, clean up only one toy at a time"), but did not deliver any rules regarding token delivery. Throughout the session, tokens and the token container were not present, and there were no programmed consequences for correct responding. During session, a research assistant placed the token bin filled with 9 tokens outside the door of the session room. At the end of session, the therapist retrieved the token bin and delivered the bin with the nine tokens to the child. The purpose of this condition was to evaluate the effects on responding when stimuli correlated with the delivery of tokens in the contingent reinforcer phase were removed, which allowed us to determine if the specific stimuli we removed might be discriminative stimuli that resulted in maintenance under FT schedules.

Single-stimulus probes (SD probes). Single-stimulus probes were conducted with one child whose responding decreased under the FT w/o S^D condition. The purpose of the single-stimulus probes was to determine which specific discriminative stimuli (specifically the presence of the therapist, setting, or the presence and delivery of tokens) might be responsible for the maintenance of responding under FT schedules. Each probe was conducted only once.

Therapist. The therapist single-stimulus probe was identical to the FT w/o S^D condition, with the exception that the therapist from Phase 1 implemented the sessions. The session was still conducted in a different session room, which was located in a different building and had different dimensions and features (e.g., different colored walls, windows, one-way mirrors). The therapist delivered rules similar to those during baseline (i.e., "It's time to clean up. You can keep playing, or you can clean up. Remember, clean up only one toy at a time)", but did not deliver any rules regarding token delivery. Throughout the session, tokens and the token container were not present, and there were no programmed consequences for correct responding. During session, a research assistant placed the token bin filled with 9 tokens outside the door of the session room. At the end of session, the therapist retrieved the token bin and delivered the bin with the nine tokens to the child. The purpose of this probe was to determine if the presence of the therapist from Phase 1 would evoke responding in the absence of other discriminative stimuli.

Setting. The setting single-stimulus probe was identical to the FT w/o S^D condition, with the exception that the session was conducted in the session room from Phase 1. The therapist from Phase 3 delivered rules similar to those during baseline (i.e., "It's time to clean up. You can keep playing, or you can clean up. Remember, clean up only one toy at a time)", but did not deliver any rules regarding token delivery. Throughout the session, tokens and the token container were not present, and there were no programmed consequences for correct responding. During session, a research assistant placed the token bin filled with 9 tokens outside the door of the session room. At the end of session, the therapist retrieved the token bin and delivered the bin with the nine tokens to the child. The purpose of this probe was to determine if the setting from Phase 1 would evoke responding in the absence of other discriminative stimuli.

Tokens. The tokens single-stimulus probe was identical to the FT w/o S^D condition, with the exception that tokens were present and delivered on an FT 20-s schedule. The session was conducted in the Phase 3 session room, which was located in a different building and had different dimensions and features (e.g., different colored walls, windows, one-way mirrors) than Phase 1. The therapist from Phase 3 delivered rules similar to those during baseline (i.e., “It’s time to clean up. You can keep playing, or you can clean up. Remember, clean up only one toy at a time”), but did not deliver any rules regarding token delivery. Throughout the session, the therapist delivered tokens + brief praise to the child on an FT 20-s schedule throughout the session. The purpose of this probe was to determine if the presence of and delivery of tokens would evoke responding in the absence of other discriminative stimuli.

Experimental Design

A reversal design was used to demonstrate experimental control (see Figure 1 for a flowchart depicting the order of sessions conducted given specific response patterns). For all children, baseline was conducted first to determine the rate of correct responding in the absence of reinforcement. Next, the FT condition was implemented to determine if correct responding would occur under FT schedules in the absence of a programmed history of contingent reinforcement. If responding did not maintain in the initial FT condition, the CR condition was conducted to provide a history of contingent reinforcement for correct responding. The FT condition was then conducted again to determine the effects of the FT schedule following a history of contingent reinforcement. Depending on responding under this condition, additional conditions were conducted to either promote responding under FT schedules (CR + FT) or to determine the mechanism of response maintenance (FT + 3-s delay, FT + 6-s delay, FT w/o S^D). Baseline conditions were interspersed in some cases to demonstrate experimental control. Because we were evaluating response maintenance under FT schedules, a reversal design allowed us to demonstrate experimental control by showing that responding decreased in the absence of reinforcement (BL) and only maintained under specific FT schedule variations. This demonstrated that maintenance of responding under FT schedules was due to features of the schedule rather than some other variable (e.g., automatic reinforcement).

Results

Bradley (Main Results)

Results for Bradley are depicted in Figure 2. During the initial baseline condition, Bradley engaged in zero levels of correct responding. Next, during the initial FT condition, Bradley continued to engage in zero levels of responding. These data suggest that an FT 20-s schedule of reinforcement without a history of contingent reinforcement was insufficient to increase and maintain Bradley's responding. Next, we implemented the CR condition, and Bradley's responding increased to high levels and maintained as the schedule of reinforcement was thinned from an FR 1 to an FI 20-s schedule of reinforcement. When we implemented the second FT condition (after a history of contingent reinforcement), Bradley continued to engage in high levels of responding. These data suggest that following a history of contingent reinforcement, responding would maintain under the FT schedule. In order to determine if this maintenance was due to adventitious reinforcement, we next implemented the FT + 3-s delay condition. During this condition, Bradley engaged in similar levels of responding as during the FT condition, suggesting that adventitious reinforcement may not be the variable that was maintaining responding. In a return to baseline, in order to demonstrate experimental control, Bradley initially engaged in variable levels of responding, which eventually decreased to zero levels. We next replicated the CR, FT, and FT + 3-s delay conditions, during which Bradley engaged in high and maintained levels of responding. In order to determine if the 3-s delay was insufficient to break the temporal contiguity between responding and reinforcer delivery, we next implemented the FT + 6-s delay condition. Similar to the FT + 3-s delay condition, Bradley engaged in maintained levels of responding, suggesting again that adventitious reinforcement was unlikely to be the mechanism for response maintenance under FT schedules. In order to determine if discriminative stimuli might be responsible for response maintenance under FT schedules, we next implemented the FT w/o S^D condition. During this condition, Bradley continued to engage in high levels of responding, suggesting that the discriminative stimuli we manipulated were not necessary for the maintenance of responding. We next returned to baseline; however, Bradley continued to engage in high levels of responding. Given these data, we were unable to show experimental control over Bradley's responding, so it is unclear as to why his responding maintained during the FT conditions. It is possible that responding came under the control of the initial instructions (i.e., instructions to clean up) that were present across all conditions (including the FT w/o S^D and BL conditions), and responding continued to maintain due to the effects of this instruction. In addition, it is also possible that after a history of pairing correct responding with reinforcer delivery, correct responding became reinforcing in and of itself, and responding continued due to automatic reinforcement.

Bradley (Contiguity Analysis)

Contiguity analysis results for Bradley are depicted in Table 2. The purpose of the contiguity analyses was to determine what proportion of reinforcer deliveries was either preceded by or followed by responding. These data were analyzed to see if reinforcers commonly followed responding, suggesting that responding may have been adventitiously reinforced. For Bradley, conditional probabilities of tokens serving as consequences when analyzed using 3-s bins or 6-s bins were relatively low (0.25 and 0.41 respectively). In addition, conditional probabilities of tokens serving as antecedents when analyzed using 3-s bins (0.21) or 6-s bins (0.35) were relatively similar to the probability of tokens serving as consequences.

Overall, these data suggest that patterns of responding may have lead to adventitious reinforcement, but do not necessarily suggest that adventitious reinforcement was more likely than stimulus control as a potential mechanism.

Sanford (Main Results)

Results for Sanford are depicted in Figure 3. Similar to Bradley, during the initial baseline and FT conditions Sanford engaged in zero levels of responding, suggesting that BL conditions and an FT-20-s schedule of reinforcement without a history of contingent reinforcement was insufficient to maintain responding for Sanford. We next implemented the CR condition, and Sanford's responding increased to high levels and maintained as the schedule of reinforcement was thinned from an FR 1 to an FI 20s schedule of reinforcement. We next implemented the second FT condition (following a history of contingent reinforcement) and like Bradley, Sanford engaged in levels of responding similar to the previous CR condition (albeit at a slightly lower rate), suggesting that following a history of contingent reinforcement, responding would continue to maintain under the FT schedule. In order to determine if this maintenance was due to adventitious reinforcement, we next implemented the FT + 3-s delay condition. During this condition, Sanford's responding maintained at similar levels to the FT condition, suggesting that adventitious reinforcement may not be the variable that is maintaining responding. In order to determine if the 3-s delay was insufficient to break the temporal contiguity between responding and reinforcer delivery, we next implemented the FT + 6-s delay condition. Similar to the FT + 3-s delay condition, Sanford continued to engage in maintained levels of responding, suggesting again that adventitious reinforcement was unlikely to be the mechanism for response maintenance under FT schedules for Sanford. In a return to baseline, in order to demonstrate experimental control, Sanford's responding immediately decreased to low levels. We next replicated the CR and FT conditions, during which Sanford's responding increased and maintained at high levels. In order to determine if discriminative stimuli might be responsible for response maintenance under FT schedules, we next implemented the FT w/o S^D condition. Unlike Bradley, Sanford's responding immediately decreased to low levels in this condition, suggesting that the discriminative stimuli we manipulated were responsible for the maintenance of responding. We next replicated the CR and FT conditions, during which Sanford's responding increased and maintained at moderate levels. Finally, we implemented the FT w/o S^D condition again and Sanford's responding immediately decreased to low levels. Overall, data for Sanford suggests that his responding maintained under FT schedules following a history of contingent reinforcement, and that responding maintained due to stimulus control.

Sanford (Contiguity Analysis)

Contiguity analysis results for Sanford are depicted in Table 2. Similar to Bradley, for Sanford, conditional probabilities of tokens serving as consequences when analyzed using 3-s bins or 6-s bins were relatively low (0.30 and 0.45, respectively). In addition, conditional probabilities of tokens serving as antecedents when analyzed using 3-s bins (0.30) or 6-s bins (0.45) were similar to the probability of tokens serving as consequences. Overall, these data suggest that patterns of responding may have lead to adventitious reinforcement, but do not necessarily suggest that adventitious reinforcement was more likely than stimulus control as a potential mechanism.

Edward (Main Results)

Results for Edward are depicted in Figure 4 and Figure 5. Similar to Bradley and Sanford, during the initial baseline, Edward engaged in zero levels of responding. When we implemented the initial FT condition, however, Edward initially engaged in high level of responding which quickly decreased to zero levels. We next implemented the CR condition, and Edwards's responding increased to high levels and maintained at moderate levels as the schedule of reinforcement was thinned from an FR 1 to an FI 20s schedule of reinforcement. We next implemented the second FT condition (following a history of contingent reinforcement) and like Bradley and Sanford, Edward engaged in levels of responding similar to the previous CR condition, suggesting that following a history of contingent reinforcement, responding would continue to maintain under the FT schedule. Because Edward was leaving the program soon and previous participants had shown that adventitious reinforcement was not the mechanism by which responding maintained, we decided to not evaluate the adventitious reinforcement mechanism with Edward. In order to determine if discriminative stimuli might be responsible for response maintenance under FT schedules, we next implemented the FT w/o S^D condition. Similar to Sanford, Edwards's responding immediately decreased to low levels in this condition, suggesting that the discriminative stimuli we manipulated were responsible for the maintenance of responding. We next replicated the CR and FT conditions, during which Edward's responding increased and maintained at moderate levels. Next, we implemented the FT w/o S^D condition again and Edward's responding immediately decreased to low levels. In order to attempt to determine which specific stimulus may have influenced response maintenance under FT schedules, we next implemented the single-stimulus probes condition. During the single-stimulus probe condition, we implemented the Setting, Therapist, and Token probes, and only the Therapist probe session evoked Edward's responding. Within-session data from the Therapist probe (see Figure 5) suggests that although the presence of the therapist evoked responding, it did not maintain for the duration of session. Overall, data for Edward showed that his responding maintained under FT schedules following a history of contingent reinforcement.

Additionally, the response maintenance occurred due to the presence of certain discriminative stimuli and the presence of the therapist from the initial CR conditions was a necessary discriminative stimulus for responding to occur.

Edward (Contiguity Analysis)

Contiguity analysis results for Edward are depicted in Table 2. Similar to Bradley and Sanford, conditional probabilities of tokens serving as consequences when analyzed using 3-s bins or 6-s bins were relatively low (0.34 and 0.48, respectively). In addition, conditional probabilities of tokens serving as antecedents when analyzed using 3-s bins (0.35) or 6-s bins (0.52) were actually higher than the probability of tokens serving as consequences. Overall, these data suggest that patterns of responding may have lead to adventitious reinforcement, but do not necessarily suggest that adventitious reinforcement was more likely than stimulus control as a potential mechanism.

Carrie (Main Results)

Results for Carrie are depicted in Figure 6. During the initial baseline condition, Carrie engaged in zero levels of responding. However, unlike the other children, when we implemented the FT condition, Carrie's responding increased to and maintained at high levels. We returned to baseline and Carrie initially engaged in variable levels of responding, but her responding decreased over time. We implemented the FT condition again in order to replicate the results of the first FT condition and again Carrie engaged in high and maintained levels of responding. In order to determine if this maintenance was due to adventitious reinforcement, we next implemented the FT + 3-s delay condition. During this condition, Carrie's responding maintained at similar levels to the FT condition, suggesting that adventitious reinforcement may not be the variable that is maintaining responding. In order to determine if the 3-s delay was insufficient to break the temporal contiguity between responding and reinforcer delivery, we next implemented the FT + 6-s delay condition. Similar to the FT + 3-s delay condition, Carrie continued to engage in maintained levels of responding, suggesting again that adventitious reinforcement was unlikely to be the mechanism for response maintenance under FT schedules for Carrie. In order to determine if discriminative stimuli might be responsible for response maintenance under FT schedules, we next implemented the FT w/o S^D condition. Similar to Sanford and Edward, Carrie's responding immediately decreased to low levels in this condition, suggesting that the discriminative stimuli we manipulated were responsible for the maintenance of responding in the FT condition. In order to reestablish responding, we next implemented the FT condition. However, unlike in the previous FT conditions, Carrie's responding did not increase, and maintained at zero levels. It is possible that exposure to the FT w/o S^D condition may have caused stimuli that were previously maintaining responding to lose their control over responding (e.g., tokens, rules). We next implemented the CR condition in order to increase responding and Carrie's responding increased and maintained as the schedule was thinned from an FR 1 to and FI 20s schedule of reinforcement. We next implemented the FT condition and again Carrie's responding decreased to zero levels. In order to increase responding under FT conditions, we implemented the CR + FT condition and Carrie's responding increased to moderate levels, although responding was variable. We finally returned to the FT condition and Carrie's responding decreased to low levels. Overall, data for Carrie suggests that her responding initially maintained under FT schedules without any *programmed* history of reinforcement. Our initial mechanism assessment suggested that responding was maintained due to stimulus control, however, we were unable to replicate these results, as responding never maintained during the FT condition following exposure to the FT w/o S^D condition. The CR +

FT condition was necessary to maintain responding for Carrie following the FT w/o S^D condition. Overall, results for Carrie suggest that her initial response maintenance under the FT conditions may have been due to discriminative stimuli effects, but due to exposure to the FT w/o S^D condition, these discriminative stimuli may have lost their evocative functions.

Carrie (Contiguity Analysis)

Contiguity analysis results for Carrie are depicted in Table 2. For Carrie, the conditional probability of tokens serving as consequences when analyzed using 3-s bins were relatively low (.37). However, when analyzed in 6-s bins, the conditional probability of tokens serving as a consequence was (0.58). These data suggest that more than half of the tokens delivered in FT sessions followed within 6 s of a response, which may suggest that adventitious reinforcement occurred during the FT condition. However, conditional probabilities of tokens serving as antecedents when analyzed using 3-s bins (0.35) or 6-s bins (0.53) were similar to the probability of tokens serving as consequences. Overall, these data suggest that patterns of responding may have lead to adventitious reinforcement, but do not necessarily suggest that adventitious reinforcement was more likely than stimulus control as a potential mechanism.

Gladice (Main Results)

Data for Gladice are depicted in Figure 7. Similar to the previous children, Gladice engaged in low to zero levels of responding during both the initial baseline and initial FT conditions. We next implemented the CR condition and Gladice's responding immediately increased and maintained at high levels, even as the reinforcement schedule was thinned from an FR 1 to and FI 20s schedule of reinforcement. We next implemented the FT condition (following a history of contingent reinforcement) and Gladice's responding initially maintained. However, Gladice's responding decreased over time to zero levels. We next returned to the CR condition and Gladice engaged in high, maintained levels of responding. Upon returning to the FT condition, Gladice's responding again initially maintained but quickly decreased to low levels. We returned to the CR condition and Gladice engaged in high levels of responding. In order to promote responding under FT conditions, we next implemented the CR + FT condition, and unlike in the previous FT conditions, Gladice engaged in high and maintained levels of responding. We returned to baseline and Gladice's responding quickly returned to low levels. Finally, we implemented the CR + FT condition again and Gladice's responding maintained at high levels. Overall we found that Gladice's responding did not maintain under FT schedules prior to or following a history of contingent reinforcement. It was only when a response-dependent reinforcer was delivered for the first response in each session that responding maintained under FT schedules.

Gladice (Contiguity Analysis)

Contiguity analysis results for Gladice are depicted in Table 2. Similar to Bradley and Sanford, for Gladice, conditional probabilities of tokens serving as consequences when analyzed using 3-s bins or 6-s bins were relatively low (0.32 and 0.44 respectively). In addition, conditional probabilities of tokens serving as antecedents when analyzed using 3-s bins (0.26) or 6-s bins (0.41) were similar to the probability of tokens serving as consequences. However, we showed that the conditional probability of tokens serving as antecedents (0.50) and consequences (0.50) increased during the CR + FT condition as compared to the FT condition. It is possible that the CR + FT condition might have been responsible for an increase in the probability of the temporal proximity of token delivery to responding, which may have accounted for response maintenance under the CR + FT condition.

Midas (Main Results)

Data for Midas are depicted in Figure 8. Similar to the previous children, Midas engaged in low to zero levels of responding during both the initial baseline and initial FT conditions. We next implemented the CR condition and Midas's responding immediately increased and maintained at high levels, although responding was highly variable across sessions. This pattern of responding continued even as the reinforcement schedule was thinned from an FR 1 to and FI 20-s schedule of reinforcement. We next implemented the FT condition (following a history of contingent reinforcement) and Midas's responding quickly decreased to zero levels. We next returned to the CR condition and Midas engaged in high, maintained levels of responding, with less variability in responding as compared to the previous CR condition. Upon returning to the FT condition, Midas's responding again quickly decreased to zero levels. We returned to the CR condition and Midas engaged in moderate, stable levels of responding. In order to promote responding under FT conditions, we next implemented the CR + FT condition, and unlike in the previous FT conditions, Midas engaged in moderate and maintained levels of responding. We returned to the FT condition and Midas's's responding quickly returned to low levels. Finally, we implemented the CR + FT condition again and Midas's responding maintained at moderate levels. Overall we found that, similar to Gladice, Midas's responding did not maintain under FT schedules prior to or following a history of contingent reinforcement. It was only when a response-dependent reinforcer was delivered for the first response in each session that responding maintained under FT schedules.

Midas (Contiguity Analysis)

Contiguity analysis results for Midas are depicted in Table 2. Similar to Bradley, Sanford, and Gladice, conditional probabilities of tokens serving as consequences when analyzed using 3-s bins or 6-s bins were relatively low (0.22 and 0.26, respectively). In addition, conditional probabilities of tokens serving as antecedents when analyzed using 3-s bins (0.21) or 6-s bins (0.25) were similar to the probability of tokens serving as consequences. Interestingly, we also showed low conditional probabilities of tokens serving as antecedents and consequences during the CR + FT condition. These data suggest that the temporal proximity of tokens to responding may not be as important for response maintenance because response maintenance occurred during the CR + FT condition and not the FT condition, even though the conditional probabilities of tokens serving as antecedents and consequences were similar across the conditions.

General Discussion

The results for all phases are summarized in Table 3. The purpose of Phase 1 was to replicate the results of previous studies (e.g., Dozier et al., 2001; Ringdahl et al., 2001), showing that responding would maintain under fixed-time schedules. In addition, if responding did not maintain under FT schedules, we evaluated the effects of a brief, within-session response-dependent reinforcer delivery on response maintenance under FT schedules (similar to Neuringer, 1970). Results of Phase 1 showed that for four out of six children, responding maintained under FT schedules. For three of those children, response maintenance under FT schedules only occurred following a history of contingent reinforcement. These results replicate previous research (e.g., Dozier et al, 2001; Ringdahl et al., 2001) in demonstrating the usefulness of FT schedules in the maintenance of responding following a history of contingent reinforcement. For one child (Carrie), responding maintained under FT schedules without a history of contingent reinforcement (similar to Gamzu & Schwartz, 1973). These data suggest that for some children, a history of contingent reinforcement may not be necessary for responding to maintain under FT schedules. These results have several practical implications. For example, it may be substantially easier for caregivers to deliver reinforcers on a time-based schedule as compared to a response-dependent schedule because under the time-based schedule, the caregiver does not necessarily need to constantly watch the behavior of interest (e.g., Allison, Wilder, Chong, Lugo, Pike, & Rudy, 2012). However, because we did not evaluate this in the current study, this is unknown at the time. In order to determine the usefulness of FT schedules in maintaining responding in more naturalistic settings, a brief assessment in which a brief history of contingent reinforcement is provided and then response maintenance is tested under FT schedules may be useful for determining which children FT schedules may be useful for maintaining appropriate behavior.

For two out of the six children, responding did not maintain under FT schedules, even following a history of contingent reinforcement. In addition, for one child (Carrie), responding initially maintained under FT schedules but ceased to maintain during later phases. These results suggest that for some children, FT schedules alone may not be sufficient to maintain responding, and in some cases suppressed responding. This is not surprising given the long line of research suggesting that time-based schedules typically reduce levels of responding (e.g., Skinner, 1938; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993). It is also possible, however, that our procedures were not ideal for producing response maintenance under FT schedules. Although the fixed-time schedules used in the current study were matched to those in the contingent reinforcement phase (FT 20 s vs. FI 20 s), which was similar to the preparation used in Ringdahl et al. (2001), we did not specifically yoke the delivery of reinforcers to the reinforcer delivery in the previous CR phase (similar to the preparation used in Dozier et al., 2001). It is possible that we might have seen more response maintenance if these conditions were yoked. In addition, Dozier et al. showed that using leaner FT schedules as compared to contingent reinforcement schedules produced even greater response maintenance. It is possible that we may have seen response maintenance with these children if he FT schedules were leaner than the preceding CR schedules.

For those children for which responding did not increase or maintain under the FT condition, however, a simple manipulation that involved providing a single within-session contingent reinforcer prior to implementing the FT schedule (i.e., the CR + FT condition) resulted in the maintenance of responding under those FT schedules. These results are similar to those found by Neuringer (1970), who showed that providing three response-dependent reinforcers produced maintenance of responding under time-based schedules in pigeons. Although the CR + FT condition was effective for all participants in increasing responding, it is unclear as to exactly what mechanism responding maintained. It is possible that the initial response-dependent reinforcer served as a discriminative stimulus for further responding in session. It is, however, also possible that providing a response-dependent reinforcer momentarily increased the rate of responding, which then contacted adventitious reinforcement. Our contiguity analysis data suggest that for two of the three children in the CR + FT condition (Gladice and Midas), the conditional probability that a token followed responding increased as compared to the FT condition in which responding did not maintain. Although these differences were small, it is possible that the additional contact with potential adventitious reinforcement conditions was responsible for response maintenance.

The purpose of Phase 2 was to determine whether maintained responding under FT schedules was due to the adventitious reinforcement of responding. In order to determine this, we conducted within-session contiguity analyses to determine the likelihood that a token followed or preceded responding. In addition, we conducted an experimental analysis for some children by removing the possibility of adventitious reinforcement by inserting delays between responding and token delivery when responding occurred close to the scheduled delivery times. The contiguity analysis data suggested that tokens commonly followed responses (within 3-s and 6-s bins) during the FT and CR + FT conditions (with probabilities ranging from 0.23 to 0.58), which suggests that adventitious reinforcement was possible (given that responding can be maintained by intermittent schedules of reinforcement (Ferster & Skinner, 1957). However, we also showed that it was equally as likely that tokens preceded responding (with probabilities ranging from 0.21 to 0.53). Overall, these data suggest that adventitious reinforcement was a possible mechanism for responding, although the probabilities of the tokens serving as antecedents make this conclusion unlikely. For the three children who participated in the experimental manipulations in this phase, responding did not decrease during those conditions (FT + 3-s delay and FT + 6-s delay) for any of the children. These results suggest that adventitious reinforcement was not the likely mechanism for response maintenance for the children in this study. In addition, these data suggest that the contiguity analyses we used may not be predictive of the actual mechanisms of response maintenance under FT schedules, because across child, although the conditional probabilities of tokens serving as consequences varied, no child's responding was shown to be maintained due to adventitious reinforcement. These data do not replicate the results of some previous research (e.g., Vollmer et al., 1997), which suggested that adventitious reinforcement might be necessary for response maintenance. However, it is also possible that the delays we used were not sufficient to break the response-reinforcer relationship. Although the contiguity analysis bins and the delays we chose for the current study were based the mean inter-response times for the children in the current study, they were still in some sense arbitrary, and it is currently unclear exactly how large of a delay is necessary to produce an extinction effect. It is possible that even with a 6-s delay, a reinforcement effect could still occur. However, these results are similar to those found by Thompson et al. (2003), which showed that when the potential for adventitious reinforcement was removed (using a DRO method), responding continued to maintain. One additional mechanism that might also be responsible, but that was not explicitly tested for, was the possibility of the adventitious reinforcement of response chains. In the current study, the dependent variable (placing a toy in a bin) can also be considered a chained response, which may include locating a toy, picking up the toy, walking towards the bin, and finally placing the toy inside the bin. Because reinforcer delivery was only delayed from the terminal response in the chain (placing the toy inside the bin), it is possible that reinforcers were delivered following some other component of the chain, which may have reinforced the entire response chain (e.g., McWilliams, Nietupski, & Hamre-Nietupski, 1990).

The purpose of Phase 3 was to determine whether maintained responding under FT schedules was due to the stimulus control exerted by various stimuli in the environment that were shared between the CR and FT conditions. In order to test this, we conducted several possible conditions that evaluated the effects of removing one (SD probes) or several (FT w/o S^D) potential discriminative stimuli. The results of Phase 3 showed that for three out of four children who participated in this phase, responding decreased under the FT w/o S^D condition, suggesting that stimulus control was the likely mechanism by which responding maintained during the FT condition. In addition, for the one child (Edward) who participated in the SD probe condition, responding only occurred during the Therapist probe, suggesting that the presence of the therapist was likely a discriminative stimulus for responding in the FT condition.

These results have several practical implications. By understanding the mechanisms that control responding under FT schedules, it may allow for improvements in the use of FT schedules for maintaining responding. For example, because FT schedules were found to maintain responding through stimulus control for most children, additional procedures to enhance the potential discriminative stimuli in the future to enhance the effectiveness of FT schedules in maintaining responding. For example, for Edward, the therapist could be made more salient by having them wear a brightly colored t-shirt, which may further promote response maintenance. Future researchers should assess the effects of not only single stimuli, but also compound stimuli (Similar to Halle and Holt, 1991) on response maintenance.

The current study has several limitations. First, for two children (Bradley and Carrie), although response maintenance occurred initially, these results were unable to be replicated or demonstrated with thorough experimental control. For Bradley, upon reestablishing responding following second baseline condition, responding maintained across all conditions including a subsequent baseline. It is possible that following a history of responding, specific discriminative stimuli that were not removed in the FT w/o S^D and baseline conditions exerted control over responding. For example, in both of those conditions, instructions to "clean up" were provided at the beginning of sessions. It is possible that these instructions may have established rule-governed behavior (as opposed to contingency-governed behavior). Research in human-operant labs has shown that rules may have a greater level of control over behavior than contingencies (e.g., Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; Kaufman, Baron, & Kopp, 1966). For Carrie, following the FT w/o S^D condition, responding would not maintain during any FT condition with the exception for the CR + FT condition. It is possible that some stimuli shared between the FT w/o S^D condition and the FT condition (e.g., tokens delivered in the absence of responding) became S-deltas for responding, and thus following the FT w/o S^D condition, responding decreased under subsequent FT conditions.

A second limitation is that although we tried to keep them as consistent as possible, instructions provided during sessions differed from condition to condition, specifically from the CR to the FT condition. The reason we used these instructions was twofold. First, we used the additional instruction, "when you clean up, you will sometimes get tokens" in the CR condition to initially evoke responding, which could then be maintained by the reinforcement contingencies in session. During the FT condition, we changed the rule to, "sometimes you will get tokens", which may have a) been an s-delta for children whom the FT condition did not maintain responding or b) continued to be a discriminative stimuli for responding for those children whose responding maintained under FT conditions. Given that responding occurred in the first session of the initial CR condition for Sanford, Gladice, and Midas, and in the first FT session for Gladice, it is likely that the presence of the rule exerted some control over their responding. However, for two of those subjects, responding did not maintain under FT schedules, suggesting that the rules, although maybe important for evoking initial responding, were not sufficient to maintain responding (or the changing of the rules was an s-delta for responding).

A third limitation is that in addition to removing the delivery of tokens in the FT w/o S^D condition, we also did not delivery praise during this condition. In addition, in the token SD probe, both praise and the delivery of tokens occurred during sessions. Although it is unclear as to exactly what role praise played in the maintenance of responding because it was always paired with the delivery of tokens, it is possible that this praise served as either a reinforcer or as a discriminative stimulus for responding. However, because praise was never assessed in isolation, it is impossible to determine exactly what effect praise may have had on responding.

A fourth limitation is that although we were able to determine that stimulus control was responsible for the maintenance of responding under FT conditions for most children, we only determined specific controlling stimuli for one subject (Edward). In addition, we only showed responding in one probe session for Edward. Within-session data for this particular session show that although responding occurred, it did not maintain throughout the session (see Figure 5). These data suggest that although the presence of the original therapist was necessary to evoke responding, it is unlikely that this stimulus alone would maintain responding. In addition, we did not assess the presence of the tokens as a potential S^D, but both the presence and delivery of the tokens. Although it is unlikely, the presence of the tokens may have had an additional effect on responding that the compound stimulus (presence and delivery of tokens) may have not. In the FT w/o S^D condition, several discriminative stimuli (e.g., therapist, setting, rules, token presence, token delivery) were changed simultaneously, and any one or a combination of these stimuli may have been responsible for the maintenance of responding under FT schedules. Future researchers should conduct additional analyses of both single and compound stimuli to determine the specific stimuli responsible for maintaining responding.

Finally, a fifth potential limitation is that we did not assess the CR + FT condition in the absence of a history of contingent reinforcement. It is possible that under the CR + FT condition, responding might have maintained in the absence of a history of contingent reinforcement, which would further increase the efficiency of this particular procedure because it would not necessarily require a long history of contingent reinforcement prior to its use. Future researchers should continue to evaluate the use of brief contingent reinforcement periods to maintain responding under response-independent schedules with and without prior histories of contingent reinforcement.

Future research should continue to be conducted to look at different dimensions of FT schedules (i.e. duration of reinforcement, schedule, magnitude of reinforcement, similarity to previous contingent schedules) and their importance in the maintenance of responding under fixed-time schedules. In addition, research should be conducted to determine under what conditions, as seen with Carrie, FT schedules will maintain responding without a history of contingent reinforcement. If these conditions could be determined, it would allow for response maintenance without the necessity for a long period of contingent reinforcement, which may be more acceptable for use in applied settings. Additionally, future research should be conducted to determine if FT schedules are superior to other procedures for maintaining responding, especially in more naturalistic settings such as classrooms. Not only should the effects of these procedures be compared, but also caregiver preference of these procedures. Researchers have suggested that when caregivers deem procedures to be acceptable, they may be more likely implement those procedures in naturalistic settings with high fidelity (Allen & Warzak, 2000; Mueller, Edwards, & Trahant, 2003). Finally, future researchers may consider conducting analyses of additional stimulus variables to determine which variables are necessary for the maintenance of responding. Doing so would potentially allow caregivers who use these procedures to better program for generalization of the effects of these procedures to different settings.

Overall, several general conclusions can be made based on the results of this study. First, for some children, following a history of contingent reinforcement, responding maintained under FT schedules. Second, for those children whose responding did not maintain under FT schedules, a simple procedure (CR + FT) was successful in promoting maintenance of responding under FT schedules. Third, for children whom mechanisms were tested, most children showed to some extent that a) adventitious reinforcement was not the primary mechanism for response maintenance under FT schedules and b) certain discriminative stimuli were responsible for the maintenance of responding under FT schedules. Fourth, we found that for one child (Carrie), responding maintained under FT schedules without a history of contingent reinforcement. Finally, within-session contiguity analyses were not particularly useful in predicting the mechanisms of response maintenance under FT schedules because in most cases, the conditional probabilities of token delivery serving as antecedents or consequences were equal. In addition, there was little difference in the conditional probabilities of tokens as antecedents or consequences between those who showed response maintenance under FT schedules and those who did not. It is possible that further refinements of this method (e.g., analyses at different delays) may be necessary to increase the predictive power of these analyses.

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Tables and Figures

Participant	Age (years)	Instruction Following	Complex Rule Followin[g]
Bradley	3.5	4-step	Yes
Sanford	4	4-step	Yes
Edward	5	4-step	Yes
Carrie	5	4-step	Yes
Gladice	5	4-step	Yes
Midas	4	4-step	Yes

Table 1. Participant characteristics. The table depicts the age in years of each participant at the start of their participation. In addition, the table depicts the number of steps in instructions the children could follow and if the children could follow complex rules based on ongoing observations and assessments in their preschool classroom.

	FT				CR + FT			
	3 second		6 second		3 second		6 second	
Participant	Antecedent	Consequence	Antecedent	Consequence	Antecedent	Consequence	Antecedent	Consequence
Bradley	0.21	0.25	0.35	0.41	N/A	N/A	N/A	N/A
Sanford	0.29	0.30	0.47	0.45	N/A	N/A	N/A	N/A
Edward	0.35	0.34	0.52	0.48	N/A	N/A	N/A	N/A
Carrie	0.35	0.37	0.53	0.58	0.17	0.17	0.29	0.25
Gladice	0.26	0.32	0.41	0.44	0.50	0.50	0.62	0.61
Midas	0.21	0.22	0.25	0.26	0.23	0.26	0.35	0.32

Table 2. Results of the contiguity analyses for all participants. The table depicts the mean conditional probability of token delivery as an antecedent or consequence based on both 3-s and 6-s criteria during the FT and CR + FT conditions.

	Response Maintenance		Mechanism	
Participant	FT	CR + FT	Adventitious Reinforcement	Stimulus Control
Bradey	Yes	N/A	No	No
Sanford	Yes	N/A	No	Yes
Edward	Yes	N/A	N/A	Yes
Carrie	Yes*	Yes	No	Yes
Gladice	No	Yes	N/A	N/A
Midas	No	Yes	N/A	N/A

Table 3. Summary of results for all participants. The table depicts whether response maintenance occurred under the FT or FT + CR conditions. Additionally, the table depicts whether adventitious reinforcement or stimulus control was found to be a mechanism for response maintenance under the FT condition. The asterisk denotes response maintenance without a history of contingent reinforcement.

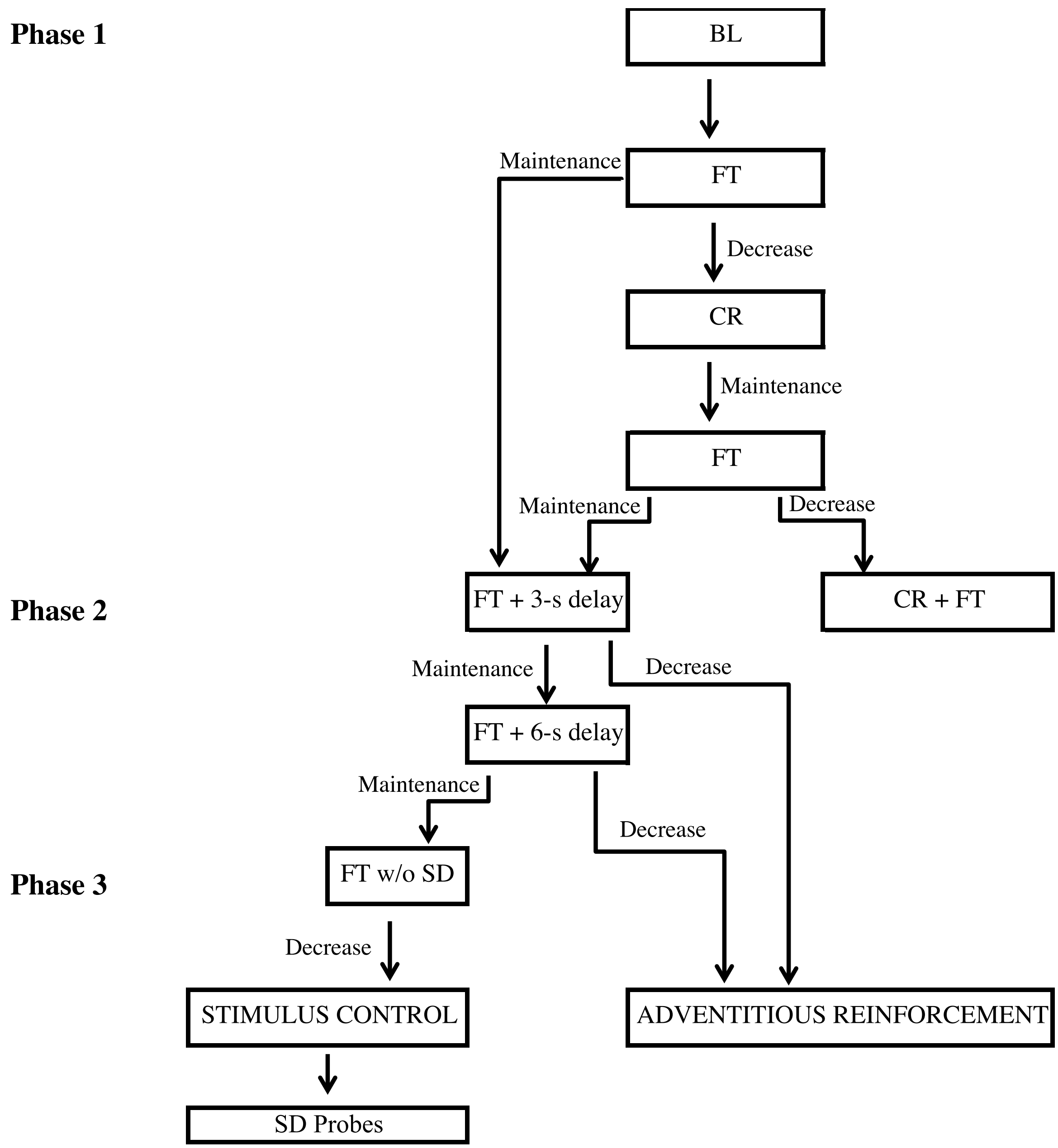

Figure 1. A flowchart depicting the conditions and implications of specific response patterns in Phases 1, 2, and 3.

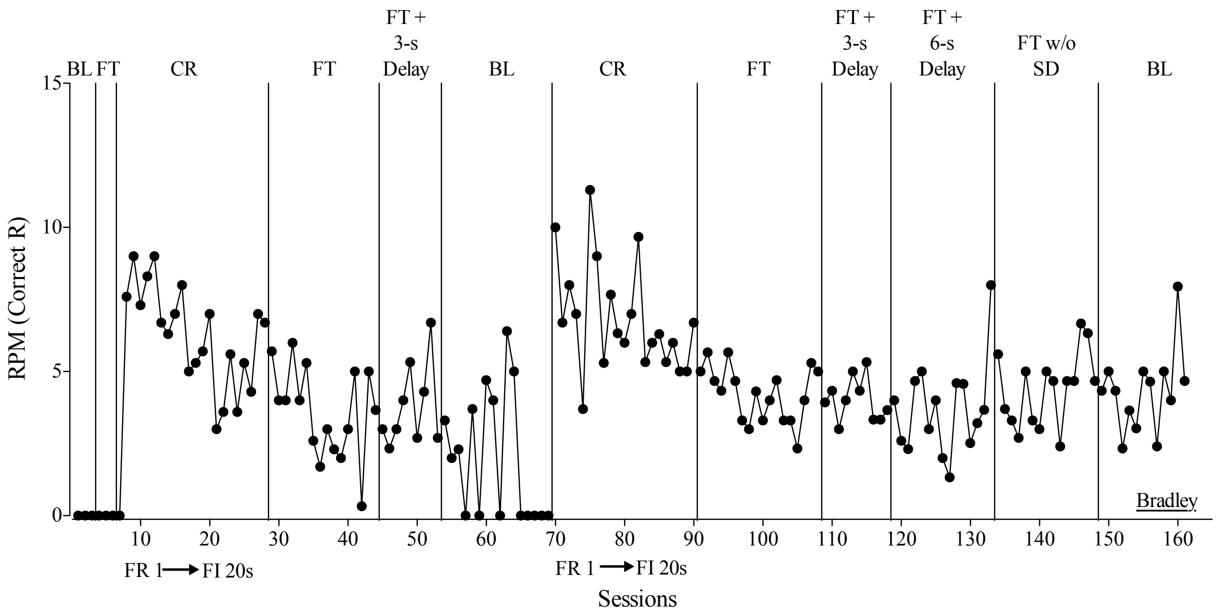

Figure 2. This graph depicts rates of correct responding during Phase 1, 2 and 3 for Bradley. Sessions are along the x-axis and responses per minute of correct responding are along the y-axis.

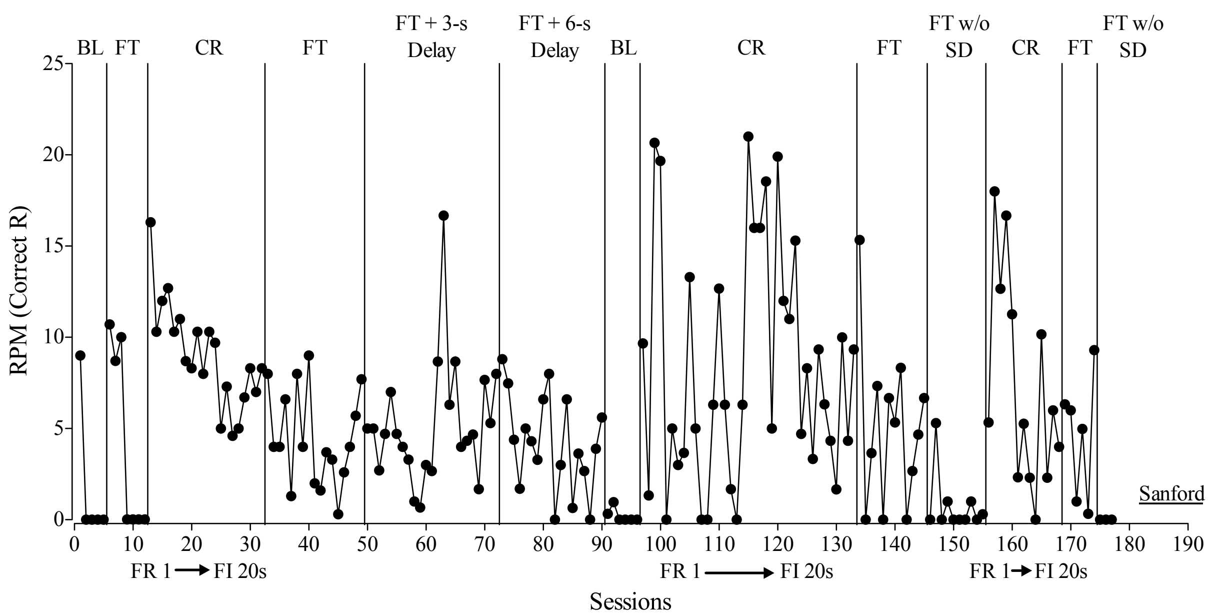

Figure 3. This graph depicts rates of correct responding during Phase 1, 2 and 3 for Sanford. Sessions are along the x-axis and responses per minute of correct responding are along the y-axis.

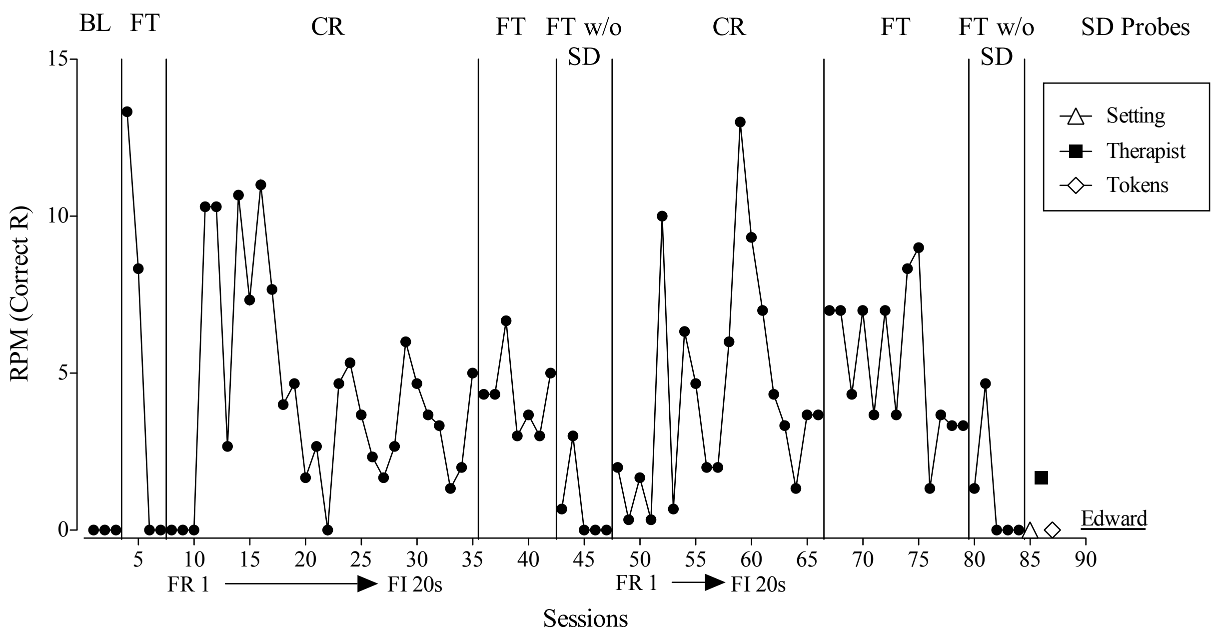

Figure 4. This graph depicts rates of correct responding during Phases 1 and 3 for Edward. Sessions are along the x-axis and responses per minute of correct responding are along the y-axis.

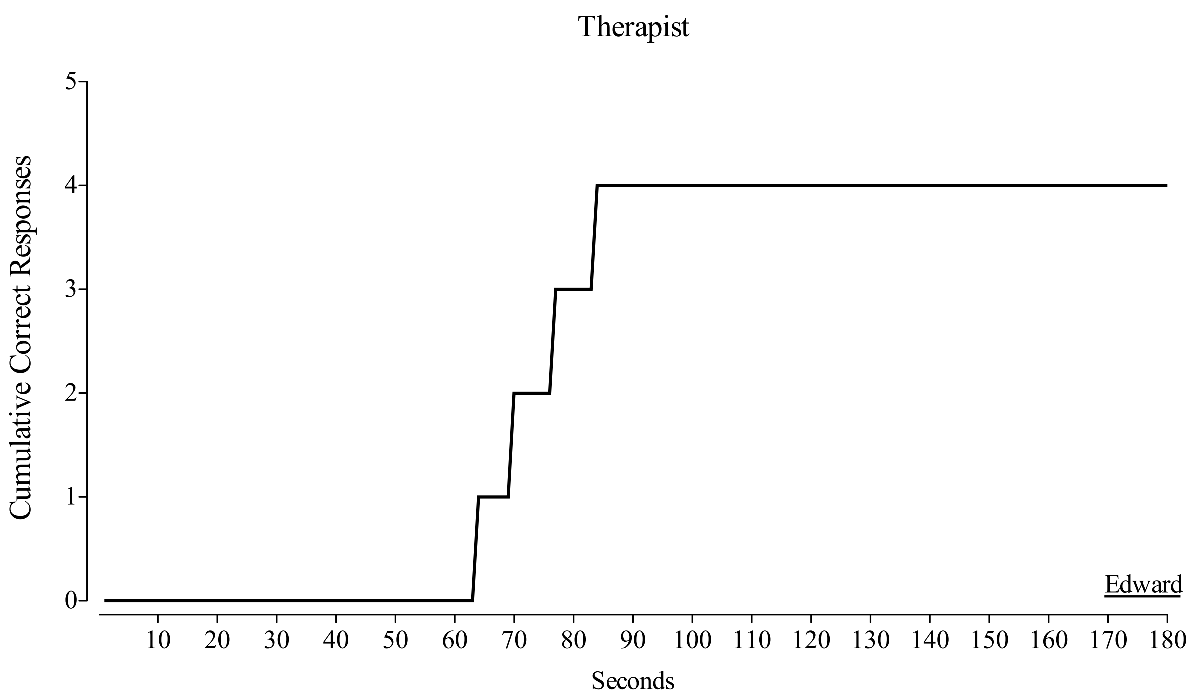

Figure 5. This graph depicts the cumulative frequency of correct responses during the teacher single-stimulus probe for Edward. Time in seconds is along the x-axis and the cumulative number of correct responses is along the y-axis.

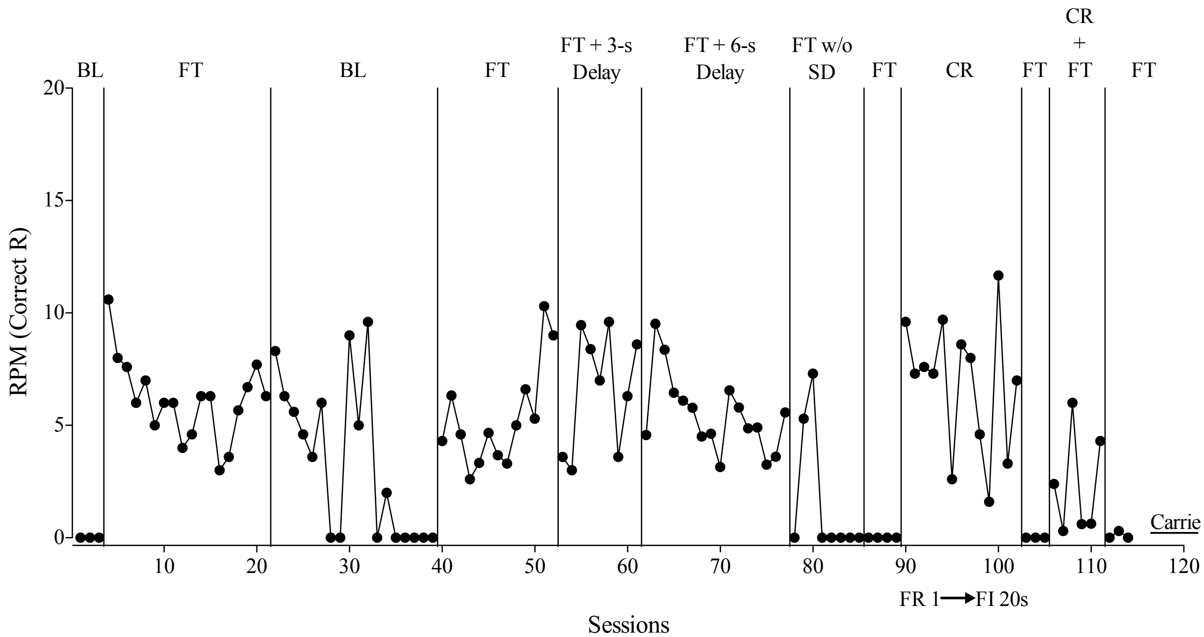

Figure 6. This graph depicts rates of correct responding during Phase 1, 2 and 3 for Carrie. Sessions are along the x-axis and responses per minute of correct responding are along the y-axis.

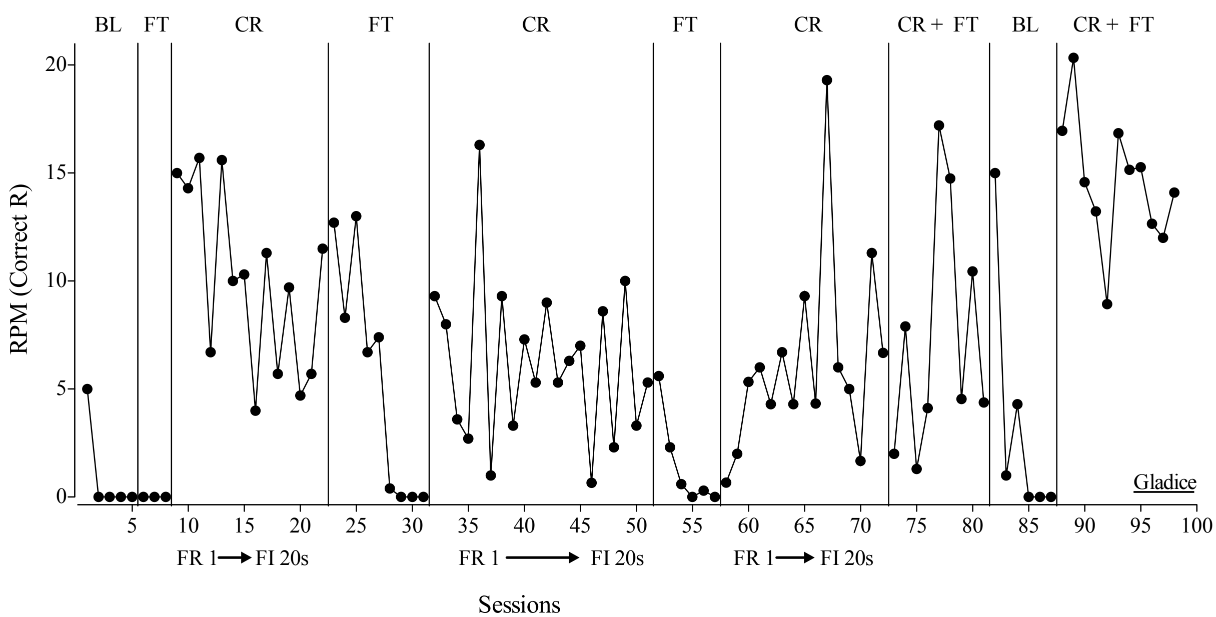

Figure 7. This graph depicts rates of correct responding during Phase 1 for Gladice. Sessions are along the x-axis and responses per minute of correct responding are along the y-axis.

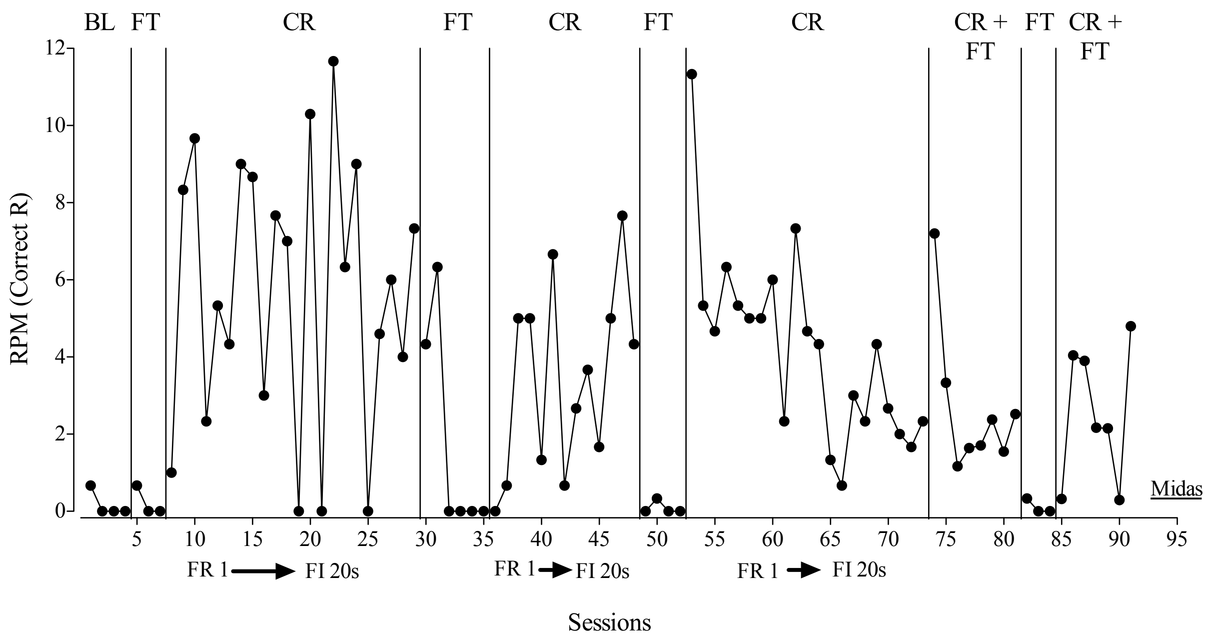

Figure 8. This graph depicts rates of correct responding during Phase 1 for Midas. Sessions are along the x-axis and responses per minute of correct responding are along the y-axis.