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MAINTAINING ACCURATE MATH RESPONSES IN ELEMENTARY SCHOOL STUDENTS: THE EFFECTS OF DELAYED INTERMITTENT REINFORCEMENT AND PROGRAMMING COMMON STIMULI

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This study examined the effect of delayed reinforcement on digits completed by elementary school children and the effect of programming stimuli common to reinforcement conditions on the maintenance of their performance. Participants exhibited similar levels of responding during intermittent and continuous reinforcement. Responding continued for a number of sessions at similar levels during a maintenance phase that included stimuli present during delayed reinforcement.

DESCRIPTORS: maintenance, mathematics, delayed and intermittent reinforcement, common stimuli

Poor performance in mathematics is a common problem in schools that has been the target of numerous behavioral intervention studies. Although researchers have identified effective interventions for mathematics failure, relatively few studies of procedures that maintain high levels of performance following interventions have been reported (Pereira & Winton, 1991). Three generalization strategies appear to be particularly promising for use with academic behaviors in schools. First, delayed reinforcement is congruent with educational practices because of the common delay between completion of assignments by students and the return of corrected work. Second, intermittent reinforcement may be acceptable because it reduces the implementation demands on teachers. Finally, programming common stimuli can readily be accomplished in educational contexts because of the consistency of classroom settings and materials. This study examined maintenance of responding on mathematics tasks during and following exposure to a delayed intermittent-reinforcement schedule. The effect of programming common stimuli in the delayed intermittent-reinforcement and maintenance phases was also examined.

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METHOD

Participants, Setting, and Materials

Four general education fourth-grade participants who had been referred by education professionals for mathematics deficits participated in this study. Susan, Pete, and Frank were 10 years old, and Kevin was 9 years old. Participants met with the experimenter twice per day in the school cafeteria. Two 5-min sessions were conducted at each meeting.

Participants were assigned an instruction-

al task based on a curriculum-based assessment (Shapiro, 1996) conducted prior to experimental procedures. Frank's target skill was multiplication of single digits. Susan, Kevin, and Pete worked on addition with regrouping. During each session, participants were provided worksheets containing 100 randomly generated problems corresponding to their target skill. The large number of problems was used to avoid ceiling effects, and no participant completed all of the problems in any session. Digits correct per 5-min session was selected as the dependent measure because of its utility as a common metric across studies, its sensitivity to instructional programming, and its positive relationship to other mathematics outcomes (Marston, 1989). Interscorer agreement data were obtained for a randomly selected 33% of sessions for each participant and was calculated based on exact agreement for each digit. Agreement was 86% for Pete, 85% for Frank, 88% for Kevin, and 86% for Susan.

Experimental Design, Procedures, and Reliability

Each participant's mathematics performance was evaluated in a reversal design followed by generalization probes. An observer measured treatment integrity for 34% of sessions using a checklist (available from the first author). Treatment integrity was 100% for all sessions.

Baseline. Participants were asked to work on problems from their worksheets for 5 min and were told that they could attempt as many or as few problems as they wanted. No programmed consequences were provided for mathematics performance, and no feedback was provided to participants. Worksheets during this phase were blue.

Reinforcement. A number was recorded on the top right corner of each worksheet. The experimenter explained to the participants that if they completed more digits correct than this goal they would be allowed to select a reward from a "goody box" containing items such as candy and mechanical pencils. The initial reinforcement goal was selected based on the median of the last three baseline sessions. Subsequent goals were based on the median of the previous three sessions, as long as this median was at or above the original goal. If the median of the previous three sessions fell below the original goal, the initial goal was used. Worksheets during this phase were green.

Delay 2 and Delay 4. These phases exposed participants to delayed intermittent reinforcement. Participants were asked to complete problems on their worksheets, but no description of the contingency in place was provided. In Delay 2 and Delay 4, a worksheet was selected at random after the participant completed two sessions and four sessions, respectively, and the reinforcement contingency was applied to the worksheet selected. If a participant asked why one of the worksheets was not graded, the experimenter replied, "I am not going to grade all of the worksheets today." Worksheets in this condition were white.

Maintenance. Three stimuli that were absent from baseline and present in the delay conditions were programmed in the maintenance condition to facilitate continued responding. Specifically, the worksheets were white, a goal was recorded on the worksheet, and the wording of the directions was identical to delay conditions. However, no contingencies were implemented for mathematics performance, and no feedback was provided. If a participant asked why none of the worksheets was graded, the experimenter replied, "I may not grade the worksheets today."

RESULTS AND DISCUSSION

Reinforcers were initially delivered on a dense schedule to all participants; however,

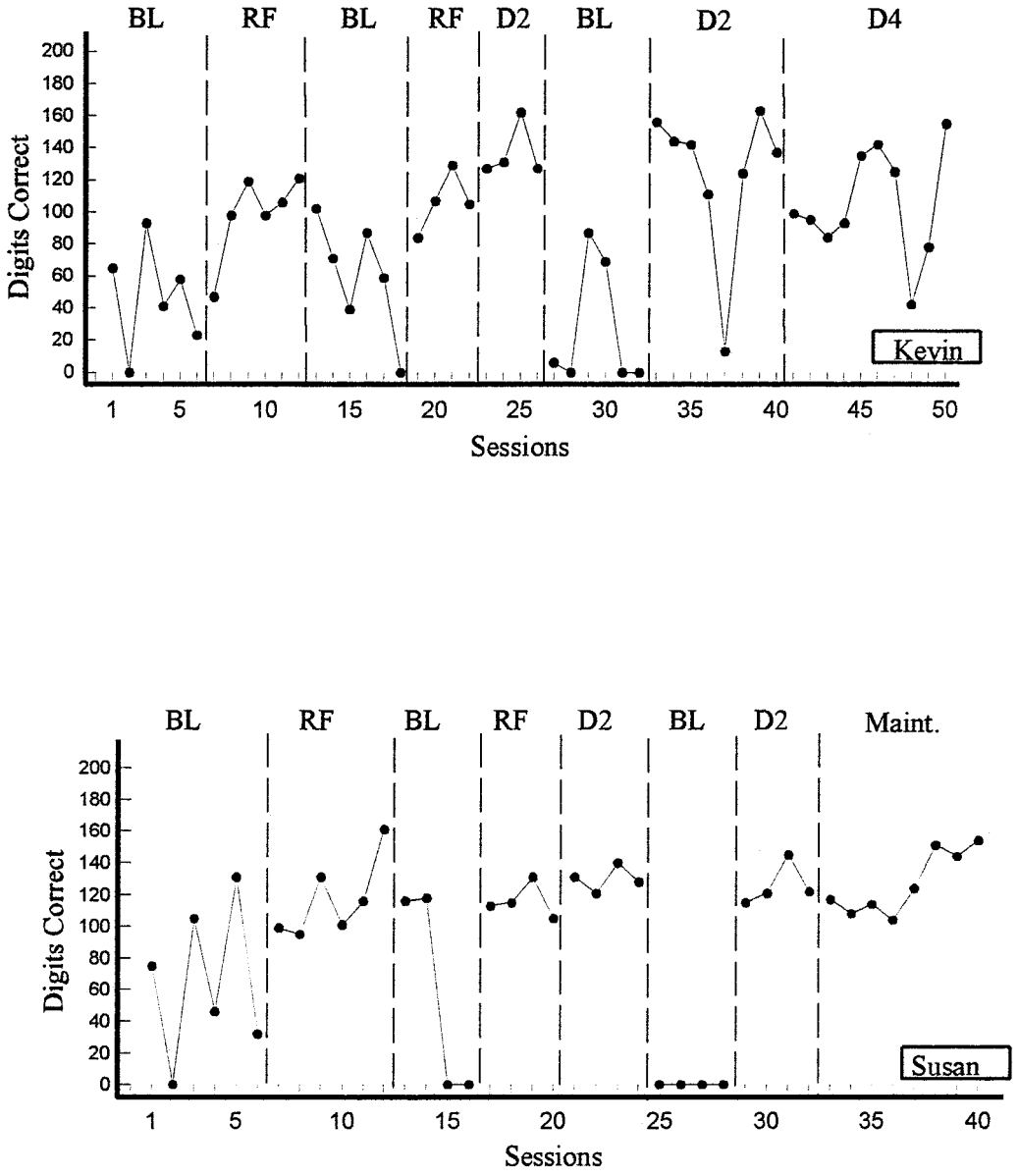

Figure 1. Digits correct during baseline (BL), reinforcement (RF), Delay 2 (D2), Delay 4 (D4), and maintenance for Kevin and Susan.

during delay phases the thinned schedule and intermittent delivery of reinforcement led to as few as one reinforcer per 10 sessions. The results for all 4 participants are presented in Figures 1 and 2. The initial baseline and reinforcement phases show that contingent access to the "goody box" functioned as a reinforcer for digits correctly completed for all participants. All of the participants maintained responding at or above previously reinforced levels during the initial delayed intermittent-reinforcement condition (Delay 2). When participants returned to baseline, which was signaled by a change in the color of the worksheet and the absence of a recorded goal, responding fell to

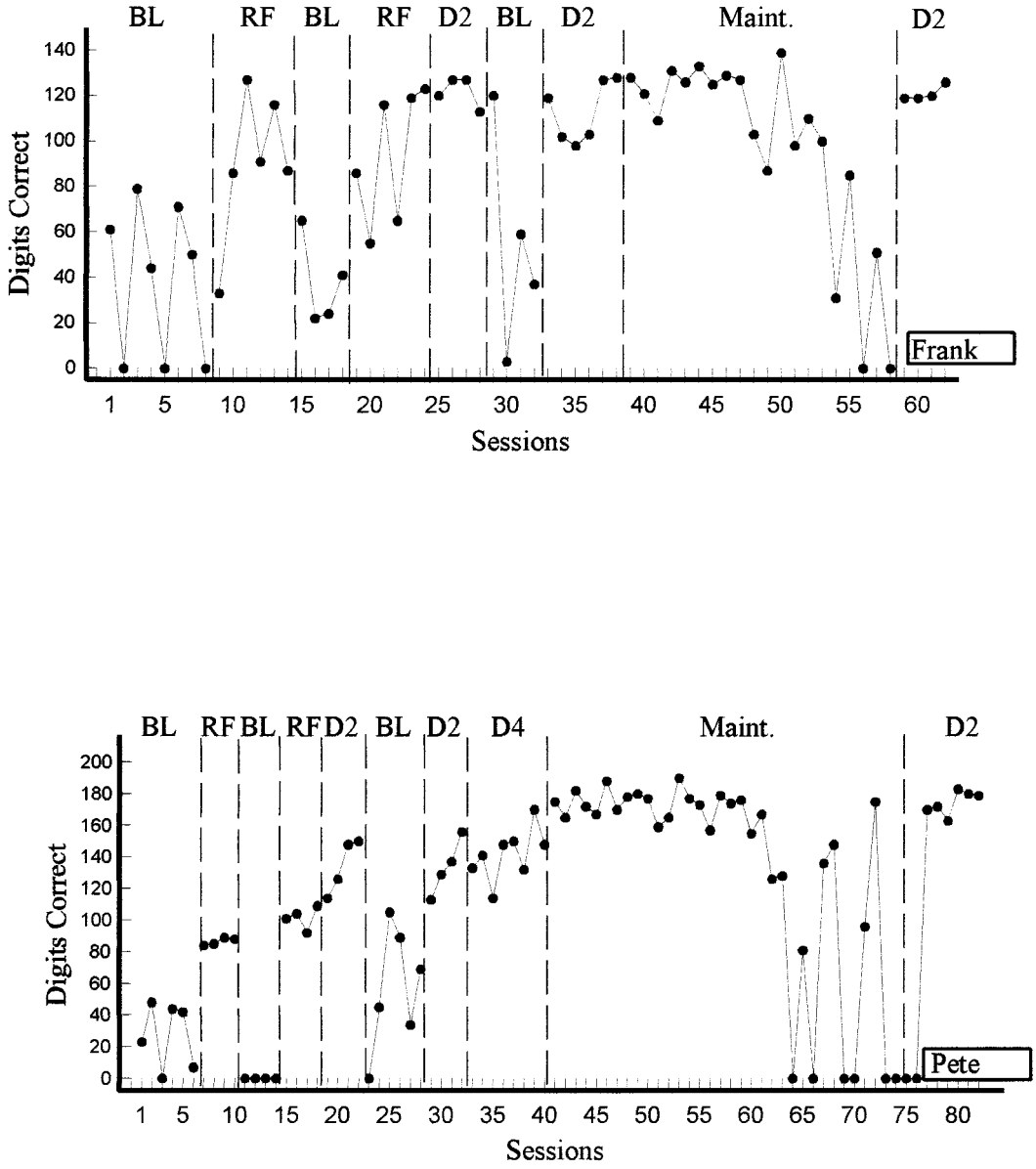

Figure 2. Digits correct during baseline (BL), reinforcement (RF), Delay 2 (D2), Delay 4 (D4), and maintenance for Frank and Pete.

or below initial baseline levels. High levels of responding resumed across participants during a return to Delay 2 conditions. Kevin exhibited some decrease in responding during the Delay 4 condition. Susan and Frank were exposed to the maintenance condition following Delay 2. Susan maintained responding for eight sessions, and Frank maintained responding for 14 sessions. Pete was exposed to Delay 4 prior to maintenance and maintained responding above baseline levels for 23 sessions. Frank's and Pete's responding returned to high levels when Delay 2 was reimplemented after an extended maintenance phase during which responding had decreased to near-zero levels. During the

terminal condition, the performance of all participants improved sufficiently to fall within the instructional ranges described by Shapiro (1996).

This study contributes two findings to the mathematics instruction literature. First, delayed reinforcement of randomly selected response opportunities maintained mathematics responding at levels similar to those previously obtained under continuous reinforcement. Delayed intermittent reinforcement may be practical in educational settings because it allows educators to schedule grading at convenient times and to deliver reinforcers on a relatively lean schedule. Second, postintervention responding was maintained only in conditions that employed program stimuli present during reinforcement phases (i.e., paper color and goal). Thus it appears that math instruction for elementary school children may benefit from the strategic use of common stimuli.

Limitations of this study include the possibility of practice effects, insufficient time for some participants to complete all phases, and the use of an analogue setting. These results suggest that systematic replication addressing these limitations could benefit mathematics instruction for young children.

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