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Explicit Instruction With or Without High-*p* Sequences: Which is More Effective to Teach Multiplication Facts?

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*Basic fact acquisition is an important component for developing higher-order math skills. However, getting students with a history of academic noncompliance to engage in activities related to skills acquisition can be difficult. Prior research demonstrates that engagement increases when nonpreferred activities are preceded by a series of brief activities with a high probability of completion. This technique, called high-*p *task/request sequences, was not fully explored within the context of skill acquisition. The purpose of this study was to examine the effects of adding high-*p *sequences to explicit instruction on the math fact acquisition of three elementary-age students in a learning support classroom. Results showed no differences in fact acquisition between explicit instruction and explicit instruction with an added high-*p *component. However, the high-*p *sessions took nearly twice as long to complete when compared to explicit instruction alone. Implications for instructional efficiency and limitations of the high-*p *procedures for acquisition tasks are discussed.*

KEY WORDS: high-*p* requests; math fact acquisition; interspersal.

Practicing and mastering the fundamental components of a skill is a time-tested routine universal in the world of sports. Other skilled performances such as playing a musical instrument also require a student to firmly grasp the basics before attempting more challenging pieces. Mathematics is no different. For example, before applying a mathematical algorithm for solving a complex problem like 234×23, a student must master basic multiplication facts (Wu, 1999). Indeed,

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to think mathematically and learn more complex skills students require a well-designed program that explicitly teaches the basics and systematically advances to higher order content (Stein, Silbert, & Carnine, 1997).

A defining principle of explicit instruction is that students maintain high levels of accuracy when learning new tasks (see Salvia & Ysseldyke, 2004; Silbert, Carnine, & Stein, 1990). One way to help ensure students are taught within this instructional range is to intersperse known material with unknown. This mixing of known with unknown results in students preferring the interspersed materials (Logan & Skinner, 1998; Wildmon, Skinner, McCurdy, & Sims, 1999), choosing to do more work (Cates & Skinner, 2000), and acquiring new material at a higher rate (Burns, 2004).

Researchers examined task interspersal across several academic content areas including reading (Roberts & Shapiro, 1996), spelling (Neef, Iwata, & Page, 1980), and math fact fluency (Cooke, Guzaukes, Pressley, & Kerr, 1993). Cooke and colleagues (1993), for example, compared a math task consisting of 100% unknown problems with an interspersed task of 30% unknown/70% known. The experimental results showed increased multiplication fact fluency in the interspersal condition.

In an early study on task interspersal Neef, Iwata, and Page (1980) compared the effects of high-density reinforcement and task interspersal on spelling word acquisition of students with mental retardation. In a baseline condition students were asked to spell 10 unknown spelling words. Correct answers resulted in verbal praise. Incorrect answers were corrected and students were asked to write each corrected word three times. Words spelled correctly for five consecutive sessions were considered learned and replaced by another unknown training word. In the high-density reinforcement condition students were similarly asked to spell 10 words and given praise for correct answers and asked to write corrected responses three times each. These students were also given 10 noncontingent social reinforcers, one for each word, for task related behaviors (e.g., writing neatly, paying attention). Other reinforcement and correction procedures were similar to baseline. In the interspersal condition students were asked to spell a series of 10 known and 10 unknown words presented in alternating order. Correct answers resulted in verbal praise and errors were corrected in a manner similar to those in baseline. Results showed that students mastered more words in the interspersal condition than in the high-density reinforcement condition. Although an analysis of the specific mechanism responsible for the results was not conducted, Neef and colleagues hypothesized that the higher levels of reinforcement within the interspersal condition helped the students pay more careful attention to the training stimuli and made negative emotional responses associated with long series of incorrect responses less likely.

To further explain the effects of task interspersal, Skinner (2002) employed the discrete task completion hypothesis (DTCH). The DTCH suggests that completed tasks act as conditioned reinforcers. Increasing task completion rates by interspersing known material increases the overall level of reinforcement for a given task. The richer schedule of reinforcement may increase attention to the task and enhance subsequent acquisition of the material.

A method related to task interspersal that increases the density of reinforcement embedded within an academic task is high-probability (high-*p*) request sequences (Lee & Laspe, 2003). In the high-*p* sequence a series of two to three tasks or requests with a high probability of completion is presented immediately prior to a task or request with a low probability (low-*p*) of completion. Because the high-*p* tasks produce higher rates of responding, and subsequent reinforcement, these modified tasks result in higher levels of reinforcement relative to more traditional forms of a task. For example, a typical math worksheet may contain 10 problems with a low probability of completion (low-*p*). A student can receive 10 reinforcers if she correctly completes each of the problems on the page. However, adding a series of two to three high-*p* problems just prior to each low-*p* problem can increase the overall level of reinforcement for the worksheet. The additional reinforcers gained from completing the added preferred problems make it more likely that the student will remain engaged in the task. Thus, high-*p* and interspersal techniques are similar in that both increase the density of reinforcement available for a given task. These techniques differ in that high-*p* sequences are generally presented at a ratio of three high-*p* to one low-*p* and result in a richer schedule of reinforcement than traditional interspersal, which is presented at a ratio of one known to three unknown.

Embedding high-*p* sequences increases responding across a variety of academic tasks. This technique was used to increase the number of words written during journal writing time (Lee & Laspe, 2003), increase rate of math problems completed (Hutchinson & Belfiore, 1998), decrease the latency to initiate nonpreferred math tasks (Belfiore, Lee, Vargas, & Skinner, 1997), and increase the number of words written during a letter copying task (Lee, Belfiore, Scheeler, Hua, & Smith, 2004).

Research on high-*p* sequences in academic settings focused primarily on performance deficits. That is, students have the skills to complete tasks, but fail to initiate or remain engaged in those tasks in order to become proficient. However, this technique was not fully examined for use with skill deficits. Students with skill deficits fail to complete tasks because they do not have the knowledge to complete those tasks. In the only study on the effects of the high-*p* procedure on acquisition, Cates, Skinner, Watson, Meadows, Weaver, and Jackson (2003) compared the effects of high-*p* sequences (three known spelling words presented prior to each unknown word), task interspersal (three unknown spelling words presented prior to each known word), and drill/practice (six unknown words presented alone) on spelling word acquisition and instructional efficiency for students in a general education classroom. Results indicated that spelling word acquisition was similar for each of the instructional methods. However, the drill and practice method was the most efficient method of instruction and resulted in more words mastered per minute of instruction for four of the five students.

The study by Cates et al. (2003) addressed some important questions regarding the effectiveness and efficiency of the high-*p* procedure for acquisition of new behavior. However, additional questions regarding the generality of their findings across populations and tasks remain. The purpose of this study was to expand the work on high-*p* sequences on acquisition to another academic subject area (mathematics) and a different population (children with mental retardation and learning disabilities). More specifically we ask, is a high-*p* procedure added to explicit instruction more effective than explicit instruction alone at teaching multiplication facts?

METHOD

Participants and Setting

Three female students receiving special education services participated in the study. Each participant was referred to the study because of a history of difficulty learning basic math facts. Kathy was 11-years old and diagnosed with mild mental retardation. Kathy's diagnosis was based upon a full scale IQ score of 71 as measured by the Wechsler Intelligence Scale for Children – 3rd edition (Wechsler, 1991), as well as below average performance in the adaptive behavior areas of communication and daily living skills as measured by the Vineland Adaptive Behavior Scale (Sparrow, Balla, Cicchetti, & Harrison, 1985). Joy and Alicia were 10-year old identical twins diagnosed with a specific learning disability. Both students had IQ scores of 98, as measured by the Stanford Binet Intelligence Scale for Children - 4th Edition (Thorndike, Hagen, & Sattler, 1986), as well as deficits in the academic areas of reading and math measured by the Brigance Diagnostic Inventory of Basic Skills Revised (Brigance & Glascoe, 1999) and visual motor and perceptual functioning, as measured by the Developmental Test of Visual Motor Integration (Beery & Buktenica, 1997).

All participants attended a resource room for reading and mathematics in a public school located in a large urban district in Eastern Pennsylvania. Classroom staff included one part-time paraeducator and one special education teacher. The students' teacher conducted the study in the back of the classroom (in an area approximately 5 m $\times$ 10 m).

Procedures

Identification of Known/Unknown Facts

Prior to the start of the study the students' teacher indicated that single digit addition and single digit multiplication problems could serve as known and unknown tasks respectively. An assessment was conducted, similar to Cooke, Guzaukes, Pressley, and Kerr (1993), to validate the known and unknown math facts. Each basic addition (1 × 1 digit) and multiplication (1 × 1 digit) fact was written on an index card (13 cm × 7.5 cm). For fact identification sessions, the teacher greeted the student and read the following instructions. "Today we are going to work on some math facts. When I show you the card with a problem, say the correct answer. It is okay if you do not know the answer to a problem." The teacher then presented the facts to the student. At the end of the session the teacher thanked the student for working. No verbal praise or other feedback was given. Each fact pool was presented once each day for two days. Facts answered correctly within 2–3 s on both trials were placed in the known fact pool. Facts answered incorrectly on both trials were placed in the unknown fact pool. Facts that were answered correctly for one of the two trials were not used in the study.

Preference Assessment

High-*p* sequences use tasks with a high-probability of completion to make it more likely students will engage in less preferred responses (i.e., low-*p*). To that end, a choice procedure was used to identify and empirically validate preference for math tasks (Belfiore, Lee, Vargas, & Skinner, 1997). Basic addition facts were selected as a potential high-*p* task because the students had acquired this skill. Multiplication facts were selected because the students had no previous experience with this skill and received no instruction on the skill other than that provided by the researchers – either before or during the study.

Prior to the start of the preference assessment all zero and one facts, as well as the inverse of facts were omitted to better control for difficulty level of the problems. Ten known addition fact cards, arranged in two columns, were placed next to ten unknown multiplication fact cards, similarly arranged in two columns. The location of the cards (right or left) was counterbalanced across trials. The teacher asked the student to pick a set of cards on which to work. After the selection was made, the teacher presented each card and asked the student to say the correct answer. Verbal praise was delivered after correct answers. Incorrect answers were ignored. One preference assessment trial was conducted each day for a period of five days. Each of the students selected the addition task more often than the multiplication task (Kathy 5/5 trials, Joy 4/5 trials, and Alicia 5/5 trials).

Fact Acquisition Phase (Set One)

Prior to the start of the fact acquisition phase unknown multiplication facts were randomly assigned to either a traditional explicit instruction (EXPL) or explicit instruction plus high-*p* (EXPL + H) pool. Facts were further divided into problem sets (Set One contained 10 problems – 5 EXPL and 5 EXPL + H, Set Two contained 6 problems – 3 EXPL and 3 EXPL + H and Set Three contained

6 problems – 3 EXPL and 3 EXPL + H). In the EXPL condition multiplication facts were presented using an explicit instruction format similar to other models in the professional literature (e.g., Carnine, Silbert, Kameenui, & Tarver, 2004; Stein, Silbert, & Carnine, 1997). This approach was comprised of model, prompt, and check steps. In the model step the teacher showed a flash card to the student and said the fact and answer aloud (e.g., "Three times four is twelve."). After the fact card was presented the teacher moved to the next fact in the set. Each fact was presented twice during the model step. For the prompt step, the teacher showed each fact card to the student and stated the fact and answer. The teacher then prompted the student for an answer using a verbal signal (e.g., "Three times four is twelve. What is three times four?"). If the student failed to respond within 3 sec the teacher said the answer and repeated the step. After the student completed the problem correctly with the prompt the teacher moved to the next fact in the set. Each fact was presented twice during the prompt step.

The check step was comprised of two parts. In the first part the teacher presented each fact card and asked the student to say the correct answer. This procedure was repeated for a total of two oral check step responses for each fact. Verbal praise such as, "good" or "great job" was given by the teacher for each correct response. For incorrect responses, the student was (a) immediately given the correct answer, (b) asked to repeat the answer, and (c) given the answer again. For instance, if the participant answered incorrectly to the math fact three times four, the teacher would have replied, "Three times four is twelve. What is three times four? (wait for student response) Good. Three times four is twelve." After the oral check step, the teacher gave the student a worksheet that contained facts from the current set. Each fact appeared twice within a single column along the right hand side of the worksheet. A blank sheet of paper (21.5 cm × 28 cm) was used to cover each fact as students wrote their answers to prevent the student from looking at previously answered facts. The praise and error correction procedures used for the oral check step were also used for the written check step.

The explicit instruction plus high-*p* condition (EXPL + H) was similar to the EXPL condition and used the same model and prompt stages. However, for the oral check stage, two to three previously identified high-*p* addition fact cards were placed between each unknown multiplication fact. Similarly, two to three high-*p* addition facts were placed horizontally just before each multiplication fact on the worksheet (e.g., $2 + 3 = \_\_\_$ $4 + 6 = \_\_\_$ $5 \times 3 = \_\_\_$). Each condition was presented on a different day, up to four days a week. Condition order was counterbalanced to control for possible order effects.

Fact Acquisition Sets 2 and 3

In Set One there were 10 unknown multiplication facts, which were split so that five multiplication facts were randomly assigned to EXPL and five to

EXPL + H. These unknown multiplication facts were modeled, prompted and checked twice within each condition. In an effort to further enhance the rate of acquisition we decided to increase the total number of models, prompts, and checks to five for each condition. In addition, the number of facts presented in each condition was reduced to three. These changes resulted in more learning trials for each fact, which has been shown to increase the rate of acquisition (Albers & Greer, 1991).

Acquisition Assessment

Students were asked to complete a fact acquisition worksheet the day following instruction for each condition and prior to any additional instruction. This worksheet consisted of all problems from a given set (both EXPL and EXPL + H). No feedback or verbal praise was given during these assessment sessions. Facts answered correctly on the next-day assessments were considered known and were removed from the instructional materials.

Experimental Design, Dependent Measures, and Agreement

A parallel treatments design (Gast & Wolery, 1988) was used to compare the effects of explicit instruction and explicit instruction plus a high-*p* component on the acquisition of unknown multiplication facts. The first dependent measure was the cumulative number of multiplication facts learned by the participants within each condition as measured by the acquisition assessments. A measure of instructional efficiency (duration of instructional sessions) was also collected. Given equal levels of skill acquisition, techniques that take less instructional time result in higher learning rates (Cates, Skinner, Watson, Meadows, Weaver, & Jackson, 2003). Efficiency of instruction can be a key variable when selecting interventions for students. Interventions that are efficient result more content coverage and more learning trials – both key variables for effective instruction (Albers & Greeer, 1991; Mastropieri & Scruggs, 1994). Session duration data were collected using a video camera that was positioned diagonal and to the right of the work area.

Interobserver agreement for the acquisition data was documented randomly across conditions for 31%, 32%, and 35% of sessions for Kathy, Joy, and Alicia respectively. Two observers independently counted the number of problems correct on each student's worksheet. Agreement was calculated by dividing the number of agreements by the number of agreements plus disagreements and then multiplying by 100. Agreement for the acquisition data was 100% for all students. For the efficiency data, two data collectors independently documented the duration of each instructional session for 13%, 15%, and 17% of sessions for Kathy, Joy, and Alicia respectively. Durations within 5 s were considered agreements. Using the same formula, the agreement for instructional efficiency was 100%. Procedural integrity data were also collected from the videotapes by a trained independent observer using a checklist of the procedures. More specifically, the observer documented the degree to which the experimenter gave the appropriate instructions and implemented models, prompts, checks, error correction, and independent practice procedures correctly. Integrity data were collected randomly across conditions for 26% of sessions for Kathy and 40% of sessions for both Joy and Alicia. Procedural integrity was 100%.

RESULTS

Multiplication fact acquisition results are shown in Figures 1–3. The traditional explicit instruction condition resulted in faster acquisition of facts for Kathy across all three sets of math facts. Kathy acquired the five Set One facts in the EXPL condition in 3 sessions compared with 11 sessions for the EXPL + H condition. Similarly, the EXPL condition produced higher rates of acquisition in Set Two with 3 sessions of instruction required to acquire the math facts. Kathy did not acquire any facts in the EXPL + H condition for Set Two. In Set Three neither intervention resulted in acquisition of all three facts in each condition. However, The EXPL condition resulted in two acquired facts, whereas the EXPL + H resulted in one in 11 sessions.

The EXPL + H condition produced slightly higher acquisition rates in both Sets One and Two for Joy. In Set One Joy acquired 4 facts in 13 sessions in the EXPL + H condition and 3 facts in 13 sessions of the EXPL condition. The EXPL + H condition resulted in 3 facts acquired in 9 sessions, whereas the EXPL resulted in acquisition of the 3 facts on 16 sessions for Set Two. The EXPL condition produced higher acquisition rates in Set Three (2 problems acquired in 5 sessions compared with 0 problems acquired in the EXPL + H condition).

Alicia completed two sets of problems with the EXPL + H producing higher acquisition rates for both sets. In Set One Alicia acquired five facts in 9 sessions in the EXPL + H condition, whereas the EXPL condition took 14 sessions. In Set Two Alicia acquired the 3 facts in the EXPL + H condition in 6 sessions, whereas the EXPL condition took 9 sessions.

As a measure of instructional efficiency we documented the duration of each instructional session. The mean duration of instruction during each session across conditions is shown in Figure 4. On average, the EXPL + H instructional sessions were 2 min 43 s longer for Kathy, 4 min 57 s longer for Joy, and 3 min 58 s longer for Alicia than the EXPL condition. The rate of learning (i.e., number of facts mastered per minute of instruction) for the EXPL condition was .11, .10, and .13 for Kathy, Joy, and Alicia respectively. The learning rates for the EXPL + H were .04 for both Kathy and Joy, and .07 for Alicia.

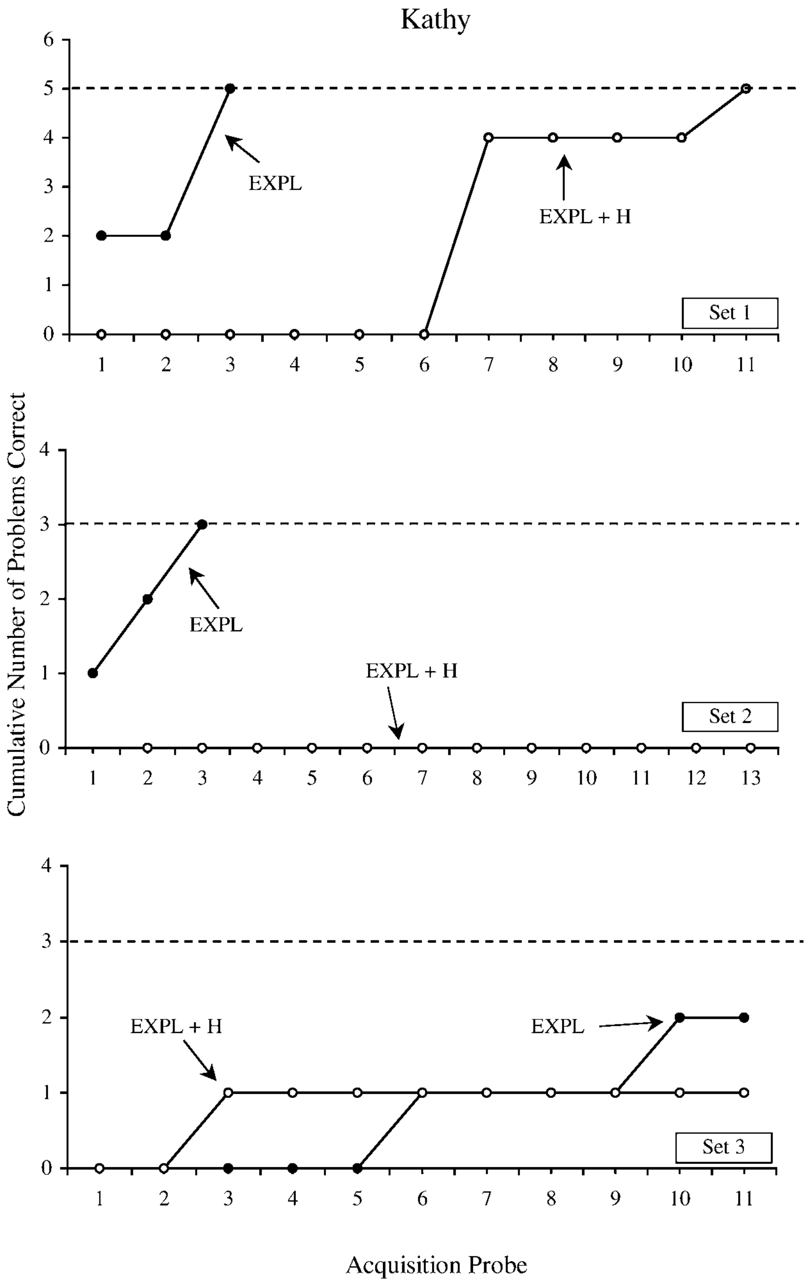

Fig. 1. Cumulative number of problems correct for Set 1, Set 2, and Set 3 across explicit only (EXPL) and explicit plus high-*p* (EXPL + H) conditions for Kathy.

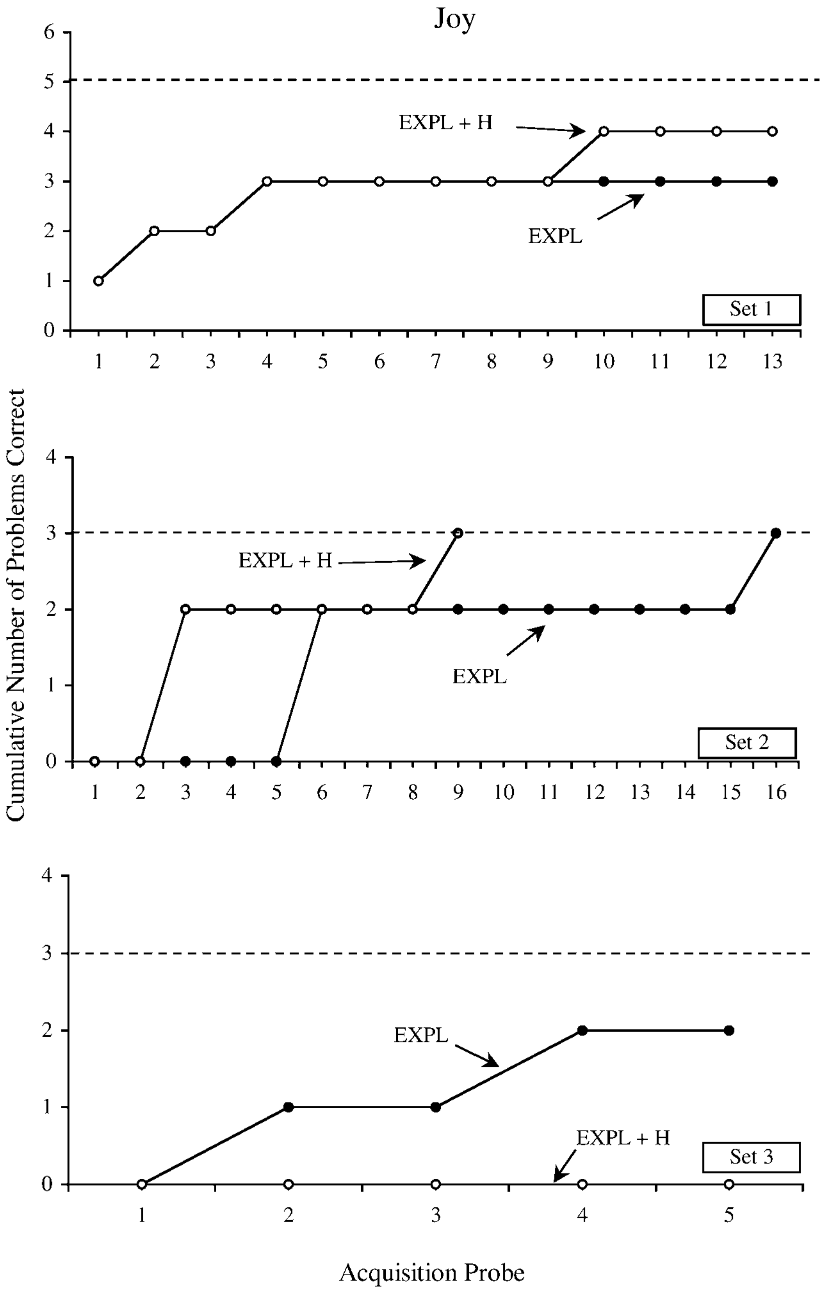

Fig. 2. Cumulative number of problems correct for Set 1, Set 2, and Set 3 across explicit only (EXPL) and explicit plus high-*p* (EXPL + H) conditions for Joy.

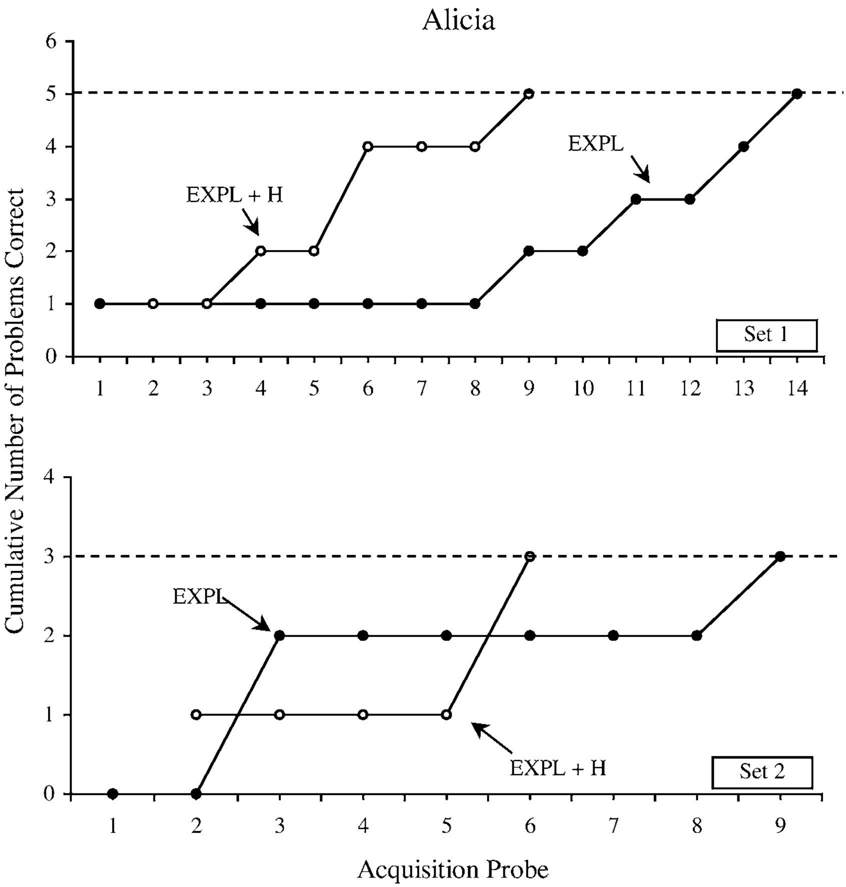

Fig. 3. Cumulative number of problems correct for Set 1 and Set 2 across explicit only (EXPL) and explicit plus high-*p* (EXPL + H) conditions for Alicia.

DISCUSSION

The purpose of this study was to compare a traditional explicit instruction procedure with a modified explicit instruction procedure for learning basic math facts. In the modified procedure, students were asked to complete a series of preferred (high-*p*) math facts during independent practice sessions immediately prior to working on targeted unknown multiplication facts. Our results were mixed and showed that the addition of the high-*p* tasks did not increase levels of acquisition beyond those produced by explicit instruction alone for all students.

Based on these data one may conclude that both interventions are, in general, equally effective. However, effective interventions should produce desired

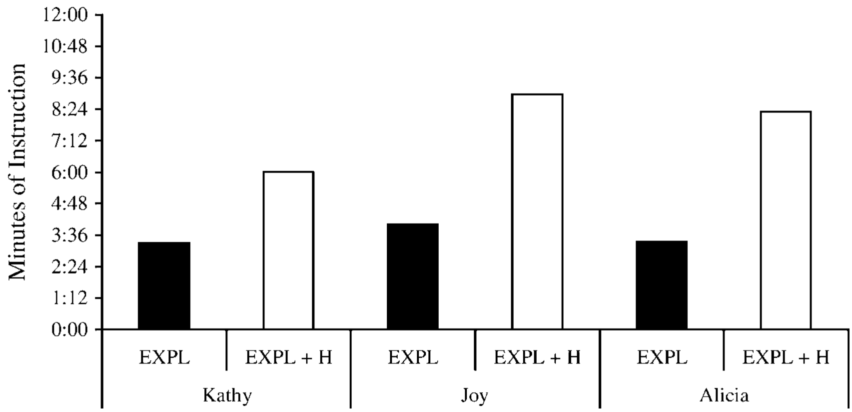

Fig. 4. Mean duration (in minutes) of instructional sessions across conditions for Kathy, Joy, and Alicia.

changes in behavior, and produce those changes within a reasonable amount of time. In the current study, the high-*p* procedure took much more time to implement than explicit instruction alone. For students who initiate and remain engaged in tasks with little teacher intervention the addition of high-*p* sequences may be unnecessary. Increasing the amount of instructional time, while decreasing the rate of learning, may result in fewer skills learned over time and adversely affect student achievement. Other students, however, refuse to begin and remain engaged in academic tasks. Desirable academic behaviors, such as task completion, occur infrequently in these students and as a result are rarely reinforced. This cycle of no behavior/no reinforcement results in academic behaviors that occur at very low rates. Interventions, such as high-*p* sequences, that increase the density of reinforcement for academic response classes can help students initiate and persist at low-*p* tasks so that reinforcers can be delivered to strengthen behaviors that may have occurred infrequently in the past. For these students interventions that facilitate task initiation and engagement, even when those interventions take more time than traditional methods of instruction, may be more appropriate.

Other researchers presented data that may seem to contradict the findings reported here. However, taken together this body of work helps to refine the applicability of high-*p* sequences in classrooms. For example, Lee and Laspe (2003) found that high-*p* sequences *increased* instructional efficiency during a writing task for elementary-age children who were receiving special services. Our data, as well as those presented by Cates et al. (2003) indicate that high-*p* interventions may nearly double instructional time, thus limiting the number of new skills taught. Differences among the participants and tasks may explain these discrepant findings. The students in the Lee and Laspe (2003) study had performance difficulties. That is, each of the students could write, but did not initiate and remain engaged in writing tasks given by their teacher. In the present study the participants had skill deficits in multiplication. The efficiency of the high-*p* intervention may depend, in part, upon the type of student deficit (e.g., skill or performance deficit).

Similarly, Belfiore, Lee, Scheeler, and Klein (2002) suggested that high-*p* sequences might make low-*p* tasks less aversive. However, anecdotally we noted that students in the present study began to make negative comments about the EXPL + H condition toward the end of the study (e.g., "I don't like to do this one. It's too long."). For some students the addition of high-*p* problems increases the length of an initially neutral task and may make that task aversive over time, thus punishing the very behaviors we wish to reinforce. Future researchers may wish to quantitatively assess task valence over time to further examine how this variable changes across independent and acquisition tasks.

These results must be viewed within the limitations of the study. First, the target task selected for this study (multiplication fact acquisition) may have been too difficult for these students at this particular time. In order to increase internal validity we selected a novel task that had not and would not be covered by the students' classroom teacher during the study. It is possible that the low rates of acquisition documented here resulted from a disconnect between the task selected for the study and the students' regular classroom instruction. Future researchers should further examine the effects of embedding high-*p* sequences into planned ongoing classroom instruction. Second, although we documented student preference for single-digit addition problems at the start of the study we did not continually assess preference for single-digit problems throughout data collection. Preference for this type of problem may have changed over time, thus reducing its effectiveness as a high-*p* task. Finally, we did not assess long-term maintenance of student responding. Future researchers may wish to collect continuous data in order to reveal possible differences in maintenance of fact acquisition over time.

Even with these limitations this study provides important information regarding high-*p* sequences and acquisition of new skills. Overall, the data obtained here partially support those collected by Cates and colleagues (2003). More specifically, our instructional efficiency data are similar to Cates and indicate that high-*p* sequences can increase the duration of instructional sessions. However, we also found that high-*p* sequences combined with explicit instruction is sometimes more effective than explicit instruction alone – something Cates and colleagues did not find. Previous research supports high-*p* task sequences as a method to help students with performance deficits initiate and remain engaged in tasks. Our current data suggest that it is premature to recommend high-*p* sequences as a method to enhance acquisition of new skills for all students. Practitioners should be careful to monitor the types of tasks and deficits and match interventions based on those assessment data.

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