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A COMPARISON OF PROCEDURAL VARIATIONS IN TEACHING BEHAVIOR CHAINS: MANUAL GUIDANCE, TRAINER COMPLETION, AND NO COMPLETION OF UNTRAINED STEPS

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We compared variations for teaching a sequence of responses through forward chaining. Seven children who had been diagnosed with autism participated in a comparison of teacher completion (TC) of steps beyond the training step and manually guiding the student (SC) to complete steps beyond the training step. A no-completion (NC) condition, in which the steps beyond the training step were not completed, was added to the comparison with 4 of the participants. Results showed that learning occurred with all procedures, although 5 participants acquired the chains most efficiently in the SC condition and the other 2 learned most efficiently in the TC condition. Of the participants for whom an NC condition was included, the tasks were acquired with the shortest average session length and total training time. Despite the potential benefits of TC and SC procedures, NC is a viable option and may be preferable for some students.

Key words: behavior chains, autism, play skills

Many socially important skills taught to children with autism and developmental disabilities consist of a series of sequenced responses. A common method for teaching these skills includes conducting a task analysis to break the chain of responses into a series of manageable steps that can be taught one at a time (Cooper, Heron, & Heward, 2007). Breaking down a complex behavior and teaching its component parts as a chain have been successful in teaching self-care skills (Horner & Keilitz, 1975; Matson, Taras, Sevin, Love, & Fridley, 1990; Stokes, Cameron, Dorsey, & Fleming, 2004), vocational tasks (Duran, 1985; Maciag, Schuster, Collins, & Cooper, 2000), following picture activity schedules (MacDuff, Krantz, & McClannahan, 1993), and play skills (Libby, Weiss, Bancroft, & Ahearn, 2008).

These chains can be taught using forward, backward, or total-task chaining procedures. In forward chaining, steps are taught in a forward sequence starting with training on the first step. After the student has demonstrated independence on this step, the second step becomes the training step. The student then independently completes the first step and receives training on the second step within each trial. This progression continues until the student independently performs each step in the chain. In backward chaining, the final step is trained first. After the student has demonstrated mastery on the final

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step, training is conducted on the second-to-last step and the student independently completes the final step. This progression continues until all steps in the chain are performed independently. In total-task chaining, training is provided on each step until all steps are completed independently.

Response prompts delivered on training steps may include vocal instruction, modeling, or physical guidance (e.g., Cuvo, Leaf, & Borakove, 1978; Glendenning, Adams, & Sternberg, 1983). Response prompts can be faded until the student is independently performing the training step. Libby et al. (2008) compared the effectiveness and efficiency of least-to-most (LTM) prompt fading, most-to-least (MTL) prompt fading, and MTL with a delay (MTLD) while teaching play skills via forward chaining. MTLD provided an opportunity for the child to initiate responding independently and showed a possible advantage over MTL prompting. Both MTLD and LTM were found to be most efficient, with fewer errors occurring with MTLD.

With forward chaining, it is unclear how to best proceed with the steps that follow the training step in each trial. The same problem is found with the steps that precede the training step in backward chains. For either type of chaining, a clinician will have to decide how to complete the steps that are not yet the target of training. In an eight-step forward chain, for instance, the student may perform Steps 1 through 3 independently while being trained on Step 4. After the student completes Step 4 with the necessary prompting on a given trial, Steps 5 through 8 are still left in the chain. One procedural option is to terminate the trial following completion of the training steps, leaving the remaining steps uncompleted (e.g., Hur & Osborne, 1993). However, the learner may benefit from exposure to the remaining steps. In addition, some behavior chains, such as washing hair or brushing teeth, may necessitate completion of the chain. Despite the lack of research in this area, practical options for completion of the untrained steps may include the teacher manually guiding the student to complete the chain or completing the chain in the presence of the student.

A teacher-completion strategy may have the advantage of allowing learning through observation of the untrained steps. Griffen, Wolery, and Schuster (1992), for example, taught a food-preparation chain to one student while other students observed the steps. When the observing students were presented with the task, they were able to complete most it. When the untrained steps become training steps, the student may master them more quickly if the steps have been modeled across many previous trials. Manually guiding the student to complete the chain may also have an advantage for similar reasons. When the student completes the steps, he or she can learn through self-observation to complete the steps or through manually completing the steps. Either of these methods may be helpful in capitalizing on learning opportunities when conducting a forward or backward chain. In other words, it may be beneficial for teachers to focus on a training step and in the same trial familiarize the student with steps not yet trained. However, both procedures add additional time to training. If the procedures do not dramatically increase the speed of acquisition, it may not be worthwhile to complete the untrained steps. Not completing the untrained steps in a chain may permit more training trials in a given learning opportunity, require less hands-on prompting, and may be preferred by some students.

In the present study, we compared the effects of procedural variations for completing the untrained steps in forward chains. We compared the effectiveness and efficiency of student completion (SC) with manual guidance, teacher completion (TC) of untrained steps, and no completion (NC) of untrained steps on the acquisition of behavior chains of similar difficulty. The method was similar to that used by Libby et al. (2008).

METHOD

Participants and Settings

Three 8-year-old girls (Tina, Pam, and Kelly) and four 10- to 16-year-old boys (Paul, Mario, Lance, and Ray) participated in the current study. All participants had been diagnosed with autism and were enrolled in a private residential treatment program for children with autism and other developmental disabilities. Tina and Pam both communicated vocally, and they were noted to request some items and engage in simple conversation with others. Kelly, Paul, Mario, and Ray used a combination of vocal utterances and augmentative communication in the form of picture exchange communication systems (PECS) or voice-output devices. Lance used PECS alone. All participants showed severe delays across all areas of skill acquisition. They had a history of exposure to complex behavior chains, such as showering or playing a game, using chaining procedures. Each participant demonstrated mastery in probes of generalized imitation as a prerequisite skill for inclusion in the study.

Sessions were conducted in either the student's classroom or in a work area in the student's residence. Each participant completed training sessions in the same location. Materials in the training sessions included a table and chairs, reinforcers, data sheets, a video camera when a secondary observer was not available, and the materials needed for the task.

Materials

Lego construction was selected as the training task with the purpose of teaching the participants an appropriate leisure activity. In addition, construction served as an analogue to other behavior chains that are typically taught. Each structure consisted of a base on which seven other pieces were placed. The bases for the four structures were the same shape and size, and were red, yellow, or green. Different base colors were assigned across conditions for each participant and were counterbalanced across participants. For each structure, the individual building pieces varied in color and shape, but only one was used for each step in the chain (see Libby et al., 2008, for an image of constructs used in this study). The four structures were evaluated by six independent raters (teachers and administrators) and judged to be of equivalent difficulty. The raters considered the difficulty of discriminating between pieces, the relative difficulty of attaching pieces to each other, and the relative symmetry of each structure.

Prior to the study, a paired-stimulus preference assessment (Fisher et al., 1992) was conducted with each of the participants to determine highly preferred food items to be used as reinforcers during training trials.

Response Measurement and Interobserver Agreement

Data were collected on the number of consecutive steps with correct independent responses on each trial. Correct order and placement of the Lego piece were required to score a step as being correctly completed. For Paul, Mario, Lance, and Ray, data also were collected on training duration. Reliability and procedural integrity were assessed by having either two observers view a videotape of sessions or having a secondary observer independently record data during a session. Two trained observers collected data and scored interobserver agreement and procedural integrity in at least 33% of sessions (range, 35% to 48%). For each session in which reliability was calculated, agreements and disagreements were determined for each step of each trial within the session. Reliability was calculated by dividing the total number of agreements by the total number of agreements plus disagreements and multiplying by 100%. Agreement scores averaged 98% across all participants (range, 94% to 100%). For procedural integrity, one observer assessed step-by step accuracy of the trainer's delivery of reinforcement, delivery of prompts, and setting the training step and prompt for each trial. The mean accuracy score for procedural integrity across trainers and prompting techniques was 98% (range, 92% to 100%).

Procedure

An eight-step task analysis was developed for each structure that determined the order of placement of the Lego pieces. At the beginning of a trial, the pieces were separated and presented in a random array in front of the participant. The first step of the task analysis was for the participant to pull the base out of the group of pieces. The second, and all following, steps involved picking up and placing one block in the order determined by the task analysis. At the beginning of each training session, the participant chose between two highly preferred food items. The chosen item was used as a reinforcer for that session. Each session consisted of one presession probe trial followed by 10 training trials.

During the probe trial, the trainer placed the pieces of the structure in front of the participant in a random array and said, "let's play." The probe trial continued until the participant made an error or went 15 s without responding. No consequences were delivered for correct or incorrect responses. The purpose of the presession probe was to determine intermittently whether or not independent performance of the complete chain had emerged. If the participant did not complete the structure correctly, the 10 training trials began. If the participant completed the structure correctly during the presession probe, an additional probe was conducted. The structure was considered mastered if the participant completed it correctly during the second probe. Performance on the probe trials was not used to prescribe training steps. The training step for a given session was based on the performance in the prior session. Probe data from the first presession probe served as baseline.

The trainer used forward chaining in all conditions. The trainer placed the pieces in front of the participant in a quasirandom arrangement and said, "let's play." Reinforcement was delivered immediately after correct completion of the training step and consisted of the trainer saying "good job" and delivering a preferred food item. Following the training step, the remaining steps of the chain were completed according to the completion condition, as described below.

Any errors made on the training step were immediately corrected with hand-over-hand guidance. Two consecutive errors led to an increase in the intrusiveness of the prompt used. Errors on previously acquired steps of the chain were immediately corrected with hand-over-hand guidance. Two consecutive errors on a previously acquired step resulted in retraining on that and all subsequent steps.

Each play structure was considered mastered following two consecutive trials of independent and accurate performance on each step. This could be achieved in two ways. Training could continue through the last step, ending with two trials of independent performance on the final training step. Alternatively, independent and accurate performance could be demonstrated on a presession probe. As mentioned previously, if performance was independent and accurate on a second probe, the play structure was considered mastered. Therefore, a structure could be mastered at the start of a session, as indicated by performance during the additional probe, or mastery could be achieved during the training trials. Following mastery, a generalization probe was conducted in a different setting with a novel therapist.

Sessions were conducted one to three times per day, 2 to 5 days per week. Multiple sessions on 1 day were separated by a minimum of 10 min of unrelated activities. The same teacher worked with each participant throughout training.

Teacher completion. In each trial, the participant had the opportunity to complete previously mastered steps in the chain. After reaching the training step, the teacher delivered prompts according to a most-to-least prompting hierarchy (see Libby et al., 2008, for a description of the prompt hierarchy). Errorless completion of the training step, given the prescribed prompt, resulted in reinforcement. As each step was mastered, the next step became the training step. After the participant completed the training step, the teacher blocked the participant from further manipulating the blocks and completed the remaining steps of the structure in front of the participant. The participant was free to observe or not to observe the remaining steps.

Student completion. The SC condition was identical to the TC condition, with the exception of the completion of the untrained steps. After student completion of the training step and delivery of a reinforcer given no errors on the training step, the teacher manually guided the student to complete the remaining steps in the chain.

No completion. The procedure in the NC condition was identical to the TC and SC conditions, except that the trial ended following the training step.

Design

An adapted alternating treatments design was used to assess the completion conditions. Each participant was taught to put together two or three eight-piece structures. Each structure was assigned to a particular condition, and the structures were counterbalanced across participants. A comparison of TC and SC was conducted with Tina, Pam, and Kelly. Paul, Mario, Lance, and Ray participated in a comparison of TC, SC, and NC. Sessions were alternated such that no more than two of any completion condition were conducted consecutively.

RESULTS

None of the participants independently completed any steps beyond the first in baseline probes. Figure 1 shows the number of independent steps completed at the end of each 10-trial session for each of the three participants in the TC and SC comparison. If, for example, the participant was training on Step 5 in the final trial of a session and had mastered Steps 1 through 4, a four was recorded as the number of steps with independent performance for that session. Sessions in which the participant demonstrated independent performance during the initial probe and again during the repeated probe are marked with asterisks. Tina acquired the chain in the TC condition in six training sessions and then showed independent performance in the following presession probes. She completed the SC condition in seven training sessions. Kelly acquired the chain in the TC condition in eight training sessions and in the SC condition in six training sessions. Pam required several sessions to complete the third step of the chain in the TC condition, taking 12 sessions (Sessions 3 through 14) to master this step. After mastering Step 3 and Step 4, Pam then demonstrated mastery of the eight-step chain in presession probes of Session 15. Although Steps 5 through 8 had never been trained using the prompt hierarchy, Pam apparently learned to complete them through observing the therapist complete the chain. In the SC condition, she made steady progress, mastering one step per session and completing the chain in nine sessions. All participants demonstrated generalization and maintenance by successfully building the structures in alternate settings with different teachers. In summary, all three participants mastered the chain in both the TC and SC conditions. Tina mastered the chain in the TC condition more quickly than in the SC condition, although the differences were negligible. Kelly and Pam mastered the chain in the SC condition in fewer sessions than in the TC session.

The results for the comparisons of SC, TC, and NC are shown in Figure 2. Paul acquired the chain in the TC condition in 11 sessions, in the SC condition in six sessions, and in the NC

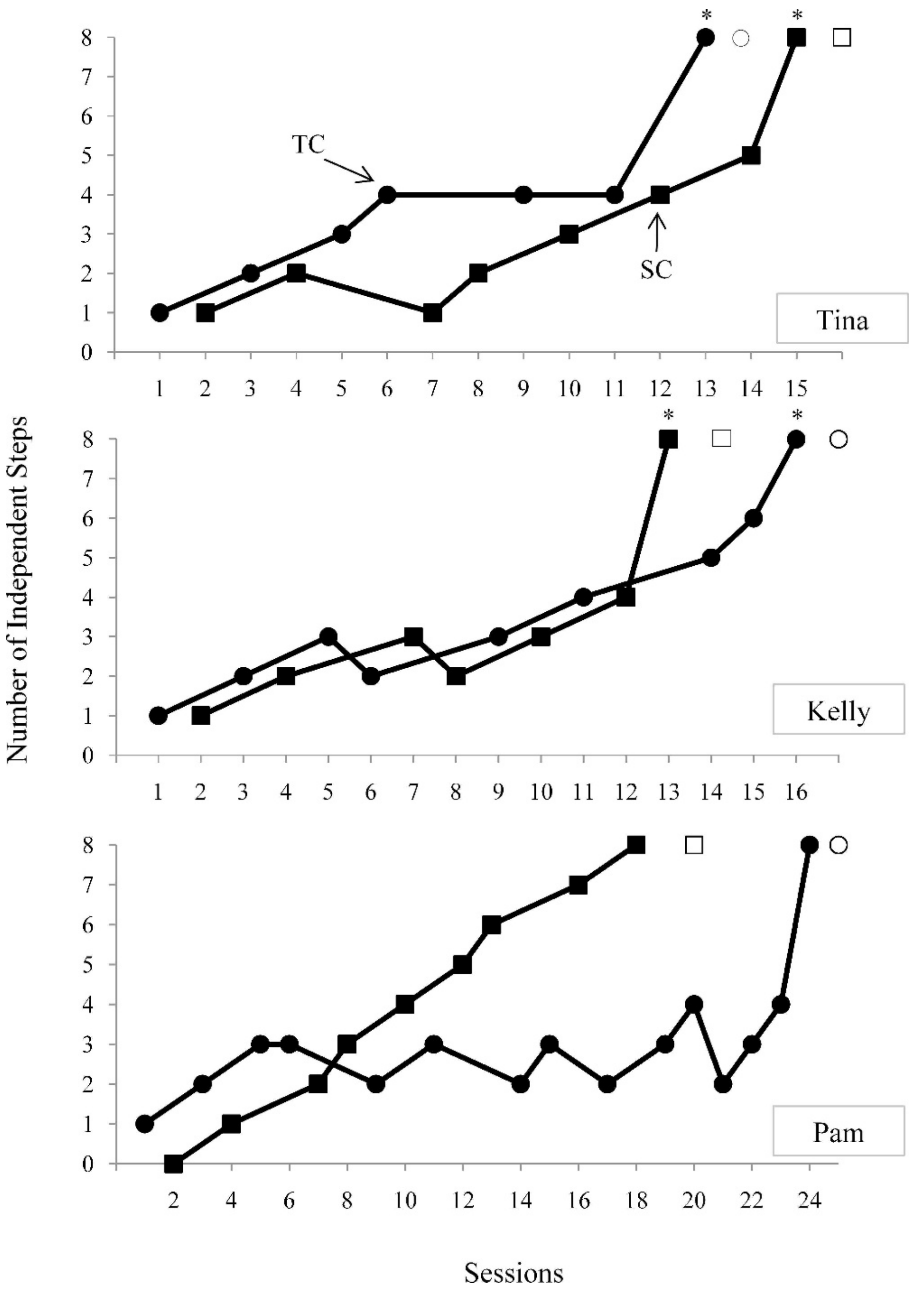

Figure 1. The number of steps of the task analysis performed independently during training with the student-completion (SC) and teacher-completion (TC) strategies for three participants. Asterisks denote trials in which mastery was demonstrated in a presession probe. The open symbols represent performance on a generalization probe for each condition.

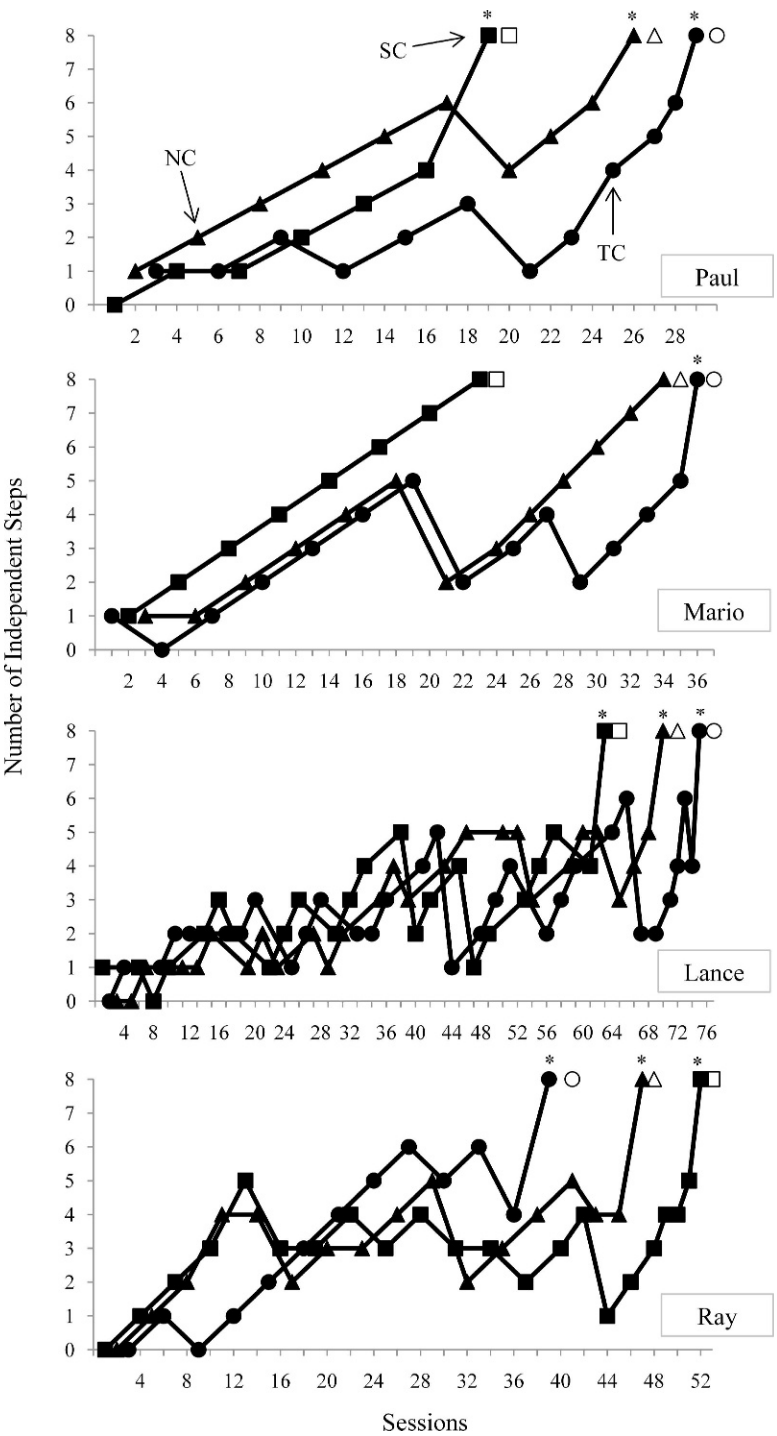

Figure 2. The number of steps of the task analysis performed independently during training with the student-completion (SC), teacher-completion (TC), and no-completion (NC) strategies for four participants. Asterisks denote trials in which mastery was demonstrated in a presession probe. The open symbols represent performance on a generalization probe for each condition.

condition in nine sessions. Mario acquired the chain in the TC condition in 14 sessions, in the SC condition in eight sessions, and in the NC condition in 13 sessions. As with Paul and Mario, it took Lance the greatest number of sessions (31) to complete the structure in the TC condition and the fewest number of sessions (23) to complete the structure in the SC condition. Lance completed the structure in the NC condition in 26 sessions. Ray's results were contrary to the other participants. It took Ray the greatest number of sessions (21) to complete the structure in the SC condition and the fewest number of sessions (12) to complete the structure in the TC condition. He completed the structure in the NC condition in 16 sessions.

All sessions in the NC comparison were timed, and average session duration in each condition is shown across participants in Figure 3. For each participant, the NC sessions were the briefest, with average session duration ranging from 3.4 to 5.7 min. This was expected, because only the steps through the training step were completed in this condition. The TC conditions were lengthier, with average session duration ranging from 6.6 to 11.2 min across participants. The SC sessions were the lengthiest, with average duration ranging from 8.3 to 14.2 min.

Table 1 shows the number of sessions to mastery, number of trials to mastery, and number of errors per training session for each participant across all conditions. Generalization trials were included in the number of trials to mastery. All participants, with the exception of Ray, completed the task in fewer trials in the SC condition than in the TC condition. All participants in the NC comparison completed the task in the NC condition in an intermediate number of sessions. Errors were consistent with this pattern, with total errors correlated with the frequency of trials across all participants. Errors per session were therefore relatively evenly distributed across conditions, with no condition producing consistently higher rates of errors.

DISCUSSION

The majority of the participants acquired the chain in the fewest number of trials with the SC procedure, with the remaining two participants acquiring the chain in the fewest number of training trials in the TC condition. For the four participants included in the three-condition comparison, the reduced session duration in NC produced the briefest overall training durations. These data may be useful in clinical settings when deciding which completion procedure to use for a particular individual. The SC condition may be the best default strategy to use with learners who tolerate physical prompting. When problem behavior is associated with physical prompting, some version of the TC condition may produce learning while minimizing the likelihood of problem behavior. In addition, if an individual is noted to be on task for only brief periods of time, an NC procedure may be optimal because session length is the briefest and more trials can be completed in a given session.

Another variable that may be considered when choosing a completion procedure for teaching a behavior chain is the total amount of training time. Although three of the four participants in the second comparison completed the structure in the SC condition in the fewest number of sessions, these sessions took longer to complete than those in the NC conditions. Structures built with the NC procedure were mastered in the shortest amount of time for all participants, ranging from 31 to 130 min. For Paul, Mario, and Lance, mastery of the structures in the SC condition took the next longest duration (range, 85 to 194 min), and mastery of structures in the TC condition took the longest duration (range, 123 to 204 min). For Ray, however, the total duration of the SC condition (174 min), was almost twice that of the TC condition (89 min). These data suggest that the additional time spent on demonstrating or manually guiding the participant through the

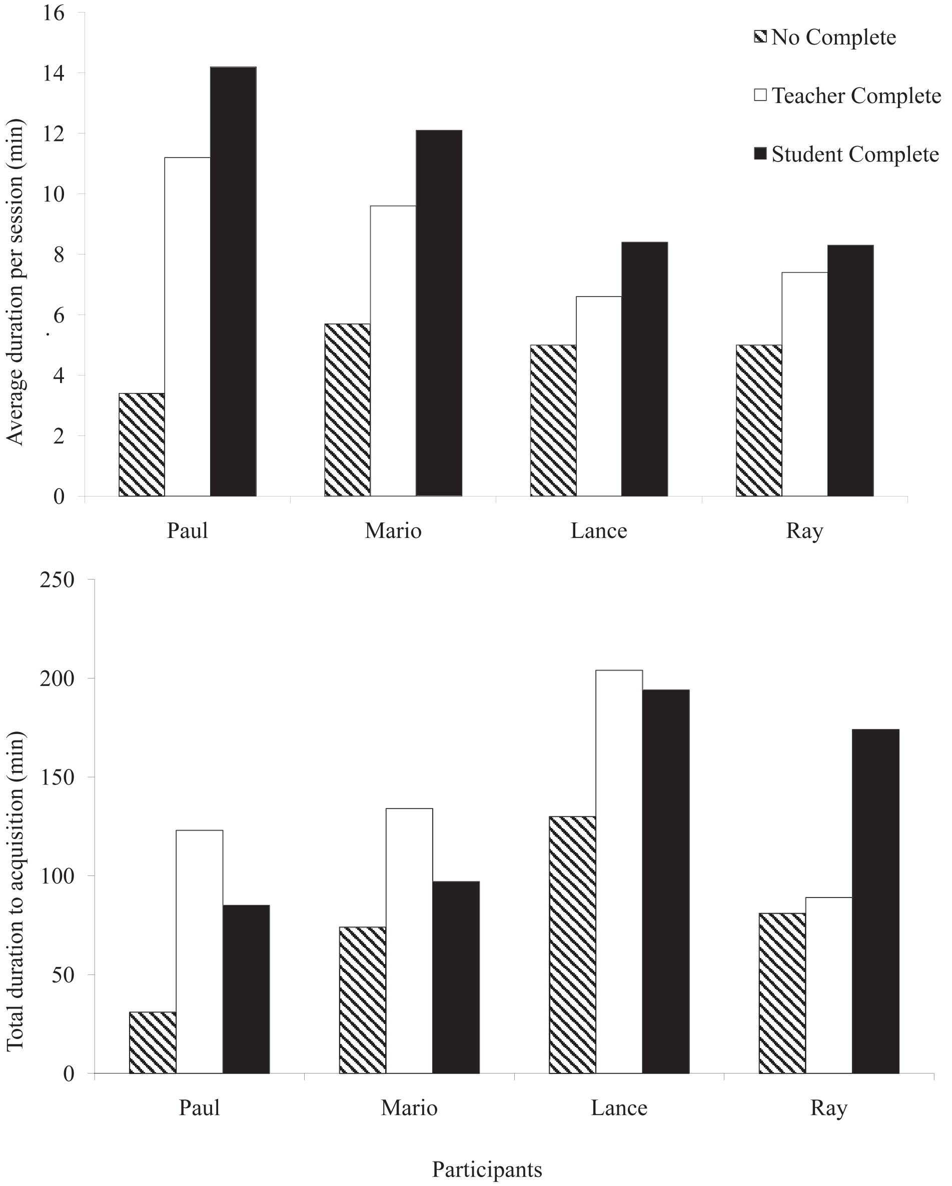

Figure 3. Average duration of sessions (top panel) and total duration of skill acquisition (bottom panel) for the student-completion, teacher-completion, and no-completion conditions for four participants.

untrained steps of the task may not lead to more efficient skill acquisition.

It is possible that participants did not always attend to the completion steps in the TC and SC conditions, limiting how much they could benefit from these approaches. A measure of overt attending was not included, because attending includes both overt and covert behavior. Given that several participants did not require training on some of the final steps, it is likely that these participants did attend to the steps (see Nevin, Davison, Odum, & Shahan, 2007).

Another limitation includes the lack of testing to determine the functioning level of the participants. Higher functioning individuals

Table 1
Number of Training Sessions, Training Trials, and Errors Per Session

	Sessions			Trials			Errors		
Participant	TC	SC	NC	TC	SC	NC	TC	SC	NC
Tina	8	7		74	64		1.5	1.12	
Pam	14	9		137	88		1.6	2.0	
Kelly	9	7		87	64		0.91	0.62	
Paul	12	7	10	114	64	94	1.41	0.43	1.2
Mario	15	8	13	144	77	124	0.8	1.5	0.69
Lance	32	24	27	314	234	264	0.36	0.27	0.38
Ray	13	22	17	124	214	164	0.45	0.22	1.12

Note. TC = teacher completion, SC = student completion, and NC = no completion.

may be more likely to benefit from the modeling or practice of untrained steps in the TC and SC conditions, respectively. More specifically, identification of necessary prerequisite skills for benefiting from TC or SC procedures requires further investigation. For instance, it is possible that an individual with an advanced imitative repertoire may benefit from the TC condition. However, given the consistently greater overall training duration for TC and SC conditions across all participants, the benefits of TC and SC procedures for individuals with advanced imitative repertoires may be limited. A final limitation of the study was the method for determining equivalent difficulty of Lego structures. Although raters were given general features of task difficulty to consider, a more stringent method for ensuring task difficulty may have been beneficial.

The opportunity to learn through observing others perform actions may be beneficial in some situations that were not examined in the current research. For example, although all participants demonstrated skill mastery in another context and with another teacher, long-term maintenance of skills was not assessed across conditions. The SC and TC procedures may produce better long-term maintenance of skills than the NC condition does because the participant typically has more exposure to each of the steps in the chain than he or she does in an NC condition. Assessments of effectiveness and efficiency of these procedures across behavior chains of various complexities may be an important extension to examine in future research.

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