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AN ASSESSMENT OF THE EFFICIENCY OF AND CHILD PREFERENCE FOR FORWARD AND BACKWARD CHAINING

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Comparative studies of forward and backward chaining have led some to suggest that sensitivity to each teaching procedure may be idiosyncratic across learners and tasks. The purposes of the current study were threefold. First, we assessed differential sensitivity to each chaining procedure within children when presented with multiple learning tasks of similar content but different complexity. Second, we evaluated whether differential sensitivity to a chaining procedure during a brief task predicted differential sensitivity during the teaching of longer tasks. Third, we directly assessed children's preferences for each teaching procedure via a concurrent-chains preference assessment. Learners acquired all target skills introduced under both chaining conditions, but individual children did not consistently learn more efficiently with either procedure. Short-duration tasks were not predictive of performance in tasks of longer duration. Both chaining procedures were preferred over a baseline condition without prompting, but participants did not demonstrate a preference for either procedure.

Key words: backward chaining, concurrent-chains preference assessment, forward chaining, preferences

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Behavior analysts frequently employ response-chaining procedures to teach multistep tasks that range from food preparation (Schuster, Gast, Wolery, & Guiltinan, 1988), family-style dining (Wilson, Reid, Phillips, & Burgio, 1984), and self-feeding (Hagopian, Farrell, & Amari, 1996) to Internet usage (Jerome, Frantino, & Sturmey, 2007), playing a game of darts (Schleien, Wehman, & Kiernan, 1981), making a corsage (Hur & Osborne, 1993), and assembling bicycle brakes, meat grinders, and carburetors (Walls, Zane, & Ellis, 1981). Response chaining involves breaking a task into its component parts via a task analysis and then sequentially teaching each individual component to mastery levels via prompting and differential reinforcement. Total task, forward chaining, and backward chaining are three variants of response chaining described in the literature (Cooper, Heron, & Heward, 2007); the current study focuses on forward and backward chaining.

Forward chaining involves teaching the initial step in a task analysis to mastery and then sequentially teaching additional steps. After a step is mastered and subsequent steps are targeted for teaching, all previous steps along with the current step are required to be accurately completed to be considered correct and result in reinforcement delivery. For instance, in a hypothetical task that requires Steps A, B, C, and D to be demonstrated in order, an instructor would teach Step A; then Steps A and B; then Steps A, B, and C; and finally, Steps A, B, C, and D. Typically, an instructor would deliver reinforcement at the completion of each successful response (i.e., the temporal location of reinforcement delivery would vary depending on the required terminal step). Backward chaining involves teaching the final step of the task analysis initially and progressively teaching early components. As earlier steps are added, all previously taught steps and the current step are required to be accurately completed in order to be considered correct and result in reinforcement delivery.

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Again, using our hypothetical task requiring Steps A, B, C, and D, Step D would be taught first; then Steps C and D; followed by Steps B, C, and D; and finally, Steps A, B, C, and D. The instructor delivers reinforcement at the completion of the last step. Thus, regardless of the stage of training, reinforcement is delivered at the "natural" location (i.e., at the end of the task).

Given the success of both forward and backward chaining in teaching multistep tasks across a variety of populations, including persons with intellectual disabilities (Hur & Osborne, 1993; Walls et al., 1981; Zane, Walls, & Thvedt, 1981) as well as persons of typical development (Ash & Holding, 1990; Smith, 1999; Weiss, 1978), some researchers have sought to compare the relative efficiency of these teaching methods (Ash & Holding, 1990; Hur & Osborne, 1993; Smith, 1999; Walls et al., 1981; Weiss, 1978). Weiss (1978) compared forward and backward chaining in the acquisition of response chains with undergraduate college students given a contrived task. Specifically, these authors developed an apparatus that consisted of six buttons and required participants to press different sequences of buttons to earn points. They taught each participant four six-step sequences using either forward or backward chaining and found forward chaining to result in fewer incorrect responses and more rapid acquisition.

In contrast, Walls et al. (1981) compared forward and backward chaining in assembling a bicycle brake, a meat grinder, and a carburetor with 22 people between the ages of 18 and 46 who had been diagnosed with mild to moderate intellectual delays and who were from a vocational rehabilitation center. The frequency of incorrect responses and total training time were similar across backward- and forward-chaining conditions. Hur and Osborne (1993) compared backward and forward chaining in teaching corsage making to children who had been diagnosed with moderate to severe mental retardation. Participants were assigned randomly to either a forward-chaining group or backward-chaining group, and both groups acquired this 18-step task in a similar number of trials.

Thus, neither forward nor backward chaining has been consistently more efficacious in promoting response acquisition. These outcomes led Spooner and Spooner (1984) in their review of chaining procedures to surmise, "it may be that different learners do better with different procedures, and when different tasks are used, different results are obtainable" (p. 123). This summary makes two fundamental assumptions: (a) All other things being equal, a given individual will consistently demonstrate differential sensitivity to one teaching procedure with a given task, and (b) although the histories that result in this differential sensitivity are highly idiosyncratic and potentially complex, we should be able to predict an individual's sensitivity to a teaching procedure given their demonstrated sensitivity to that procedure in the past. Researchers have not empirically validated these assumptions. If they are accurate, the identification of differential sensitivity to one teaching procedure should be valuable to teachers who are responsible for teaching complex skills, specifically in helping them to identify the most efficacious teaching procedure possible. If these assumptions are inaccurate, teachers and researchers may be expending their energy and resources unnecessarily in attempting to compare and predict the effectiveness and efficiency of these procedures. The initial purpose of this study was to determine if, by holding all other factors constant, children would indeed demonstrate a consistent sensitivity to one teaching procedure, and if so, if this sensitivity could be identified by presenting a brief assessment task that then could guide teachers' selections of efficient teaching procedures for longer response chains.

In addition to the relative efficiency of each procedure, teachers also may select teaching procedures by considering individual children's preferences for the available alternatives. Children, particularly those with disabilities, rarely are afforded the opportunity to voice their preferences for therapeutic programming. Providing such opportunities, in addition to respecting the individual's autonomy, may result in increased time on task and may limit the occurrence of problem behavior during instruction (Hanley, 2010; Mason, McGee, Farmer-Dougan, & Risley, 1989; Powell & Nelson, 1997; Ringdahl, Vollmer, Marcus, & Roane, 1997).

Assessment of children's preferences for teaching strategies may be complicated, particularly when individuals have limited vocal repertoires. Hanley and colleagues described the use of a concurrent-chains procedure that offered a direct, nonverbal assessment of individuals' preferences and has been effective in determining preferences for behavioral interventions, classroom behavior-management strategies, and teaching strategies with individuals of both typical and atypical development (Hanley, 2010; Hanley, Piazza, Fisher, Contrucci, & Maglieri, 1997; Heal & Hanley, 2007; Heal, Hanley, & Layer, 2009; Tiger, Hanley, & Heal, 2006). This procedure simply involves correlating salient stimuli with the interventions or teaching strategies and then allowing participants to select the correlated stimuli to gain brief access to the different interventions or teaching strategies.

We conducted our current study in two parts. The first involved an efficiency assessment in which participants were taught 3-, 6-, 9-, and 18-step motor sequences using both forward and backward chaining. We examined the outcomes of this assessment to determine (a) if children exhibited a consistent differential sensitivity to backward or forward chaining with similar tasks and (b) if we could predict differential acquisition of the 18-step tasks via learner performance with the tasks of shorter length (i.e., correspondence between the outcomes of the 3-, 6-, and 9-step comparisons with the outcome of the 18-step task). The second part involved a preference assessment using the concurrent-chains methodology of Hanley (2010), in which we introduced a novel task and provided participants the opportunity to select whether the skill was taught using forward-, backward-, or no-chaining methods.

METHOD

Participants and Setting

We recruited four participants from a local school for children with developmental and learning disabilities. Each class at this school offered small student-to-teacher ratios and some one-to-one instruction on a daily basis. All participants, except Daniel, were behind their peers in academic functioning and, according to teacher report, rarely followed two-step instructions. Further, teachers reported that none of the participants had experience with either chaining procedure prior to the study. Bella was a 10-year-old girl who had been diagnosed with attention deficit hyperactivity disorder (ADHD); her teacher reported that she was having trouble focusing during school instruction. Paul was an 11-year-old boy who had been diagnosed with ADHD; his teacher reported that he had trouble concentrating long enough to complete several steps of a task. Daniel was an 11-year-old boy with speech delays; his teacher reported that although he was within grade level on academic tasks, he had a stutter and displayed occasional slowed speech. Katie was a 12-year-old girl with learning deficits; her teacher reported she was behind grade level in almost every area of academics. We obtained parental consent and daily assent for each child; all study procedures were preapproved by the Institutional Review Board of Louisiana State University. The first author conducted all sessions in a vacant room in the school.

Preexperimental Preference Assessments

Prior to initiating the formal experiment, we conducted two preference assessments. First, we

Table 1
Operational Definitions of Motor Movements in Motor Chains

Touch head	Place either hand on top of the head
Touch lap	Place both hands on top of the thighs
Clap	Contact two palms of hands together
Touch eye	Use either pointer finger to contact either eye
Touch ear	Use either pointer finger to contact either ear
Touch nose	Use either pointer finger to contact one's nose

conducted a color preference assessment based on the procedures described by Heal et al. (2009) to eliminate bias in the colors associated with initial-link stimuli during our concurrent-chains preference assessment. We used 10 different-colored sheets of construction paper and presented each sheet to participants in pairs. We instructed participants to select the color they "liked more" on each trial and provided a brief statement of praise (e.g., "thanks") after each selection. After we paired each colored sheet with each other colored sheet, we then ranked color preference based on selection percentages (i.e., number of times selected divided by the number of times presented). We selected three colors that were ranked similarly from the lower end of the preference hierarchy and randomly assigned each color to be correlated with each condition in our concurrent-chains preference assessment.

Next we conducted a leisure-item preference assessment based on the procedures described by Fisher et al. (1992) to identify activities to which access was delivered as a reinforcer during teaching conditions. We identified items to include via an interview with each participant's classroom teacher and presented items in paired arrays to identify highly preferred activities. We included access to the top three items to be used as reinforcers in the study. There were also instances in which participants requested an item not in their top three, and we allowed them to obtain that item as reinforcement for that day.

Procedure

To develop our experimental motor sequences, we first selected six motor movements from which each motor sequence would be derived; these were touching one's nose, eye, and ear; patting one's head and lap; and clapping one's hands (we present operational definitions of these behaviors in Table 1). We then randomly selected from these movements to design pairs of motor sequences that included 3, 6, 9, and 18 steps (we made selections without replacement until all six movements were selected and then restarted for the 9- and 18-step motor sequences). We randomly assigned members of a motor sequence pair to either forward or backward chaining in a counterbalanced order across participants such that any unintended differences in motor sequence difficulty would be balanced across participants. For example, we assigned three-step Motor Sequence A to the forward-chaining condition and three-step Motor Sequence B to the backward-chaining condition for Daniel and Paul, and we assigned the three-step Motor Sequence B to the forward-chaining condition and the three-step Motor Sequence B to the backward-chaining condition for Bella and Katie. We then compared the efficiency of forward and backward chaining sequentially across each motor-sequence pair. That is, we taught one three-step sequence with forward chaining and one three-step sequence with backward chaining in alternating sessions. After both sequences reached mastery, we taught both six-step sequences, followed by both nine- and 18-step sequences. We compared backward and forward chaining across each sequence length in an adapted alternating treatments design.

Efficiency assessment. Prior to each pair of teaching sessions, the participant selected a leisure item from an array of preferred items; we delivered the selected item as a reinforcer during the next pair of sessions to ensure that the quality of reinforcement was identical across chaining conditions. We conducted one to six 10-trial sessions per day within a daily 45-min session block allocated to each participant, typically 4 days per week. Individual session duration depended on the number of steps in the motor sequence and participant responding during sessions (i.e., sessions that required prompting were longer than sessions with independent responding). Anecdotally, session durations ranged from about 5 min up to 25 min. In accordance with our experimental design, we alternated forward- and backward-chaining sessions in a random and counterbalanced order by flipping a coin to determine which would be conducted first.

At the onset of each comparison, we conducted a minimum of three baseline trials to ensure that participants could not engage in the motor sequence prior to instruction. During baseline trials, the teacher instructed the participant to complete a motor sequence (e.g., "Do the — dance"; we assigned each dance an arbitrary name to facilitate discrimination of the experimental conditions). The teacher did not provide any consequences for correct or incorrect responding, and after 5 s she instructed the participant to complete the motor sequence again, initiating a new trial. Following these baseline trials, we initiated instruction of the motor sequence.

During forward-chaining conditions, we initially targeted only the first step of the motor sequence. That is, after the instruction, "Do the — dance," if the child completed the targeted steps of the motor sequence independently, the teacher delivered praise (e.g., "Great job!"), physically guided the participant to complete all untargeted steps, and delivered access to the preselected leisure item for 30 s. We provided physical guidance for untrained steps to equate exposure to these steps during this condition with the exposure experienced during backward-chaining sessions described below. If the child did not complete the required step independently within 5 s of the instruction or the engaged in an incorrect response, the teacher provided a model prompt that demonstrated the required step. If the child did not then complete the required step within 5 s, the teacher physically guided the child to engage in the targeted step and then all remaining untargeted steps. The teacher then waited 5 s after completion of the trial to deliver an instruction to initiate the next trial. This training continued for the first step until the participant correctly and independently engaged in that step on three consecutive trials (mastery criterion). After meeting this mastery criterion, the teacher then targeted Steps 1 and 2 together, then Steps 1, 2, and 3, and so on. Subsequent trials were similar except that both the targeted step and all previously mastered steps were then required to produce reinforcement. If the participant did not initiate the motor sequence, engaged in any incorrect responses, or delayed by more than 1 s between any previously mastered steps in the sequence, the teacher provided a model of all currently targeted components (i.e., the current step and any previously mastered steps) and provided the participant the opportunity to respond again. If the correct motor sequence was not emitted following the model, the teacher then physically guided the participant to complete the targeted and any previously mastered steps in the sequence.

Teaching trials were similar during backward-chaining conditions, except that we initially targeted only the terminal step of the motor sequence. That is, immediately after the instruction, the teacher physically guided the participant to complete all steps except for the last step in the sequence. Correct responding resulted in praise and access to a preferred leisure item, and incorrect responding or a failure to respond within 5 s resulted in the delivery of a model prompt of all steps. If the child did not engage in the correct response within 5 s of the model prompt, the teacher physically guided the child to complete the response. The mastery criterion for that step was identical to the criterion used in the forward-chaining condition (i.e., three consecutive, independently correct trials). After mastery on the terminal step had been achieved, the teacher initiated the next trial with the instruction and immediately physically guided the participant to complete all but the last two steps and provided a 5-s delay, and so on. Again, all previously mastered steps were required to be demonstrated with less than 1-s delay between responses to avoid more intrusive prompting. The teacher delivered praise and 30-s access to the identified preferred leisure item only after independent responses that included both the current and all previously mastered steps in the correct order.

In both forward- and backward-chaining conditions, we set the terminal mastery criterion as three consecutive trials of independently correct responding of the complete motor sequence following the initial instruction. After a participant met the terminal mastery criterion for a motor sequence, we continued to conduct training trials for the other motor sequence until it also met mastery. Each participant learned the 3-, 6-, 9-, and 18-step sequences in consecutive order. We determined the relative sensitivity to a chaining procedure based on the differential number of trials required to meet the terminal mastery criterion in each comparison. Following mastery of these motor sequences, we initiated the preference assessment.

Preference assessment. We presented three colored cards on a table in front of each participant to start the initial link of a preference assessment trial. Selections of (i.e., touching) one card completed the initial link and resulted in the onset of the terminal link of the chain in which the teacher taught a novel three-step motor sequence to completion using one of the two chaining procedures or a control procedure, depending on which card the participant selected. The teacher conducted backward- and forward-chaining terminal links similarly to those described during the efficiency assessments, except that teaching continued until participants met mastery criterion of independently completing the motor sequence following three consecutive instructions (i.e., sessions were no longer defined by 10-trial blocks; instead, terminal-link experiences continued until participants mastered the motor sequences). In this regard, the speed of each participant's acquisition of the motor sequence determined the number of trials and duration of exposure to each terminal link; participants required no more than 20 trials to master a task. The teacher conducted control terminal links similarly to baseline sessions, except that she terminated sessions based on time. Specifically, we measured the duration from the onset of the first instruction to the moment the mastery criterion was met during the forward- and backward-chaining terminal links and yoked the duration of control sessions to be equal to the mean of the previous two chaining terminal links. We initiated control sessions by providing the same initial instruction, "Do the — dance," but did not provide any additional prompting. The teacher did not otherwise interact with the participant during these terminal links. Anecdotally, participants generally sat quietly during these periods and awaited the next initial-link opportunity.

We interspersed forced-choice sessions, in which the teacher presented only one initial-link card on each trial and physically guided the participant to complete the initial-link selection, in order to promote continued exposure to each of the terminal-link conditions. We began the preference assessment with three forced-choice exposure trials (one each for forward chaining, backward chaining, and the control condition) and included three additional forced-choice exposure trials following every five free-choice trials; we considered only selections during free-choice trials with all three colored cards present in determining preference. Between two and eight preference assessment trials were conducted per day, with no more than five free-choice trials in one day. The preference assessment duration ranged from 3 days to 9 days. Individual terminal-link experiences ranged from 2 min to 4 min. We terminated the preference assessment following free-choice selections of one initial link that totaled six selections greater than the next closest initial link or following 15 total free-choice trials.

Measures and Interobserver Agreement

Observers collected data on participant responding on a trial-by-trial basis using pencil-and-paper data sheets. During the efficacy assessment, observers coded a trial with an independently correct response if the participant initiated the motor sequence within 5 s of the instruction and completed the correct target step and all previously mastered steps in the correct sequence with no more than 1 s between each step. Observers coded a trial with a correct response following a model if the participant initiated the motor sequence within 5 s of the model prompt and completed the correct target step and all previously mastered steps in the correct sequence with no more than 1 s between each step. Observers coded a trial with a physically guided response if the teacher physically guided the participant to complete the target response sequence. During baseline trials only, observers coded a trial with no response or incorrect response if the participant failed to initiate the correct motor sequence within 5 s of the instruction or engaged in an incorrect response; these data were coded only during baseline because the programmed contingencies during teaching conditions resulted in additional prompting and the code captured this behavior in the other response categories.

A second observer simultaneously but independently collected data to provide an indicator of the reliability of measurement during 40%, 55%, 80%, and 64% of sessions during Paul's, Daniel's, Bella's, and Katie's teaching evaluations, respectively. For the teaching evaluations, we compared observers' records on a trial-by-trial basis; a trial was scored in agreement if both observers coded the same response category (i.e., independently correct, correct following a model, physically guided, or no response or incorrect) and in disagreement if the observers' records did not match. We then summed the number of trials scored in agreement, divided this sum by the total number of trials, and converted this to a percentage, resulting in mean interobserver agreement coefficients of 99% (range, 80% to 100%) for Paul, 97% (range, 80% to 100%) for Daniel, 99% (range, 80% to 100%) for Bella, and 99% (range, 90% to 100%) for Katie.

In addition, we collected data on participants' selections during the initial links of the preference assessment. On each trial, an observer noted the color of the selected card; selection was defined as contact of the participant's hand to a colored card. We compared observers' records of colored cards selected during 43%, 25%, 67%, and 25% of initial-link trials for Paul, Daniel, Bella, and Katie, respectively. Observers' records were scored in agreement if they both coded the same colored card selected and in disagreement if their records did not match; observers agreed on 100% of the selections across all participants.

RESULTS

Efficiency Assessment

We present a summary of each participant's acquisition of motor sequences in Figure 1, which depicts the number of trials to mastery given forward- and backward-chaining conditions across each motor sequence comparison. None of the participants engaged in an independently correct response during baseline. Paul acquired the three-step motor sequence taught via backward chaining in 12 fewer trials than the three-step motor sequence taught with forward chaining (20 and 32 trials, respectively). We observed a similar pattern during the six-step motor sequence comparison in which Paul met the mastery criterion in 13 fewer trials given backward chaining (39 and 52 trials for the backward-chaining and forward-chaining motor sequences, respectively). However, we did not observe these differences during the nine-step motor sequence comparison; he acquired both motor sequences following exactly 78 trials. Paul acquired the 18-step backward-chaining motor sequence in seven

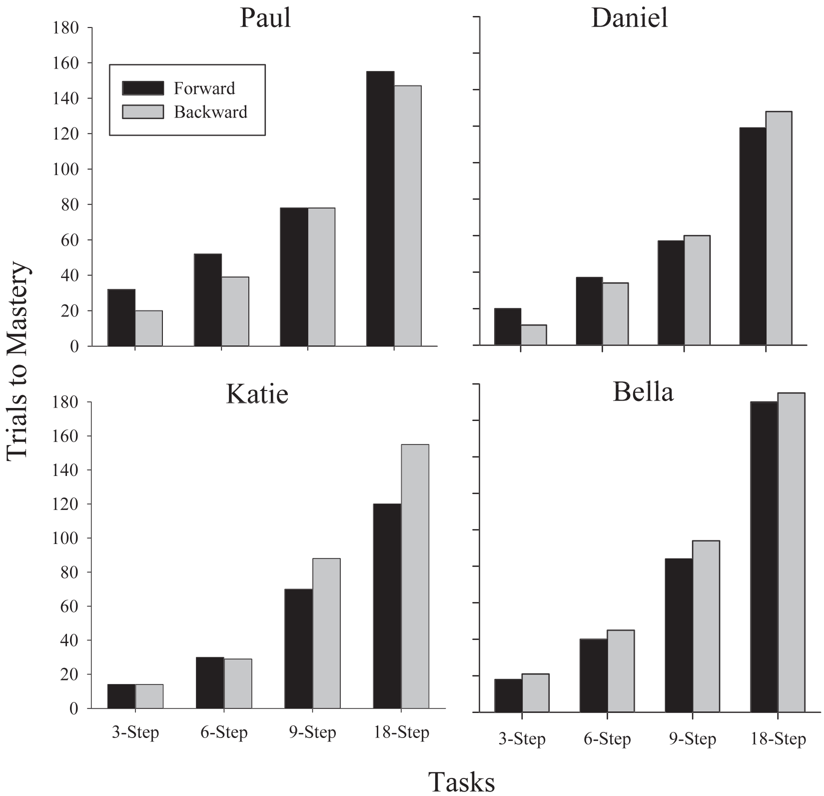

Figure 1. Overall performance of all participants on the 3-, 6-, 9-, and 18-step motor tasks taught with forward and backward chaining.

fewer trials than the forward-chaining motor sequence (147 and 155 trials, respectively).

Daniel demonstrated more variable performances across the different motor sequence lengths. He acquired the three-step backward-chaining motor sequence in nine fewer trials than the three-step forward-chaining motor sequence (11 and 20 trials for backward and forward chaining, respectively). Similarly, he met mastery criteria for the six-step backward-chaining motor sequence in three fewer trials than the six-step forward-chaining motor sequence (34 and 37 trials for backward and forward chaining, respectively). The reverse pattern was true for the longer motor sequences. During the nine-step motor-sequence comparison, Daniel met the mastery criterion during the forward-chaining condition in three fewer trials than the backward-chaining condition (60 and 57 trials for backward and forward chaining, respectively). During the 18-step comparison, Daniel reached mastery in nine fewer trials during the forward-chaining condition than during the backward-chaining condition (128 and 119 trials for backward and forward chaining, respectively).

Katie acquired both three-step motor sequences in the same number of trials with forward and backward chaining (14 trials). She mastered the six-step backward-chaining motor sequence in one fewer trial than the six-step forward-chaining motor sequence (29 and 30 trials for backward and forward chaining, respectively). We observed larger differences in her acquisition of the nine- and 18-step motor sequences. She mastered the nine-step forward-chaining motor sequence in 18 fewer trials than the backward-chaining motor sequence (88 and

Table 2
Correspondence Between Outcomes of the Short- and Long-Chain (18-Step) Motor Sequences

Participant	3-step	6-step	9-step	18-step
Paul	backward	backward	tie	backward
Daniel	backward	backward	forward	forward
Katie	tie	backward	forward	forward
Bella	forward	forward	forward	forward
Percentage correspondence	50	50	75	

70 trials for backward and forward chaining, respectively) and the 18-step motor sequence in 35 fewer trials (155 and 120 trials for backward and forward chaining, respectively).

The outcomes for Bella were the most consistent across comparisons; she always met mastery criterion in fewer trials given forward chaining, requiring three fewer trials in the three-step motor-sequence comparison (21 and 18 trials for backward and forward chaining, respectively), five fewer trials in the six-step motor sequence comparison (45 and 40 trials for backward and forward chaining, respectively), 10 fewer trials in the nine-step comparison (94 and 84 trials for backward and forward chaining, respectively), and five fewer trials in the 18-step comparison (175 and 170 trials for backward and forward chaining, respectively).

In summary of the aforementioned results, backward chaining was associated with fewer trials to mastery in three of four comparisons for Paul with an equal number of trials in the nine-step comparison. Backward chaining was associated with more rapid acquisition in two comparisons and slower acquisition in two comparisons for Daniel. Forward chaining was associated with more rapid acquisition in two comparisons, slower acquisition in one comparison, and equal acquisition in one comparison for Katie. Finally, forward chaining was associated with more rapid acquisition in all four comparisons for Bella.

We then examined the outcomes of the 3-step, 6-step, and 9-step comparisons to the 18-step comparison to determine the level of correspondence between the relatively shorter motor sequences and the longer motor sequences (i.e., would the determination of a "winner" from a brief comparison predict children's sensitivity in one of the longer duration comparisons?). These data are shown in Table 2. The outcomes of the three-step and six-step comparisons corresponded with the outcomes of the 18-step comparison in only two of four cases (50%), which is equivalent to chance. The nine-step comparison may have been slightly more predictive, with correspondence in three of four cases (75%); however, the small number of participants prohibits any definitive conclusions.

Preference Assessment

We show each participant's cumulative initial-link selections from the preference portion of our study in Figure 2; these data represent responding only during free-choice trials. Daniel and Katie alternated between forward- and backward-chaining selections consistently. They both made seven selections of forward chaining and eight selections of backward chaining, and neither participant chose the control condition during the assessment. Bella similarly alternated between selections of forward chaining (six selections) and backward chaining (seven selections), but she selected the control condition on two trials. We terminated Daniel's, Katie's, and Bella's assessments after the 15-trial stop criterion with the determination that they each preferred backward and forward chaining similarly, and preferred both chaining conditions over the control condition. A preference for one chaining procedure emerged only for Paul. After choosing the control condition on the first trial, he then selected forward chaining in the next seven consecutive opportunities.

DISCUSSION

We compared the acquisition of motor sequences across a sample of children with

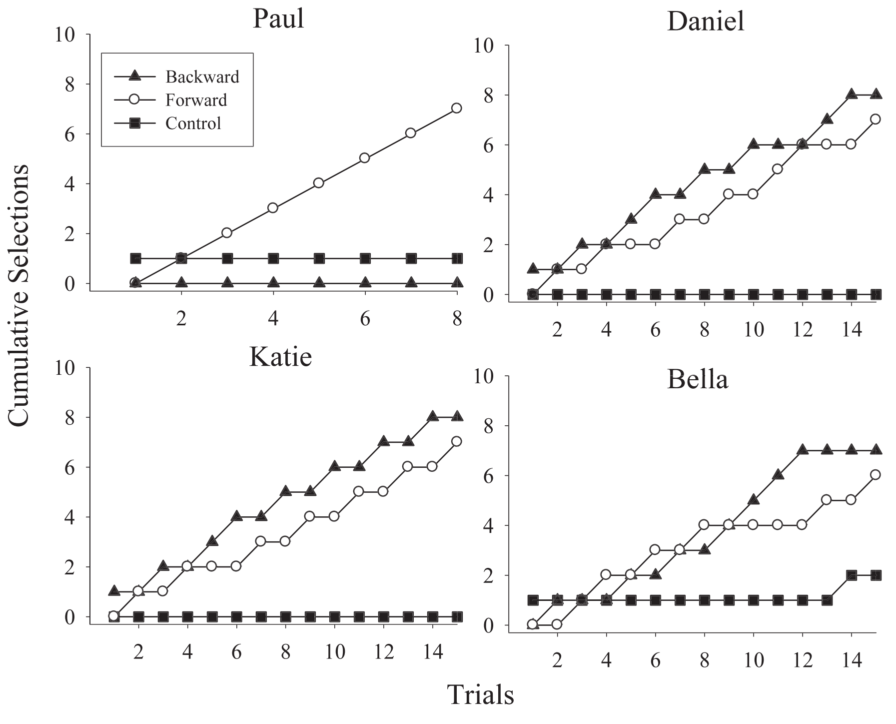

Figure 2. Cumulative selections during free-choice trials of the concurrent-chains preference assessment.

special needs using both forward and backward chaining. Across our four participants, this provided a total of 16 comparisons of forward and backward chaining. Forward chaining was associated with fewer trials to mastery in eight comparisons, backward chaining was associated with fewer trials to mastery in six comparisons, and no difference in trials to mastery was obtained in two comparisons. With the exception of the nine- and 18-step motor sequences for Katie, we observed marginal differences between backward and forward chaining (M = 5.79 difference in trials to mastery; range, 0 to 13).

Only one of the four participants demonstrated a consistent differential sensitivity to a particular teaching condition in each of her four comparisons; Bella consistently met the mastery criterion more quickly under the forward-chaining conditions (M = 5.75 trials difference). Paul met the mastery criterion more rapidly in the backward-chaining conditions for three of the four comparisons. Although Daniel and Katie met mastery more quickly in the backward-chaining conditions or in an equal number of trials for the shorter motor sequences, both met mastery criteria more rapidly during the forward-chaining conditions of the nine- and 18-step motor sequences. Thus, it did not appear that there were consistent differences in an individual's sensitivity to either teaching procedure, despite the use of similar tasks.

We also sought to determine if differentially rapid acquisition of a shorter motor sequence could serve as a behavioral assessment to predict differential sensitivity in acquisition of a longer motor sequence. We found correspondence between the three- and six-step motor sequences and the 18-step motor sequence for two of the participants (Paul and Bella), and the nine-step motor sequence was predictive for three of the participants (Daniel, Katie, and Bella). However, given the overall variability within each participant, it seems most appropriate to conclude that these correspondences were chance occurrences. That is, there were no consistencies in individuals' acquisition of motor sequences given forward and backward chaining, and thus any differences in the 18-step motor sequences could be predicted equally well by a coin flip or by previous performance.

In total, the results of our efficiency assessment ran contrary to Spooner and Spooner's (1984) assertion that there are idiosyncratic differences in sensitivity to chaining procedures that would be consistent in individual learners. In the current study, we assessed children's sensitivity to each teaching procedure repeatedly using highly similar tasks. Despite holding the task and the learner constant, we did not identify any consistencies in sensitivity to one teaching procedure beyond what would be expected by chance. Based on the variability in outcomes of comparisons in the literature and the results of the current study, it is likely safe to conclude that forward- and backward-chaining procedures are similarly effective in establishing behavior chains.

In addition to assessing the differential efficiency of these procedures, we also assessed participants' preferences for these procedures relative to a control condition. All participants preferred either chaining procedure over the no-chaining control, and three of the four participants displayed no preference for one chaining procedure over another. That is, similar to there being a lack of difference in the efficiency of these procedures, the children who experienced these teaching procedures were also indifferent regarding the procedure they received. The fourth participant, Paul, did meet our preference criteria for forward chaining. However, we believe that this may not be an accurate reflection of his preference; instead, his initial selection resulted in reinforcement and was strengthened immediately and differentially to the exclusion of the other options. For instance, at one point he asked the therapist, "Why would I switch to another color if I get my toy with purple [the color of the initial-link card associated with the forward-chaining condition]?"

These results draw attention to an important methodological feature of the concurrent-chains procedure, specifically the inclusion of the control condition. Had we included only the initial links from the backward- and forward-chaining conditions in the present assessment, we would have been unable to determine if the resultant data were indicative of indifference or of a failure to discriminate the contingencies associated with the initial links. By including a control condition that was unlikely to occasion selections, we can be fairly confident that our participants were indeed discriminating between the outcomes of their initial-link selections based on their minimal selections of the control condition; they were indifferent with regards to which chaining procedure they experienced.

The overall results of this evaluation suggest that (a) there is no consistent difference in task acquisition given instruction consisting of forward or backward chaining between or within participants, (b) it probably is not possible to use differential sensitivity during a brief task to predict differential sensitivity during longer tasks, and (c) these procedures are neither differentially efficient nor differentially preferred.

The lack of difference between these procedures, both in terms of efficiency and preference, is not an unimportant finding. Rather, these findings indicate that both procedures are effective at engendering complex chains of new behavior, and both are preferred by the consumers that experience them. From a practitioner's perspective, these results suggest that teachers and interventionists should be comfortable implementing either procedure with their clientele.

Our data did not completely rule out the possibility that some tasks may be taught more effectively with either forward or backward chaining. We chose to compare acquisition across similar motor tasks to rule out differences in task difficulty as a potential confounding effect. It may be that greater sensitivity to a particular chaining procedure would be identified for a different type of task. For instance, in making a sandwich, spreading peanut butter across one side of the bread creates a continuous visual discriminative stimulus to occasion the next response in the task (e.g., putting the knife down). It may be that such continuous stimuli exert stronger stimulus control than the presumably brief stimuli of a motor movement (e.g., one can no longer experience touching one's nose after that response has ended). These continuous discriminative stimuli may better set the occasion for a subsequent response, although it is unclear how this presentation would differentially favor one chaining procedure over the other.

It also may be the case that some tasks allow more natural or direct sources of reinforcement to result from the completion of the chain using backward chaining in lieu of socially contrived or indirect reinforcement when using forward chaining. For instance, in making a peanut butter sandwich, the immediate natural consequence of completing a targeted step with backward chaining would be access to the completed sandwich. By contrast, completing an early step via forward chaining (e.g., laying pieces of bread side by side) would not result in the same automatic consequence (i.e., complete sandwich), and thus teachers would need to rely on delivering another reinforcer (e.g., praise, edible item). Thompson and Iwata (2000) found that direct contingencies may result in more rapid acquisition. By arranging a reinforcement contingency that was not a direct product of the behavior (i.e., completion of a motor sequence resulted in the teacher delivering a toy), we may have obscured this benefit of backward chaining. The methods of the current study would be applicable to conducting additional comparisons of forward and backward chaining with disparate tasks and more natural reinforcement contingencies. It also would be interesting to compare the efficiency of and children's preferences for chaining methods relative to total-task presentation. During total-task presentation, all steps in a multistep task are targeted from the onset of instruction, and prompts are provided as needed to occasion each component response (e.g., Kayser, Billingsley, & Neel, 1986; McDonnell & McFarland, 1988).

In practice, it is common to physically guide learners through the early steps of a task with backward chaining. For instance, in teaching an individual to remove his or her sweater independently, it is common to guide pulling each arm out of its sleeve and placing hands under the collar to set the occasion for him or her to push the sweater over the head. To minimize the likelihood that this level of exposure to future targeted steps did not differentially favor backward chaining, we chose to include physical guidance on the untrained steps in both forward- and backward-chaining conditions. It is possible that this additional prompting and exposure to future targeted steps were in part responsible for the marginal differences between conditions by resulting in rapid acquisition in both conditions. If we had not prompted untrained steps prior to targeting them for instruction, differences between forward and backward chaining may have been more apparent. Future research may evaluate these procedures without additional prompting in place.

Finally, although the children did not demonstrate a preference for one of these teaching procedures, it is likely that teachers may have a distinct preference for one procedure over the other. If students are indifferent, then teachers' preferences certainly may be honored when instructional methods are selected. Future research may consider the systematic evaluation of teachers' preferences for these procedures.

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