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An Assessment of the Effectiveness of and Child Preference for Forward and Backward Chaining

by

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Undergraduate honors thesis under the direction of

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Abstract

Forward and backward chaining are procedures used to teach multi-step tasks by breaking a complex skill into component parts and teaching each sequentially. Comparative studies of forward and backward chaining have provided an insubstantial amount of evidence illustrating either as consistently more effective and have led some to suggest that sensitivity to each teaching procedure may be idiosyncratic across learners and tasks. Such an assumption posits that there would be a consistent sensitivity to one chaining procedure relative to the other within individual learners; however, research has not yet evaluated this assumption. 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 (i.e., number of steps required). Second, we evaluated whether differential sensitivity to a chaining procedure during a brief task was predictive of differential sensitivity during the teaching of longer tasks. Third, we directly assessed children’s preferences for each teaching procedure as a means to socially validate the two teaching strategies. Learners acquired all target skills introduced under both chaining conditions, but individual children did not consistently learn more efficiently with either procedure. Due to this variability, short-duration tasks were not predictive of participant performance in longer-duration tasks. Both chaining procedures were preferred relative to a baseline condition without prompting, but participants did not demonstrate a preference for either procedure. Backward and forward chaining procedures were equally effective and preferred for teaching multi-step tasks. 

Keywords: autism, backward chaining, concurrent-chains preference assessment, forward chaining, preferences
An Assessment of the Effectiveness of and Child Preference for Forward and Backward Chaining

Teaching tasks requiring multiple steps (e.g., assembling furniture, reciting phone numbers, following a recipe) can be difficult, especially for teachers of children with developmental delays or intellectual disabilities. Researchers have approached teaching multi-step tasks primarily via two methods, frequently referred to as the “whole” or “part” methods (Walls, Zane, & Ellis, 1981). When using the “whole” method, a teacher introduces a task in its entirety during each trial, as opposed to the “part”, or chaining, method which involves breaking a complex skill into its component parts (i.e., utilizing a task analysis) and then teaching individual components, or steps, in succession. For instance, when teaching how to make a sandwich using the whole method, each trial would consist of prompting completion of the entire task (e.g., saying, “make the sandwich” followed by physical prompts to compete the entire task). By contrast, teaching using a chaining procedure would involve separately training each step. For instance, the learner might be taught simply to lay the bread side by side prior to learning to pick up the lunchmeat, etc.

Generally, findings suggest teaching via a chaining method is more effective and efficient than the whole-task method (Walls et al., 1981; Ash & Holding, 1990). Ash and Holding taught musical-keyboard skills to undergraduate students, assigning participants to either the whole-training condition, or one of two chaining conditions. Specifically, they taught participants to identify the notes C, D, E, F, and G on a keyboard and then to play a series of notes using either whole or partial methods. Participants experiencing the two chaining methods acquired the skill more rapidly and engaged in fewer errors than those in the whole-method group.

There are two important variants of response chaining in the literature termed forward and backward chaining (Ash & Holding, 1990). Forward chaining involves teaching the initial
step in a task analysis to mastery and then sequentially introducing additional steps. For instance, in a task that requires behaviors 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 will vary depending upon the required terminal step).

Backward chaining involves teaching the final step of the response chain initially and progressively requiring additional early components. Again, using a task requiring steps A, B, C, and D as an example, 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. An instructor would deliver reinforcement at the completion of the last step, and thus regardless of the stage of training, reinforcement would be delivered at the “natural” location (i.e., at the end of the task).

Researchers have demonstrated both forward and backward chaining to be efficacious at teaching a vast array of skills. Hagopian, Farrell, and Amari (1996) taught a child with a pediatric feeding disorder who displayed liquid refusal to accept sips from a cup. These researchers task-analyzed drinking into three steps: (a) bringing the cup to the mouth, (b) accepting the liquid, and (c) swallowing the liquid. They targeted these steps in reverse order, in accordance with backward chaining resulting in acquisition of cup drinking for this participant. Jerome, Frantino, and Sturmey (2007) taught mentally-delayed adults Internet skills in a 13-step task analysis with backward chaining in which the terminal response resulted in access to a preferred website or game.

A number of studies have compared the teaching efficacy of forward- and backward-chaining methods (Weiss, 1978; Walls et al., 1981; Hur & Osborne, 1993; Ash & Holding, 1990; Smith, 1999); however, the outcomes of these studies have not offered clarity for teachers in
selecting their teaching strategies. For instance, Weiss compared forward and backward chaining in the acquisition of response chains with undergraduate college students. These authors developed an apparatus consisting of 6 buttons and required participants to press different sequences of buttons in order to earn points. They taught each participant 4, 6-step sequences using either forward or backward chaining; forward chaining resulted in fewer incorrect responses across each participant.

Walls et al. (1981) also compared forward and backward chaining in assembling a bicycle brake, a meat grinder, and a carburetor. Their findings regarding errors and training time led them to conclude that backward and forward chaining were equally effective across tasks. Hur and Osborne (1993) taught children with moderate to severe mental retardation how to make corsages using the same 18-step task analysis. Subjects were either assigned to the forward- or backward-chaining condition. They found forward and backward chaining to be equally efficacious across treatment groups. Thus across studies, one chaining strategy has not been consistently more effective in promoting response acquisition.

A number of researchers have attempted to determine features of the chaining procedure as well as features of the tasks presented that may be predictive of the most effective chaining procedure. Some researchers suspected the length or difficulty of the task may result in differential sensitivity to a chaining method (Ash & Holding, 1990; Smith, 1999). Ash and Holding compared backward and forward chaining in which the position of a more difficult segment of notes in a musical sequence was altered, either placed at the beginning or the end of a task; however, both chaining procedures were equally efficacious regardless of placement of the difficult step. Smith suggested longer response chains would be more sensitive to differences between the two procedures. Specifically, he compared backward and forward chaining in the acquisition of a 120-step task, concluding in his first experiment that forward and backward
chaining were more effective than the whole method; however, the two chaining procedures were equally effective. In his second experiment, whole method and forward chaining resulted in more rapid acquisition than backward chaining. In addition to procedural differences, studies have implemented these procedures with both persons with mental retardation (Walls et al., 1981; Hur & Osborne, 1993; Zane, Walls, & Thvedt, 1981) as well as persons of typical development (Ash & Holding, 1990; Weiss, 1978; Smith, 1999).

In a review of the published literature pertaining to response-chaining methods, Spooner and Spooner (1984) surmised, “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 child 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 children’s sensitivity to a teaching procedure given their demonstrated sensitivity to that teaching procedure in the past. Researchers have not empirically validated these assumptions; however, the identification of differential sensitivity to one teaching procedure should prove valuable to teachers responsible for teaching complex skills, specifically in helping them identify the most efficacious teaching procedures possible.

In addition to the relative efficacy of each procedure, teachers may also consider child preferences for teaching procedures an important factor. Children, particularly those with disabilities, are rarely 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 problem behavior (Powell & Nelson, 1997; Ringdahl, Vollmer, Marcus, & Roane, 1997; Mason, McGee, Farmer-Dougan, & Risley, 1989).
Assessing children’s preferences for teaching strategies may be complicated, particularly when individuals present with limited vocal repertoires. Hanley and colleagues described the use of a concurrent-chains procedure that offers a direct, non-verbal 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, Piazza, Fisher, Contrucci, & Maglieri, 1997; Heal & Hanley, 2007; Heal, Hanley & Layer, 2009, Tiger, Hanley, & Heal, 2006). For instance, Hanley et al. assessed three individuals’, who engaged in severe destructive behavior maintained by attention, preferences for treatment conditions in which problem behavior no longer resulted in attention, but attention was delivered either following a communicative response (FCT) or delivered independent of responding on a fixed-time schedule (NCR). After experiencing both conditions, participants’ preferences were assessed in what is called the initial link of the chain. That is, each treatment was associated with a particular discriminative stimulus (in this case a large colored poster board). Children were presented with two similarly colored micro-switch buttons and were prompted to select one. They then participated in a therapy session based upon their initial-link selection in the terminal link of the chain. After exposure to these contingencies, all children demonstrated a preference for the FCT method, even though both methods were effective in decreasing destructive behavior.

The current study was conducted in two parts. The first involved an efficacy assessment in which participants were taught 3-, 6-, 9-, and 18-step motor tasks using both forward and backward chaining. We examined the outcomes of this assessment to determine if (a) children exhibited a consistent differential sensitivity to backward or forward chaining with similar tasks and (b) if differential acquisition of the 18-step tasks was predicted by differential acquisition of the previous tasks (i.e., correspondence between the outcomes of the 3-, 6-, and 9-step tasks with
the outcome of the 18-step task). The second part involved a preference assessment using the concurrent-chains methodology of Hanley et al. (1997) in which we introduced a novel skill and provided participants the opportunity to select whether the skill was trained using forward-, backward-, or no-chaining methods.

Method

Participants and Setting

We recruited 4 participants from a local school for children with disabilities based on referrals from their teachers indicating the child presented with difficulties completing multiple-step tasks. Both Bella and Paul were diagnosed with ADHD, Daniel exhibited mild to moderate speech delays, and Katie had learning deficits. The children’s ages ranged from 9 to 12 years. We obtained parental consent and daily assent for each child. We conducted all sessions in a vacant room in the school.

Measures and Interobserver Agreement

We developed a series of motor tasks requiring sequences of 3, 6, 9, and 18 steps (See Appendices A, B, C, and D for definitions of each component response); throughout the study we termed these “dances.” Each session consisted of 10 trials. Each trial involved one opportunity to complete the current step(s) of a 3-, 6-, 9- or 18-step dance. Each trial was scored as either independently correct, correct following a model prompt, or physically guided. An observer scored an independently correct response if the participant completed the current step in the correct order according to the operational definition within 5 s of a vocal prompt. An observer scored correct following a model if the participant completed the step correctly following the model prompt and physically guided, if the participant did not attempt the step after 5 s following a model prompt, did not complete the step according to the operational definition, or completed a step correctly but in the incorrect order, resulting in physical guidance
of the steps. In addition, we collected data on participants’ selections during the preference assessment portion of our study. Selection was defined as contact of the participant’s hand to a colored card.

A second observer simultaneously, but independently, collected data to provide an indicator of the reliability of measurement during 39.9%, 54.9%, 79.7%, and 63.6% of sessions during Paul, Daniel, Bella, and Katie’s teaching evaluations, respectively. For the teaching evaluations, we compared observers’ records on a trial-by-trial basis. We scored a trial in agreement if both observers coded the same response category (i.e., independently correct, correct following a model, or physically guided) 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 IOA coefficients of 99.2% (range, 80% to 100%) for Paul, 96.6% (range, 80% to 100%) for Daniel, 98.6% (range, 80% to 100%) for Bella and 99.5% (range, 90% to 100%) for Katie.

For the preference assessments, we compared observers’ records of colored cards selected during 42.9%, 25%, 66.7%, and 25% of selections for Paul, Daniel, Bella, and Katie, respectively. We scored observers’ records 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.

**Procedural Overview**

All dances involved a random combination of 6 fine- and gross-motor movements (touching one’s nose, eye, and ear, patting one’s head and lap, and clapping one’s hands). Two dances each were designed to include 3, 6, 9, and 18 steps. We randomly assigned dances to either the forward- or backward-chaining condition for each participant. We alternated teaching each dance in 10-trial clusters in accordance with a multi-element design. We compared
conditions based upon the number of trials required to meet mastery criterion. Each individual step required 3 consecutive trials of independently correct responding to be considered mastered with 3 consecutive independently correct trials at the final step to meet task mastery.

**Efficacy Assessment Procedure**

**Baseline.** During an initial baseline, each participant was vocally prompted to complete a dance (e.g., “Do the red dance”); we assigned each dance an arbitrary color name to facilitate discrimination of the experimental conditions. We did not provide any consequences for correct or incorrect responding except that after 5 s, the participant was prompted to complete the task again, initiating a new trial. After a 3-trial baseline for each task, we moved on to the first phase of training the assessment task.

**Training.** Prior to each training session, the participant selected a leisure item from an array of preferred items; we delivered the selected item as a reinforcer during training sessions. Trials during this phase were similar to the baseline condition with a few modifications. First, following the verbal prompt, if the child complied with the task independently, he or she received reinforcement in the form of verbal praise and access to a preferred leisure item for 30 s. If the child did not complete the required steps independently within 5 s of the vocal prompt, the instructor provided a model prompt demonstrating the required steps. If the child did not then complete the required steps within 5 s, completed them not according to the operational definition, or completed them in the incorrect order, the instructor physically guided the child to engage in the required steps. The instructor then waited 5 s following the completion of the trial to deliver a prompt to initiate the next trial.

During *forward-chaining* sessions, we targeted Step 1 of each task, followed by Step 2, then Step 3, etc. Following an independent completion of the targeted step, the participant was physically guided to complete the remaining untargeted steps. During *backward-chaining*
sessions, we targeted the terminal step of the chain initially, followed by the last two steps, etc. In each session, the participant was physically guided to complete all initial steps prior to those being targeted. The 6-, 9- and 18-step dances were taught in the same manner.

**Preference Assessment Procedures**

We presented three colored cards on a table in front of each participant to start a preference-assessment trial. This selection period constituted the initial link of the concurrent-chains schedule. 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 instructor taught a novel 3-step dance to completion using one of the two chaining procedures or a control procedure, dependent upon which card the participant selected (See Appendix E). Backward and forward terminal links were identical to conditions described during the efficacy assessments except that sessions continued until tasks were mastered. Control terminal links were similar to baseline sessions except that sessions were terminated based upon time; the termination time was yoked to the mean duration of time it took the child to complete the forward and backward chaining 3-step tasks.

In order to promote continued exposure to each of the terminal-link conditions, we interspersed forced-choice sessions in which only one card was presented on each trial, and participants were physically guided to complete the initial-link selection. Three forced-choice exposure trials occurred following every five free-choice trials. We terminated the preference assessment following free-choice selections of 1 initial link totaling 6 selections greater than the next closest initial link or following 15 total free-choice trials.

**Results**

**Efficacy Assessment Results**

Each participant acquired each of the eight tasks using both chaining procedures during the efficacy assessment. We present Paul’s data in Figure 1 as the cumulative number of correct
responses across each step of the chaining procedure. Paul acquired the 3-step tasks in 12 fewer trials with backward chaining (20 vs. 32 trials for backward and forward chaining, respectively). We observed a similar pattern during the 6-step comparison in which Paul met mastery criteria in 13 fewer trials given backward chaining (39 vs. 52 trials for backward chaining and forward chaining respectively; third and fourth panels of Figure 1). However, we did not observe these differences during the 9-step task comparison (fifth and sixth panels of Figure 1); Paul acquired both dances following 78 trials. Paul acquired the 18-step tasks in 7 fewer trials with backward chaining (147 vs. 155 trials; seventh and eight panels of Figure 1).

Our second participant, Daniel, had more inconsistencies in performance across the different task lengths. As shown in Figure 2, backward chaining was more efficient than forward chaining in the 3-step tasks, requiring 9 less trials (11 vs. 20 trials for backward and forward chaining, respectively) as well as the 6-step tasks, requiring 3 less trials (34 vs. 37 trials for backward and forward chaining, respectively). The reverse was true of the longer tasks. For the 9-step comparison, forward chaining required 3 fewer trials than backward chaining (60 vs. 57 trials for backward and forward chaining, respectively), while the 18-step dances showed a difference of 9 trials (128 vs. 119 trials for backward and forward chaining, respectively).

We present Katie’s data in Figure 3. Katie acquired both the 3-step dances in the same number of trials with forward and backward chaining (14 trials; first and second panels of Figure 3). While the 6-step task was mastered in 1 less trial in backward chaining (29 vs. 30 trials for backward and forward chaining, respectively), she seemed to show a larger difference in efficacy for both the 9- and 18-step dances. Forward chaining was mastered 18 trials earlier in the 9-step dances (88 vs. 70 trials for backward and forward chaining, respectively) and 35 trials earlier in the 18-step dances (155 vs. 120 trials for backward and forward chaining, respectively).
Our final participant, Bella, showed regularity throughout each task length. She was always more efficient with forward chaining, requiring 3 less trials in the 3-step task (21 vs. 18 trials for backward and forward chaining, respectively), 5 less trials in the 6-step task (45 vs. 40 trials for backward and forward chaining, respectively), 10 less trials in the 9-step task (94 vs. 84 trials for backward and forward chaining, respectively), and 5 less trials in the 18-step task (175 vs. 170 trials for backward and forward chaining, respectively). We provide a summary of all participants’ performance in Figure 5.

Preference Assessment Results

Cumulative selections made in the preference portion of our study are shown for each participant in Figure 6. Daniel and Katie alternated between forward and backward chaining consistently. Both participants had 7 selections of forward chaining and 8 selections of backward chaining, and neither participant chose the control condition once. Bella alternated between selections of forward chaining (6 selections) and backward chaining (7 selections). She intermittently selected the control condition 2 times. Daniel, Katie, and Bella’s assessments were terminated following the 15-session stop criterion with the finding that both forward and backward chaining were equally preferred. Only for one participant, Paul, did a preference emerge for one chaining procedure. As depicted in the figure, after choosing the control condition for the first session, he selected forward chaining the next 7 consecutive opportunities.

Discussion

We compared the acquisition of motor tasks across a sample of children with special needs using both forward and backward chaining. Across our four participants this provided a total of 16 comparisons of both forward and backward chaining. Forward chaining was associated with fewer trials to mastery in 8 comparisons, backward chaining was associated with fewer trials to mastery in 6 comparisons, and no difference in trials to mastery was obtained in 2
comparisons. With the exception of the 9- and 18-step tasks 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 our four participants demonstrated a consistent differential sensitivity to a particular teaching condition across each of their four comparisons; Bella consistently met mastery criteria more quickly under the forward-chaining conditions ($M = 5.75$ trials difference). Paul met mastery criteria more rapidly in the backward-chaining conditions for three of the four comparisons. While Daniel and Katie met mastery more quickly in the backward-chaining conditions or in an equal number of trials for the shorter tasks, both met mastery criteria more rapidly during the forward-chaining conditions of the 9- and 18-step tasks. 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 assessed whether one of the shorter tasks could serve as an assessment to predict differential sensitivity in acquisition of a longer task, in this case the 18-step task. We found the 3- and 6-step tasks were predictive for two of our four participants, and the 9-step task was predictive for three out of four. However, given such a small sample size, it is difficult to suggest that these outcomes are more than chance correspondence.

All participants preferred either chaining procedures relative to baseline, or no chaining; three of the four participants displayed no preference for one chaining procedure over another. The fourth participant, Paul, did show a preference for forward chaining; however, anecdotally we believe this may not be an accurate reflection of his preference, but rather his initial selection resulted in reinforcement and thus was immediately and differentially strengthened 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)?"

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) due to this variability, it is likely not possible to use differential sensitivity during a brief task to predict differential sensitivity during longer tasks, and (c) not only are these procedures not differentially effective, they are also not differentially preferred. That is, participants were perfectly ambivalent regarding which teaching procedure they experienced.

These results are consistent with the mixed results provided in previous research comparing these procedures. As Hur and Osborn (1993) found, we taught similar tasks of different lengths with both forward and backward chaining. Across all participants, the two procedures were found to be similarly effective. Also, when comparing our study to Spooner and Spooner’s (1984) prediction, we not only found idiosyncratic results across participants in learning efficacy between forward and backward chaining, we found that even within participants, one procedure was not consistently more effective. Based upon our data and previous data, we would conclude that teachers can select either chaining procedure for use with their students without concern for differences in their efficacy.

There were a couple limitations to our study that may guide future research on this topic. 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 tasks to rule out task variability as a potential confound. It may be that if we chose a different type of task (i.e., verbal tasks), a more consistent sensitivity would have been identified. We also paired chaining with “follow-through” on the untrained steps. It is possible that this additional prompting and exposure to future targeted steps were in part responsible for the lack
of difference between conditions. If we had not assisted with untrained steps, differences between forward and backward chaining may have been more apparent. Because the follow-through is an essential component of backward chaining, we included it as well in our forward chaining to equate those conditions as much as possible.

Finally, although children did not demonstrate a distinct preference for these teaching procedures it is likely that teachers may have a distinct preference for one procedure versus the others. If student-learner preferences are ambivalent, then teacher preferences certainly can be honored when selecting instructional methods. Future research may consider systematically evaluating teachers’ preferences for these procedures.
References


Appendix A

3-Step Tasks for Experiment 1

Task 1 A: We will ask the participant to do the “Red” dance. There will be three steps to the dance.

1. Touch ear
2. Clap
3. Touch nose

Task 1 B: We will ask the participant to do the “Green” dance. There will be three steps to the dance.

1. Touch top of head
2. Touch two hands on lap
3. Touch eye
Appendix B

6-Step Tasks for Experiment 1

Task 2 A: We will ask the participant to do the “Blue” dance. There will be six steps to the dance.

1. Touch eye
2. Touch top of head
3. Touch ear
4. Clap
5. Touch nose
6. Two hands on lap

Task 2 B: We will ask the participant to do the “Yellow” dance. There will be six steps to the dance.

1. Clap
2. Touch nose
3. Touch ear
4. Touch eye
5. Touch top of head
6. Two hands on lap
Appendix C

9-Step Tasks for Experiment 1

Task 3 A: We will ask the participant to do the “Black” dance. There will be nine steps to the dance.

1. Touch nose
2. Clap
3. Touch ear
4. Two hands on lap
5. Touch top of head
6. Touch eye
7. Touch nose
8. Touch ear
9. Clap

Task 3 B: We will ask the participant to do the “White” dance. There will be three steps to the dance.

1. Touch ear
2. Clap
3. Touch eye
4. Touch top of head
5. Two hands on lap
6. Touch nose
7. Touch top of head
8. Two hands on lap
9. Touch eye
Appendix D

18-Step Tasks for Experiment 1

Task 4 A: We will ask the participant to do the “Brown” dance. There will be eighteen steps to the dance.

1. Clap
2. Touch ear
3. Two hands on lap
4. Touch top of head
5. Touch nose
6. Touch eye
7. Touch ear
8. Two hands on lap
9. Touch top of head
10. Touch eye
11. Clap
12. Touch nose
13. Clap
14. Touch top of head
15. Touch eye
16. Two hands on lap
17. Touch ear
18. Touch nose
Task 4 B: We will ask the participant to do the “Gray” dance. There will be eighteen steps to the dance.

1. Touch nose
2. Touch eye
3. Touch top of head
4. Two hands on lap
5. Clap
6. Touch ear
7. Touch eye
8. Two hands on lap
9. Touch top of head
10. Clap
11. Touch ear
12. Touch nose
13. Touch top of head
14. Touch nose
15. Two hands on lap
16. Touch eye
17. Touch nose
18. Touch ear
Appendix E

Tasks for Experiment 2

Task 1
1. Touch nose
2. Touch eye
3. Touch ear

Task 2
1. Touch top of head
2. Touch ear
3. Clap

Task 3
1. Two hands on lap
2. Touch nose
3. Touch top of head

Task 4
1. Touch eye
2. Clap
3. Two hands on lap

Task 5
1. Touch ear
2. Clap
3. Touch nose

Task 6
1. Touch nose
2. Two hands on lap
3. Touch ear

Task 7
1. Touch ear
2. Two hands on lap
3. Touch eye

Task 8
1. Two hands on lap
2. Touch top of head
3. Touch eye

Task 9
1. Touch ear
2. Two hands on lap
3. Clap

Task 10
1. Touch eye
2. Clap
3. Two hands on lap
Task 11
1. Touch top of head
2. Touch ear
3. Touch eye

Task 12
1. Touch ear
2. Touch top of head
3. Touch eye

Task 13
1. Touch nose
2. Touch eye
3. Touch top of head

Task 14
1. Touch eye
2. Touch nose
3. Clap

Task 15
1. Two hands on lap
2. Touch top of head
3. Touch eye

Task 16
1. Touch eye
2. Touch top of head
3. Touch nose

Task 17
1. Clap
2. Touch eye
3. Touch ear

Task 18
1. Touch nose
2. Touch top of head
3. Touch ear

Task 19
1. Touch nose
2. Two hands on lap
3. Touch ear

Task 20
1. Touch top of head
2. Clap
3. Touch eye
Task 21

1. Ear
2. Lap
3. Head

Task 22

1. Clap
2. Eye
3. Nose

Task 23

1. Lap
2. Eye
3. Nose

Task 24

1. Clap
2. Ear
3. Lap

Task 25

1. Eye
2. Lap
3. Nose

Task 26

1. Head
2. Lap
3. Clap

Task 27

1. Eye
2. Clap
3. Ear

Task 28

1. Nose
2. Eye
3. Head

Task 29

1. Lap
2. Ear
3. Clap

Task 30

1. Nose
2. Head
3. Ear
Table 1
Correlation between tasks

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<th>Katie</th>
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Figure 1

Paul
Figure 2

Daniel
Figure 4

Bella

Trials
Figure 5

![Graphs showing trials to mastery for Paul, Daniel, Katie, and Bella. Each graph compares forward and backward chaining across different steps (3-step, 6-step, 9-step, 18-step).]
Figure 6

- **Paul**
  - Backward
  - Forward
  - Control

- **Daniel**

- **Katie**

- **Bella**

Trials vs. Cumulative Selections for different conditions.
Figure Captions

*Figure 1.* Paul’s cumulative responses to the 3-, 6-, 9-, and 18-step tasks with forward and backward chaining.

*Figure 2.* Daniel’s cumulative responses to the 3-, 6-, 9-, and 18-step tasks with forward and backward chaining.

*Figure 3.* Katie’s cumulative responses to the 3-, 6-, 9-, and 18-step tasks with forward and backward chaining.

*Figure 4.* Bella’s cumulative responses to the 3-, 6-, 9-, and 18-step tasks with forward and backward chaining.

*Figure 5.* Overall performance of all participants on the 3-, 6-, 9-, and 18-step tasks with forward and backward chaining.

*Figure 6.* Cumulative selections during the concurrent-chains procedure for all four participants.