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## Comparison of backward and forward chaining in the acquisition of play and vocational skills

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**Comparison of Backward and Forward Chaining in the Acquisition of Play and  
Vocational Skills**

**A Thesis Presented**

**by**

**Emily Pabarue Bennett**

The Department of Counseling and Applied Educational Psychology

In partial fulfillment of the requirements

for the degree of

**Master of Science**

**in the field of**

**Applied Behavior Analysis**

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Play and Vocational Skills

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**Comparison of Backward and Forward Chaining in the Acquisition of Play and Vocational  
Skills**

by

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Submitted in partial fulfillment of the requirements for the degree of  
Master of Science in Applied Behavior Analysis  
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The Effects of Response Interruption and Redirection on Stereotypic and

Academic Responding

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## Abstract

Three studies are presented comparing forward and backward chaining techniques. In the Experiment 1, an 8-step Lego® play construct was taught. In one condition, a construct was taught using forward chaining techniques and in the other condition a construct was taught using backward chaining techniques in an alternating treatments design. In the Experiment 2, a 12-step Lego® construct was taught using the same procedures outlined above. Finally, in Experiment 3, a pre-vocational task, building chess pieces, was taught. Efficiency of both chaining procedures was measured by number of trials to acquisition and number of error rates across conditions and participants. Results show that both chaining procedures were equally effective; all participants acquired the behavior chains with both chaining procedures and there was little difference in acquisition time and error rate between the two procedures.

## Comparison of Forward and Backward Chaining in the Acquisition of Play and Vocational Skills

A behavior chain is a link between a series of discrete responses that together make up a more complex behavior. Often individuals with disabilities have difficulty performing these complex chains, such as brushing one's teeth. When training a complex behavior, it is sometimes necessary to break down a task into a series of discrete responses and analyze each response. One way to teach a complex behavior chain free of errors and pauses is to use task analysis. Task analysis is used for training individuals with developmental delays for any number of complex behaviors. Using task analysis is often necessary in order to develop independence in a behavior chain.

Each response, or step in the behavior chain, is associated with a specific stimulus condition. Each link functions as a discriminative stimulus for the next response in the chain (Cooper, Heron, & Heward, 2007). For instance, when brushing teeth, picking up the toothbrush (the first step) changes the stimulus conditions and signals the next step – applying toothpaste. Reinforcement occurs at the end of the chain (either contrived or natural) and this reinforcer maintains the effectiveness of previous steps, by making a step a conditioned reinforcer for the step that precedes it. Knowing how a behavior chain works, the training issue “becomes how best to teach a sequence of responses so that the dual function of the associated stimuli is established and subsequent responding is free of errors and pauses” (Spooner, 1984, p. 15).

Horner and Keilitz (1975) successfully taught six developmentally delayed individuals to independently brush their teeth using task analysis. Task analyses are not limited to training self-care activities, however. Task analyses have been used to train vocational skills, such as building small assemblies and solitary play skills (Libby, Weiss, Bancroft, & Ahearn, 2008;

Walls, Zane, & Ellis, 1981). In order to train a task analysis, however, some preparatory work is required.

Prior to training a task analysis, the behavior chain needs to be developed and examined closely. There are three steps necessary to complete prior to training a task analysis (Cooper et al., 2007). The first step is to determine the exact steps and order of the steps for the chain. This integral first step often determines the success of the task analysis. In order to determine the steps of the chain, there are a number of methods that may be used. The designer could observe others performing the task and determine steps from the observations (Foxy, 1982).

Alternatively, if the task is something that the designer is not familiar with, the designer could consult with experts (Cooper et al.).

The next step to complete prior to training is validating the chain of discrete responses. The behavior chain should be evaluated based on many variables. For instance: is the chain natural or awkward, and does the chain make functional sense? One method to determine the success of the chain is to have a second person perform the steps exactly as they are read to them. This may help identify missing steps or to clarify unclear descriptions.

Finally, the designer must determine the best way to implement training. Prior to training, the trainer should watch the individual attempt to perform the response in order to determine which steps are independent, or which prove challenging and need to be broken down further. In addition, there are many procedural variables that determine the course of training. Procedural variables primarily consist of chaining and response prompting sequences. Task analyses promote independence in behavior chains, particularly for developmentally delayed individuals, and choosing the most efficient procedure is imperative for the success of these chains.

Identifying the best teaching procedures for behavior chains can be an involved process because of the number of variations available to trainers. Determining which procedural variables are appropriate depends on which measure of efficacy is used. There are a number of ways to measure the effectiveness and efficiency of procedural variables. The first measure of effectiveness is the efficiency of the procedure. Efficiency can be measured in terms of trials to mastery or how long each trial takes to complete (Spooner & Spooner, 1984). Another way to determine the best training method is to determine the number of errors to mastery, that is, how many errors the individual makes during training. Walls, Crist, Sienicki, and Grant (1981) compared chaining techniques; their primary measurement was what types of errors were made: order or placement errors. Often, research comparing procedural variations reports both errors and how many trials are required before the individuals master the chain to determine the most effective variant (Weiss, 1978). Both determinants are important to determine the effectiveness of a task analysis. There are many procedural variations to take into account in light of the above determinants. The most significant decision to be made when implementing task analyses is deciding which procedural variations are the most effective based upon research; however there have been few comparative studies until recently.

### *Prompt Hierarchies*

There are many types of response prompting hierarchies commonly used to train behavior chains. Most include the use of a physical prompt to complete a behavior chain, however, sometimes a picture prompt procedure is used to occasion a response. These can be extremely effective when training a long behavior chain comprised of many different activities, and can facilitate generalization. In a study by Wacker and colleagues, the researchers trained participants to use picture prompts to complete the behavior chain (Wacker, Berg, Berrie, &

Swatta, 1985). In generalization probes, two of the three participants were able to generalize the picture prompt training to dissimilar tasks than those used during training. It is important to note that these picture prompts are given at each step, and the chain is not necessarily learned because it may not be performed without any pictures.

*Least-to-most.* Least-to-Most (LTM) is a commonly employed prompting hierarchy during acquisition of complex behavior chains. Generally these prompting sequences begin with a verbal prompt, modeling, and then physical prompts. Cuvo et al. (1983) successfully taught participants athletic skills using LTM prompting. A procedural issue with LTM is that the participant must make an error in order to receive a more restrictive prompt. Errors during training have been shown to impair discrimination learning (Terrace, 1963) and may increase the likelihood of problem behavior during instruction (Weeks & Gaylord-Ross, 1981). An advantage of LTM prompting is potential efficiency of training. For instance, restrictive prompts are not implemented to train a step if the trainee does not require the prompt. Therefore, there is no time spent using restrictive prompts when they are not necessary.

*Most-to-least.* Another common prompting procedure is most-to-least (MTL). MTL involves applying the most restrictive prompt first and then systematically fading the prompts. Variations of this procedure include most-to-least with a delay imbedded in the prompt sequence and graduated guidance. Walls et al. (1981) compared LTM and MTL prompting hierarchies across mild and moderately disabled individuals. They found that both prompt hierarchies were equally effective at training the individuals and no differences in performance were attributable to the hierarchy. In contrast, Libby et al. (2008) compared MTL and LTM when training five individuals with disabilities to build Lego® constructs. Three of the five participants acquired the behavior chain more quickly with LTM procedures, however 2 participants did not learn the

constructs using the LTM procedure. This suggests that some learners require errorless teaching procedures to acquire behavior chains.

*Most-to-least with delay.* Most-to-least with a delay introduces a delay between the naturally occurring discriminative stimulus and the prompt. This provides the learner with an opportunity to make an independent correct response prior to the response prompt (Handen & Zane, 1987). There are two different types of delay, progressive (the delay increases across sessions) and constant (the delay stays the same, the prompt fades across sessions). There has been research done evaluating a delay imbedded in the prompt hierarchy. Gast, Doyle, Wolery, Ault, and Farmer (1991) compared a progressive time delay with a system of least prompts to train sight word recognition. They found that both prompt hierarchies, with and without verbal consequences, successfully established independent performance. Libby et al. (2008) also compared most-to-least prompting with a constant time delay to LTM and MTL prompt hierarchies. For all three participants in this study, MTL with a constant delay was more effective than MTL, indicating that introducing a delay into the MTL hierarchy is good training option for many individuals.

*Graduated guidance.* Another commonly used prompting strategy is graduated guidance. Graduated guidance is defined by Foxx (1982) as a “technique combining physical guidance and fading, in which the physical guidance is systematically and gradually reduced and then faded completely” (p. 129). Within each trial, full guidance, partial guidance, or shadowing can be used depending on the needs of the trainee at the moment and then fading the prompt immediately. In other words, the level of intrusiveness of a prompt can vary within the trial. Some advantages of this prompting strategy are: feedback is provided immediately to the trainee in the way of physical guidance (or lack thereof), and the trainee does not need to respond before

a prompt is given. A potential disadvantage is that the trainee finds physical guidance reinforcing and waits for the physical prompt from the trainer. Another disadvantage is that graduated guidance requires more expertise on the part of the trainer compared to other prompting strategies.

Despite these disadvantages, there is some research confirming the effectiveness of graduated guidance. MacDuff, Krantz, and McClannahan (1993) successfully taught four boys with autism to follow a photographic picture activity schedule using graduated guidance. The training resulted in more on-task and on-schedule behavior, and enabled the participants to engage in lengthy response chains without adult supervision. Engleman, Altus, Mosier, and Matthews (2003) employed graduated guidance to increase independent dressing in patients with dementia. Nursing assistants were trained to use prompts ranging from least assistance to most assistance. All participants were able to complete the dressing task analysis with less assistance after training.

The research on prompting hierarchies suggest that prompting hierarchies work best when they are individualized to take into account learning styles, learning history with prompting procedures, and whether the learner has imitation or observational skills (Demchak, 1990; Libby et al., 2008). Demchak reviewed the literature on prompting hierarchies and determined that there are many variables to consider when choosing a prompt hierarchy, some of which include: individual learner variables, the goal of the training (fluency or acquisition), and the type of task being trained.

### *Chaining Procedures*

One of the major procedural variations is chaining procedure. There are varying ways of training a task analysis; the question is often which direction to train the steps: forward, backward, or all of the steps at once.

*Forward chaining.* In a forward chain approach, the first step of a task analysis is trained and reinforcement is delivered following that step. The participant performs the first step to a predetermined criterion, and the following steps are added one at a time, until the entire chain has been trained (Spooner, 1984). There are significant benefits to using forward chaining. One is that the individual is only trained on one step at a time, and each response of the chain is paired with the reinforcer while that response is being trained (Weiss, 1978). Pairing the training step with the reinforcer may increase the chances of that step becoming a conditioned reinforcer, which is key to acquiring a behavior chain. Another benefit to using forward chaining is the ease of implementation. Training staff to implement a forward chain appears to be simpler than other options. A disadvantage of using forward chaining is that the learner is not meeting the natural reinforcer at the end of the chain from the beginning of training. For instance, if a student is learning to brush her teeth, the natural contingency is having clean teeth and the task being completed. With forward chaining, this contingency would not be met as a result of her own behavior until the end of training.

There are many studies in the literature that evaluate the effectiveness of forward chains. Cuvo, Leaf, and Borakove (1978) taught janitorial skills to 6 participants with mental retardation using a forward chaining procedure. They used most-to-least prompting during acquisition trials. That is, when the participants completed one step independently, the next step in the sequence was added. The task analysis for cleaning a restroom (consisting of 181 steps) was broken down

into 6 subtasks, and only one subtask (around 20 steps) was targeted at a time. The targeted subtask was trained using forward chaining and least to most guidance as necessary. All six participants acquired the chains rapidly and met mastery criterion at the end of training. This chaining was not compared to any other chaining procedures.

*Total task.* Total task is another chaining option. With total task, the learner begins with the first step and then every step in the sequence is trained during every trial. The teacher prompts completion of a step if it is not performed in a specific amount of time or performed incorrectly. This continues until the learner can independently perform the task (Spooner, 1984). A possible benefit to using a total task method is the potential to increased acquisition because training occurs at every opportunity. The trainee is exposed to each discriminative stimulus and response necessary in each trial and receives training on each step in each session, which may increase the effectiveness of training. However, there are some significant limitations of using this chaining technique. For instance, the learner does not need to be independent in order to add another step to the chain. Not requiring mastery before adding another step may lead to the trainee becoming overwhelmed by learning too many responses at once. Prompt dependency may occur because reinforcement is not contingent upon independently completing the chain, therefore an individual could be prompted throughout the entire chain and still receive reinforcement. Finally, each individual training session may be much longer than other chaining procedures, potentially decreasing the effectiveness if measured by training time until mastery.

Many studies have demonstrated the effectiveness of using total task procedures to train complex behavior chains. Neef, Iwata, and Page (1978) used total task presentation to teach five participants with disabilities to use public transportation. Total task has been shown to be effective, but few studies compare total task with other chaining procedures.

In one study that compared total task to backward chaining, they found that total task promoted more independence at a faster rate than did backward chaining (Spooner, 1984). There are some major limitations to this study, however. Only one participant was trained per condition, and the acquisition data for this participant was compared to another participant's, not controlling for various learning styles across individuals. Also, the prompt hierarchy was not described, nor were all of the results reported. Given the limitations of this study, the results should not be overstated.

*Backward chaining.* Backward chaining is yet another chaining option available. In a backward chain procedure, one step is trained at a time, beginning with the last step. Once the last step is mastered, the second to last step becomes the "training step." The trainee is prompted to complete the "training step" at the prescribed prompt level and then performs the last step independently, followed by reinforcement. This continues until the participant performs the entire chain independently (Spooner, 1984). Foxx (1982) indicates that a backward chain may be necessary if the individual does not have the behaviors in the chain within their repertoire. Foxx (1982) proposes that a backward chain may be more effective for some learners because the last response in the chain is closest to the terminal reinforcer. Since this response is always paired with the terminal reinforcer, it is the strongest response in the chain. In addition, unlike forward chaining the individual is more likely to meet the natural contingency as a result of his/her independent performance.

As mentioned earlier, Spooner (1984) compared backward chaining and total task. The participants trained using backward chaining did not make progress as quickly as the total task participants, but did learn the chain eventually. The authors concluded that total task was preferable to backward chaining because more independence was achieved when viewed in

relation to the time spent training, however, the participants made more errors in the total task condition. Weiss (1978) compared backward and forward chaining procedures. Participants were ten first-year undergraduate students (no developmental delay) with no previous exposure to chaining procedures. The participants were taught to press buttons in a certain sequence using forward and backward chaining. Results indicated that the participants did learn the chains using both chaining procedures, but the error rate was higher with backward chaining. Also, the chains taught were very short compared to the length of behavioral chaining commonly used.

There have been some studies completed comparing the effectiveness of all three chaining procedures. Walls et al. (1981) trained twenty-two participants to assemble three different vocational tasks using the three chaining methods discussed. They measured correct response and two different types of errors (order and placement). Across all participants, errors made during forward and backward chaining were similar compared to a significant increase in error rate using the total task method. Spooner and Spooner (1984) did a review of the chaining literature and found that the chaining techniques are relatively stable across studies; the dependent variable used to determine the efficacy of chaining procedures was not. Studies most often used rate correct and incorrect responses per minute, percent correct, or number of errors. Other variables that were altered across studies included the population and the task trained. After reviewing the literature, various investigations had radically different results, not providing a clear picture of the best chaining procedure and indicating a need for more research in this area (Spooner & Spooner, 1984).

The varying training options when training a task analysis can lead to confusion on the part of the trainer when making daily judgments concerning the best training practices for individuals. More research is necessary to provide a clear picture of the best practice,

particularly concerning chaining procedures. The purpose of this study is to compare the effectiveness and efficiency of forward and backward chaining procedures when training solitary play and vocational skills. Two behavioral chains in each will be taught to participants in an alternating treatment design, one with forward chaining, one with backward chaining. The number of sessions to mastery, trials to mastery, and errors in each condition will be examined.

## Method

### *Participant and Setting*

The participants were 3 males and 1 female diagnosed with an Autism Spectrum Disorder. All lived in a residential school for persons with PDD and were chosen because they possessed the necessary pre-requisite skills for the tasks that were being trained.

Richard, a 17-year-old student, was the oldest participant. Richard had consistently been taught task analyses for self-care and had a limited repertoire with vocational tasks. Richard was verbal and communicated using full sentences. He could follow 2-to-3 step directions and was grouped with a 1:2 teacher to student ratio throughout the day. Harry, a 15-year-old student, had just reached an age that he could participate in vocational tasks. Harry was also verbal and communicated using full sentences. Harry could follow 2-to-3 step directions and was grouped throughout the day. Ted, a 13-year-old student, also participated in this study. He was a verbal student and emitted frequent instances of motor stereotypy throughout the day. Ted had a 1:1 teacher student ratio throughout the day. Finally, Ellen participated in the study. She was 15 years old and communicated using a PECS book.

The study was conducted in a classroom at the school, or in an academic room at the residence. The room contained two chairs and a table and various task materials relevant to the study and the condition being conducted at the time. For Experiment 1, four 8-step Lego® play

constructs were developed. Each play construct consisted of a Lego® base that were different colors but the same size and shape and 7 Lego® pieces associated with a location on the the base. Each step in the task analysis consisted of picking up and placing the Lego® piece in the appropriate location on the base. In Experiment 2, three 12-step Lego® play constructs were developed. Similar to Experiment 1, each play construct consisted of a Lego® base that were different colors and had 11 Lego® pieces to be placed on the base. For Experiment 3, two pre-vocational tasks were developed. The pre-vocational tasks were assembling chess pieces using a screw, bolt, and washers. The chains were each 12-steps, each step consisted on picking up and placing the piece onto the screw. In each experiment, the tasks had the same number of steps and were of a comparable level of difficulty. Each task was trained using forward or backward chaining to compare the effectiveness and efficiency of both chaining techniques. Two 11-trial sessions were conducted per day, 5 days a week.

### *Procedure*

Prior to the study an edible preference assessment was conducted to identify highly preferred edibles for each participant (Fisher et al., 1992). The two most highly preferred edibles were identified for each participant. At the beginning of each session, the participant chose between two stimuli and that item was used as the consequence for correct responding during that session.

Each session consisted of one probe trial followed by 10 training trials. Probe trials were not used to prescribe training steps. The training step was based on the performance in the prior session; rather, the probe trials were designed to provide an opportunity for independent performance so the participant could meet mastery criteria. During the probe trial, the materials for the appropriate construct were placed in front of the participant in random order and the

participant was told to “Build Legos” or “Build the chess piece.” The probe trial was not reinforced and continued until the participant made an error or went 5 s without responding. Data were taken on number of independent correct steps.

The chains were taught using most-to-least prompting with a 2 second constant time delay, either in a forward or backward direction. Each chaining procedure was associated with a different construct in each experiment; the constructs were counterbalanced across participants.

*Prompt Hierarchy.* Most-to-least prompting with a constant time delay began with hand over hand manual guidance. A 2 second delay was given prior to the next 3 levels of the prompt hierarchy: manual guidance at the forearm, manual guidance at the upper arm, and light touch to shadow. The last prompt level was independent.

The following training criteria were used for most-to-least with 2 s delay prompting. An increase to the next prompt level followed 2 successful trials at the prescribed prompt on the training step. An increase to the next training step occurred if the participant successfully anticipated and completed the step independent of the prompt for two consecutive trials, or following two successful trials at independent.

Each training trial began with the materials for the appropriate construct in front of the participant in random order and the participant was told to “Build Legos” or “Build the chess piece.” During the *forward chain* condition, reinforcement was delivered immediately upon correct completion of the training step at the prescribed prompt or independently. For the *backward chaining* condition, reinforcement was delivered following the last step in the chain, if the participant completed the training step at the prescribed prompt or independently.

Errors made on the training step or on a previously mastered step were immediately corrected with hand over hand manual guidance. If two consecutive errors were made on the

training step, an increase in prompt level was prescribed. If two consecutive errors were made on a previously mastered step, that step was retrained, starting with hand over hand manual guidance.

Mastery criterion was met when all steps in the chain were completed independently for two consecutive trials. If performance was 100% correct on a probe trial, another probe trial was run. If both were 100% correct, the pre-vocational construct was mastered. Following mastery, generalization probes were conducted by a novel trainer in a different environment; generally the same day mastery was achieved.

#### *Response Measurement and Interobserver Agreement*

Each step in the task analyses consisted of picking up and placing a piece in the appropriate location. During training, each response was recorded as independent, prompted, or as an error. A response was designated as independent if the participant performs the training step independent of a prompt. For example, if the participant was training on step 2 at a delayed prompt at the upper arm and successfully anticipated and completed the step independent of the prompt, the response was scored as independent. A response was scored as prompted at the training step if the participant performed the step at the prescribed prompt. Finally, a response was scored as an error if the participant did not correctly complete the training step at the designated prompt, or if they made an error on a previously mastered step.

In Experiment 1, interobserver agreement was collected in 40% of sessions for each participant. A second observer determined if the primary observer correctly scored the participants responses accurately (independent, prompted, or an error) in a given trial. Procedural integrity data was also collected in 40% of trials. A second observer recorded if the correct prompt at the training step was used, if the steps in the task analysis were presented and

completed in the correct order, and if reinforcement was delivered according to the training criteria. In the first experiment, mean interobserver agreement exceeded 95% (with a range of 90% to 100%) for both conditions. Procedural integrity scores exceeded 95% (with a range of 92% to 100%) across both conditions.

Interobserver agreement and procedural integrity data in Experiment 2 were collected using the same procedures as Experiment 1. For Experiment 2, mean interobserver agreement was 95% (with a range of 90% to 100%) across both conditions. Procedural integrity was 98% (with a range of 95% to 100%) for both conditions.

In Experiment 3, interobserver agreement and procedural integrity was collected using identical procedures to the first two experiments. Mean interobserver agreement was 94% (with a range of 80% to 100%) and procedural integrity was 95% (with a range of 92% to 100%) across both conditions.

### Results and Discussion

Acquisition graphs for Experiment 1, the 8 step Lego® constructs, are depicted in Figures 1-4. The acquisition graphs depict the last step independently performed on the last training trial for each session. Ted and Harry, our first 2 participants mastered the forward chain and the backward chain in the same amount of sessions. Richard and Ellen mastered the forward chain slightly more quickly than the backward chain, but only by one session each. Following mastery, all participants showed generalization to a new therapist and a new setting. Figure 5 shows the number of trials to mastery for each participant across conditions. There are 10 trials in each session, so if the participant had a 1 session difference in mastery, there could be up to a 10 trial difference. Table 1 shows each participant's number of sessions, total errors, and average errors per session across both conditions. There is virtually no difference in the number

of errors between conditions. Due to the short length of the behavior chains trained in Experiment 1, we thought it possible that the results would be different given a longer chain, which is closer in length to behavior chains typically trained.

In Experiment 2, all procedures were held the same as Experiment 1, except the length of the Lego® constructs. In Experiment 2, we trained 12-step Lego® constructs. Acquisition graphs for Experiment 2, the 12-step Lego® construct, are shown in Figures 6 through 8. Similar to Experiment 1, the graphs depict the last step independently performed on the last trial of each session. Harry and Richard participated in this experiment. Figure 6 shows the acquisition data for Harry. Harry mastered the forward chain in 9 sessions and the backward chain in 7 sessions. Figure 7 shows Richard's data. Richard met mastery criteria for the forward chain in 16 sessions and the backward chain in 14 sessions. Following mastery, both participants showed generalization to a new therapist and a new setting. Figure 8 shows the number of trials to mastery for each participant across conditions. Harry mastered the forward chain in 80 trials and the backward chain in 70 trials. Richard mastered the forward chain in 150 trials and the backward chain in 136 trials. Table 2 shows each participant's number of sessions, total errors, and average errors per session across both conditions. There is no difference in error rate between conditions. In typical training situations, the level of difficulty for different behavior chains is likely to vary. We thought it possible that the level of difficulty may impact the outcome of the experiments, which led us to our third experiment.

In Experiment 3, all procedures were held constant except the behavior chains taught. The behavior chains were vocational tasks, building chess pieces. Once again, both Harry and Richard participated in Experiment 3. Their acquisition graphs are shown in Figures 9 through 11. As the other acquisition graphs, these graphs depict the last step independently performed on

the last trial of each session. Figure 9 shows the acquisition data for Harry. Harry mastered the forward chain in 9 sessions and the backward chain in 11 sessions. Figure 10 shows Richard's data. Richard met mastery criteria for the forward chain in 10 sessions and the backward chain in 11 sessions. Following mastery, both participants showed generalization to a new therapist and a new setting. Figure 11 shows the number of trials to mastery for each participant across conditions. Harry mastered the forward chain in 100 trials and the backward chain in 80 trials. Richard mastered the forward chain in 90 trials and the backward chain in 110 trials. Finally, Table 3 shows each participant's number of sessions, total errors, and average errors per session across both conditions. There was no marked difference in error rate between conditions.

### General Discussion

Overall, the results of these experiments do not support past research that indicated there were clear clinical advantages to one chaining technique relative to the other (Spooner, 1984; Weiss, 1978). For all participants, both the backward and forward chaining procedures were of equal effectiveness, in terms of rate of acquisition and number of errors during acquisition. These results also confirmed that there may be minor differences in rate of acquisition from one learner to another for a variety of reasons.

In Experiment 1, there was no substantial difference in number of trials to acquisition or error rates. For instance, Richard took almost 10 trials longer to learn the forward chain than the backward chain. As confirmed by Experiments 2 and 3, this was not a consistent finding with him across other tasks. It is possible that the relatively short length of the chain in Experiment 1 impacted these results. The chain was only 8 steps in length, and perhaps did not provide enough opportunity for differences resulting from the teaching procedure to emerge. A longer

chain, which is more frequently used when training self-care and vocational tasks, may impact the results.

In Experiment 2, we lengthened the behavior chain to 12 steps, which is comparable in length to typical behavior chains frequently trained. Both participants learned more rapidly with backward chaining than forward chaining, however the differences were, once again, minimal. The greatest difference between chaining techniques observed during this experiment was 15 trials. This is more savings than were observed during Experiment 1, however it is not significantly different. While we increased the length of the chain to be more comparable to typical behavior chains that are trained daily, we did not account for the level of difficulty. In typical training situations, the level of difficulty for different behavior chains is likely to vary. We thought that perhaps it was the case that with “easier” behavior chains there is no difference between chaining techniques, but with more difficult chains a difference would emerge.

In Experiment 3, we trained a more difficult behavior chain, building chess pieces. The participants had no previous experience with this type of task (unlike the Legos®) and the skills necessary to complete this task were more difficult to train, given the smaller materials and the different fine motor skills required (screwing a nut onto a bolt). For both participants in Experiment 3, the forward chaining technique was more efficient. This experiment also had the biggest difference between conditions than the first 2 experiments, a 20 trial difference.

There were some limitations in this study. All of the participants were individuals diagnosed with an autism spectrum disorder, between 13 and 18 years of age who lived in the same residential facility. It is possible that these results may not generalize to other individuals, such as those who do not have an autism spectrum disorder but have some type of intellectual disability. Additionally, the tasks trained during these experiments may not be frequently trained

in typical training situations. These results may not generalize to daily living skills and other types of play and vocational skills that are more frequently trained.

It appears, for these participants and tasks, there is no significant difference between forward and backward chaining. However, it is likely that there are situations in which the chaining technique will make a difference. Whether forward or backward chaining is superior may depend on: individual learner characteristics, current knowledge of sequences within the chain, characteristics of the task, and procedural integrity variables. Further research on chaining techniques is necessary to evaluate the potential impact these variables will have on the efficiency of chaining techniques.

An individual's learning history may impact which chaining technique is more effective. If an individual has learned ten behavior chains using forward chaining, switching to backward chaining may result in delays. Additionally, an individual's knowledge of sequences within a longer chain may impact the efficiency of a given chaining technique. For instance, if an individual already knows how to complete the preparation for tooth brushing, but does not know how to brush their teeth, forward chaining may be more effective, because the trainer would be building upon the individual's current knowledge.

In addition, characteristics of the task may play a significant part in which chaining technique is more efficient. If the end point of a chain is salient to the learner, it is possible that backward chaining would be more effective. One of the reasons that backward chaining may be more efficient than forward chaining for teaching specific chains is because each trial ends with the terminal reinforcer. Foxx (1982) indicated that the "immediate delivery of the terminal reinforcer" is extremely important because it is a powerful reinforcer (p. 110). For instance, if one is training a learner to tie their shoes, backward chaining may be more effective because

each trial ends with the inherent reinforcer (shoes are tied). However, for a task like brushing teeth, the terminal reinforcer may not be as inherently reinforcing or as salient as tying shoes.

Finally, procedural integrity may impact forward or backward chaining differently. It is possible that trainers may have more difficulty running one chaining procedure than the other. A study by Paquette (2008) found that procedural integrity levels at or below 50% resulted in significant delays in learning, or no learning at all. Whether a particular task is more simply run in one direction than another, or trainers are more competent at one chaining technique or the other should be taken into account when choosing chaining procedures. Additionally, does procedural integrity adversely impact one chaining technique more than the other?

Developing efficient and effective procedures for teaching individuals with developmental delays is an extremely important aspect of applied behavior analysis. It appears that there is no significant difference between forward and backward chaining, and as stated before, it is likely that there are a number of variables that may impact the effectiveness of chaining techniques. At this point, it seems important to develop a system for determining chaining procedures that is not solely based on habit or belief that one works for a particular learner, rather than another. There are potentially a number of variables that may impact the results. Further investigation into those variables is the next step in this puzzle.

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Table 1  
*Error Rates Across Conditions in Experiment 1*

Participants	Backward			Forward		
	Total sessions	Total Errors	Avg. errors per session	Total Sessions	Total Errors	Avg. Errors per session
Ted	5	6	1.2	5	3	.6
Harry	4	3	.75	4	4	1
Richard	6	13	2.13	5	15	3
Ellen	5	10	2	4	5	1.25

Table 2

*Error Rates Across Conditions for Experiment 2*

Participants	<i>Backward</i>			<i>Forward</i>		
	Total Sessions	Total Errors	Avg. Errors per Session	Total Sessions	Total Errors	Avg. Errors per session
Harry	6	14	2.3	8	16	2
Richard	14	97	6.9	15	96	6.4

Table 3

*Error Rates Across Conditions in Experiment 3*

Participants	<i>Backward</i>			<i>Forward</i>		
	Total Sessions	Total Errors	Avg. Errors per Session	Total Sessions	Total Errors	Avg. Errors per session
Harry	11	23	2.1	9	30	3.3
Richard	11	54	4.9	10	39	3.9

## Figure Captions

- Figure 1.* The number of sessions to mastery for the 8-step chains for Ted.
- Figure 2.* The number of sessions to mastery for the 8-step chains for Harry.
- Figure 3.* The number of sessions to mastery for the 8-step chains for Richard.
- Figure 4.* The number of sessions to mastery for the 8-step chains for Ellen.
- Figure 5.* The number of trials to mastery for the 8-step chains for all participants.
- Figure 6.* The number of sessions to mastery for the 12-step chains for Harry.
- Figure 7.* The number of sessions to mastery for the 12-step chains for Richard.
- Figure 8.* Number of trials to mastery for the 12-step chains for all participants.
- Figure 9.* Number of sessions to mastery for the vocational chains for Harry.
- Figure 10.* Number of sessions to mastery for the vocational chains for Richard.
- Figure 11.* Number of trials to mastery for the vocational chains for all participants.

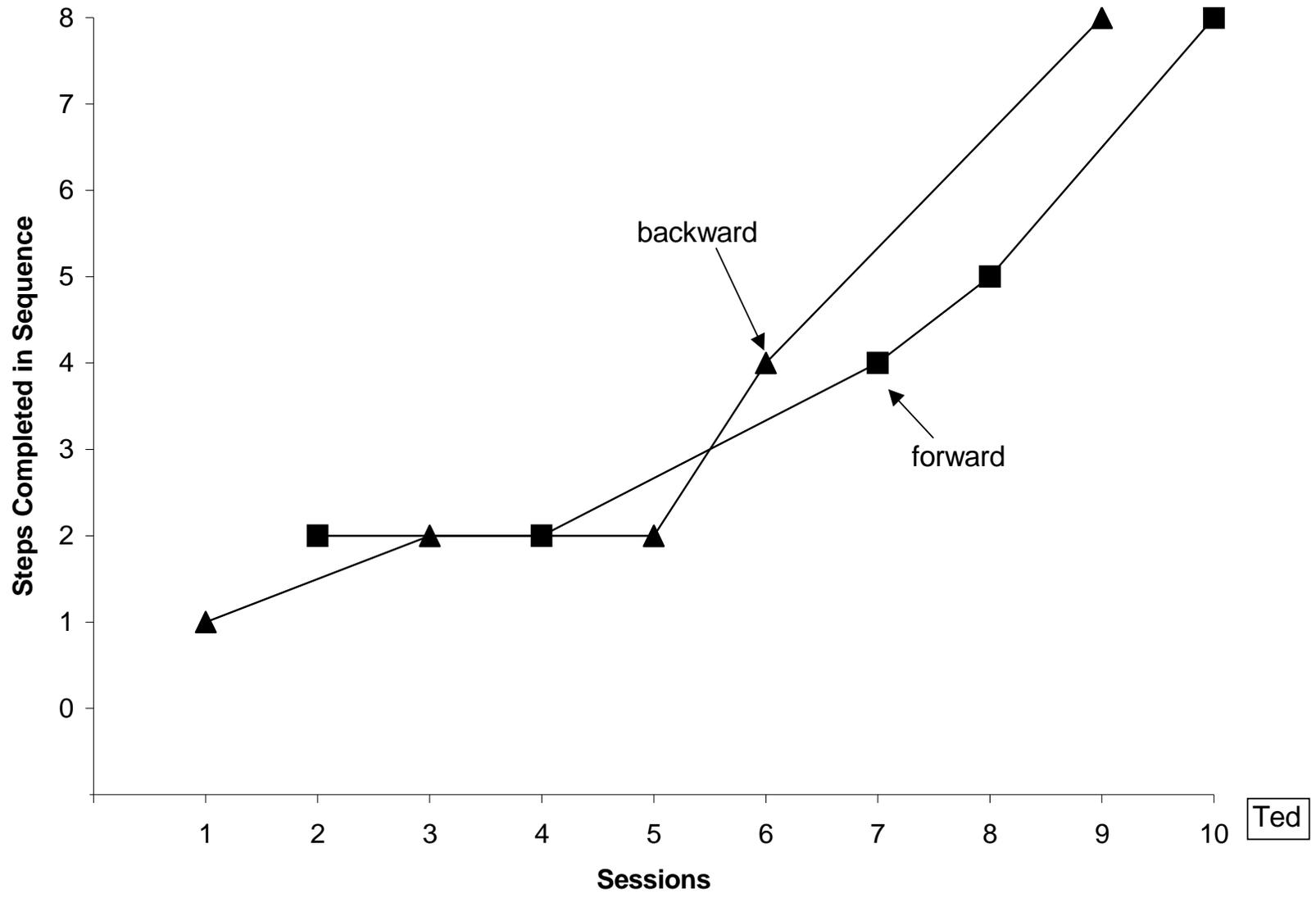


Figure 1.

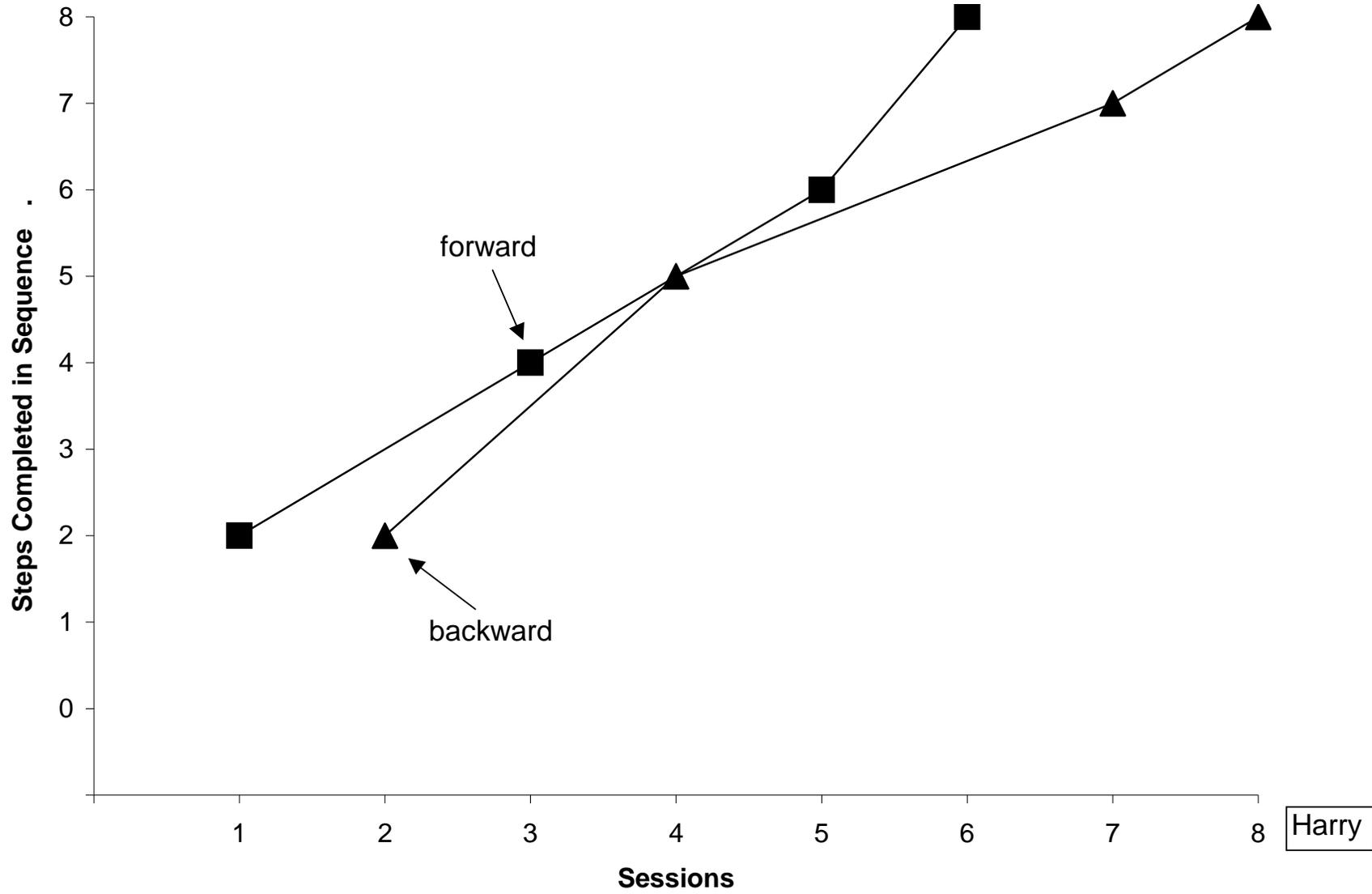
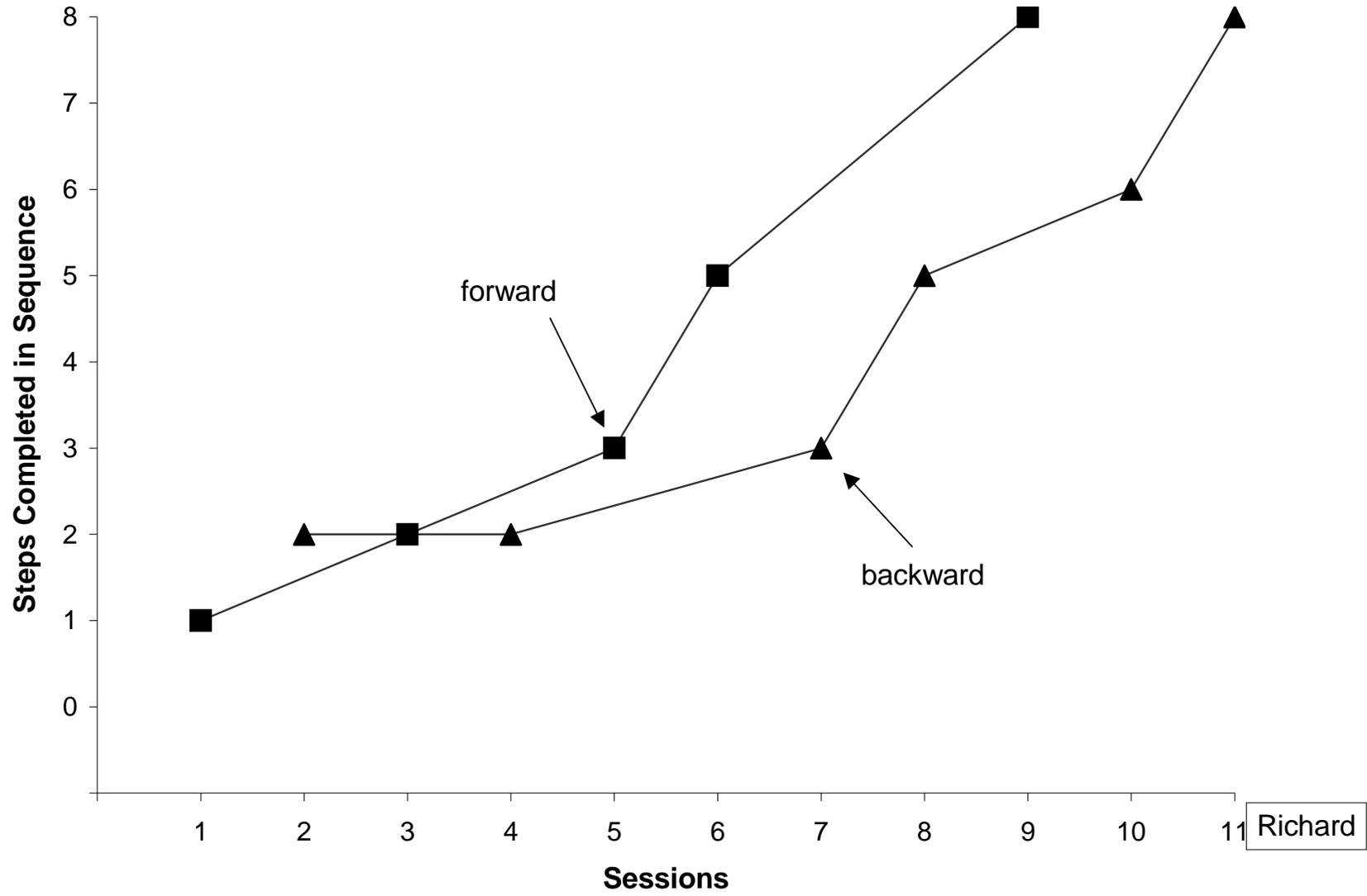


Figure 2.



Richard

Figure 3.

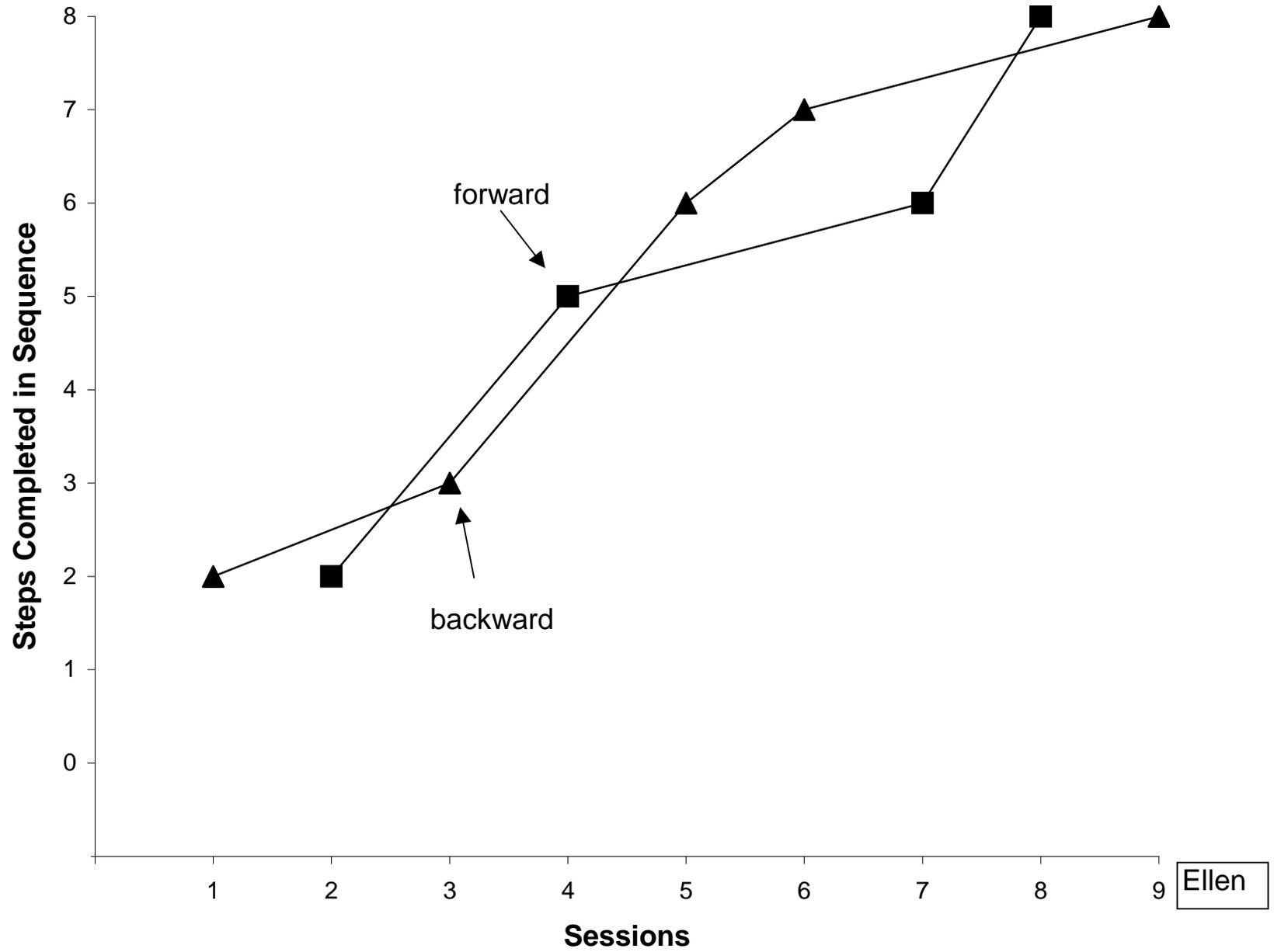


Figure 4.

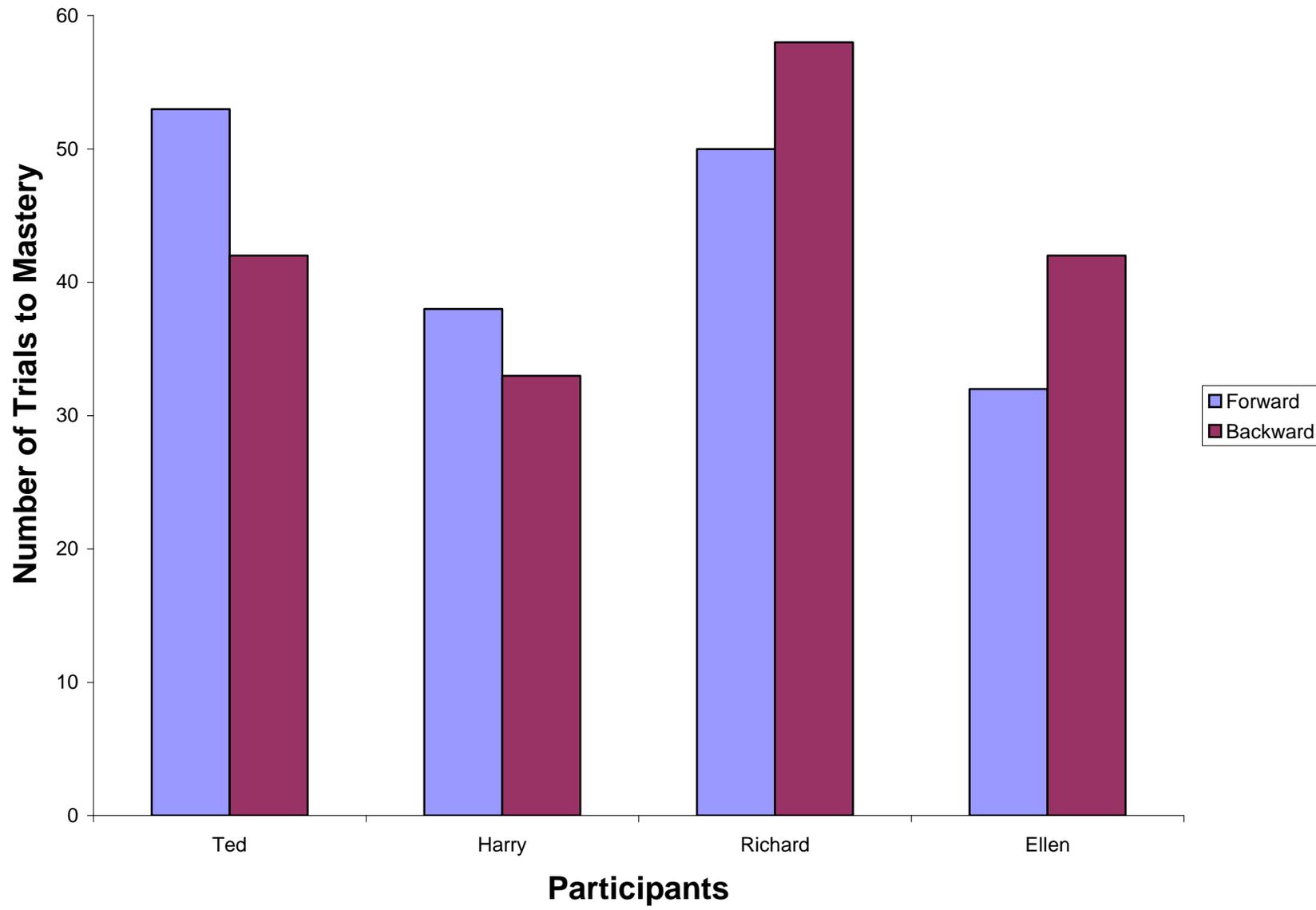


Figure 5.

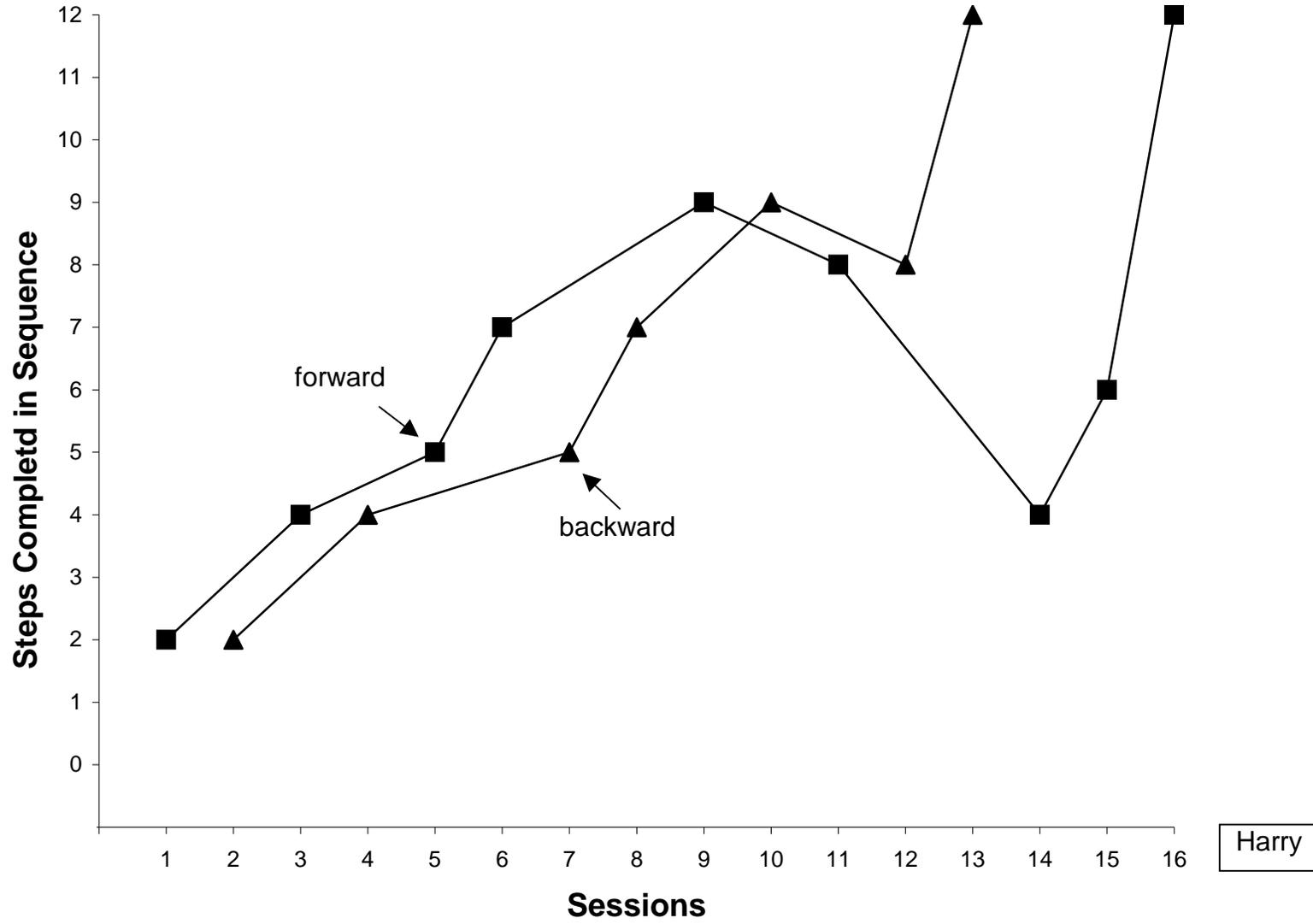


Figure 6

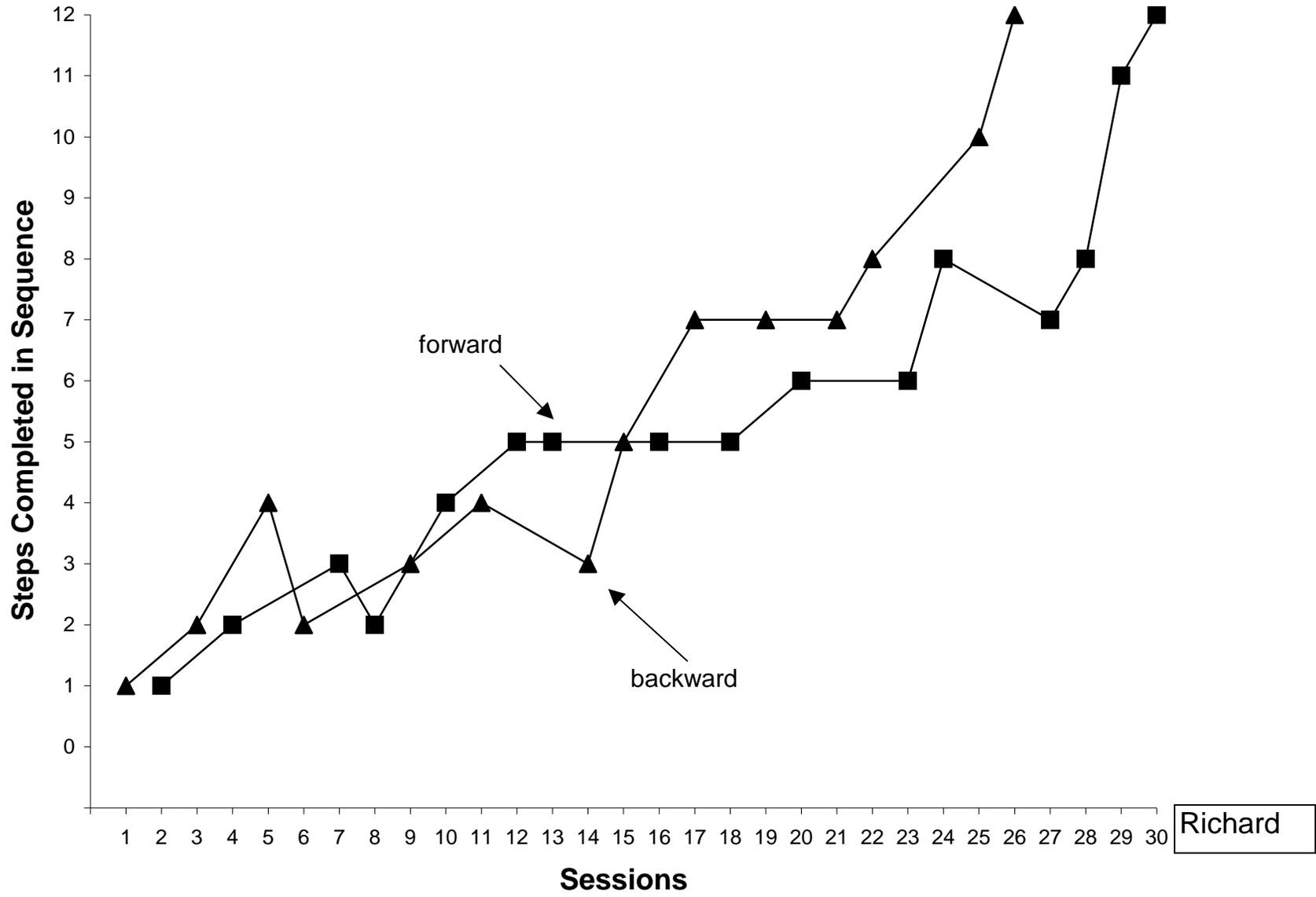


Figure 7

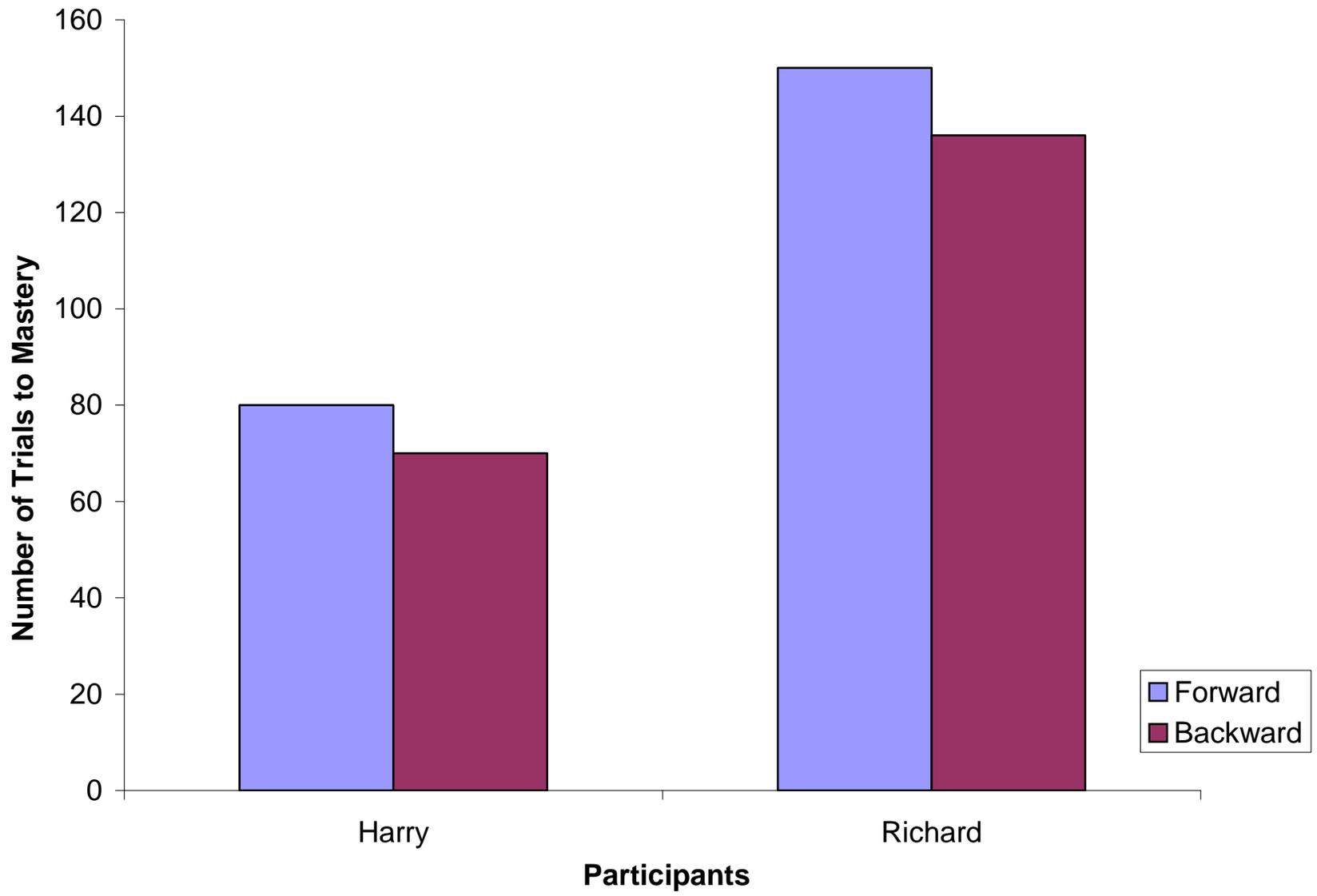


Figure 8.

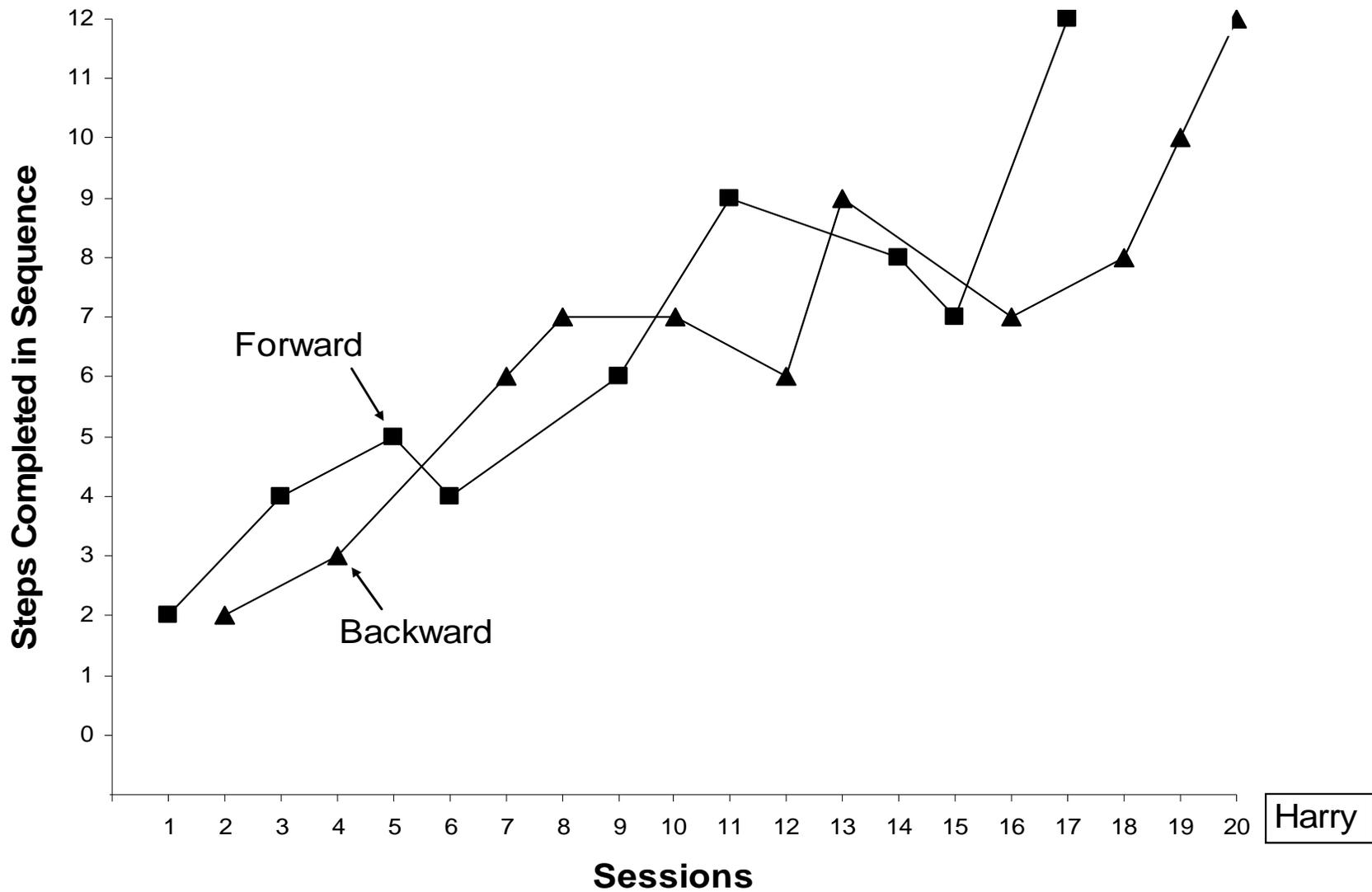


Figure 9.

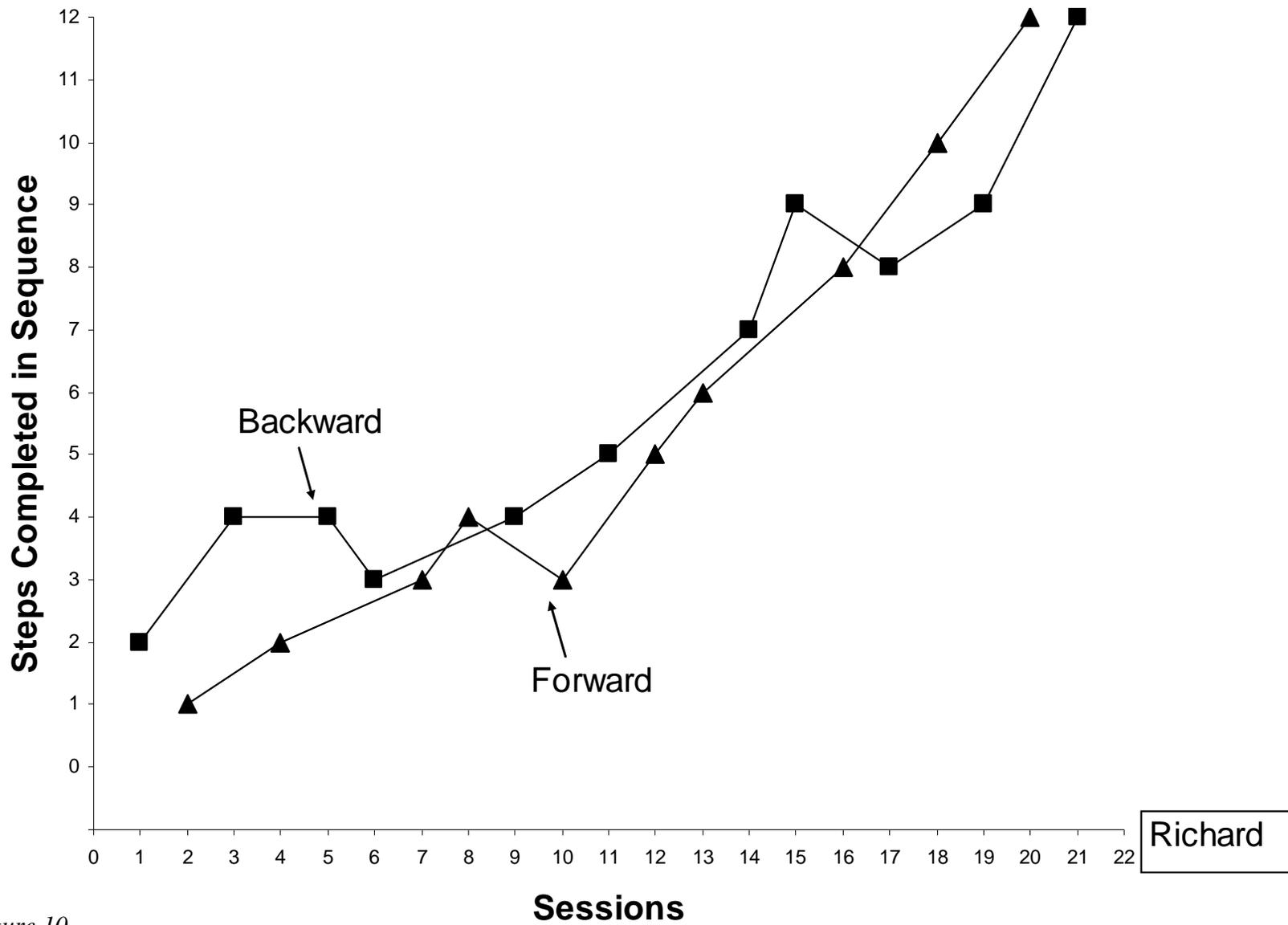


Figure 10.

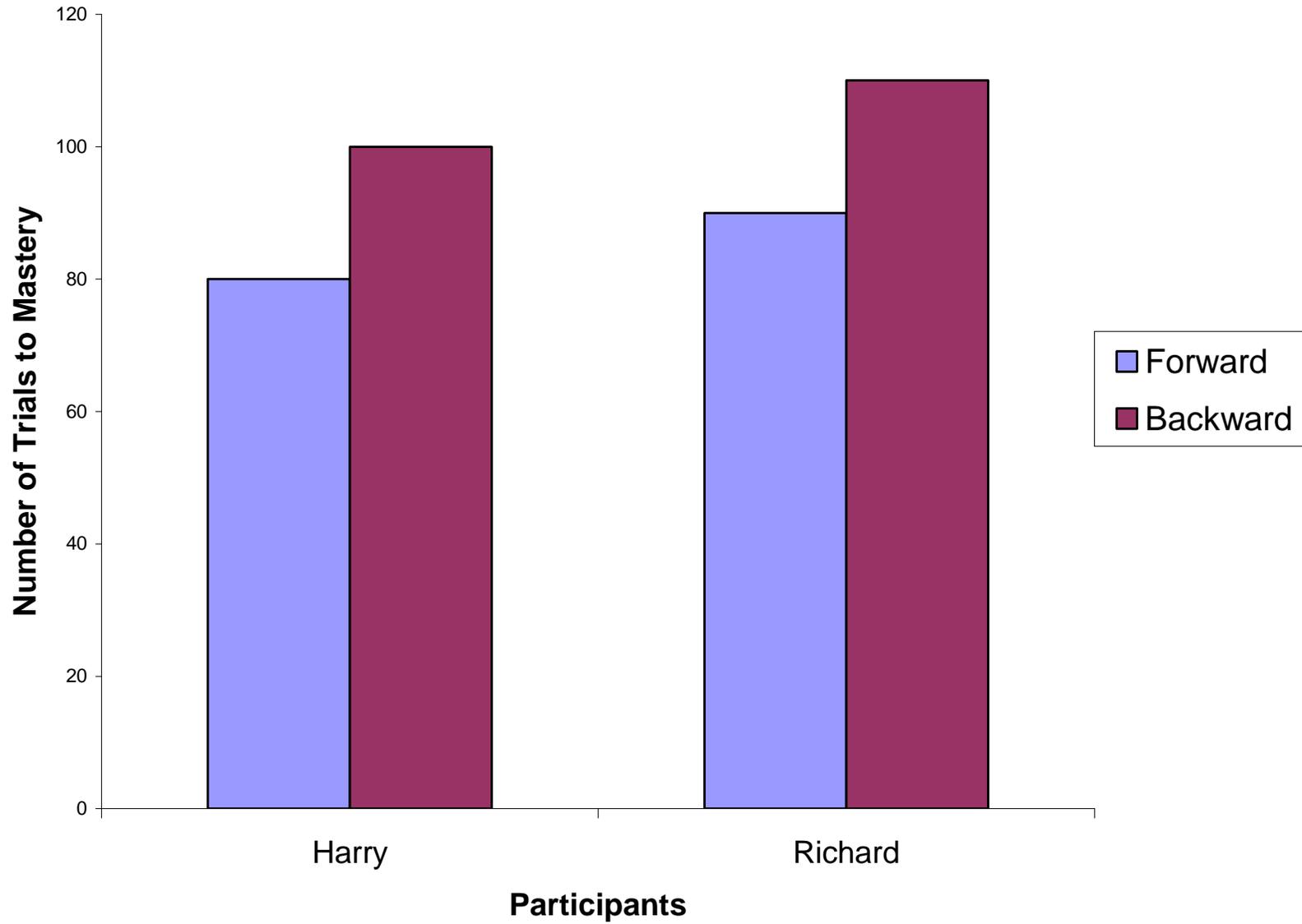


Figure 11