Comparison of Error-Correction Procedures for Teaching Topography- and Selection-Based Responses

by

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Abstract

Discrete-trials teaching is a technique that is commonly used for teaching functional skills to individuals with developmental disabilities. On each trial, a correct response typically leads to a reinforcer while an error leads to a correction procedure. Several studies have compared different error-correction procedures that involved different amounts of practice following an error in teaching different skills such as sight word reading (e.g., Worsdell et al., 2005), math skills (e.g., Rapp et al., 2012), and visual discriminations (e.g., Smith et al., 2006). Although results were mixed, practicing the correct response was generally more effective than no practice for teaching what might be classified as "topography-based" responses, but not for teaching "selection-based" responses. This raises the question: Does the amount of practice following an error interact with the response classes being taught? The present study attempted to address this question by comparing multiple-practice and no-practice error-correction procedures in teaching topography-based (signing or daily living skills) and selection-based responses (2-choice non-identity matching tasks) with 6 adults diagnosed with an intellectual disability and with limited communication skills. The error-correction procedures were compared in an alternating-treatments design to teach topography-based and selection-based tasks within each participant. By excluding 3 comparisons in which the participants did not master any tasks in topography-based training, results on task mastery showed that 4 of the 6 comparisons favored the multiple-practice procedure while 1 comparison favored the no-practice procedure. The remaining comparison showed no difference across procedures. By excluding 1 comparison in which the participant did not master any tasks in selection-based training, results on task mastery showed that 1 of the 4 comparisons favored the no-practice procedure, and 1 comparison showed no difference across procedures. The remaining 2 comparisons favored the multiple-practice procedure. The findings of this study suggest that a multiple-practice error-correction procedure is slightly more effective than a no-practice error-correction procedure for teaching topography-based responses, but not for teaching selection-based responses. If the present results are generalizable, practitioners may wish to use the simpler and less time consuming no-practice procedure for teaching selection-based tasks and reserve the use of a multiple-practice procedure for teaching topography-based tasks.

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Early intensive behavioral intervention has been proven to be an effective treatment for individuals with autism spectrum disorder (Cohen, Amerine-Dickens, & Smith, 2006; Smith, 2008; Smith, Groen, & Wynn, 2000). One of the common teaching strategies used in this intervention is discrete-trials teaching. Research shows that discrete-trials teaching is an effective tool for teaching functional skills not only to individuals with autism spectrum disorder, but also to individuals with intellectual disability (Downs, Downs, Fossum, & Rau, 2008; Downs, Downs, Johansen, & Fossum, 2007; Duker, Didden, & Sigafoos, 2004; Lovaas, 2003; Mash & Barkley, 1998; Maurice, 1996; Smith, 2001; Sundberg & Partington, 1998). Researchers have also developed a number of training programs that could be used to train university students, parents, and practitioners in delivering discrete-trials teaching reliably (Downs, Downs, & Rau, 2008; Thomson, Martin, Arnal, Fazzio, & Yu, 2009). Typically, during discrete-trials teaching, a session contains a block of trials delivered in rapid succession, and each trial includes: (a) an antecedent (e.g., a discriminative stimulus); (b) a response; (c) a consequence following the response; and (d) an inter-trial interval (Ghezzi, 2007; Sigafoos et al., 2006; Smith, 2001; Steege, Mace, Perry, & Longenecker, 2007). For example, on a teaching trial involving sight word reading, the teacher presents a printed word and asks "what's the word" (antecedent). If the student emits a correct response, the teacher praises the student and provides a preferred consequence (e.g., an edible or a preferred activity for a brief period), which will likely be a reinforcer (e.g., Lee, Yu, Martin, & Martin, 2010). If the student emits an incorrect response, the teacher corrects the error. After a brief pause of a few seconds (inter-trial interval), the teacher presents the next trial (another printed word). The training trials are usually repeated until a pre-determined learning criterion is met. There are a number of ways to facilitate learning during discrete-trials teaching such as using antecedent prompt-fading (e.g., Hetzroni & Shalem, 2005; Lorah, Crouser, Gilroy, Tincani, & Hantula, 2014), positive reinforcement contingent upon correct responding (e.g., Francis, 1988; Terrell, Terrell, & Taylor, 1981), manipulating the inter-trial interval (Skinner, Fletcher, & Henington, 1996; Skinner, Smith, & McLean, 1994), interspersing brief and simple tasks (Hawkins, Skinner, & Oliver, 2005; Skinner, 2002), and error correction following incorrect responses. In particular, error-correction procedures that involve different amounts of practice following an incorrect response has been an area of research interest (e.g., Barbetta, Heward, & Bradley, 1993; Barbetta, Heward, Bradley, & Miller, 1994; Worsdell et al., 2005), and is also the focus of the present study.

Error correction during discrete-trials teaching typically consists of the following components: (a) providing verbal feedback (e.g., “No, that’s not right.”), (b) modeling the correct response, (c) requiring the student to practice the correct response, and (d) praising the student for the corrected response (e.g., Barbetta, Heron, & Heward, 1993; Ferkis, Belfiore, & Skinner, 1997; Smith, Mruzek, Wheat, & Hughes, 2006). Several studies have compared no practice to different amounts of practice following an error in teaching different skills such as sight word reading, math skills, and visual discriminations (e.g., Marvin et al., 2010; Rapp et al., 2012). Although results were mixed, practicing the correct response was generally more effective than no practice for teaching what might be classified as “topography-based” responses, but not for teaching “selection-based” responses. This raises the question: Does the amount of required practice following an error interact with the response classes being taught? Although a number of studies have compared different error-correction procedures, previous research has taught either topography-based or selection-based tasks within each study. Differences in participants’ characteristics across studies limit the evaluation of a potential interaction between error-correction procedures and response classes. The present study attempted to address this limitation by teaching both response classes to each participant. In subsequent sections, the concepts of topography-based and selection-based responses are first introduced. Next, research on error-correction procedures grouped by these two response classes is reviewed. The purpose and method of this study are then described, followed by the results and discussion of the findings.

Research on Topography- and Selection-Based Behaviors

Language is verbal behavior produced by a speaker and the behavior is reinforced by a listener (Skinner, 1957). According to Skinner, verbal behavior is defined by the function or causes of a speaker’s response rather than by the form of a response, which may be vocal (e.g., speaking) or non-vocal (e.g., writing, typing, signing, and pointing to pictures). Michael (1985) classified verbal behavior into two general types: topography-based and selection-based verbal behavior. Topography-based verbal behavior involves emitting a response that is unique from another verbal behavior, whereas selection-based behavior involves emitting the same selection response toward an array of stimuli. For example, reading printed words is a topography-based behavior in that different printed words will control or evoke spoken responses that sound different from one another. In contrast, an auditory-visual discrimination that involves pointing to a requested picture in the presence of several pictures is a selection-based behavior in that the pointing response is similar for all pictures. Potter and Brown (1997) pointed out that when learning new topography-based responses, a student must learn to engage in the correct topography and to emit that response in the presence of the appropriate stimulus. When learning selection-based responses; however, a student must learn to emit an effective scanning repertoire and to emit the selection response towards the appropriate stimulus. Catania, Sveinsdottir, DeLeon, Christensen, and Hineline (2002) distinguished topography-based manding from selection-based manding and stated that the former behavior was developed through shaping whereas the latter behavior might be established through discrimination training using stimuli that are different in topographies (e.g., objects that are topographically different in an array).

Since Michael's (1985) conceptualization of the two response classes, there has been considerable research on the relative ease or difficulty in teaching topography-based versus selection-based responses. Results appear to be mixed depending on the type of verbal operants being taught. For example, for tact (e.g., naming responses) and intraverbal (e.g., a verbal response to a verbal stimulus) relations, topography-based responses appeared to be easier to learn than selection-based responses (e.g., Sundberg & Sundberg, 1990). However, for mand relations (e.g., requests), the opposite result was observed (e.g., Barlow, Tiger, Slocum, & Miller, 2013). A more detailed review of the literature in this area can be found in Appendix A.

In the last two decades, researchers have compared the effectiveness of different amounts of practice of correct responses after an error in teaching a variety of skills. This body of research is reviewed below and is grouped by topography-based and selection-based tasks being taught. It should be noted that only studies that compared different amounts of practice following an error during discrete-trials teaching are included in this review.

Error Correction While Teaching Topography-Based Responses

Barbetta et al. (1993) evaluated active-practice versus no-practice following an error during sight word reading with six children with mild to moderate developmental disabilities. During the 8-week training period, 20 unknown words (words read incorrectly twice during an assessment) were identified at the beginning of each week for training. These unknown words, matched on number of syllables, were assigned to the two training procedures and compared in an alternating-treatments design. Each session was comprised of three steps: a pre-session assessment, training trials, and a post-session assessment. In each pre-session assessment, all 20 words (i.e., 10 words in each condition) were presented individually once and in a random order. No programmed consequence was provided in the pre-session assessment for correct or incorrect responses. During training trials, all words in a condition were randomly presented one at a time, and the sequence was repeated twice. Each correct response was followed by praise in both training conditions. Following an error in the active-practice condition, the teacher provided verbal feedback, modeled the correct response, requested a response (e.g., “No, this word is car. What word?”), and praised the student for repeating the word correctly. In the no-practice condition, the error-correction procedure was the same except that the teacher requested the student to look at the word instead of repeating it (e.g., “No, this word is car. Look at it.”). Immediately following the training trials, a post-session assessment was conducted in the same manner as in the pre-session assessment.

A follow-up assessment was also conducted two weeks after the last training session of a given set of words. The results showed that the percentage of correct responses was higher for the words taught in the active-practice condition than for the words taught in the no-practice condition during pre- and post-session assessments, training trials, and the 2-week follow-up assessment for all children except that one student maintained the same level of correct responding in both conditions in the follow-up assessment. Moreover, words corrected in the active-practice condition were read correctly in the next presentation more often than words corrected in the no-practice condition for five of the six children.

Barbetta and Heward (1993) sought to replicate and extend the findings of Barbetta et al. (1993) by comparing the active-practice and the no-practice error-correction procedures during geography facts teaching with three elementary students with learning disabilities and with a Full Scale IQ score between 81 to 90. During the 4-week training period, 14 unknown capitals (capitals stated incorrectly twice during an assessment) were identified at the beginning of each week for training. Each unknown capital was printed on an index card with the corresponding state or country printed on the other side. These unknown capitals were randomly assigned to the two training procedures and compared in an alternating-treatments design. Training procedures were similar to those in Barbetta et al. except that all 14 capitals were randomly presented one at a time and the sequence was repeated twice. Each correct response was followed by praise in both training conditions. Following an error in the active-practice condition, the teacher provided verbal feedback, turned over the index card showing the written correct response while modeling the vocal correct response, requested a response (e.g., “No, its

Denver. Which capital?"), and praised the student for repeating the word correctly. In the no-practice condition, the error-correction procedure was the same except that the teacher requested the student to look at the correct written response instead of repeating it (e.g., "No, it's Denver. Look at it."). The results showed that the percentage of correct responses was higher for the capitals taught in the active-practice condition than for the capitals taught in the no-practice condition during pre- and post-session assessments, training trials, and the 1-week follow-up assessment for all students.

Drevno et al. (1994) examined whether the findings of Barbetta et al. (1993) and Barbetta and Heward (1993) would generalize to: (a) a more complex academic task, and (b) two different populations. Specifically, Drevno et al. compared active-practice and no-practice following errors during science vocabulary teaching with five elementary students, two were gifted and talented students while three were considered at risk for academic failure. A set of 12 unknown science terms were identified at the beginning of each week for training for all students except that a set of eight unknown terms were identified for one of the at-risk students. Each science term was printed on an index card with a 4- to 13-word definition printed on the other side. These unknown science terms were randomly assigned to the two training procedures and compared in an alternating-treatments design. Training procedures were identical to those in Barbetta et al. A response was defined as correct if the student provided a definition which was identical to the definition printed at the back of the index card. In the active-practice condition, the teacher provided verbal feedback, turned over the index card showing the correct written definition while modeling the correct response, asked the student to repeat the definition once, and praised the student for repeating the definition correctly. In the no-practice condition, the error-correction procedure was the same except that the teacher requested the student to look at the definition instead of repeating it. The authors observed that the percentage of correct responses was higher for the vocabularies taught in the active-practice condition than for the vocabularies taught in the no-practice condition during pre- and post-session assessments, and during training trials for all students. Mixed results were observed in the 1-week follow-up assessment.

In a multi-experiment study, Cuvo, Ashley, Marso, Zhang, and Fry (1995) compared single practice, multiple-relevant practice, and multiple-irrelevant practice (control) following errors during spelling (Experiment 3) and sight word reading (Experiment 4) with children with a behavior disorder and an intellectual disability. In Experiment 3, 45 unknown words that were named correctly but spelled incorrectly were identified and randomly assigned to three training conditions (i.e., 15 words in each condition). Fifteen additional words, with more letters and from the higher reading level than the training words, were used in the multiple-irrelevant-practice condition. An alternating-treatments design was used in which two unknown words from each training condition were selected and trained in each training session. During each session, all six unknown words were randomly presented verbally one at a time, and the sequence was presented twice. In each condition, correct responses were praised whereas incorrect responses were followed by one of the three error-correction procedures. In the single-practice condition, the teacher provided verbal feedback (e.g., "No, that is incorrect."), modeled the correct written response and requested the student to imitate the written response once. In the multiple-relevant-practice condition, the teacher provided verbal feedback, modeled the correct written response once and then requested the student to repeat the written response five times. In the multiple-irrelevant-practice condition, the teacher provided verbal feedback, modeled the correct written response once, presented an irrelevant word (from the 15 additional words) and modeled the written response, and then requested the student to repeat the irrelevant word five times. Weekly maintenance assessments were conducted for four consecutive weeks in which all the words mastered previously were assessed. All five children with a behavior disorder required a similar number of assessment trials to meet the acquisition criterion (i.e., word spelled correctly for two consecutive assessment sessions) in all three training conditions. Four of the five children maintained the majority of words in all conditions and the other participant maintained more words in the multiple-relevant-practice conditions than in the single- and multiple-irrelevant-practice conditions. In Experiment 4, the procedures were similar to those in Experiment 3 with exceptions: (a) sight word reading was taught to individuals with intellectual disability, (b) unknown words that were named incorrectly were used for training, (c) each unknown word was individually presented on an index card instead of verbally presented by the teacher, (d) the teacher modeled the correct response by naming the word following an error, and (e) the child imitated the correct response verbally during error corrections. Similar to the results of Experiment 3, four of the five children required a similar number of assessment trials to meet the acquisition criterion in all three training conditions. The remaining participant learned slightly slower in the multiple-irrelevant-practice condition. All children maintained the majority of words in all three conditions. The lack of difference among conditions, however, may have been due to the rapid alternation of the procedures, which was changed after every trial such that the effects of one procedure may have carried over across conditions.

In another study, Ferkis et al. (1997) evaluated the effectiveness and efficiency of single and multiple responses during error corrections with three elementary students in a reading remediation program (one student dropped out in Study 2). Words included in the baseline phase were chosen from the textbooks which were at least one semester higher than the students' reading grade level. Words used in the training phase were those that the student either pronounced incorrectly or did not respond to within 3 s of presentation for three consecutive baseline sessions. An alternating-treatments design was used in which each training session included two training conditions, and the order of the conditions was counterbalanced across sessions. Training was terminated until a pool of approximately 50 unknown words was mastered, and was followed by a 1-week and a 3-week retention test. A word was defined as mastered if it was read correctly within 3 s of the presentation and for three consecutive sessions. The mastered word was then replaced with a new word in the next session. In Study 1, five unknown words were presented randomly once in each training condition. Correct responses were acknowledged (e.g., "Yes, the word is car.") while incorrect responses were followed by one of the two error-correction procedures. In the single-response condition, the teacher provided verbal feedback (e.g., "No, the word is car. Say it."), and requested the student to imitate the response once. In the repeated-response condition, the error-correction procedure was similar to those in the single-response condition except that the student was required to repeat the correct response four more times. In Study 2, the procedure was similar to Study 1 except that the 5-word set was presented three times (total of 15 training trials). The results of both studies showed that all students mastered a similar number of words in both training conditions which was consistent with the findings of Cuvo et al. (1995).

The authors also found that the single-response error-correction procedure was more efficient than the repeated-response error-correction procedure in terms of overall training time.

Worsdell et al. (2005) examined different types of repeated practice on sight word reading with adults with mild to moderate developmental disabilities. Words were screened in the same way as Barbetta et al. (1993) and all words selected were at least one grade higher than each participant's reading grade level. Words trained in each condition were matched on number of syllables. A learned word was defined as three consecutive correct responses within a session and it was replaced with a new word in the next session. Retention tests were conducted daily for words learned in the last training session and weekly for words learned during the previous week. In Experiment 1, the authors compared single- and multiple-practice with six participants in an alternating-treatments design, after an initial differential reinforcement baseline phase in which errors were ignored. In all conditions, the experimenter asked the participant to read a word presented on a card on each trial, and provided an edible or a preferred activity immediately following a correct response. During the single-practice condition, an incorrect response was followed by the teacher providing verbal feedback, modeling the correct response and requesting the student to imitate the response once (e.g., "No, the word is car. Say car."). During the multiple-practice condition, an incorrect response was followed by the teacher providing verbal feedback, modeling the correct response and requesting the student to repeat the response five times with the word card present. In both conditions, the teacher presented the next training trial regardless of whether the student repeated the response correctly. All participants learned to read more words in the multiple-practice condition than in the differential reinforcement baseline and the single-practice condition, but the difference between multiple- and single-practice conditions was small. Four of the six participants retained more words learned in the multiple-practice condition than in the single-practice condition during daily retention tests and all six participants did so during the weekly retention tests. In Experiment 3, Worsdell et al. compared multiple-relevant- and multiple-irrelevant-practice for sight word reading with nine participants. The multiple-relevant-practice condition was the same as the multiple-practice condition in Experiment 1. In the multiple-irrelevant-practice condition, instead of repeating the correct response five times, the teacher provided verbal feedback, modeled the correct response, presented a new word card which was not being trained, modeled the response for the new word, and requested the participant to repeat the new word five times. Three of the nine participants learned more words in the multiple-relevant-practice condition, one learned more words in the multiple-irrelevant-practice condition, and the other five participants performed equally well in both conditions. Mixed results were also observed in the retention tests. In the daily retention tests, five participants retained more words learned under the multiple-relevant-practice condition while four participants retained more words learned under the multiple-irrelevant-practice condition. In the weekly retention tests, six participants retained more words learned under the multiple-relevant-practice condition while two participants retained more words learned under the multiple-irrelevant-practice condition.

Marvin et al. (2010) pointed out that the study by Worsdell et al. (2005) was not designed to examine: (a) whether the effects of error-correction procedures would generalize to the untrained words and contexts, and (b) whether the error-correction procedures could be implemented by the school personnel with minimal training. Therefore, Marvin et al. sought to extend the findings of Worsdell et al. by evaluating the effects of the multiple-response error-correction procedure on sight word acquisition with four students using a multiple-baseline-across-sets-of-sight-words research design. Unknown words were selected from the Instant Fry Word List (Fry, 1980) and were randomly assigned to three to four sets of 10-20 sight words, which were then introduced to each participant sequentially. During the baseline phase (no practice), on each trial, a sight word was presented together with a verbal instruction "what is this?" Students were praised for each correct response whereas they were acknowledged with the word "okay" for each incorrect response. During the response-repetition phase, the procedure was similar to that of the baseline phase except that students were required to repeat the correct response five times following each incorrect response. Training was introduced to a new word set if the current training set was mastered or achieved stabilization. A word set was mastered if the student responded correctly on 80% or more of the training trials for two of three consecutive sessions. A stable rate of responding was defined as correct responding that did not vary more than 15% across at least three sessions with no trend. Generalization assessment was also conducted with two of the four students to examine if the correct responding generalized to a school setting taught by a classroom teacher for one participant, and to a passages format for the other participant. The findings indicated that the response-repetition error-correction procedure was effective in increasing the sight word acquisition rates for all students. The authors observed that correct responding generalized to the untrained word sets in the baseline phase for one of the four students, to the untrained school setting for another student, and to both untrained word sets in the baseline phase and passage reading for the third student. No generalization was observed for the remaining participant.

Rapp et al. (2012) systematically replicated the study by Marvin et al. (2010) to evaluate: (a) whether the effects of the response-repetition error-correction procedure would increase math facts acquisition rates and math computation accuracy, and (b) whether the training effects would generalize to the untrained math problems, with four children with intellectual disability. A concurrent multiple-baseline-across-sets-of-math-problems research design was used for each participant. A nonconcurrent multiple-baseline across participants research design was also used by introducing the response-repetition error-correction procedure sequentially to each participant for the first set of math problems to examine the between-subject effects. Three to six sets of math facts or problems were identified for each participant, and each training set involved only one type of mathematical operation. During the baseline phase, on each trial, a math problem was presented and the participant was instructed to solve the problem. Similar to the study of Marvin et al., participants were praised for each correct response whereas they were acknowledged with the word “okay” for each incorrect response. During the response-repetition phase, the procedure was similar to that of the baseline phase except that participants were required to verbally repeat the correct response five times following each incorrect response for three of four participants. For the remaining participant, instead of repeating the correct response five times, he was prompted to solve the math problem correctly following an error, and then required to solve two additional math problems involving the same type of mathematical operation. This was done to avoid the participant memorizing the answer of the question. Training was introduced to a new set of math problems if the current training set was mastered or achieved stabilization. The mastery and stabilization criterion were the same as those in Marvin et al. A generalization assessment to math problems presented in a different format (e.g., left-right or top-down format) was conducted with two of the four participants. The findings extended previous research by showing that the response-repetition error-correction procedure was effective in increasing math facts acquisition rates and math computation accuracy for three of the four participants, and correct responding generalized to the untrained math sets for one of these participants. The authors also found that the learned skills generalized to the math problems presented in the different format without training for both participants.

A summary of studies that compared different amounts of practice during error corrections for topography-based response training is shown in Table 1. In conclusion, all five studies that compared practice to no practice during error corrections showed that students had higher correct responding or acquisition rates in the practice condition than in the no-practice condition. Among the five studies that involved different amounts of practice during error corrections, four studies found that students' performances were similar regardless of the amounts of practice required, and the remaining study favored the procedure that involved more practice.

Error Correction While Teaching Selection-Based Responses

Rodgers and Iwata (1991) evaluated three error-correction procedures during visual discrimination training with seven adults with severe to profound developmental disabilities using a multielement design. Participants were taught either an identity or a nonidentity, 3-choice visual matching-to-sample task. Task stimuli were computer-

Table 1

Studies that Compared Different Amounts of Practice Following an Error for Topography-Based Tasks

Authors	Task	Participants	Procedures	Results
Practice versus no practice				
Barbetta, Heron, & Heward (1993)	Sight word reading	6 children, mild to moderate DD	1. *Active practice* - vocal feedback, model, & 1 practice. 2. *No practice* - vocal feedback, model, & look at the word.	More words read correctly in the active-practice condition during training and maintenance for all children except 1 child maintained same level of correct responding during follow-up assessment.
Barbetta & Heward (1993)	Geography facts	3 students, learning disabilities, IQ 81-90	1. *Active practice* - vocal feedback, show the correct written response, model, & 1 practice. 2. *No practice* - vocal feedback, show the correct written response, model, & look at the word.	More words read correctly in the active-practice condition during training and maintenance for all children.
Drevno et al. (1994)	Science vocabularies	2 gifted students, 3 at-risk students	1. *Active practice* - vocal feedback, show the correct written definition, model, & 1 practice. 2. *No practice* - vocal feedback, show the correct written definition, model, & look at the definition.	More words read correctly in the active-practice condition during training for all children. Mixed results were observed in the follow-up assessment.

Table 1 (cont'd).

Studies that Compared Different Amounts of Practice Following an Error for Topography-Based Tasks

Authors	Task	Participants	Procedures	Results
Marvin et al. (2010)	Sight word reading	4 children, Asperger, ADHD, ESL, moderate ID	1. *No practice* (baseline) - "Okay" after an error. 2. *Response repetition* - same as baseline plus 5 practices.	Response repetition increased words mastered over baseline for all students. Some generalization was observed.
Rapp et al. (2012)	Math problems	4 children, ID	1. *No practice* (baseline) - "Okay" after an error. 2. *Response repetition* - same as baseline plus 5 practices or 1written practice plus solving 2 additional math problems.	Response repetition increased math computation accuracy over baseline for 3 students. Limited generalization was observed.

Table 1 (cont'd)

Studies that Compared Different Amounts of Practice Following an Error for Topography-Based Tasks

Authors	Task	Participants	Procedures	Results
Different amounts of practice				
Cuvo, Ashley, Marso, Zhang, & Fry (1995), Exp. 3	Spelling	5 male students, behavior disorders, IQ 86-105	1. *One relevant practice* - vocal feedback, model the correct written response, & 1 written practice. 2. *Five relevant practice* - vocal feedback, model the correct written response, & 5 written practices. 3. *Five irrelevant practice* - vocal feedback, model the correct written response, present and model an irrelevant word, & 5 written practices with the irrelevant word.	No difference in acquisition rates was observed in all 3 training conditions for all students. All students maintained majority of words in all conditions except 1 student maintained more words with the multiple-relevant-practice condition.
Cuvo, Ashley, Marso, Zhang, & Fry (1995), Exp. 4	Sight word reading	2 female and 3 male students, IQ 40-65	1. *One relevant practice* - vocal feedback, model, & 1 practice. 2. *Five relevant practice* - vocal feedback, model, & 5 practices. 3. *Five irrelevant practice* - vocal feedback, model, present and model an irrelevant word, & 5 practices with the irrelevant word.	Rates of acquisition were similar across training conditions for all students except 1 student learned slightly slower with the multiple-irrelevant-practice condition. No difference was observed among 3 training conditions during maintenance.

Table 1 (cont'd)

Studies that Compared Different Amounts of Practice Following an Error for Topography-Based Tasks

Authors	Task	Participants	Procedures	Results
Ferkis, Belfiore, & Skinner (1997), Exp. 1	Sight word reading	3 students in the reading remediation program	1. *Single response* - vocal feedback, model, & 1 practice. 2. *Repeated response* - vocal feedback, model, & 5 practices.	No difference was observed on word mastery between two training conditions. Single-practice was more efficient than repeated-practice in terms of overall training time.
Ferkis, Belfiore, & Skinner (1997), Exp. 2	Sight word reading	2 students from Exp. 1	Procedures were identical to those in Exp. 1 except that the sequence of presentation was repeated twice.	No difference was observed on word mastery between two training conditions. Single-practice was more efficient than repeated-practice in terms of overall training time.
Worsdell et al. (2005), Exp. 1	Sight word reading	6 adults, mild to moderate DD	1. *Single practice* - vocal feedback, model, 1 practice. 2. *Multiple practice* - vocal feedback, model, 5 practices.	More words mastered with multiple-practice procedure than with single-practice or differential reinforcement baseline for all participants. Weekly retention favored multiple-practice.

generated symbols, geometric shapes, and Greek letters. In all procedures, a correct response was praised and consequated with either an edible or a penny. Pennies could be exchanged for a soft drink at the end of the session. In the differential reinforcement condition, each error was followed only by the teacher's verbal feedback (e.g., "No, that's wrong."). In the practice condition, each error was followed by the teacher repeating the same training trial until the participant emitted a correct response. During practice trials, correct responses were initially praised and reinforced by an edible or a penny; however, only praise was given once the participant had mastered several matching tasks. In the avoidance condition, each error was followed by the teacher presenting a color-matching task. The number of the color-matching trials and verbal praise statements were yoked to those provided during the preceding session in the practice condition. The results showed that discrimination skills improved rapidly in all three conditions, with one participant showing more cumulative correct responses in the differential reinforcement condition, two participants showing more cumulative correct responses in the practice condition, and three participants showing more cumulative correct responses in the avoidance condition. The remaining participant had a similar number of cumulative correct responses in all three conditions.

Smith et al. (2006) examined the effects of three error correction components on teaching 3-choice word-to-picture matching to six children with an autism spectrum disorder. In all conditions, each correct response was followed by praise and a token (which could be exchanged for a preferred toy or activity once 10 tokens were cumulated). In the no feedback condition, the teacher removed the task materials from the table and then presented the next trial. In the error statement condition, the word "No" in a neutral tone was delivered immediately after an incorrect response. In the modeling condition, the teacher modeled the correct response while saying, “This is matching.” A matching task was defined as mastered if the child responded correctly on 80% or more of the unprompted training trials for two consecutive sessions. Mixed results were observed. Specifically, one child required fewer training trials to reach the criterion of mastery in the error statement condition while another child learned faster in the modeling condition. Two children learned slightly faster in the error statement and the modeling conditions than in the no feedback condition. No difference was observed among the three conditions for the remaining two children.

Magee and Ellis (2006) examined the role of error-correction procedures in reinforcing errors using an A-B research design replicated across participants. Auditory-visual discriminations were taught to 16 undergraduate students with a major in behavior analysis. Task stimuli were one- to three-word behavior terms written in Japanese. In Study 1, on each trial, 10 stimuli were presented on a table and the trainer asked the students to touch the targeted stimulus card when the English translation of a behavior term was given. In both baseline and a 1-week retention assessment, no consequence was provided following a participant’s response. During the training phase, each correct response was praised. In the prompt-all-errors condition, the trainer would model the correct response if the student touched the incorrect stimulus or did not respond within 10 s. In the prompt-incorrect condition, the trainer would model the correct response only if the student touched the incorrect stimulus. In the prompt-no-response condition, the trainer would model the correct response only if the student did not respond within 10 s. In the no-prompt condition, the trainer removed the task materials from the table without providing any feedback, and then presented the next trial. Training was terminated when the student responded correctly on all training trials for four consecutive sets of stimuli. The results showed that students trained in the prompt-all-errors, prompt-incorrect, and prompt-no-response conditions learned faster than those trained in the no-prompt condition during the training phase. However, students trained in the no-prompt condition performed better than those trained in the other conditions during the 1-week retention assessment.

Recently, McGhan and Lerman (2013) examined the reliability of a screening procedure to identify the most effective error-correction procedure for teaching auditory-visual discriminations to five students with autism spectrum disorder. In Phase 1, the authors compared the effectiveness of four error-correction procedures with the procedures presented in a random order. In all conditions, the therapist asked the participant to touch the target stimulus in an array of between three to five stimuli on each trial, and provided an edible immediately following a correct response. In the error statement condition, an incorrect response was immediately followed by the therapist providing verbal feedback (e.g., “No, that is not car.”) in a neutral tone. In the model condition, the therapist re-presented the instruction (e.g., “Touch the car”), and modeled the correct response (e.g., “That’s car” while touching the car) following an incorrect response. In the active student response condition, the consequence of an incorrect response was similar to those in the model condition except that the student was required to emit a correct response with a physical prompt (if needed) after the therapist modeled it once. In the directed rehearsal condition, instead of emitting a single correct prompted or unprompted response during error correction, the student was required to emit three consecutive correct unprompted responses. A task was defined as mastered if the student responded correctly on all the training trials for three consecutive sessions. All students except one required fewer training trials to reach the criterion of mastery in the model condition. The remaining student learned faster in the active student response condition.

A summary of studies that compared different amounts of practice during error corrections for selection-based response training is shown in Table 2. Smith et al. (2006) and Magee and Ellis (2006) were excluded from the table because all error-correction procedures in both studies did not involve practicing the correct responses. In conclusion, contrary to the findings of teaching topography-based responses, both studies that compared practice to no practice during error corrections showed that practicing the correct response was no more effective than no practice following an error in teaching selection-based responses.

Statement of the Problem

In the literature reviewed above, research showed that practicing the correct response, regardless of the amounts of practice, was better than no practice in topography-based response teaching (see Table 1). However, these results were not replicated in selection-based teaching (see Table 2). It is possible that practice is more effective than no practice for teaching topography-based responses because the extra practice facilitates the development of the topographically different responses whereas the benefits are less for developing topographically similar (selection-based) responses. Previous research that compared practice versus no practice procedures taught participants either topography-based or selection-based responses, but not both within the

Table 2

Studies that Compared Different Amounts of Practice Following an Error for Selection-Based Tasks

Authors	Task	Participants	Procedures	Results
Rodgers & Iwata (1991)	3-choice identity or non-identity matching	7 adults with 5 male and 2 female, severe to profound DD	1. *Differential reinforcement* (no practice) - vocal feedback. 2. *Practice* - practice until 1 correct response. 3. *Avoidance* - color matching trials yoked to practice condition.	Correct responses increased in all three conditions with 1 participant favoring differential reinforcement, 2 favoring practice, 3 favoring avoidance, and 1 showed no difference across 3 conditions.
McGhan & Lerman (2013)	Auditory-visual discriminations	5 boys, ASD	1. *Error statement* (no practice) - vocal feedback. 2. *Model* (no practice) – model. 3. *Active response* - model, 1 practice with prompts if needed. 4. *Direct rehearsal* - model, repeat until 3 consecutive correct unprompted responses.	4 students required fewer trials to mastery criterion in the model condition and 1 student did best in the active response condition.

same study. A recent study by Turan, Moroz, and Croteau (2012) taught both response classes. However, the two error-correction procedures did not involve comparing different amounts of practice so it is not possible to directly evaluate the impact of varying amounts of practice on response acquisition across the two response classes. In addition, participants in previous studies involving topography-based responses (Table 1) functioned at a higher level of cognitive ability, and the training tasks were vocal except for Experiment 3 in Cuvo et al. (1995). Research is needed to replicate these findings with individuals who functioned at a lower level of cognitive ability and with the non-vocal tasks so this population would also benefit from the improved efficacy in teaching procedures.

The purpose of the present study was to compare multiple-practice and no-practice error-correction procedures in teaching topography-based responses (signing or daily living skills) and selection-based responses (2-choice non-identity matching tasks) with individuals with severe to moderate intellectual disability. Moreover, non-vocal responses were involved in topography-based tasks and attempts were made to teach both response classes to each participant. It was hypothesized that participants would learn topography-based responses more quickly in the multiple-practice condition than in the no-practice condition, and they would learn selection-based responses more quickly or at a similar rate in the no-practice condition than in the multiple-practice condition.

Method

Participants and Setting

Six adults with intellectual disability and with limited communication skills were recruited from a residential and community resource center for individuals with developmental disabilities. The *Assessment of Basic Learning Abilities* (ABLA) test was conducted with each participant prior to the study to assess his/her ability in learning a simple imitation and five 2-choice discriminations (Martin, Thorsteinsson, Yu, Martin, & Vause, 2008). In previous research, ABLA assessment results have reliably predicted an individual's ability to learn a variety of everyday tasks with standard prompting and reinforcement procedures (Thorsteinsson et al., 2007). All participants in this study had at least passed up to Level 3 (a 2-choice visual discrimination) on the ABLA test, showing that they were able to learn the selection-based training tasks (2-choice non-identity matching tasks) with standard prompting and reinforcement procedures (e.g., matching the word "cat" with the corresponding picture in an array of two pictures). All participants were able to imitate some motor behaviors (e.g., clapping hands, shaking head, blowing kisses, and stomping foot). Participants' characteristics were obtained from their health records, with consent, and are provided in Table 3.

All sessions were conducted in an assessment room, except for Participant 5 whose research sessions were conducted in the bedroom of his community home. The experimenter sat across a table from the participant during each session, and an observer was present during some sessions to conduct reliability and procedural integrity checks (described below).

Task Materials and Equipment

Topography-based tasks. For signs training, materials included color pictures and printed words. Color pictures (each measuring 10 cm x 10 cm) of various objects were presented on a white background (one object per picture). Words were printed in lower case, 54 points Arial Black font on the 12 cm x 7 cm white cards (one word per

Table 3

Participant Characteristics

Participant	Sex	Age	Diagnosis	Communication Skills	Discrimination Skills
1	F	58	Moderate developmental disabilities	No speech, would follow some simple verbal instructions	Able to perform a 2-choice auditory-visual discrimination
2	M	51	Severe developmental disabilities	Able to say a few words, would follow some simple verbal instructions	Able to perform a 2-choice auditory-visual discrimination
3	M	47	Moderate to severe intellectual disability	Able to say a few words, would follow some simple verbal instructions	Able to perform a 2-choice visual discrimination
4	M	43	Autism, developmental disabilities, aggression	Echolalia, able to say 2- to 3-word utterances, would follow some simple verbal instructions	Able to perform a 2-choice visual discrimination
5	M	32	Intellectual disability	No speech, indicate preference via gesture, would follow some simple verbal instructions	Able to perform a 2-choice visual quasi-identity match-to-sample discrimination
6	M	41	Autism, developmental disabilities	No speech, would follow some simple verbal instructions	Able to perform a 2-choice visual discrimination

Note. Discrimination skills were assessed by the *Assessment of Basic Learning Abilities* test (Martin, Thorsteinsson, Yu, Martin, & Vause, 2008).

card). Words trained by each error-correction procedure were matched on the number of letters. Signs trained by each procedure were different response topographies, and they were developed according to the participants' range of body movement. For example, some of the response topographies for Participant 1 included having her fingers extended upward with the palm facing away from the body, sticking her tongue out beyond her lips, and nodding her head up and down. Once the signs were identified, they were randomly paired with either color pictures or printed words to form the baseline tasks. Following the baseline phase, each task was then randomly (except for Participant 2) assigned to each procedure. For Participant 2, tasks were quasi-randomly assigned to the two procedures in order to counterbalance the number of letter words between the two procedures.

For daily living skills training, the materials included all the items needed to perform the tasks. Tasks trained by each procedure were matched as closely as possible based on the number of steps involved in each task.

Table 4 shows a summary of topography-based task characteristics that included information on training types and training stimuli, number of tasks assessed during baseline and taught in the training phase, and the number of an appendix showing the task details for each participant.

Selection-based tasks. All participants were taught to perform 2-choice nonidentity matching tasks. Table 5 shows a summary of the selection-based task characteristics that included information on types of sample and comparison stimuli, number of tasks assessed during baseline and taught in the training phase, and the number

Table 4

Summary of Topography-Based Task Characteristics

Participant	Training Phase	Training Type	Training Stimulus	Number of Tasks Assessed in Baseline	Number of Tasks Taught	Appendix Showed the Task Details
1	1	Signs	Word	21	6	B
	2	Signs	Picture	30	8	C
2	1	Signs	Word	30	9	D
	2	Signs	Word	30	8	E
3	1	Signs	Picture	10	8	F
	2	Daily Living Skills	Object	33	8	G
4	–	Signs	Picture	16	2	H
5	–	Signs	Word	18	6	I
6	–	Daily Living Skills	Object	26	6	J

Table 5

Summary of Selection-Based Task Characteristics

Participant	Sample Stimulus	Comparison Stimulus	Number of Tasks Assessed in Baseline	Number of Tasks Taught	Appendix Showed the Task Details
1	Word	Picture	35	9	K
2	Picture	Word	33	9	L
3	Word	Picture	8	2	M
5	Word	Word	44	10	N
6	Object	Object	23	7	O

of an appendix showing the task details for each participant. For all participants, except for Participant 6, words trained by each procedure were matched on the number of letters. For Participant 6, the objects used in each procedure were matched on the number of different dimensions between the comparison and the sample stimuli.

Edibles and recording equipment. Edibles, identified by the participants' caregivers, were used as reinforcers for all participants. A camcorder was also used to record sessions for later reliability and procedural integrity checks.

Research Design and Phases

For Participants 1, 4, and 5, tasks that were identified for training were assigned randomly to one of the two training procedures (no-practice and multiple-practice). For the remaining participants, tasks were assigned quasi-randomly to ensure the tasks were similar in complexity as much as possible between the two procedures. The training procedures were compared in an alternating-treatments design (Barlow & Hersen, 1984; Martin & Pear, 2015). For Participants 2 through 6, two sessions were conducted on each day, one using the no-practice procedure and the other using the multiple-practice procedure, and the order of the procedures was alternated across days. For Participant 1, one session was conducted on each day with the error-correction procedures alternated across days. This was done because Participant 1 tended to become excessively fatigued when participating in more than one session per day.

The order of topography- and selection-based response training was counterbalanced across participants (see Table 6). Participants 1, 2, and 6 were first trained on selection-based tasks followed by topography-based tasks and the order was reversed for Participants 3 through 5. However, Participant 4 did not master any

Table 6

Order of Training Phases and Type of Tasks

Participant	Phase 1	Phase 2	Phase 3
1	Selection-based Matching printed words to pictures	Topography-based Signing-2[b] to printed words	Topography-based Signing-2[b] to pictures
2	Selection-based Matching pictures to printed words	Topography-based Signing-1[a] to printed words	Topography-based Signing-2[b] to printed words
3	Topography-based Signing-1[a] to pictures	Selection-based Matching printed words to pictures	Topography-based Daily living skills
4	Topography-based Signing-2[b] to pictures	–[c]	–
5	Topography-based Signing-2[b] to printed words	Selection-based Matching printed words to printed words	–
6	Selection-based Matching objects to objects	Topography-based Daily living skills	–

[a] Signing-1 involved signs that were topographically similar such as touching different parts of the body (see Appendices D and F).

[b] Signing-2 involved signs that were topographically different (see Appendices B, C, E, H, and I).

[c] Participant 4 was terminated from the study after Phase 1.

topography-based tasks during training and he exhibited escalating problem behaviors across sessions. Therefore, his involvement in the study was terminated after receiving topography-based training and, consequently, he did not receive selection-based training. In addition, topography-based response training was provided twice to Participants 1 through 3 for various reasons to be described later.

Dependent Variables

The primary dependent variable was number of tasks mastered in each training procedure (no-practice and multiple-practice). The number of tasks mastered was plotted cumulatively across sessions. The secondary dependent variable was the number of correct responses in each training procedure. The definition of a correct response varied depending on the task being trained and is described later. For retention assessment, the dependent variable was the percentage of correct responses per session for tasks mastered with each training procedure.

Procedures for Topography-Based Responses

Baseline phase. During each baseline session for signing (Participants 1 through 3, and 5), two stimuli (either color pictures or printed words) were presented individually six times each in a random order, except for Participant 2 (for whom trials per session was reduced by half because he could not tolerate a longer session). The same stimulus was not presented for more than two consecutive trials. On each trial, the experimenter placed the stimulus on the table in front of the participant, asked the participant to look at it, and asked “What is it?” A correct response was defined as performing the designated sign within 20 s. An incorrect response was defined as performing any other response, initiating but not completing the designated sign within 20 s, or not responding within 20

s. The experimenter provided a brief praise statement (e.g., “great job!”) and allowed the participant to choose one of the six edibles presented on a small dish after a correct response. The experimenter said nothing and provided no other consequences after an incorrect response. Six different praise statements were pre-determined and used in rotation across correct responses (i.e., excellent, way to go, super, wonderful, fantastic, and great job). The experimenter recorded the participant’s response before presenting the next trial. A pair of stimuli was included for training if the participant responded incorrectly on at least 6 of the 12 presentations, with at least three incorrect responses per stimulus. For Participant 2, a pair of stimuli was included for training if he responded incorrectly on at least three of the six presentations for two consecutive sessions with at least three incorrect responses per stimulus across two sessions.

During each baseline trial for daily living skills (Participants 3 and 6), the experimenter placed the necessary items on the table in front of the participant, asked the participant to look at it, and requested the participant to perform the task (e.g., the experimenter said “hang the shirt” after a hanger and a shirt were placed in front of the participant). A correct response was defined as performing all the steps of a task correctly within 30 s. An incorrect response was defined as performing the task with missing step(s), engaging in any response other than performing the requested task, initiating the response but not completing the requested task within 30 s, or not responding within 30 s. Similar to the baseline sessions for signing, each task was presented individually six times each and the same task was not presented for more than two consecutive trials. Moreover, the consequences for correct and incorrect responses, and the inclusion criterion were identical to those for signing.

Training procedure with no-practice error-correction. Each training session included 12 trials (Participant 2 received six trials per session). The training procedure was the same as the baseline procedure as described above, except that following an incorrect response, the experimenter removed the stimulus for 3 s, re-presented the stimulus, and asked the participant to watch while she modeled the correct response once. No practice was required.

A pair of stimuli was considered mastered if the participant responded correctly on at least 10 of the 12 training trials, with no more than one error per stimulus. For Participant 2, the criterion was modified to at least five of the six trials for two consecutive sessions with no more than one error per stimulus across two sessions. After a pair of stimuli had met the mastery criterion, a new pair of stimuli was introduced for training in the next session. A pair of stimuli was replaced if the mastery criterion was not met after it had been presented for 17 training sessions (204 training trials). For Participant 2, the replacement criterion was modified to 34 training sessions.

Training procedure with multiple-practice error-correction. The procedure with multiple-practice error-correction was the same as the no-practice procedure in all aspects with one exception: the participant was requested to practice the correct response five times following an error. Specifically, following an incorrect response, the experimenter removed the stimulus for 3 s, re-presented the stimulus, asked the participant to watch while she modeled the correct response once, and requested the participant to practice the response five times by saying “What is it” for each practice. During the practice trials, the experimenter provided the least amount of prompting (e.g., gesture, light physical guidance, or full physical guidance) necessary to ensure that each response was correct, and the experimenter said "good" in a neutral tone after each correct response.

Reinforcement for non-training tasks. During each session in both baseline and training phases, to maintain the participant's attending behaviors, the experimenter requested the participant to emit a motor behavior unrelated to the task stimuli (e.g., stacking two blocks) after every three trials, except for Participant 5. Physical guidance was provided when necessary to ensure a correct response which was followed immediately by praise. In addition, the participant was asked to choose an edible presented on a small dish. For Participant 5, his attending behavior was excellent within the session. Therefore, he was not requested to emit the motor behavior between trials in order to maintain the momentum of the training trials.

Modified procedures for Participant 4. Procedures were changed to facilitate learning for Participant 4. For the baseline phase, procedures for signing were similar to those as mentioned above except that a verbal instruction of "Show me what to do" was given on each trial. This change was made because he would occasionally emit a vocal response by naming the picture instead of emitting a motor response when the verbal instruction "What is it?" was given to him.

For the training phase, procedures were similar to those as mentioned above at the beginning of the training phase. However, some modifications were made across the training phase to facilitate his learning. First, the verbal instruction "Show me what to do" was repeated once if he touched the stimulus without responding or did not respond within 10 s after the first instruction was given. If he did not respond within 10 s after the second instruction, an incorrect response was recorded. Second, new reinforcers were introduced, and the reinforcement for non-training tasks was terminated to reduce the number of reinforcers given within a session that were not contingent on correct responding during training trials. Third, only one session with 24 training trials was conducted per day using the same procedure to increase the opportunity to practice the correct responses. Fourth, the participant tended to engage in the same response across trials regardless of the antecedent stimulus. Therefore, three motor imitation trials for the less frequently emitted response were immediately given prior to each training trial to increase the probability of that response.

Procedures for Selection-Based Responses

Baseline phase. During each baseline session, a 2-choice non-identity matching task was presented for 12 trials, except for Participant 2 (for whom the trials per session were reduced by half). One sample and two comparisons (correct and incorrect) were presented on each trial. Each sample was presented on half of the trials in a random order, and the left-right positions of the comparisons were counterbalanced across trials. Each sample was not presented for more than two consecutive trials, and the correct comparison was not presented in the same position for more than two consecutive trials.

On each trial, the experimenter presented the comparisons side-by-side on the table in front of the participant and asked the participant to look at the comparisons one by one. The experimenter then showed the sample at the participant's eye level, said "match", and gave the sample to the participant. A correct response was defined as placing the sample on top or in front of the correct comparison within 5 s. An incorrect response was defined as placing the sample anywhere else within 5 s, or not responding within 5 s. The experimenter provided a pre-determined praise statement (e.g., "great job!") and allowed the participant to choose an edible after a correct response, and said nothing after an incorrect response. The experimenter then recorded the participant's response before presenting the next trial. A matching task was included for training if the participant responded incorrectly on at least 6 of the 12 presentations with at least three incorrect responses per sample. For Participant 2, the stimuli were included for training if he responded incorrectly on at least three of the six presentations for two consecutive sessions with at least three incorrect responses per sample across two sessions.

Training procedure with no-practice error-correction. Each training session included 12 trials (Participant 2 received six trials per session), and the training procedure was similar to that of the baseline procedure except that the no-practice error-correction procedure was implemented following an incorrect response during a training trial. Specifically, following an incorrect response, the experimenter removed the stimuli for 3 s, re-presented the stimuli, and asked the participant to watch while she modeled the correct response once by placing the sample on top of the correct comparison. No practice was required.

A matching task was considered mastered if the participant responded correctly on at least 10 of the 12 training trials with no more than one error per sample, except for Participant 2. For Participant 2, a matching task was considered mastered if he responded correctly on at least five of the six presentations for two consecutive sessions with no more than one error per sample across two sessions. After a task was mastered, a new matching task was introduced for training in the next session. A matching task was replaced with a new task if the mastery criterion was not met after 22 training sessions

(264 training trials). For Participant 2, the replacement criterion was modified to 44 sessions.

Training procedure with multiple-practice error-correction. The training procedure with multiple-practice error-correction was the same as the no-practice procedure as described above in all aspects with one exception: the participant was required to practice the correct response five times immediately after the experimenter had modeled the correct response. Specifically, following an incorrect response, the experimenter removed the stimuli for 3 s, re-presented the stimuli, asked the participant to watch while she modeled the correct response once, and requested the participant to practice the response five times by saying “match” for each practice response. Similar to the multiple-practice error-correction procedure for topography-based tasks, during the practice trials, the experimenter provided the least amount of prompting (e.g., gesture, light physical guidance, or full physical guidance) necessary to ensure that each response was correct, and the experimenter said “good” in a neutral tone after each correct response.

Reinforcement for non-training tasks. The procedure was identical to that for topography-based tasks in which the experimenter requested the participant to emit a motor behavior unrelated to the task stimuli after every three trials for the purpose of maintaining the participant’s attending behavior. Again, Participant 5 was not requested to emit the motor behavior between trials in order to maintain the momentum of the training trials.

Retention Assessment

Retention assessment was conducted between seven to nine days after a task was mastered. During the assessment, tasks that were mastered in the previous week were presented four times each. The assessment procedures were identical to those in the baseline phase.

Interobserver Agreement and Procedural Integrity Checks

A trained observer conducted interobserver agreement and procedural integrity checks, either through live observations or randomly selected videotaped sessions. During live observations, the observer independently recorded the participant’s response on each trial prior to the experimenter recording the response on the same trial. When videotapes were used, the observer stopped the video after the participant’s response on each trial and recorded the response before continuing. For each participant, at least 20% of the sessions in each phase and training procedure were evaluated.

Interobserver agreement on participant’s responses was evaluated using percent agreement scores between the observer and the experimenter. The response being evaluated on each trial included whether the participant performed the designated response topography correctly within 20 s during signs training, whether the participant performed all the steps required by a task correctly within 30 s during daily living skills training, and whether the participant placed the sample on top of or in front of the correct comparison within 5 s during the training for non-identity matching. A trial was scored as an agreement if the observer and the experimenter had recorded the same response (correct or incorrect); otherwise, it was scored as a disagreement. Percent agreement per session was calculated by dividing the number of agreements by the sum of agreements and disagreements, and multiplying the quotient by 100 (Martin & Pear, 2015).

To evaluate procedural integrity, the observer scored the experimenter's behaviors on each trial using a procedural checklist, which included whether the experimenter presented the correct stimuli in the correct positions, provided the correct verbal instruction and prompt when needed (verbal prompts were given to Participant 4 only), and delivered the correct consequence (e.g., correct praise statement, choice of edibles, or error-correction) following the participant's response. A trial was scored as delivered correctly if all the checklist items had been followed; otherwise, it was scored as an error. Percentage of trials delivered correctly per session was calculated. The results of interobserver agreement and procedural integrity for each phase and training procedure are shown in Table 7 for topography-based responses and in Table 8 for selection-based responses.

Assessment of Praise Enthusiasm

The level of enthusiasm in praise delivery during topography- and selection-based training was assessed for potential bias. For each participant, at least 15% of the videotaped sessions for each error-correction procedure in each training phase were randomly selected for evaluation. An equal number of praise statements, up to three statements, were randomly selected from each selected session. All selected praise statements were copied into one video file and arranged in a random order. An observer viewed the video with the praise statements and rated the level of enthusiasm of each statement on a 5-point scale (1 = "not enthusiastic", 3 = "enthusiastic", and 5 = "very enthusiastic").

Table 7

Mean Percent of Interobserver Agreement and Procedural Integrity for Topography-Based Tasks

	No-Practice Procedure (%)			Multiple-Practice Procedure (%)		
Participant	Sessions Checked	Interobserver Agreement	Procedural Integrity	Sessions Checked	Interobserver Agreement	Procedural Integrity
Baseline Phase						
1	63	100	100	63	100	100
2	88	100	99.0 (92-100)	90	100	100
3	23	100	100	23	100	100
4	33	100	100	66	100	100
5	20	100	100	100	100	100
6	60	100	100	100	100	100
Training Phase						
1	48	100	99.1 (92-100)	60	99.8 (92-100)	99.3 (92-100)
2	43	100	100	42	100	100
3	38	100	100	40	99.9 (92-100)	99.9 (98-100)
4	31	100	100	37	99.6 (92-100)	99.2 (92-100)
5	22	100	100	22	100	100
6	80	100	100	98	99.6 (92-100)	100
Retention Assessment						
1	67	100	97.3 (92-100)	60	100	100
2	63	100	100	60	100	98.4 (92-100)
3	33	100	100	33	100	100
4	–	–	–	–	–	–
5	60	100	100	100	100	100
6	–	–	–	100	100	100

Note. Dashes indicate no training task was mastered.

Table 8

Mean Percent of Interobserver Agreement and Procedural Integrity for Selection-Based Response Tasks

	No-Practice Procedure (%)			Multiple-Practice Procedure (%)		
Participant	Sessions Checked	Interobserver Agreement	Procedural Integrity	Sessions Checked	Interobserver Agreement	Procedural Integrity
Baseline Phase						
1	40	100	96 (92-100)	60	100	100
2	40	100	100	60	100	100
3	100	100	100	100	100	100
5	20	100	100	20	100	100
6	20	100	100	20	100	100
Training Phase						
1	58	100	100	33	100	98.1 (92-100)
2	66	100	99.1 (92-100)	95	100	99.5 (92-100)
3	73	100	100	73	100	100
5	46	100	98.3 (92-100)	46	100	100
6	59	100	99.5 (92-100)	68	100	99.1 (92-100)
Retention Assessment						
1	33	100	100	20	100	100
2	100	100	100	100	100	100
3	–	–	–	–	–	–
5	40	100	100	60	100	100
6	40	100	100	–	–	–

Note. Dashes indicate no training task was mastered.

Results

Topography-Based Responses

Baseline. Table 9 shows the percent of correct responses during baseline for topography-based tasks that were randomly assigned to the two procedures for training. Although performance varied across tasks and participants, ranging from 0% to 67% correct, performance was generally comparable between the two procedures within each participant with one exception. That is, for Participant 1, the difference in percent of correct responses between the two procedures was 20.9% for the second set of training tasks, which was the highest among all the participants.

Training. Figure 1 shows the cumulative number of training tasks mastered across sessions for each procedure for Participants 1 through 3, who received training on two sets of tasks (see Table 6). With the first set of topography-based tasks (graphs on the left in Figure 1), Participants 1 and 3 did not meet mastery criterion on any tasks with either procedure after 102 (17 sessions x 3 tasks x 2 procedures) and 136 (17 sessions x 4 tasks x 2 procedures) training sessions, respectively. Participant 2's performance favored the multiple-practice procedure only slightly. He mastered four tasks after 56 sessions (average 14 sessions per task, ranging from 9 to 21) with the no-practice procedure and five tasks after 53 sessions (average 10.6 sessions per task, ranging from 4 to 24) with the multiple-practice procedure, respectively. With the second set of topography-based tasks (graphs on the right in Figure 1), Participants 1 and 2 met mastery criterion on more training tasks with the multiple-practice than with the no-practice procedure. Participant 1 mastered three tasks after 15 sessions with the no-practice procedure (average 5 sessions

Table 9

Percent of Correct Responses during Baseline for Topography-Based Tasks that Received Training

		Tasks Assigned to No-Practice (%)						Tasks Assigned to Multiple-Practice (%)					
Participant	Task Sets	1	2	3	4	5	**Mean**	1	2	3	4	5	**Mean**
1	1	17	33	58	–	–	**36.0**	17	25	42	–	–	**28.0**
	2	42	25	25	–	–	**30.7**	17	8	8	8	8	**9.8**
2	1	50	17	58	50	–	**43.8**	42	42	42	50	50	**45.2**
	2	33	67	25	–	–	**41.7**	67	42	42	67	42	**52.0**
3	1	0	0	0	0	–	**0.0**	0	8	0	8	–	**4.0**
	2	0	0	0	–	–	**0.0**	0	0	0	–	–	**0.0**
4	-	0	–	–	–	–	**0.0**	0	–	–	–	–	**0.0**
5	-	42	50	67	50	67	**55.2**	42	–	–	–	–	**42.0**
6	-	0	8	0	–	–	**2.7**	0	0	0	–	–	**0.0**

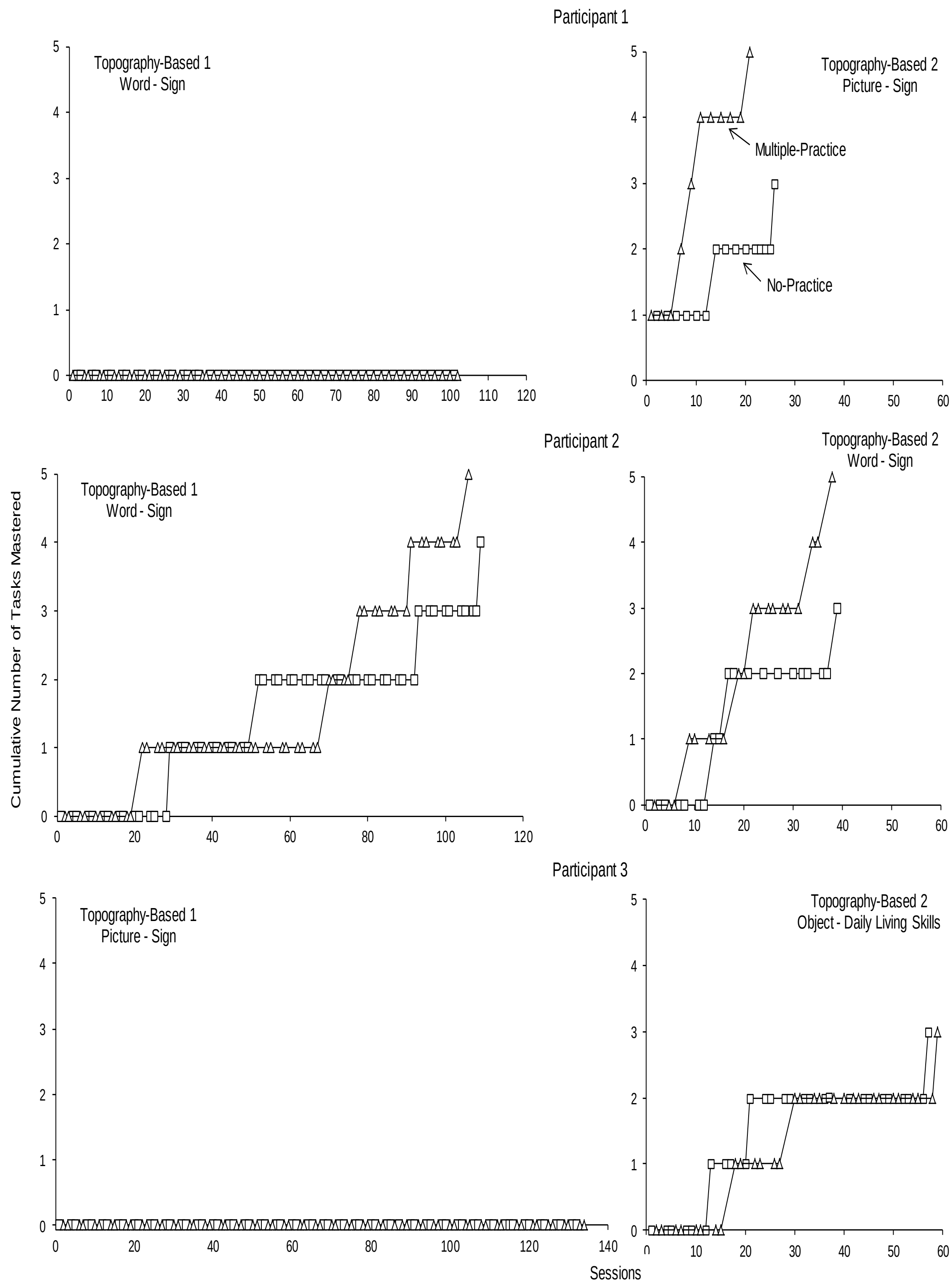

Figure 1. Cumulative number of tasks mastered across sessions during topography-based response training for Participants 1 through 3.

per task, range 1 to 8) and mastered five tasks after 11 sessions with the multiple-practice procedure (average 2.2 sessions per task, range 1 to 5) when picture stimuli were used. Participant 2 mastered three tasks after 20 sessions with the no-practice procedure (average 6.7 sessions per task, range 2 to 10) and mastered five tasks after 19 sessions with the multiple-practice procedure (average 3.8 sessions per task, range 2 to 7) when signs were topographically different from each other. Participant 3 performed similarly with both procedures when he was trained in performing daily living skills. He mastered three tasks with each procedure after 29 no-practice training sessions (average 9.7 sessions per task, range 4 to 18) and after 30 multiple-practice training sessions (average 10 sessions per task, range 6 to 15), respectively.

Figure 2 shows the cumulative number of training tasks mastered across sessions for each procedure for Participants 4 through 6. Participant 4 did not master any tasks after 106 sessions, despite several modifications to the teaching procedures described earlier. Participant 5 mastered five training tasks with the no-practice procedure after 9 sessions (average 1.8 sessions per task, range 1 to 4) and only one task with the multiple-practice procedure after 9 sessions (no range). Participant 6 did not master any tasks after 51 sessions (17 sessions x 3 tasks) with the no-practice procedure, but he mastered three tasks after 40 sessions with the multiple-practice procedure (average 13.3 sessions per task, range 8 to 16).

Overall, four out of nine comparisons favored multiple-practice procedure, and one favored the no-practice procedure. The remaining four comparisons showed no difference between the two procedures, and three of them did not have any training tasks mastered in either procedure.

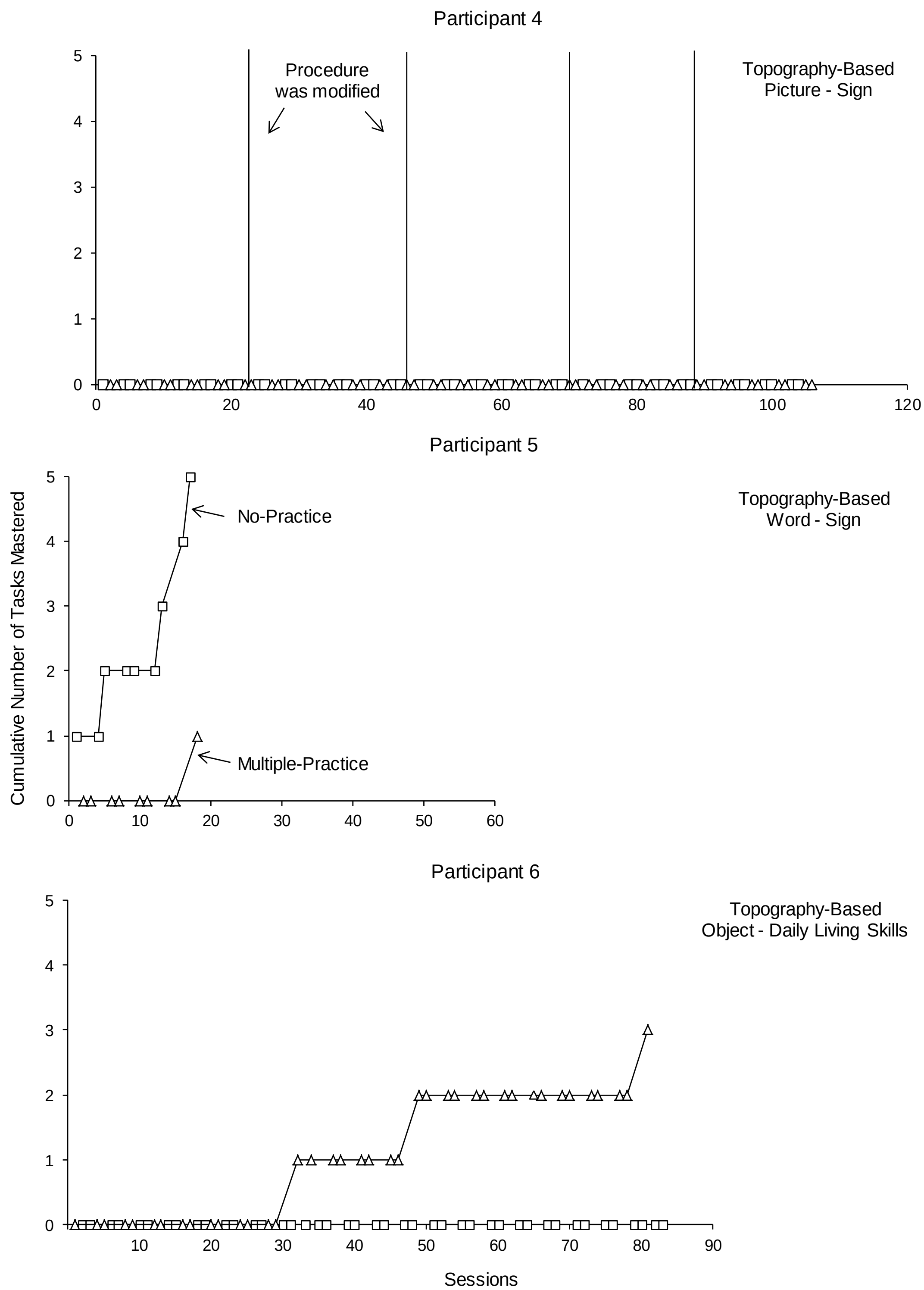

Figure 2. Cumulative number of tasks mastered across sessions during topography-based response training for Participants 4 through 6.

Figures 3 and 4 show the cumulative number of correct responses across sessions for the topography-based response training. Two observations should be noted from these results. First, a procedure that resulted in more task mastery in Figures 1 and 2 (Participant 1 second set of tasks, Participant 2 both sets of tasks, Participant 5 and Participant 6) also showed more correct responses with one exception: Participant 2's first set of tasks showed no difference in correct responses although the difference in task mastery was small. Second, among the four comparisons that showed no difference in task mastery in Figures 1 and 2, differences in correct responses can be seen in Figures 3 and 4, with three comparisons favoring multiple-practice (Participant 1 first set of tasks, Participant 3 second set of tasks, Participant 4).

Retention assessment. Table 10 shows the mean percent of correct responses during the retention assessment for mastered topography-based tasks. Across participants, the mean percent of correct responses was variable and fairly low, ranging from 0 to 75%. When at least one task had been mastered with each procedure during training, the mean retention accuracy was higher for tasks mastered with the multiple-practice procedure.

Selection-Based Responses

Baseline. Table 11 shows the percent of correct responses during baseline for selection-based tasks that were randomly assigned to the two procedures for training. Performance ranged from 17 to 67% correct across tasks and participants, and was generally comparable between the two procedures within each participant.

Training. Figure 5 shows the cumulative number of training tasks mastered across sessions for each procedure during selection-based response training. In general,

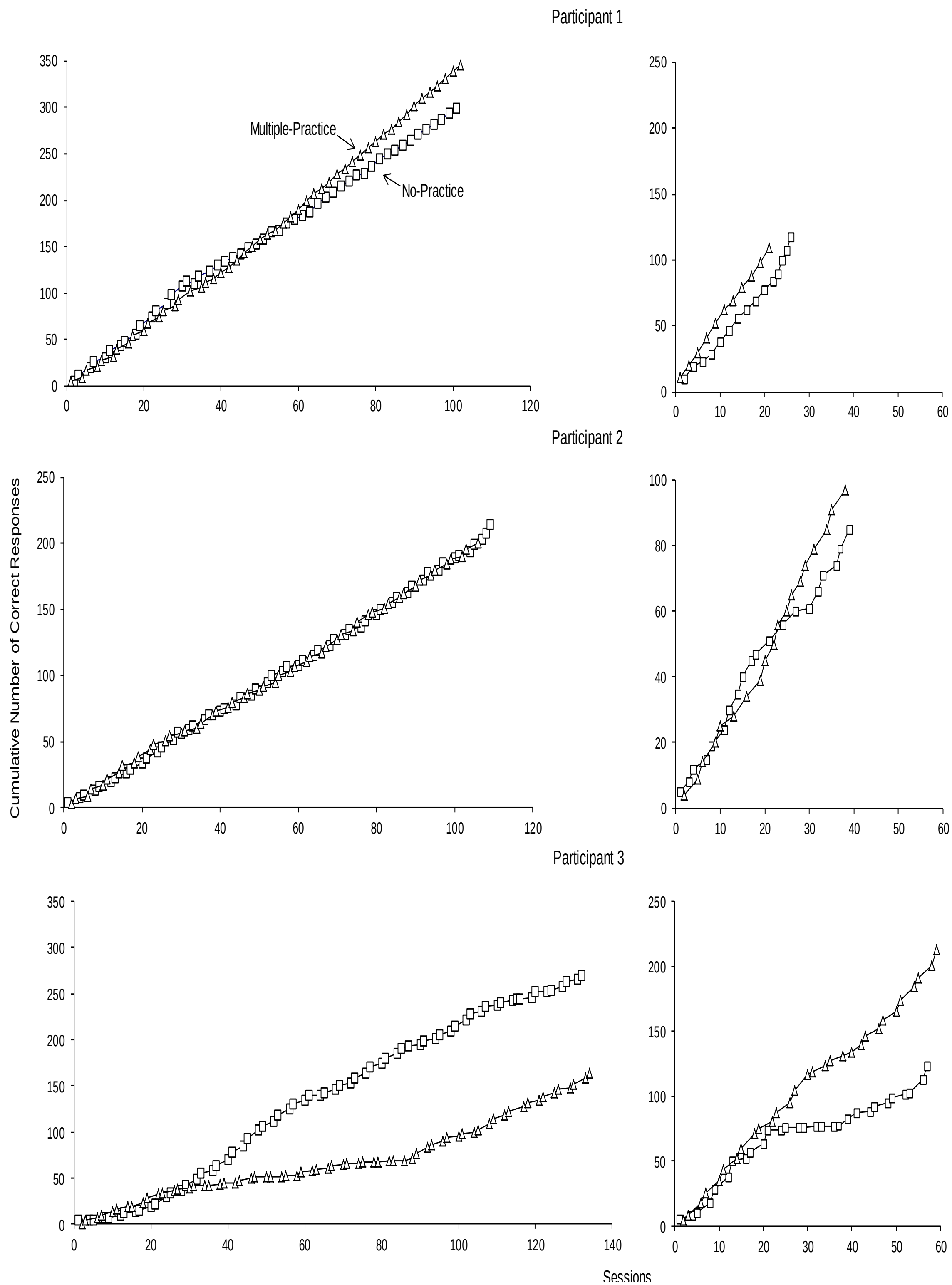

Figure 3. Cumulative number of correct responses across sessions during topography-based response training for Participants 1 through 3.

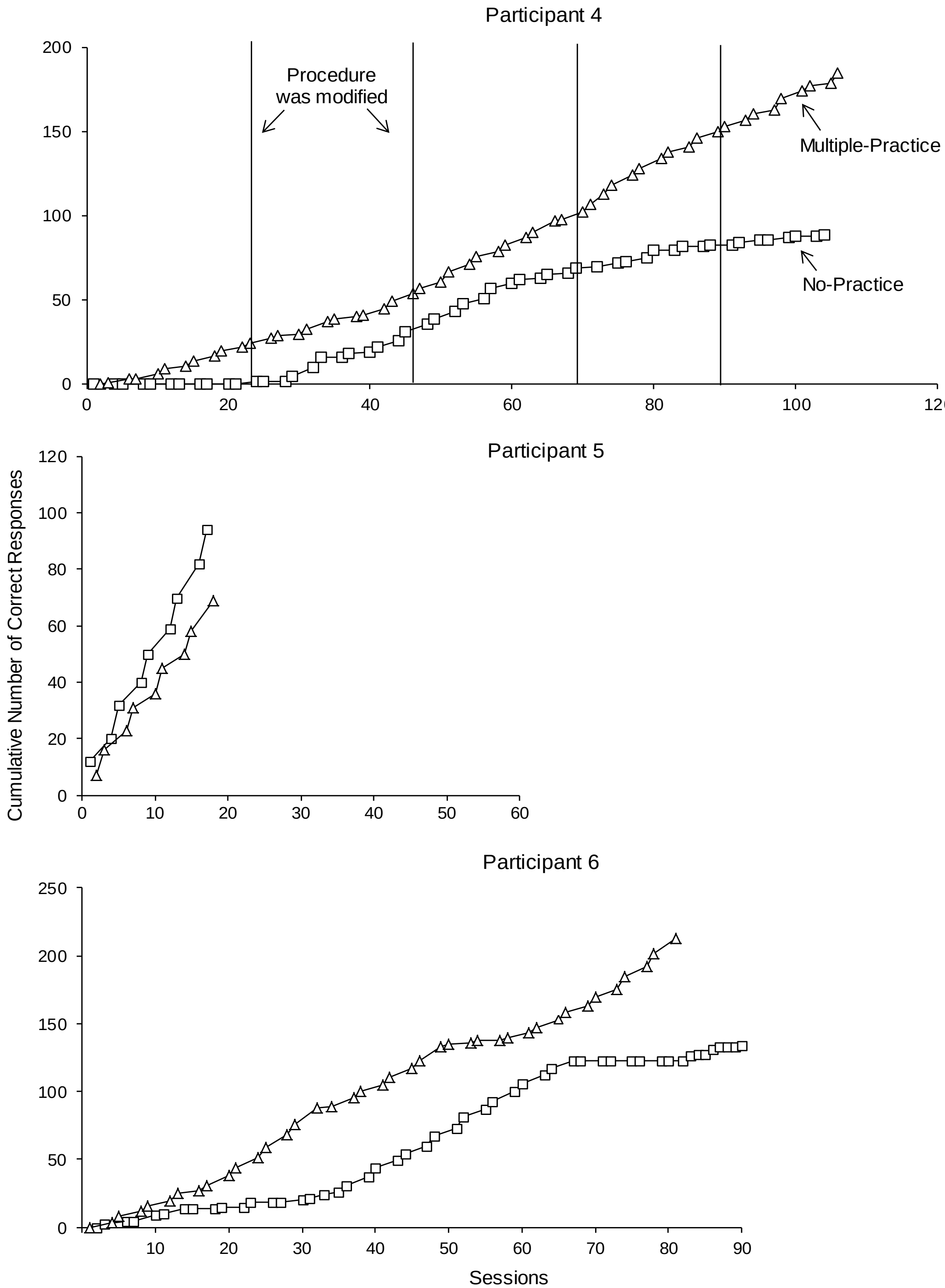

Figure 4. Cumulative number of correct responses across sessions during topography-based response training for Participants 4 through 6.

Table 10

Mean Percent of Correct Responses during Retention Assessment for Topography-Based Tasks

Participant	Task Sets	No-Practice Procedure (%)	Multiple-Practice Procedure (%)
1	1	–	–
	2	0 (no range)	**25 (range 0-50)**
2	1	50 (range 25-75)	**58 (range 25-100)**
	2	0 (no range)	**5 (range 0-25)**
3	1	–	–
	2	**58 (range 50-75)***	**75 (range 50-100)***
4	-	–	–
5	-	**10 (range 0-50)**	25 (no range)
6	-	–	**17 (range 0-50)**

Note. Bolded values represent the procedure for which a participant required fewer training sessions to reach mastery criterion. Dashes indicate no training task was mastered.

* Participant required similar number of training sessions to reach the criterion of mastery in both training procedures.

Table 11

Percent of Correct Responses during Baseline for Selection-Based Tasks that Received Training

	Tasks Assigned to No-Practice (%)						Tasks Assigned to Multiple-Practice (%)					
Participant	1	2	3	4	5	**Mean**	1	2	3	4	5	**Mean**
1	58	33	17	25	–	**33.3**	50	33	50	17	25	**35.0**
2	38	38	38	50	–	**41.0**	50	38	38	50	50	**45.2**
3	33	–	–	–	–	**33.0**	33	–	–	–	–	**33.0**
5	42	50	50	58	50	**50.0**	42	50	50	50	58	**50.0**
6	25	42	50	58	67	**48.4**	42	58	–	–	–	**50.0**

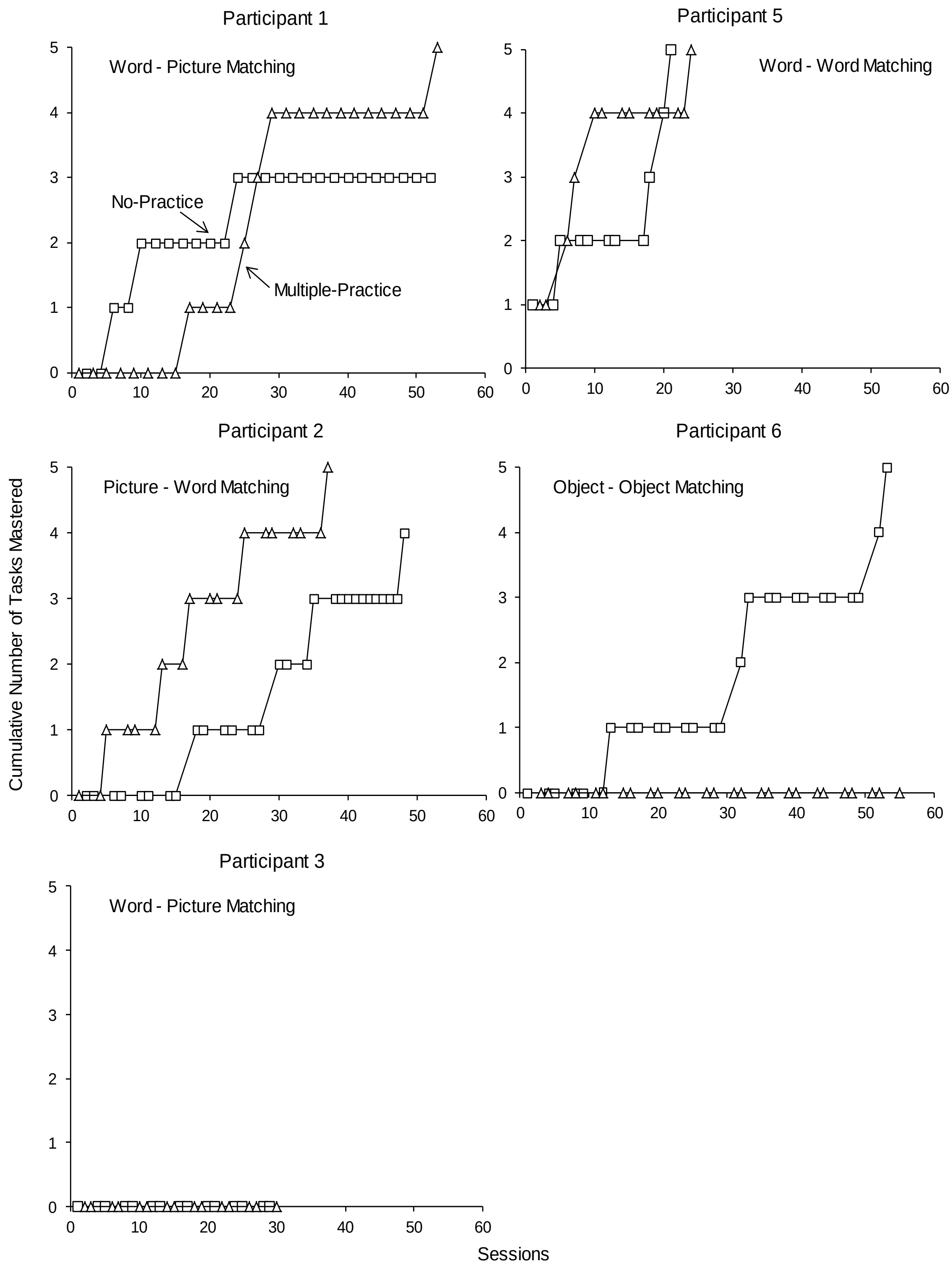

Figure 5. Cumulative number of tasks mastered across sessions during selection-based response training.

Participants 1 and 2 favored multiple-practice, Participant 6 favored no-practice, and Participants 3 and 5 showed similar results with both procedures although Participant 3 did not master any task with either procedure.

Participant 1 mastered three tasks after 26 sessions with the no-practice procedure (average 4 sessions per task, range 2 to 7) and mastered five tasks after 27 sessions with the multiple-practice procedure (average 5.4 sessions per task, range 1 to 12). Participant 2 mastered four tasks after 29 training sessions with the no-practice procedure (average 7.2 sessions per task, range 3 to 11) and mastered five tasks after 19 sessions with the multiple-practice procedure (average 3.8 sessions per task, range 2 to 6). Participant 6 showed the opposite results. He mastered five tasks after 27 sessions with the no-practice procedure (average 5.4 sessions per task, range 1 to 9) and mastered no task after 27 multiple-practice training sessions.

Participant 5 mastered five tasks with each procedure after 11 no-practice training sessions (average 2.2 sessions per task, range 1 to 6) and 13 multiple-practice training sessions (average 2.6 sessions per task, range 1 to 8), respectively. Participant 3 did not master any training tasks after 30 sessions with both training procedures. During this training phase, he had spent 15 sessions in learning one task with each procedure. Position bias was observed during sessions, and training was discontinued.

Figure 6 shows the cumulative number of correct responses across sessions for each procedure during selection-based response training. As expected, Participants 1 and 6 displayed higher correct responses with the procedure in which they mastered more

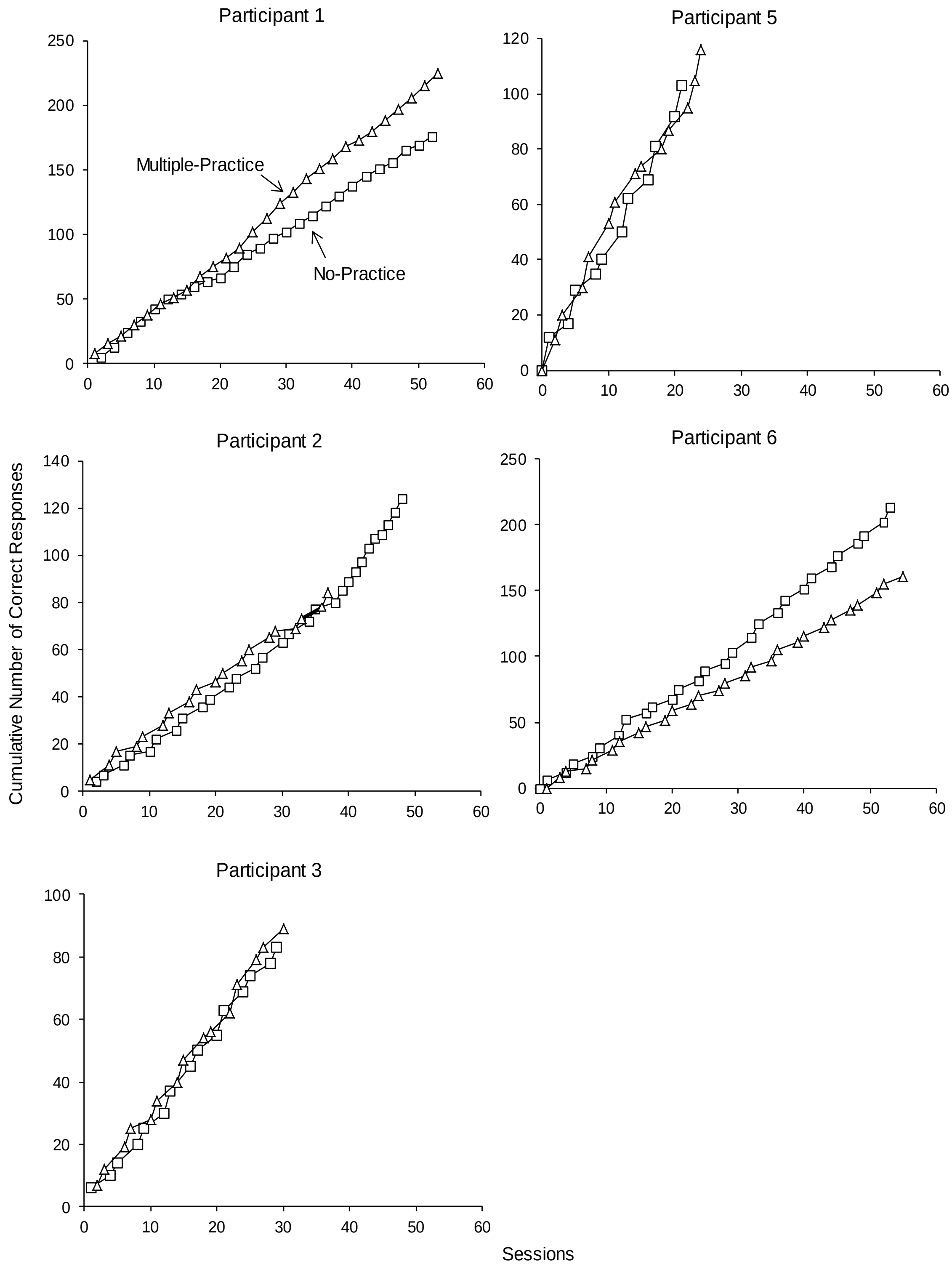

Figure 6. Cumulative number of correct responses across sessions during selection-based response training.

tasks, and correct responses did not differ between procedures for Participants 3 and 5 who showed no difference in task mastery. However, correct responses did not differ between procedures for Participant 2 who mastered more tasks with the multiple-practice procedure.

Retention assessment. Table 12 shows the mean percent of correct responses across retention sessions for mastered selection-based tasks. For the three participants who had mastered at least one task with each procedure (Participants 1, 2, and 5), mean retention accuracy was higher for tasks mastered with the no-practice procedure in two cases.

Assessment of Praise Enthusiasm

Table 13 shows the praise enthusiasm ratings across the two procedures. The mean ratings of praise enthusiasm were quite similar across training procedures, with the largest difference being 0.54 points on a 5-point scale (during the second set of topography-based training tasks for Participant 3). Moreover, higher praise enthusiasm scores were not consistently associated with the training procedure that required fewer training sessions to reach mastery criterion.

Discussion

This study attempted to evaluate the relative effects of no-practice and multiple-practice error-correction procedures for teaching topography-based and selection-based tasks. It was hypothesized that participants would: (a) perform better with the multiple-practice procedure than with the no-practice procedure for topography-based tasks, and (b) perform better in the no-practice procedure or perform similarly with both procedures for selection-based tasks. The findings of this study offer moderate support for these two

Table 12

Mean Percent of Correct Responses during Retention Assessment for Selection-Based Tasks

Participant	No-Practice Procedure (%)	Multiple-Practice Procedure (%)
1	**58 (range 50-75)**	75 (range 50-100)
2	87 (range 75-100)	**75 (no range)**
3	–	–
5	**85 (range 75-100)***	**65 (range 0-100)***
6	**60 (range 25-100)**	–

Note. Bolded values represent the procedure for which a participant required fewer training sessions to reach mastery criterion. Dashes indicate no training task was mastered.

* Participant required similar number of training sessions to reach the criterion of mastery in both training procedures.

Table 13

Praise Enthusiasm Ratings (1 = Not Enthusiastic; 5 = Very Enthusiastic)

Participant	Training set	No-Practice Procedure		Multiple-Practice Procedure	
		Sessions Assessed	Mean (Range)	Sessions Assessed	Mean (Range)
Topography-Based Response Training					
1	1	47.0%	4.13 (3-5)**	47.0%	4.36 (3-5)**
	2	66.7%	4.87 (4-5)	90.9%	**4.63 (4-5)**
2	1	46.4%	4.36 (2-5)	**49.0%**	**4.40 (3-5)**
	2	50.0%	4.86 (4-5)	52.6%	**4.90 (4-5)**
3	1	14.9%	4.05 (3-5)**	14.9%	4.29 (3-5)**
	2	27.6%	**4.62 (4-5)***	26.7%	**4.08 (3-5)***
4	-	34.6%	5.00 (no range)**	33.3%	5.00 (no range)**
5	-	88.9%	**4.79 (4-5)**	88.9%	4.79 (4-5)
6	-	30.0%	4.19 (3-5)	37.5%	**4.66 (3-5)**
Selection-Based Response Training					
1	-	53.8%	**3.72 (2-5)**	51.8%	4.15 (3-5)
2	-	62.1%	4.31 (3-5)	94.7%	**3.94 (3-5)**
3	-	60.0%	4.27 (3-5)**	60.0%	4.35 (3-5)**
5	-	81.8%	**3.83 (2-5)***	69.2%	**3.72 (2-5)***
6	-	74.1%	**3.98 (2-5)**	74.1%	4.05 (2-5)

Note. Bolded values represent the procedure that required fewer training sessions to reach mastery criterion.

* Participants required similar number of training sessions to reach the criterion of mastery in both training procedures.

** Participants did not master any tasks in both training procedures.

hypotheses taken individually. For the first hypothesis, after excluding the three comparisons in which the participants did not master any topography-based tasks, four of the six comparisons on task mastery as shown in Figures 1 and 2 favored multiple-practice (Participant 1 second set of tasks, Participant 2 both sets of tasks, and Participant 6), and one comparison favored no-practice (Participant 5).It should be noted that three comparisons with no mastered tasks (Participants 1 and 3 first set of tasks, and Participant 4), differences were observed in correct responding in all these cases with two comparisons favoring the multiple-practice procedure as shown in Figures 3 and 4. For these three comparisons, the lack of mastery may represent a floor effect because the tasks were too difficult for the participants.

Second, mixed results were observed for the second hypothesis. By excluding the one comparison in which the participant did not master any selection-based tasks, one of the four comparisons favored no-practice (Participant 6 in Figure 5) on task mastery, one comparison showed no difference (Participant 5 in Figure 5), and the remaining two comparisons favored the multiple-practice procedure. Although mixed results were observed, they appear to be consistent with previous research that involved selection-based discrimination tasks (see Table 2).

Although the results obtained in this study seem to be consistent with previous literature that examined the impact of error-correction procedures in either topography- or selection-based response training, results from the five participants exposed to both topography- and selection-based tasks do not seem to support the anticipated interaction effect of greater benefit of multiple-practice for topography-based response training and greater benefit of no-practice (or no difference) for selection-based response training. For example, Participant 2 performed better in task mastery with the multiple-practice procedure than with the no-practice procedure for both types of tasks, and Participant 3 showed no difference between the procedures for both types of tasks. In fact, only the data obtained from Participant 6 provided the expected interaction profile.

Retention of mastered tasks was fairly poor in this study compared to previous research (e.g., Ferkis et al., 1997; Worsdell et al., 2005). One factor that may have influenced the outcome is the assessment procedure. Once a task was mastered, training continued with a new task until the one-week retention assessment occurred. The introduction of the new training task may have interfered with the retention performance. It should be noted that the cognitive functioning of participants in this study might have been more severe than those in previous research (discussed below) and might have been more sensitive to interference.

This study adds to the literature on error correction in several ways. Methodologically, this is unique in that it examined the interaction between error-correction procedures that involved different amounts of practice and response classes within the same participants (i.e., by exposing each participant to both topography- and selection-based tasks) using exclusively non-vocal responses. Further, this study included two features not found in previous studies in this area to control for systematic bias in reinforcement. First, the inclusion of a choice of edible reinforcers immediately followed every correct response and ensured that the most preferred food item was used across trials throughout training. This minimized potential differences between procedures that could have resulted from varying degrees of motivation or varying reinforcing values of edibles as opposed to the error-correction procedures. Second, praise statements were standardized across procedures. Moreover, the level of enthusiasm of the social praises provided was assessed and found to be comparable across procedures. These features add to our confidence that the observed differences were a result of the error-correction procedures.

This study also extends previous research by including participants with more severe disabilities. For example, reported IQs in previous research ranged from 40 to 105 (see Table 1). Although IQ scores were not available for participants in this study, their reported level of functioning, as obtained from their health records, ranged from severe to moderate (corresponding to an IQ range of 20 to 55 according to DSM-IV-TR specifiers; American Psychiatric Association, 2000). Moreover, the extremely limited communication skills of the participants in this study suggests that they may be functioning at a lower level of cognitive ability relative to the participants in previous research. It is possible that level of cognitive ability may interact with the correction procedures and task complexity (e.g., resulting in the floor effect described earlier), and that this may influence the degree of interaction between error-correction procedures and response classes. The fact that Participants 1 and 3 did not master any tasks with either procedure for the first set of topography-based tasks, but were able to master some tasks in the second set that appeared to be less difficult is consistent with this interpretation.

Another contribution of this study involves extending previous literature in comparing error-correction procedures for both topography- and selection-based tasks. Only two studies have compared error-correction procedures for teaching selection-based discrimination tasks (see Table 2). Therefore, this study adds to this limited body of research. As for topography-based tasks, except the Experiment 3 in Cuvo et al. (1995), all previous research that compared error-correction procedures involved reading and answering questions vocally. Across all studies in Table 1, only 6 out of the combined 41 participants gave a written response (five participants in Cuvo et al., 1995, and one in Rapp et al., 2012). This is the first study in the last decade following Cuvo et al. that compared error-correction procedures using exclusively non-vocal topography-based responses, ranging from simple signs to multi-step daily living skills.

Several limitations of this study must be noted. First, the present study lacks within-subject replications across the response classes. Only three of the six participants were exposed to topography-based response training twice, which was done because either no difference was observed between procedures or the participant did not master any tasks with either procedure during the first set of topography-based tasks. The results could be strengthened if each participant received training for topography- and selection-based responses in an ABAB design.

Although the retention assessment procedure used in this study had been used in previous research (e.g., Worsdell et al., 2005), it may not be suitable for individuals with severe intellectual disability who are sensitive to interference. Future research should consider minimizing interference by conducting retention assessment of mastered words first before introducing new training tasks. Future research might also evaluate the use of a more stringent mastery criterion (e.g., more than 80% correct responses for three consecutive sessions) to improve retention.

This study included only a small number of participants and tasks, and future research is needed with more participants before the generality of these results can be confirmed. In particular, it may be worthwhile to examine the level of intellectual disability as an independent variable. Topography-based tasks that have been examined by previous research have been confined mostly to vocal responses. This study introduced non-vocal responses and multi-step motor responses. Future research is needed to examine not only non-vocal responses, but both vocal and non-vocal responses of varying complexities.

In conclusion, this study extended previous research on error-correction procedures by comparing no-practice and multiple-practice error-correction procedures in teaching both topography- and selection-based responses. The findings of this study suggest that a multiple-practice error-correction procedure is slightly more effective than a no-practice error-correction procedure for teaching topography-based responses, but not for teaching selection-based responses. If the present results are generalizable, practitioners may wish to use the simpler and less time consuming no-practice error-correction procedure for teaching selection-based tasks and reserve the use of a multiple-practice procedure for teaching topography-based tasks.

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Appendix A

Research Compared Topography- and Selection-Based Verbal Behavior in Teaching Different Verbal Operants

Tact and Intraverbal Relations

Sundberg and Sundberg (1990) taught four adults with mild to moderate intellectual disability to name a set of objects (a tact relation; Skinner, 1957) by making different signs (topography-based) and to name a different set of objects by pointing to the correct symbol among three different symbols (selection-based) in the presence of the object and the verbal request "What's this". All participants learned the topography-based responses more rapidly than the selection-based responses. One participant did not meet the mastery criterion on the selection-based responses even after 841 training trials had been provided. The researchers then taught the three participants, who met mastery criterion with both topography- and selection-based responses, to respond to the dictated names of each object (an intraverbal relation; Skinner, 1957). On each training trial, in the presence of "What's <name of object>", each participant was taught to sign the object name or to point to the correct symbol among several symbols as described above. Again, participants learned the topography-based responses more rapidly than the selection-based responses although the difference in trials to criterion was small. Moreover, in a transfer test (of stimulus equivalence; Sidman & Tailby, 1982) with two participants, which required them to select the correct objects in the presence of their dictated names, both participants had more correct responses with object names they had learned to sign than with object names they had learned to select.

Appendix A (cont'd)

Research Compared Topography- and Selection-Based Verbal Behavior
in Teaching Different Verbal Operants

Wraikat, Sundberg, and Michael (1991) systematically replicated Sundberg and Sundberg (1990) by varying the number of objects being taught in each relation for some students who have a poor verbal repertoire. Also, an interspersal training procedure was used in which learned relations were alternated with the unlearned relations in each training session. The results showed that five of the seven participants learned all the relations faster in the topography-based condition than in the selection-based condition. One participant learned the tact relation (object naming) equally well in both conditions, but learned the intraverbal relation (responding to dictated names) faster in topography-based condition. The other student learned the tact relation faster in the selection-based condition than in the topography-based condition; however, the opposite was observed in learning intraverbal relation. In transfer tests, six of the seven participants had higher percentage of correct responses in the topography-based condition than in the selection-based condition for all relations.

Vignes (2007) also replicated the study by Sundberg and Sundberg (1990) with three children with typical development and three individuals with autism. Contrary to the previous findings, the results of this study favored selection-based responses. Specifically, all participants with autism and one participant with typical development had better performance in the selection-based condition during all training phases and the transfer tests. The author suspected that participants with autisms, who had received early intensive behavioral intervention, might have been trained intensively in receptive

Appendix A (cont'd)

Research Compared Topography- and Selection-Based Verbal Behavior
in Teaching Different Verbal Operants

language using a teaching format similar to the selection-based tasks taught in the study, and this learning history may have influenced the results.

Mand Relation

Adkins and Axelrod (2001) taught a seven-year old boy with pervasive developmental disorder and attention deficit hyperactivity disorder to request his favorite items using American Sign Language (ASL; topography-based response) and Picture Exchange Communication System (PECS; selection-based response). Results showed that the boy learned to mand for his preferred items faster with topography-based responses than with selection-based responses. Moreover, rates of spontaneous requests and generalization were higher with topography-based responses than with selection-based responses.

Tincani (2004) also compared the effects of PECS and ASL in teaching mand repertoire to two elementary students with autism using an alternating-treatments research design. Mixed results were observed. Specifically, one student had more independent responses in PECS training while the other student had more independent responses in ASL training. Both students named the preferred items more often in ASL training than in PECS training. The findings of the study also suggested that individuals with better motor imitation skills might perform better in ASL training than in PECS training and vice versa. Gregory, DeLeon, and Richman (2009) further examined the relationship between the prerequisite skills and the acquisitions of manual signs and

Appendix A (cont'd)

Research Compared Topography- and Selection-Based Verbal Behavior
in Teaching Different Verbal Operants

exchanged-based communicative responses with six children with developmental disabilities. Similar results were observed and the authors concluded that matching and motor imitation skills were correlated with the acquisitions of these two verbal responses.

Ziomek and Rehfeldt (2008) compared the use of PECS and the simplified version of ASL in mand training with three individuals with severe developmental disabilities using an alternating-treatments research design. Mand was taught in two different situations. Participants were taught to request their preferred items and the items that were needed to complete a chained task (e.g., items needed to prepare pudding) using PECS and simplified ASL in the classroom and the kitchen, respectively. The results of the two participants who completed the training showed that both of them learned to mand their preferred items faster with PECS than with ASL. Moreover, the learned mand repertoire was generalized to the untrained verbal operants (tacts for one participant and intraverbal for the other participant). In addition, the participant who was trained to request items needed to complete a chained task also learned faster with PECS than with ASL. However, the learned repertoire did not generalize to the untrained verbal operants. The authors stressed that the results should be interpreted with caution because the response topographies for various signs might not present in the participant's repertories prior to the study, and the prompting strategies were varied across training conditions.

Appendix A (cont'd)

Research Compared Topography- and Selection-Based Verbal Behavior
in Teaching Different Verbal Operants

Barlow et al. (2013) recently compared the efficiency of selection- and topography-based mand training by addressing some of the limitations in previous research with three children with autism spectrum disorder and severe language deficits. Specifically, Barlow et al. tried to control a number of variables that might lead to an inaccurate comparison in their study. These variables included the use of identical manded stimuli (preferred items) and identical prompting procedures in both training conditions, and the presentation of an array of three different pictures on each selection-based training trial because only one picture was presented in some of the previous studies. All children mastered the tasks (ranged from one to three tasks in total) taught in the selection-based condition but did not master any tasks taught in the topography-based condition.

Although only modified version of ASL was taught in the above studies of mand training, vocal mand could also be taught as a topography-based response. Bourret, Vollmer, and Rapp (2004) identified a reliable vocal mand assessment which could be used to develop effective topography-based mand training procedures for individuals who were lack of vocal mand repertoires. Moreover, Gutierrez et al. (2007) manipulated the establishing operation for requesting the preferred items using pictures when selection-based mand was taught.

Appendix B

Stimuli and Topographies for Each Topography-Based Training Task in Phase 1 for Participant 1

	No-Practice Procedure		Multiple-Practice Procedure	
Task	Printed word	Response Topography	Printed word	Response Topography
1	jet	Palm of left hand place on lap, lift up vertically and return down to lap, repeat once*	bag	Palm of left hand place on belly and move in circular motion*
	pot	Close left fist, move back and forth in horizontal motion across mouth, repeat twice*	key	Nod head up and down, repeat once*
2	hat	Palm of left hand place on left wheelchair arm, move back and forth along wheelchair arm, repeat twice*	gun	Fingers of left hand extend upward with palm facing away from body*
	fox	Closed fist with thumb extend in vertical position*	mop	Palms of left and right hands bring up to cover left and right ears*
3	pin	Closed left fist lift above the table and move down to touch the table, repeat once*	bee	Pinch nose with left thumb and index finger*
	car	Palms of left and right hands bring together to touch each other and rest alongside left cheek*	pan	Palm of left hand bring up to touch right shoulder*

* Non-mastered tasks

Appendix C

Stimuli and Topographies for Each Topography-Based Training Task in Phase 2 for Participant 1

	No-Practice Procedure		Multiple-Practice Procedure	
Task	Picture	Response Topography	Picture	Response Topography
1	binder clip	Left palm face down with back and forth horizontal motion across body, repeat twice	lemon	Palm of left hand bring up to touch right shoulder
	violin	Palms of left and right hands bring up to cover left and right ears	car	Nod head up and down, repeat once
2	fox	Fingers of left hand extend upward with palm facing away from body	raspberry	Palms of left and right hands bring together to touch each other and rest alongside left cheek
	lock	Stick tongue out beyond lips	socks	Fingers and thumb of left hand grasp around right wrist
3	ship	Thumb of left hand bring up to touch left side of the neck while fingers rest on right side of neck	cake	Palm of left hand place on belly and move in circular motion
	hammer	Closed fist with left index finger extend in the direction of the experimenter	box	Closed left fist bring up next to left shoulder and closed right fist bring up to left fist, and then right fist extend downward
4			bacon	With mouth open, insert left index finger beyond plane of lips
			whisk	Left and right arms bent horizontally parallel in front of chest with closed fists rotate around one another in clockwise motion
5			orange	Left arm extend to the left with hand open, palm face down and move up and down, repeat twice
			book	Palms of left and right hands face each other with shoulder length apart, and bring together to touch each other

Appendix D

Stimuli and Topographies for Each Topography-Based Training Task in Phase 1 for Participant 2

	No-Practice Procedure		Multiple-Practice Procedure	
Task	Printed Word	Response Topography	Printed Word	Response Topography
1	wedding	Exhale breath from mouth with lips puckered	storage	Palm of left hand bring up to cover left ear
	curling	Exhale breath with mouth opened, and nod head up and down, repeat once	diamond	Palm of left hand bring up to touch nose
2	arrow	Palms of left and right hands face each other with shoulder length apart, and bring together to touch each other	daisy	Palm of left hand bring up to face to cover left eye
	comma	Palm of left hand face down with back and forth horizontal motion across body, repeat once	tulip	Palm of left hand placed on left wheelchair arm
3	property	With mouth open, insert left index finger beyond plane of lips	feverish	Lift right leg and rest on top of left leg
	appetite	Turn head toward left shoulder	ancestor	Closed fist with right index finger extend in the direction of the experimenter
4	box	Palm of left hand place on left thigh	axe	Left arm extend in front of body with hand open and palm face down, move up and down, repeat once
	car	Palm of left hand bring up to touch left cheek	cup	Closed fist with left index finger extend in vertical position
5			colobus	Open mouth and lift jaw up until lips touch each other, repeat twice
			jacobus	Palm of left hand place on left wheelchair arm and palm of right hand rest on right wheelchair arm

Appendix E

Stimuli and Topographies for Each Topography-Based Training Task in Phase 2 for Participant 2

	No-Practice Procedure		Multiple-Practice Procedure	
Task	Printed Word	Response Topography	Printed Word	Response Topography
1	gyrodus	Palm of left hand bring up to face to cover left eye	unicorn	Start with both hands together with palms facing down, move together horizontally from the left to the right side of the body, move back to the left side of the body, repeat twice
	impalla	Exhale breath from mouth with lips puckered	damages	Palm of left hand bring up to touch top of head and rotate in a circular motion once
2	kruller	Turn head toward left shoulder	epicarp	Thumb and fingers of the left hand wrap around buckle of wheelchair seatbelt
	zygosis	Left palm face up, fingers touch the under-side of the table, and thumb place on the top of the table	youngth	Lift left foot vertically for at least 3 inches and return to the floor from seated position
3	fan	Palms of left and right hands place on lap and lift up vertically and return down to lap, repeat twice	lur	Palms of left and right hands bring up to touch left and right ears
	hip	Closed fist with left index finger extend in the direction of the experimenter	cep	Palm of left hand place on belly and move in circular motion
4			blimp	Both arms bring up above head and close fists
			whack	Pinch nose with left thumb and index finger
5			quire	Thumb of the left hand bring up to touch left side of the neck while fingers rest on the right side of neck
			talcs	Open mouth and jaw lift up until lips touch each other, repeat twice

Appendix F

Stimuli and Topographies for Each Topography-Based Training Task in Phase 1 for Participant 3

	No-Practice Procedure		Multiple-Practice Procedure	
Task	Picture	Response Topography	Picture	Response Topography
1	kite	Palm of right hand placed on left elbow of flexed arm*	boot	Palm of right hand bring up to touch chin*
	pant	Palm of right hand bring up to face to touch cheek*	lock	Palms of left and right hands face each other with shoulder length apart and bring together to touch each other*
2	bed	Palm of right hand bring up to touch left shoulder*	clip	Palm of right hand bring up to touch right ear*
	cup	Palm of right hand bring up to touch top of head*	bike	Palm of right hand bring up to touch chest*
3	car	Palm of right hand place on belly*	box	Palm of right hand bring up to touch nose*
	pin	Closed right fist lift above the table and move down to touch the table, repeat once*	egg	Palm of left hand place on left thigh and palm of right hand place on right thigh*
4	shop	Lift right foot up vertically for at least 3 inches*	ball	Palm of right hand place on right thigh*
	door	Palm of right hand bring up to face to cover right eye*	sock	Palm of right hand bring up to touch forehead*

* Non-mastered tasks

Appendix G

Stimuli and Topographies for Each Topography-Based Training Task in Phase 2 for Participant 3

	No-Practice Procedure		Multiple-Practice Procedure	
Task	Object	Response Topography	Object	Response Topography
1	Toy teapot with lid and tea cup	Put the lid on the teapot and pour tea in the cup	CD case and CD	Place the CD in case and close the case
	Playdoh® and plastic knife	Use the knife to cut the Playdoh® twice	Toy cellphone	Press the keypad of the phone twice
2	Scrapbook	Open the scrapbook and tear out two sheets	Spoon and glass	Put the spoon in the glass and stir twice
	Pencil and pencil sharpener	Put the pencil into the pencil sharpener and turn twice	Spray bottle and paper towel	Spray water on the table and wipe twice
3	Paper clip, papers, and staple	Remove paper clip from the stack of paper and staple papers together	Toy human head, toy hair dryer, and mini comb	Blow the doll hair with the hair dryer, and comb the hair
	Container with lid and paper towel	Wipe the container lid and put the lid on the container	Toy camera and film	Place film in the camera and press the bar to advance the film

Appendix H

Stimuli and Topographies for Each Topography-Based Training Task for Participant 4

	No-Practice Procedure		Multiple-Practice Procedure	
Task	Picture	Response Topography	Picture	Response Topography
1	pillow	Palms of left and right hands bring together to touch each other and rest alongside left cheek*	cymbal	Palms of left and right hands face each other with shoulder length apart and bring together to touch each other*
	dumbbell	Left arm bring above head and close fist*	towel	Palm face down, move back and forth in horizontal motion across body, repeat twice*

* Non-mastered tasks

Appendix I

Stimuli and Topographies for Each Topography-Based Training Task for Participant 5

	No-Practice Procedure		Multiple-Practice Procedure	
Task	Printed Word	Response Topography	Printed Word	Response Topography
1	tow	Palm of left hand bring up to touch right shoulder while palm of right hand bring up to touch left shoulder	yam	Turn head toward left shoulder and then turn head until facing right shoulder, repeat twice
	bug	Close fist with left index finger extend in downward direction, move from left to right	wet	Palm of left hand place on belly and move in circular motion
2	six	Left thumb place under the base of left ear and index finger place around the top of the left ear		
	fly	Palms of left and right hands face each other with shoulder length apart and bring together to touch each other		
3	job	Closed fists bring up to eye level with elbows pointing down and rotate wrists twice		
	zen	Nod head up and down, repeat once		
4	gym	Left arm bring above head and close fist		
	hat	Closed left fist lift above the table and move down to touch the table, repeat twice		
5	air	Palms of left and right hands bring together to touch each other and rest alongside left cheek		
	cue	Closed fist with left index finger extend in downward direction, and move in circular motion once		

Appendix J

Stimuli and Topographies for Each Topography-Based Training Task for Participant 6

	No-Practice Procedure		Multiple-Practice Procedure	
Task	Object	Response Topography	Object	Response Topography
1	Hanger and shirt	Place both sides of the shirt on the hanger*	Glue, cut out shaped paper, and plain paper	Apply glue on the shaped paper and paste the shape on the plain paper
	Paper and hole puncher	Put the paper into the hole puncher and press down on the handle*	Ball, spoon, and two boxes	Use a spoon to transfer a ball from one box to the other box
2	Gift bag, gift box, and tissue paper	Open the gift bag, put the gift box in the bag, and put the tissue paper in the bag*	Binder and hole-punched paper	Open the binder, put the paper in the binder, and close the binder
	Runner with shoelace	Put the shoelace through two different holes*	Papers and paper clip	Stack two piece of papers together and put the paper clip on
3	Envelope and pamphlet	Put the pamphlet into the envelope, remove the strip, and seal the envelope*	Hanger, towel, and clothespin	Hold the hanger, put the towel over the hanger, and put the clothespin on
	Spray bottle and paper towel	Spray water on the table and wipe the table*	Key chain and key	Press the key chain lock down and put the key on the right

* Non-mastered tasks

Appendix K

Stimuli for Each Selection-Based Training Task for Participant 1

Task	No-Practice Procedure: Printed Word as Sample and Picture as Comparison	Multiple-Practice Procedure: Printed Word as Sample and Picture as Comparison
1	pin	axe
	cat	box
2	bus	cup
	pot	key
3	fox	jet
	bee	pan
4	hat*	saw
	mop*	bed
5		car
		dog

* Non-mastered tasks

Appendix L

Stimuli for Each Selection-Based Training Task for Participant 2

	No-Practice Procedure	Multiple-Practice Procedure
Task	Picture as Sample and Printed Word as Comparison	Picture as Sample and Printed Word as Comparison
1	lychee	hammer
	pepper	bucket
2	cricket	spinach
	bannock	printer
3	sunshine	capsules
	cassette	bracelet
4	tent	clip
	wisk	rose
5		shedder
		compass

Appendix M

Stimuli for Each Selection-Based Training Task for Participant 3

	No-Practice Procedure	Multiple-Practice Procedure
Task	Printed Word as Sample and Picture as Comparison	Printed Word as Sample and Picture as Comparison
1	bus*	jet*
	fan*	dog*

* Non-mastered tasks

Appendix N

Stimuli for Each Selection-Based Training Task for Participant 5

	No-Practice Procedure		Multiple-Practice Procedure	
	Printed Word		Printed Word	
Task	Sample	Comparison	Sample	Comparison
1	emu	daw	sip	tea
	bat	fox	hen	cow
2	lur	saz	uno	rex
	yam	cep	sei	yak
3	van	bus	fly	jet
	big	toe	jaw	gum
4	nut	fig	pjs	hat
	dog	paw	lot	few
5	kid	boy	tug	ark
	bun	ham	elk	dzo

Appendix O

Stimuli Used and Dimension Differences in Each Selection-Based Training Task for Participant 6

Task	No-Practice Procedure: Object: Sample	No-Practice Procedure: Object: Comparison	No-Practice Procedure: Difference in Dimension	Multiple-Practice Procedure: Object: Sample	Multiple-Practice Procedure: Object: Comparison	Multiple-Practice Procedure: Difference in Dimension
1	Small blue x'mas bell	Big gold x'mas bell	Size and color	Yellow 2-hole Lego® block*	Yellow star	Shape & size
	Small red baking bowl	Big white baking bowl		Green 2-hole Lego® block*	Green star	
2	Small white Rubbermaid® box	Large blue Rubbermaid® box	Size and color	Small pink candy cane*	Big white candy cane	Size and color
	Small red button magnetic	Large yellow button magnetic		Small yellow cutter*	Big silver cutter	
3	Yellow high-lighter	Purple high-lighter	Color			
	Red magnetic clip	Green magnetic clip				
4	Scope®	Shampoo	Color and shape			
	Blue square gift box	Pink circle gift box				
5	Green plastic cup	Green plastic bowl	Shape			
	Pink square gift box	Pink hexagon gift box				

* Non-mastered task