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## An analysis of remedial trials on math skill acquisition

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Running head: AN ANALYSIS OF REMEDIAL TRIALS

**An Analysis of Remedial Trials**

**on Math Skill Acquisition**

**A Thesis Presented**

**By**

**Ashley N. Weimar**

The Department of Counseling and Applied Educational Psychology

in partial fulfillment of the requirements for the degree of

**Master of Science**

**In the field of**

**Applied Behavior Analysis**

Northeastern University

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Boston-Bouve College of Health Sciences Graduate School

Thesis Title: An Analysis of Remedial Trials on Math Skill Acquisition

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Approved for Thesis Requirements of Master of Science Degree

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Date

**An Analysis of Remedial Trials  
on Math Skill Acquisition**

**by**

**Ashley Weimar**

**M.S. Psychology**

Submitted in partial fulfillment of the requirements for the degree of

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In the Bouve College of Health Sciences Graduate School of

Northeastern University, March 2012

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## An Analysis of Remedial Trials on Math Skill Acquisition

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### Abstract

The purpose of the present study was to compare rates of multiplication fact acquisition in a control condition with two other remedial trial conditions. The participants were two school-aged children with autism. During a pretest, the participants were presented with flashcards containing unsolved multiplication facts and were asked to solve the problems. Problems which were solved incorrectly were considered unknown and were randomly assigned to the three training conditions. During training, praise was delivered contingent on correct responding across all conditions. In the baseline condition (differential reinforcement), an error produced no consequences. In both remedial trial conditions, incorrect responses resulted in the experimenter providing the correct response followed by repetition of the trial. In the relevant condition, the participant was required to repeat the solution to the incorrectly solved multiplication problem three times, whereas in the irrelevant condition the participant was required to repeat three unrelated words. Results indicated that both remedial trial conditions resulted in faster skill acquisition for both participants over differential reinforcement alone. Furthermore, both participants exhibited higher rates of acquisition during the irrelevant remedial trial condition compared to the relevant remedial trial condition. These data suggest that remedial trials enhance performance by creating a negative reinforcement paradigm for correct responding. Suggestions for future research are discussed.

## An Analysis of Remedial Trials on Math Skill Acquisition

Discrete trial teaching (DTT) has been shown to be an effective teaching strategy for individuals with autism. In DTT learning tasks are broken down into smaller units of instruction called discrete trials. These trials are typically implemented by a teacher who works one-on-one with an individual in an environment that has limited distractions. Each discrete trial consists of four components (Smith, 2001). The first component - is - called a discriminative stimulus ( $S^D$ ). An  $S^D$  is a brief, clear instruction or question, such as “Do this” or “What is \_\_\_ doing?,” which is delivered by the teacher to the individual. The next component is a teacher prompt which is delivered simultaneously or immediately following the  $S^D$ . These teacher prompts can either be physical or verbal depending on whether the question is receptive or expressive in nature. When an individual responds correctly, the teacher gradually fades out and eventually eliminates the prompt so that the individual learns to respond to the  $S^D$  alone. The third component -is the individual’s response or answer to the  $S^D$ . The individual’s response can be either correct or incorrect.

Based on the response, the fourth component, a consequence, is delivered. If the individual provides a correct response, the teacher delivers positive reinforcement such as praise, hugs, small bites of food, access to leisure items, or other activities which have been demonstrated to be reinforcers to the individual. Significant research has demonstrated increases in correct responding during acquisition when positive reinforcement is used (Copper, Heron, & Heward, 2007). Much less research, however, has been conducted on consequences for incorrect responses. It is imperative to evaluate the influence of consequences for incorrect responses, because it is possible that these consequences play an equally important role in increasing correct responding (Worsdell, Iwata, Dozier, Johnson, Neidert, & Thomason, 2005).

- Four general strategies are utilized when an individual makes an incorrect response. The first two techniques do not entail the delivery of consequences, per se. The first strategy involves the absence of a programmed consequence for incorrect responses. This strategy is equivalent to the extinction component of differential reinforcement. For example, Hall, Lund, and Jackson (1968) significantly increased study behavior in six highly disruptive elementary-aged students using only positive reinforcement for correct responses.

A second approach to addressing incorrect responses is the manipulation of the inter-trial interval. Contingent on an incorrect response, a delay is imposed prior to the next learning trial. These delays are typically brief, lasting between 10 to 30 seconds. The rationale behind the use of these time-out intervals is that they establish a less dense schedule of positive reinforcement for incorrect responses than that found with extinction (Barton, 1970).

The third approach to error correction, involves teacher presentation of discrete events following errors. There is great variety among this technique, but a communality of this approach is that no additional response is required of the student. It is instead the teacher who responds to the error. Previous research has indicated effectiveness of these procedures when they have incorporated punishment or response cost for errors (Rodgers & Iwata, 1991).

The fourth strategy for responding to errors involves active student responding. Contingent on an incorrect response, a remedial trial is presented to the student. The trial is repeated until a predetermined criterion is met. For example, Rodgers and Iwata (1991) repeated trials until a correct response occurred; Marvin, Rapp, Stenske, Rojas, Swanson, and Bartlett (2010) repeated trials five times; in comparison, Barbetta, Heward, Bradley, and Miller (1994) repeated trials only one time. While the authors found that repetition of the trial increased skill acquisition, it is unclear what function these remedial trials served.

Rodgers and Iwata (1991) proposed two hypotheses regarding the function of remedial trials during skill acquisition. First, remedial trials merely provide exposure to stimuli and practice for the correct response. Second, remedial trials set up an avoidance contingency for the correct response. To test these hypotheses, Rodgers and Iwata compared the effects of a control condition, utilizing only positive reinforcement for correct responses, with two conditions involving repetition of a trial contingent on error in match-to-sample discrimination training.

In all conditions correct responses were followed by praise and either food or pennies. In the practice condition, an error was followed by repetition of the trial until a correct response occurred. In the avoidance condition, an error was followed by additional trials consisting of irrelevant stimuli. The introduction of irrelevant stimuli during the avoidance condition enabled the separation of the effects of repeated exposure to the same task from those of negative reinforcement, both of which existed in the practice condition. For all seven of the participants skill acquisition increased during the control condition (differential reinforcement), however, skill acquisition was greatest for five of the seven participants during one of the error-correction conditions. For two of the participants the practice condition produced better performance, and for the remaining three participants the avoidance condition produced better performance.

Worsdell, Iwata, Dozier, Johnson, Neidert, & Thomason (2005) used a similar procedure to examine acquisition during sight word reading. During the relevant (practice) condition, errors were followed by multiple repetition of the trial using the relevant word (i.e. the word that was misread). In the irrelevant (avoidance) condition, errors were followed by multiple repetition of the trial using a non-training word. Results showed that all participants' sight word performances increased during error correction relative to baseline. For five of the nine participants performance was similar during relevant and irrelevant conditions. Performance for three

participants during the relevant condition significantly exceeded that during the irrelevant condition, whereas for one participant performance during the irrelevant condition significantly exceeded that during the relevant condition.

These data indicate that error correction procedures more effectively enhance performance when compared to differential reinforcement alone. It remains unclear, however, as to what function remedial trials serve. A mechanism common to both the avoidance and practice conditions in both Rodgers and Iwata (1991) and Worsdell et al. (2005) was negative reinforcement. Negative reinforcement alone, however, accounted for only some of the improvement in performance. Practice with relevant stimuli was a necessary component for some individuals. As with other behavioral procedures and processes, between-subject variability across error-correction procedures suggests that individual history affects performance.

The purpose of the current study was to systematically replicate the findings of Rodgers and Iwata (1991), and Worsdell et al. (2005) and to extend those procedures to the math-skill acquisition of children with autism. The current study sought to determine 1) if remedial trials enhance skill acquisition, and 2) what function remedial trials serve.

## Method

### *Participants*

Two school-aged children, Kim and Mike, participated in the study. Both were selected based on their expressive language, educational objectives to increase math skills, experience with discrete trial training, and limited, if any, prior exposure to multiplication.

Kim was a 15-year-old female diagnosed with autism. She attended a private school for students with disabilities. Throughout the school-day she received the majority of her instruction through discrete trial training. Mike was an 8-year-old male diagnosed with Pervasive

Developmental Disorder-NOS. He attended a sub-separate classroom within a public elementary school.

### *Settings and Materials*

For both participants all pre-tests, reinforcement assessment, and training sessions took place in private rooms in which distractions were limited. For Kim the setting was her individual classroom and for Mike it was his family's home office. The experimenter or a trained staff person conducted all sessions.

Materials present during reinforcer assessments included a timer, a tally counter, and a 3 inch by 3 inch piece of pink paper. During pretesting sessions, white 3 inch by 5 inch cards with unsolved multiplication problems (e.g.  $2 \times 2 = \underline{\quad}$ ) printed in 48pt Times New Roman font were present. The facts chosen for selection were 2x, 3x, 4x, and 5x facts from 0-10. Facts answered correctly during the first pretest were omitted from the fact list, and the remaining facts were pretested a second time. Facts answered incorrectly during both pretests were considered unknown and were used as training stimuli.

The same materials were present during the training sessions except that the unknown facts from the pretest were included as training stimuli. An initial set of eight unknown facts were assigned to the baseline condition and to each of the two training conditions. In an attempt to equate fact difficulty across conditions, an equal number of 2x, 3x, 4x, and 5x facts were included within each condition. Facts were printed in 48pt Times New Roman font on 3 inch by 5 inch cards. Different card colors were used to designate the baseline set and the two training sets.

### *Dependent Variables, Operational Definitions, and Measurement*

During reinforcer assessments, the dependent variable was a touch to a pink square. A touch was defined as one of the participant's index fingers making contact with the pink square. Between responses, the finger was raised at least 2 inches above the pink square. The number of responses was measured using a tally counter.

The frequency of correct responses in each condition for each session was the dependent variable during pretesting and training sessions. A response was scored as correct if the participant accurately verbally solved the multiplication problem within 5 s of its presentation. A response was scored as incorrect if (a) the participants' vocal response was not the solution to the multiplication problem, or (b) the participant said "I don't know," or failed to respond within 5 s of the presentation of the card. During pretesting and training sessions, correct responses were recorded by a "+", and incorrect selection was recorded as a "-".

#### *Inter-observer Agreement and Procedural Integrity*

Inter-observer agreement (IOA) was assessed by having a second observer simultaneously, but independently, collect data with the primary observer during 50% of reinforcer assessments, 50% of pretesting sessions, and 33% of training sessions for both participants.

IOA scores were calculated by dividing the number of agreements by the number of agreements plus disagreements and then multiplying by 100%. IOA scores for all reinforcer assessments, pretests, and training sessions were 100% for both participants.

Procedural integrity data was assessed by having a second observer simultaneously but independently collect data with the primary observer during 50% of reinforcer assessments, 50% of pretesting sessions, and 33% of training sessions. During reinforcer assessments, a second observer recorded the occurrence or non-occurrence of experimenter behaviors using an 8-item

checklist. During pretesting sessions, a second observer recorded the occurrence or non-occurrence of experimenter behaviors using a 5-item checklist. For all sessions, the occurrence or non-occurrence of behavior was recorded by marking a check in the corresponding column (e.g, +/-) on the data sheet. A procedural integrity score was calculated by multiplying the total number of behaviors that occurred by the total number of items. Procedural integrity for all reinforcer assessment and pretest sessions was 100% for both participants.

During training sessions, a second observer simultaneously but independently collected procedural integrity data on a trial-by-trial basis. Each training session data sheet contained a column for scoring procedural integrity during each trial. Abbreviations for each of the two experimenter behaviors were listed for each trial. The second observer circled a corresponding abbreviation if the experimenter said the correct discriminative stimulus and delivered the correct consequence. A procedural integrity score was calculated by dividing the total number of occurrences of behavior by the total number of occurrences of behavior by the total number of behavior multiplied by 100%. The mean procedural integrity score for all training sessions was 100% for both participants.

### *Procedure*

#### Reinforcer Assessment

During each reinforcer assessment, the participant was seated at a table. The pink square was positioned on the table approximately one foot in front of him/her. Each reinforcer assessment included three baseline conditions followed by one reinforcer condition. Each condition lasted one minute with an inter-condition delay of one minute. During the inter-conditions delay, the experimenter removed the pink square and gave no instructions while the

participant remained at the table. Reinforcer assessment sessions were conducted once per day for three days.

During the baseline conditions, the experimenter said “Do this” and modeled touching the pink square. Contingent on the participant imitating the response, the experimenter said “Good job! Now you can do this (and modeled the touching response again) as much or as little as you want but you will not earn anything.” There were no programmed consequences for touching the pink square during baseline.

After the three baseline conditions, the experimenter conducted one reinforcer condition. The reinforcer condition was identical to the baseline condition, except after the participant imitated the touching response, the experimenter said, “Good job! Now you can do this (and modeled response again) as much or as little as you want and I will say “Good job!” During the reinforcer assessment praise (e.g, “Good job!”) was delivered on a fixed-ratio (FR) 1 schedule.

### Pretesting

A pretest was conducted to ensure the participants were unfamiliar with the training stimuli. During pretest sessions, participants were instructed to try their best to solve each problem without making a mistake. Unsolved multiplication problems (e.g.  $2 \times 3 = \underline{\quad}$ ) were presented one at a time on index cards, and participants were given 5 s to respond. No consequences were delivered for either correct or incorrect responses, but non-contingent praise (e.g, “nice sitting”) was delivered intermittently to maintain attention to the task. Multiplication problems solved correctly during the first pretest were omitted from the set of problems, and remaining problems were pretested a second time. Multiplication problems solved incorrectly during both pretests were considered unknown and were used as training stimuli.

### Training

An initial set of five unsolved multiplication problems were assigned to each of the three conditions. A mastery criterion was developed so that correctly solved problems in each set were continually replaced by new, unknown problems. A problem was considered to be mastered if it was solved correctly on all three presentations within a training session. Once a problem was mastered, it was removed from the set and was replaced with a new, unknown problem.

Baseline, relevant, and irrelevant remedial trial conditions were alternated in a multielement design. Both training conditions utilized multiple response (MR) remedial trials, however, the conditions differed with respect to the content of the response that was repeated after an incorrect response was made.

*Baseline (differential reinforcement)*

A set of five cards containing unsolved multiplication problems was presented three times per session, yielding 15 trials. Multiplication cards were presented one at a time, and the experimenter read the problem (e.g., “2 x3=”) to the participant. The participant was given 5 s to respond. A correct response was immediately followed by the experimenter saying, “Good job!” or some similar statement for both participants. An incorrect response resulted in presentation of the next card.

*MR (relevant)*

The presentation of multiplication cards and the consequences for correct responses were identical to baseline. However, contingent on an incorrect response, the experimenter said, “No, a X b =[correct answer]” and proceeded to implement MR remedial trials using the relevant answer (i.e., the answer to the problem solved incorrectly). Following three correct or incorrect repetitions of the relevant answer (i.e. “Say \_\_\_), the next card was presented.

*MR (irrelevant)*

Procedures were identical to the relevant condition described above, except for the content used during the MR remedial trials. Contingent on an incorrect response, the experimenter said, “No \_a\_X\_b\_ = [correct answer]. Say [irrelevant word].” The irrelevant words chosen for both participants were “banana,” “apple,” “orange,” and “grape.” These irrelevant words were presented in a semi-random within each MR remedial trial. Following three correct or incorrect repetitions of the irrelevant word, the next card was presented.

### Results

Results for both participants’ preference assessments are displayed in Figure 1. During baseline, Kim’s average response rate per minute was \_\_\_ and Mike’s average response rate per minute was \_\_\_. Across 3 sessions of reinforcer assessments, Kim’s average response rate was \_\_\_ per minute for praise Mike’s average response rate was \_\_\_ per minute for praise.

Figure 2 displays the cumulative number of correct responses across blocks of 15 trials during baseline and remedial trial conditions for Kim and Mike. Both participants’ multiplication problem solving performance increased during error correction relative to baseline. For Kim there was a large discrepancy in performance between the two error correction conditions. During the irrelevant condition Kim correctly responded to 35% more multiplication problems compared to the relevant condition. Mike’s performance was slightly higher during irrelevant conditions than relevant. During the irrelevant condition Mike correctly responded to 10% more multiplication problems compared to the relevant condition.

Figure 4 shows both participants’ mean number of correct multiplication problems solved during the relevant and irrelevant conditions. More multiplication problems were solved correctly during irrelevant error correction sessions for both participants. Kim made an average of 5.75 correct responses during irrelevant sessions compared to 3.75 during relevant sessions.

Mike correctly solved an average of 7.43 multiplication problems during irrelevant sessions compared to 6.71 during relevant sessions.

### Discussion

The purpose of the present study was to compare rates of multiplication fact acquisition in a control condition, in which only correct responses received a consequence, with two other conditions (relevant and irrelevant) involving the presentation of remedial trials contingent on errors. The two remedial trial conditions separated the effects of repeated practice and negative reinforcement. While much research exist supporting higher rates of skill acquisition with remedial trials over non-contingent reinforcement alone, less empirical evidence is available pertaining to the function of the remedial trials.

In the present study, both remedial trial conditions resulted in faster multiplication fact acquisition for both participants over differential reinforcement alone. Furthermore, both participants exhibited higher rates of acquisition during the irrelevant remedial trial condition compared to the relevant remedial trial condition. The difference in acquisition rates between the remedial trial conditions, however, was only significant for one of the participants. These results support previous research which suggests that remedial trials may enhance performance during skill acquisition (Rodgers & Iwata, 1991, Worsdell et al. 2005).

Furthermore, the results of the current study support the hypothesis that negative reinforcement contributed to increases in skill acquisition. Negative reinforcement was a component common to both the relevant and irrelevant conditions, in that correct responses in both conditions allowed subjects to avoid remedial trials. Although rates of skill acquisition were slightly higher in irrelevant conditions, the use of relevant stimuli during remedial trials might be recommended for several reasons. First, relevant error correction capitalizes on two learning

processes, positive practice and negative reinforcement. Second, the relevant condition may show superiority over the irrelevant condition with other types of performance. For example, in Worsdell et al. (2005), the majority of the participants' sight word acquisitions were greater during relevant error correction. Lastly, the use of relevant remedial trials may receive higher social validity scores by teachers and parents.

The present study had several limitations. Follow-up probes were not conducted. It would be interesting to see if the participants maintained their ability to solve mastered multiplication problems and if retention differed across the conditions. In addition, the generality of these findings is limited due to the use of only two participants. While the study lacks formal follow-up data, some evidence of maintenance was reported by the parent and teacher of one of the participants.

In summary, the results of this study confirm previous research findings that the presentation of remedial trials contingent on errors may enhance performance during acquisition. The data provides an extension of previous research by evaluating the utility of remedial trials on math skill acquisition. While it is possible that negative reinforcement contributed to increases in skill acquisition, the function of remedial trials remains relatively inconclusive. Similar to other behavioral processes and procedures performance may be affected by individual history. Future research should attempt to systematically isolate components common to different remedial trial procedures. Furthermore, future research should evaluate the effect of topographical similarity between the training stimuli and the irrelevant stimuli. Additional application of error correction procedures should be made to other math skills such as number identification, addition, and time telling.

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## Appendix A:

List of all multiplication problems used for training.

## Kim

2 x 0	3 x 0	4 x 0	5 x 0
2 x 1	3 x 1	4 x 1	5 x 1
2 x 2	3 x 2	4 x 2	5 x 2
2 x 3	3 x 3	4 x 3	5 x 3
2 x 4	3 x 4	4 x 4	5 x 4
2 x 5	3 x 5	4 x 5	5 x 5
2 x 6	3 x 6	4 x 6	5 x 6
2 x 7	3 x 7	4 x 7	5 x 7
2 x 8	3 x 8	4 x 8	5 x 8
2 x 9	3 x 9	4 x 9	5 x 9
2 x 10	3 x 10	4 x 10	5 x 10

## Mike

2 x 2	3 x 0	4 x 2	5 x 1
2 x 3	3 x 3	4 x 3	5 x 2
2 x 4	3 x 4	4 x 4	5 x 3
2 x 5	3 x 5	4 x 5	5 x 4
2 x 6	3 x 6	4 x 6	5 x 5
2 x 7	3 x 7	4 x 7	5 x 6
2 x 8	3 x 8	4 x 8	5 x 7
2 x 9	3 x 9	4 x 9	5 x 8
2 x 10	3 x 10	4 x 10	5 x 9
			5 x 10

## Figure Captions

*Figure 1:* Number of responses of touching the pink square observed for Kim and Mike across all sessions of baseline and reinforcement.

*Figure 2:* The cumulative number of correct responses across blocks of 15 trials for Kim and Mike across all experimental conditions.

*Figure 3:* Mean number of correct responses per session for Kim and Mike across all experimental conditions.

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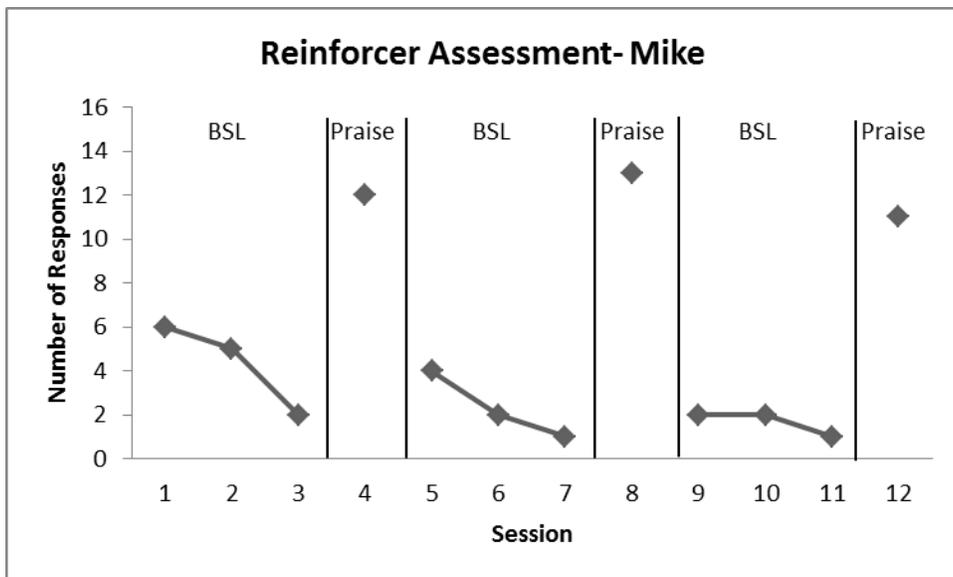
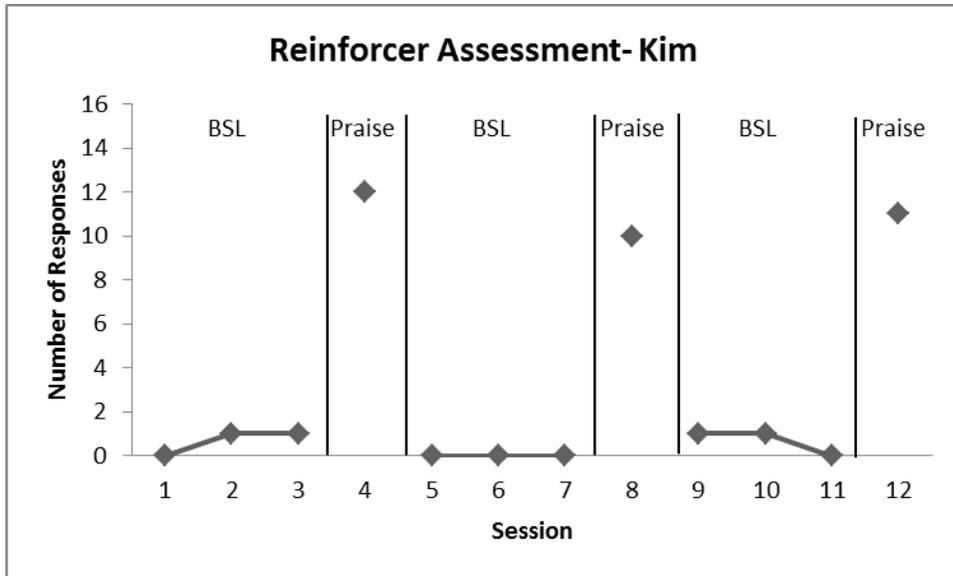


Figure 1

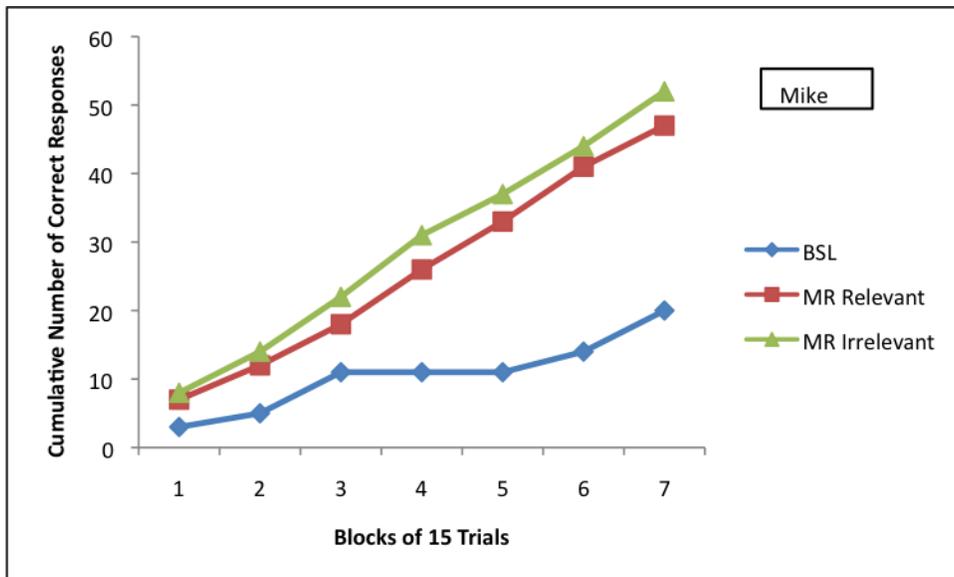
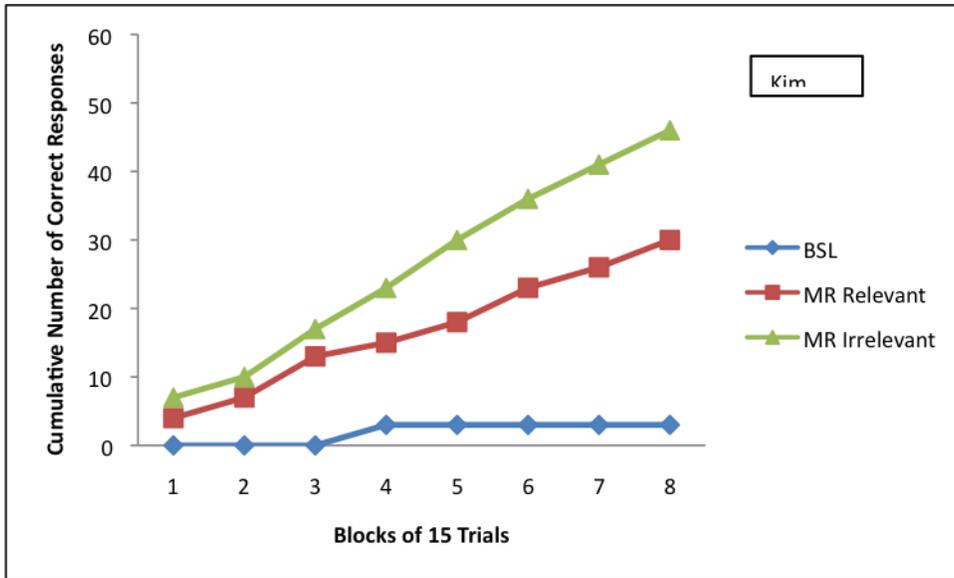


Figure 2

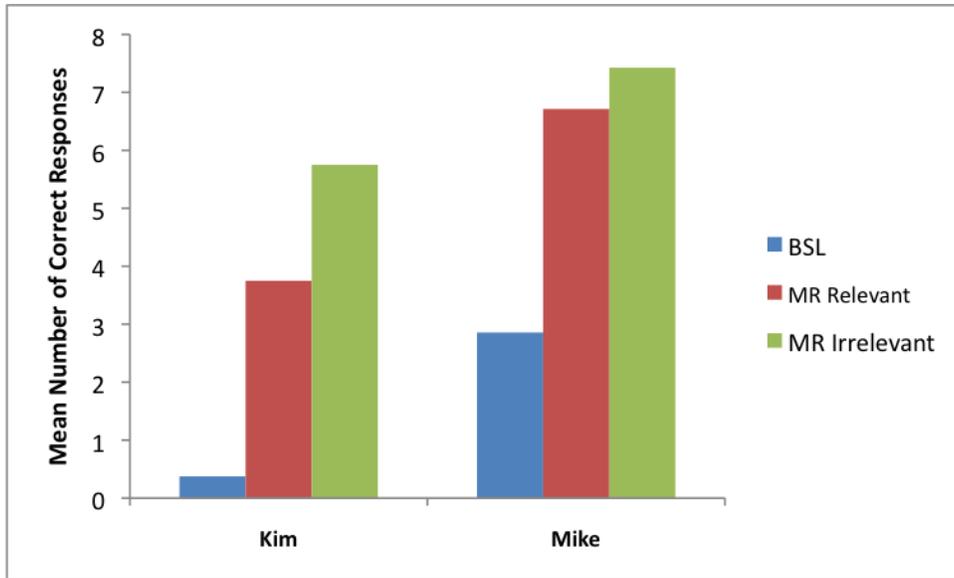


Figure 3