Effects of Conditional Discrimination Training and Stimulus Shaping on the Emergence of Reading Comprehension

Gabriel Rodriguez Jr.

A Thesis Submitted to the Faculty of

The Chicago School of Professional Psychology

In Partial Fulfillment of the Requirements

For the Degree of Master of Science in Applied Behavior Analysis

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Abstract

A significant percentage of school-age children who fail to establish age-appropriate reading comprehension skills by age 9 are at risk for academic failure throughout elementary, middle, and high school. Furthermore, children with poor reading skills may experience low self-esteem and difficulties securing jobs in which reading is a pertinent duty. As such, the purpose of the current study was to the evaluate the effects of conditional discrimination training and stimulus shaping on the emergence of novel stimulus relations between pictures, their dictated names, and text (i.e., reading comprehension) in typically developing preschool children between 3- and 4-years-old. Participants were taught to select pictures upon hearing the dictated name (if not previously established) and to select transformations of pictures into text across three stages when given the dictated name. Participants were given tests to evaluate emergence of other relations among the stimuli that were not directly taught. Tests consisted of visual-visual matching, auditory-visual matching, tacting, and textual responses. The results demonstrated that conditional discrimination training and stimulus shaping led to the emergence of novel relations among stimuli for all participants. The results support the use of equivalence-based instruction and stimulus shaping given their efficacy and efficiency.

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Introduction

The acquisition of reading skills is a pivotal development that is a foundation for academic achievement for children (Lonigan, Purpura, Wilson, Walker, & Clancy-Menchetti, 2013). As children progress in school, so do the reading skills necessary to complete the assignments given. A critical change takes place from “learning to read” to “reading to learn” as children advance beyond the third grade (Barth, 2012). G. Reid Lyon, the former chief of the Child Development and Behavior Branch within the National Institute of Child Health and Human Development (NICHD) at the National Institute of Health (NIH), gave testimony to the United States Senate Committee on Labor and Human Resources in 1998 that revealed that approximately 75% of children whose reading comprehension skills are not up to par by age 9 will continue to have lasting difficulties with reading through elementary, middle, and high school. Furthermore, of those students whose reading skills are not at grade level standards, 10% to 15% will drop out of high school.

Attempting to build subsequent skills on a foundational skill that has not been properly established can result in difficulties with future performance. Cumulative dysfluency can occur when a learner begins to move on to more advanced tasks that require building upon skills that have not be adequately developed (McDowell & Keenan, 2001). Consequently, students with poor reading skills typically have negative self-concepts and are more likely to give up and avoid reading-related tasks (Chapman & Tunmer, 2003). Additionally, unskilled readers are more likely to engage in behaviors that interfere with academic success and lead to disciplinary actions (Barth, 2012). McIntosh, Horner, Chard, Dickey, and Braun (2008) found that there was a functional relation between problem behavior (i.e., school discipline referrals) and escape or avoidance of academic tasks for students whose reading skills were far below average. As students fall behind, academic tasks become increasingly more aversive, establishing motivation for escape or avoidant behaviors for such tasks.

In addition to academic success, reading skills have become increasingly important for occupational purposes as more employment opportunities which involve technical and informational duties are being created compared to service and manufacturing duties (Lonigan et al., 2013). This, in large part, is due to the increase in cloud computing, big data storage, mobile computing, and the need for all things being accessible via the internet (U.S. Department of Labor, 2015). In regards to employment opportunities, the unemployment rate of high school drop outs ranged from 19.8% to 49.6% between 2000 and 2012 compared to 9.5% to 28.4% for high school graduates (Statista, 2016; U.S. Department of Labor, 2013). Adequate reading skills will continue to grow as a necessity to accomplish tasks for jobs as informational and technical fields are expected to add approximately 500,000 jobs between 2014 and 2024 compared to manufacturing jobs which are expected to lose approximately 550,000 jobs by 2022 (Torpey, 2014; U.S. Department of Labor, 2015). As such, establishing strong reading skills at an early age is critical.

When breaking down reading in order to evaluate its components, reading comprehension typically begins by matching words, read either phonetically or by recognition, to the pictures they represent (Sidman, 1971). Reading comprehension at this level (matching words and pictures) is a basic conditional discrimination (Sidman, 1971). A conditional discrimination is a unit of stimulus control which can be better understood by examining the two types of simple discriminations (Saunders & Williams, 1998). A simple discrimination consists of a three-term contingency: an antecedent stimulus, a response, and a consequence (Green, 2001). The two types of simple discriminations are successive and simultaneous discriminations (Saunders & Spradlin, 1990, 1993; Saunders & Williams, 1998). In a successive discrimination, a single stimulus is presented, typically for a period of time. This stimulus could be a positive stimulus (S^+) or negative stimulus (S^-; Saunders & Spradlin, 1990, 1993; Saunders & Williams, 1998). In a simultaneous discrimination, two or more stimuli are presented at the same time (an S^+ and one or more S^-; Saunders & Spradlin, 1990, 1993; Saunders & Williams, 1998). In both procedures, responses made to the S^+ are reinforced and responses made to the S^- are extinguished.

Conditional discriminations build on simple discriminations by adding a fourth stimulus; a conditional stimulus is added before or in combination with the antecedent stimulus in the simple discrimination (Green, 2001; Saunders & Williams, 1998). In a conditional discrimination, the conditional stimulus, or sample, is presented along with comparison stimuli (an S^+ and one or more S^-). The individual responds to one and an appropriate consequence follows (Saunders & Spradlin, 1989, 1990). The function of the comparison stimuli changes based on the given sample stimulus (e.g., if A then B, if X then Y; Saunders & Williams, 1998; Sidman, 1994; Sidman & Tailby, 1982). As such, conditional discrimination training involves both types of simple discriminations as the individual is required to discriminate among the varying sample stimuli across trials (successive discrimination) as well as among the multiple comparison stimuli (simultaneous discrimination) within each trial (Green, 2001; Zaine, Domeniconi, & De Rose, 2014).

Match-to-sample (MTS) procedures have long been used to train conditional discriminations (Green, 2001; Saunders & Williams, 1998). An MTS trial typically consists of a sample stimulus, an observing response, comparison stimuli, a response, and a consequence

(Green, 2001; Saunders & Williams, 1998). The sample stimulus is a conditional stimulus that will change the function of the comparison stimuli (Saunders & Williams, 1998; Sidman, 1994). Following the presentation of the sample stimulus, a learner is often required to engage in an observing response to the sample stimulus, most commonly by touching it when visual stimuli are used (Green, 2001). The observing response helps to ensure the individual attends to the sample stimulus which will develop stimulus control over responses (Green, 2001; Saunders & Spradlin, 1989, 1990, 1993). Once an observing response is made, the comparison stimuli (consisting of an S^+ and one or more S^-) are revealed. The comparison stimulus which matches the sample stimulus is the S^+ and, thus, functions as the discriminative stimulus. Responses to this stimulus are reinforced, and responses to the S^- stimuli are extinguished and/or an error correction procedure is implemented (Grannan & Rehfeldt, 2012; Green, 2001; Saunders & Williams, 1998). For example, in the presence of sample stimulus A1, comparison stimulus A1 functions as the S^+ but functions as the S^- in the presence of sample stimulus A2. However, in the presence of sample stimulus A2, comparison stimulus A2 functions as the S^+.

Two different types of matching, identity and arbitrary, are often trained using MTS procedures (Green, 2001). In identity matching, the positive comparison stimulus is identical (physically the same) to the sample stimulus (Sidman, 1994). This is evidenced in the previous example (i.e., A1=A1). In arbitrary matching, the sample stimulus and comparison stimuli have differing physical properties (e.g., picture of ball and the word “ball”; Saunders & Spradlin, 1990). This differs from identity matching as, following the presentation of sample stimulus A1, comparison stimuli B1, C1, and D1 may all function as S^+s despite having differing in physical properties from A1; however, each stimulus functions as an S^- in the presence of sample stimulus A2. Although in the presence of sample stimulus A2, comparison stimuli B2, C2, and D2 will function as S^+s. Reading comprehension at the level of matching the picture with the text can be demonstrated through arbitrary MTS procedures.

More recent interest in MTS procedures lie in its use for producing stimulus equivalence (Green, Sigurdardottir, & Saunders, 1991). Stimulus equivalence can occur as a result of MTS procedures when investigating conditional relations (Miguel, Yang, Finn, & Ahearn, 2009). Stimulus equivalence is the emergence of novel stimulus-stimulus relations among a group of stimuli following the training of some, but not all, relations among them (Keintz, Miguel, Kao, & Finn, 2011). Stimulus equivalence is commonly demonstrated with three stimuli, A, B, and C. Within these three stimuli, two stimulus-stimulus relations are directly trained (e.g., A=B and B=C). Stimulus equivalence is then demonstrated when the properties of reflexivity, symmetry, and transitivity emerge without direct training (Green et al., 1991; Kennedy, Itkonen, & Lindquist, 1994). Reflexivity is characterized by generalized identity matching of each stimulus absent of explicit training. Reflexivity is demonstrated when each stimulus establishes a relationship to itself (e.g., A=A, B=B, C=C; De Rose, De Souza, & Hanna, 1996; Sidman, Kirk, & Willson-Morris, 1985; Sidman & Tailby, 1982). This requires an individual to select a given stimulus from the array of comparison stimuli when presented with itself as a sample stimulus without differential reinforcement or outlined instruction to do so (Sidman & Tailby, 1982). Symmetry is characterized by the reversal of sample and comparison stimulus relations following the training of the original conditional discrimination (e.g., if A=B then B=A and if B=C then C=B; De Rose et al., 1996; Sidman et al., 1985). This is demonstrated when an individual selects the positive comparison stimulus given the target sample stimulus and then can select the target sample stimulus when presented in the comparison array given the previous positive comparison stimulus as the sample without differential reinforcement or outlined instruction to do so (Sidman & Tailby, 1982). Finally, the property of transitivity is characterized by the emergence of an entirely new stimulus-stimulus relation following the training of at least two other stimulus-stimulus relations which share a common stimulus (e.g., if A=B and B=C then A=C and C=A; De Rose et al., 1996; Sidman et al., 1985). This occurs when a new relationship emerges without differential reinforcement or outlined instruction between stimuli that served as both the sample stimulus and positive comparison for a common stimulus (Sidman & Tailby, 1982).

Equivalence-based instruction has become a popular technology in educational settings with various populations as the teaching process and learning outcomes are efficient and effective (Keintz et al., 2011; Zaine et al., 2014). This instructional method has shown to be efficient in regards to learning outcomes as they are in positive disproportion to the teaching resources used (Lane & Critchfield, 1998). In many studies, less resources (e.g., time and materials) are required in relation to the performance results when equivalence-based instruction is used because more relations are learned than taught (Green et al., 1991; Lane & Critchfield, 1998; Zaine et al., 2014). Areas of academic skills in which this procedure has been applied range from simple reading comprehension to more complex areas taught to college students (Fields, Travis, Yadlovker, de Aguiar-Rocha, & Sturmey, 2009; Zaine et al., 2014).

Equivalence-based instruction has been used to produce novel relations with a variety of stimuli including relations between coins and their value (Keintz et al., 2011), following activity schedules with derived textual relations (Miguel et al., 2009), and teaching reading comprehension (Groskreutz, Karsin, Miguel, & Groskreutz, 2010; Sidman, 1971). Equivalence-based instruction is prime to establish reading comprehension between pictures and text. The first study in stimulus equivalence was conducted by Sidman (1971) who observed that a 17-

year-old boy with severe mental retardation could read with comprehension following some simple training. Visual stimuli were presented in a nine-panel window (3 x 3 matrix) with the sample in the center square and the comparisons around the sample when applicable. When an auditory stimulus was played, it was repeated in 2 s intervals. During testing, correct responses were followed by a bell chime, one piece of candy, and one penny whereas incorrect responses resulted in no consequence. The participant was tested on six relations among the stimuli. Pretests showed the boy could already select pictures when provided with the spoken name and tact by speaking the name of the pictures but could not read text aloud or read with comprehension. The participant was then taught to select text upon hearing its name. Eight comparison stimuli were presented around a black center square. A spoken name was presented, and the participant was required to select the correct text. Correct responses received a bell chime and a piece of candy. After incorrect responses, an error correction procedure was used in which the textual stimuli remained until the correct text was chosen. Correct responses made after one or more errors received a bell chime only. Following auditory-visual training, the boy scored high across all relations during posttests and could vocally read the text and respond to the text with comprehension by matching text to pictures and pictures to text without any direct training.

While much of the research has shown MTS conditional discrimination training to be effective, there are some limitations to previous research. First, some studies which utilized MTS-only formats did not reliably result in stimulus equivalence (Carp & Petursdottir, 2015; Fields, Doran, & Marroquin, 2009). Second, in some cases, MTS alone has resulted in lower responding to tact and intraverbal relations compared to visual-visual and auditory-visual relations (Carp & Petursdottir, 2015; Keintz et al., 2010). Keintz et al. (2011) used a MTS procedure to investigate stimulus equivalence between coins, their dictated names, their dictated prices, and their printed prices. Following a pretest of seven relations among the stimuli that were expected to emerge, the participants were taught three additional relations. Following mastery, participants were tested again to determine if the seven relations emerged. The results indicated that the procedure was effective for one participant as all seven possible relations emerged. For the other participant, however, only four of the seven relations emerged with the original training. Specifically, tact and intraverbal relations did not emerge. The participant was unable to tact the price when given the written price, say the price when the coin name was dictated, and say the coin name when the price was dictated. Thereafter, subsequent training was required before full emergence was observed.

Carp and Petursdottir (2015) conducted a study with six typically developing kids between 5 and 7 years of age to evaluate the effects of conditional discrimination training on the emergence of equivalence between state map outlines, state birds, and state flowers. The participants were first taught to categorize each picture as a bird, state, or flower and then taught to tact each specific picture (e.g., Texas, blue jay, sunflower). Following an intraverbal pretest, conditional discrimination training was conducted in which the participant was taught to select the picture of the corresponding bird given the state outline and to select the picture of the corresponding flower given the state outline. Following training, the participants were given equivalence and intraverbal tests. Three of the six participants failed some or all of the equivalence tests and an additional participant only passed after a modification was added. The three participants that were unable to pass the equivalence tests were given additional training. They were taught to select the picture of the flower given the picture of the bird. Following this training, emergence of symmetry of this relation was observed. Intraverbal tests were only passed by four participants, but only once equivalence was demonstrated.

Given some of the limitations of MTS alone to produce stimulus equivalence (Carp & Petursdottir, 2015; Fields, Doran, et al., 2009; Keintz et al., 2011), other procedures may be beneficial in establishing derived responding. One of these procedures is stimulus shaping. Stimulus shaping is a process that involves "manipulating the topographical configuration of visual stimuli" (Schilmoeller, Schilmoeller, Etzel, & LeBlanc, 1979, p. 402); an initial stimulus is slowly changed until it is a completely different stimulus (Stoddard & Sidman, 1967). In regards to reading comprehension, pictures can be slowly and systematically changed into the text which correspond to them. Each change acts as a within-stimulus prompt to maintain accurate responding based on criterion-related cues (Mosk & Bucher, 1984). For example, a picture of a car which an individual can tact is slowly changed during three steps to fade out the picture aspects and fade in the textual aspects of "car."

Stimulus shaping has been shown to be an effective teaching method when typical methods of instruction have been ineffective for learners (Etzel & LeBlanc, 1979). Schilmoeller et al. (1979) compared the effects of stimulus shaping, stimulus fading, and trial-and-error on the acquisition of conditional discriminations in typically developing 4- and 5-year-old children. The children were divided into three groups, and each received a different training procedure. The results suggested that stimulus shaping was the most effective procedure for participants to meet criterion for acquiring conditional discriminations. Twelve out of sixteen participants reached criterion when stimulus shaping was used while only three out of sixteen participants reached criterion when stimulus fading was used and two out of eight participants reached criterion when trial-and-error was used. Of the twelve participants who reached criterion with stimulus shaping, nine did so without errors and three made only a single error.

This low rate of errors can be beneficial and has been replicated in additional research. Mosk and Bucher (1984) compared the effects of stimulus shaping plus prompting and a standard prompting procedure alone on teaching visual-motor discriminations in six children diagnosed with mental retardation. Three participants were trained to complete one task using a least-to-most (LTM) prompting procedure only and the other three were taught using a stimulus shaping procedure plus the LTM prompting procedure. This was reversed for a second task. The researchers implemented a prompting hierarchy consisting of pointing, modeling, physical prompting, and hand-over-hand guidance if participants did not respond correctly during the task. The results suggested that stimulus shaping plus prompting resulted in significantly fewer cumulative errors in reaching criterion than the standard prompting procedure alone.

The overall results of the previous literature (Mosk & Bucher, 1984; Schimoeller et al., 1979) demonstrate the benefit of stimulus shaping in that it has occasioned correct responding and limited the number of errors made during training. This resulted in more frequent contact with reinforcement and less frustration as well as less overall time spent during training. As such, stimulus shaping may maintain accurate responding during MTS procedures and aide in the transfer of stimulus control from pictures to text. Additionally, this may create more contact between the learner and all of the stimuli within the relations in order to aide in producing stimulus equivalence. As such, combining stimulus shaping within conditional discrimination training may ensure success while limiting errors in performance. This can save time and resources and may help facilitate stimulus equivalence when it is not otherwise observed. Thus, the purpose of the current study was to evaluate the effects of conditional discrimination training and stimulus shaping on the emergence of novel stimulus relations between pictures, their dictated names, and text in typically developing preschool children.

Method

Participants and Setting

Three typically developing children participated in this study. Gio was a 4-year-old boy. He did not recognize any letters (i.e., tact letters or select letters from an array when given the spoken name). Kiara was a 4-year-old girl. She was able to recognize some letters such as “s,” “a,” and “c.” Genie was a 3-year-old girl. She did not recognize any letters. All participants were able to speak in full sentences, follow simple one-step instructions, attend to a task for 3 to 5 min, and did not engage in interfering behaviors. None of the participants had formal training in reading.

Sessions took place in a quiet room with minimal distractions at the daycare that all three participants attended. The room contained a small table and chairs where the experimenter and participant sat during experimental sessions. Also, in the room was a desk, book shelf, cabinet, computer, printer, and phone. Sessions typically occurred three times per week and lasted no more than 30 min per session during pre- and posttests and 20 min per session during training.

Relations

Six relations between stimuli were included in this study (see Figure 1). Two relations, AB and AC, were trained (see Table 1). With the AB relation, the participant was provided an auditory stimulus and required to select a picture that corresponded to the auditory stimulus from an array. For the AC relation, the participant was presented with an auditory stimulus and required to select a textual stimulus that corresponded to the auditory stimulus from an array. This relation was trained through stimulus shaping.

Four relations were tested for emergence, BD, CD, BC, and CB. For the BD relation, the participant was presented with a picture and required to tact the item. For the CD relation, the participant was presented with a textual stimulus and required emit textual behavior. For the BC relation, the participant was presented with a picture and required to select the corresponding textual stimulus from an array. For the CB relation, the participant was presented with a textual stimulus and required to select the corresponding picture from an array.

Materials

A variety of materials were used in this study. Pre-experimental training was conducted using three pictures, tree, shoe, and ball, which differed from the target stimuli (See Figure 2). The primary materials included pictures and textual names of a cow, rocket, and sheep. In addition, three sets of hand-drawn transformation stages from pictures to texts were used during the stimulus shaping condition (see Figure 3). The pictures and transformation stimuli were hand drawn in black marker. The textual stimuli were hand written in black marker. All stimuli were on laminated, white cards that varied in size within each set of stimuli and between each set of stimuli. The pictures themselves along with the first set of transformation stimuli were 13 cm x 6 cm (cow) and 11 cm x 6 cm (rocket and sheep). The second transformation stage stimuli were 11 cm x 5 cm (cow), 11 cm x 4 cm (rocket), and 10 cm x 5 cm (sheep). The stimuli of the third stage of transformation measured 10 cm x 4 cm (cow), 11 cm x 4 cm (rocket), and 10 cm x 5 cm (sheep). The textual stimuli measured 10 cm x 4 cm (cow), 11 cm x 5 cm (rocket), and 10 cm x 5 cm (sheep).

Materials also included laminated pictures of poker chips used as tokens, small items for reinforcement, and small items that could be engaged with during breaks. Items such as stickers, small crayon packs, markers, and pencils of various themes and characters were available in exchange for tokens. Toys and activities such as small cars and puzzles were available during breaks for the participants to engage with. In addition, an Apple® iPad 2™ was used to record each session.

Response Measurement

The primary dependent variable was the number of correct responses during tests. In addition, the number of correct responses was also measured during training. Correct and incorrect responses were scored on a trial-by-trial basis. During MTS trials, a correct response was defined as the participant touching the positive comparison stimulus within 5 s. An incorrect response was defined as the participant touching a negative comparison stimulus or not responding within 5 s. For tact and textual trials, a correct response was defined as the participant vocally stating the name corresponding to the sample stimulus. An incorrect response was defined as the participant vocally stating a name that did not correspond to the sample stimulus or not responding within 5 s.

In addition to tests and training, data were collected during pre-experimental training on the completion of an observing response and the number of correct MTS responses. An observing response was considered independently completed if the participant touched a blank, laminated card within 5 s of its presentation. An incorrect response occurred if the participant did not touch the laminated card within 5 s. For MTS responses, a correct response was defined as the participant touching the positive comparison stimulus within 5 s. An incorrect response was defined as the participant touching a negative comparison stimulus or not responding within 5 s. A trial was considered correct if the participant responded correctly to both components of the trial.

Interobserver Agreement (IOA)

IOA was assessed by having a second observer independently collect data from video. An agreement was defined as both observers scoring a response as correct or both scoring it as incorrect. IOA was calculated on a trial-by-trial basis by dividing the number of trials with agreements by the total number of trials and then multiplying by 100.

For Gio, IOA was collected for 37% of trials during the pretest (due to recording equipment difficulties), 100% of trials during the posttest, and 33% of sessions during training. IOA was 100% during both testing and training sessions. For Kiara, IOA was collected for 100% of sessions during tests and 38% of sessions during training. IOA was 98% during tests (range, 96% to 100%) and 100% during training. Finally, for Genie, IOA was collected for 100% of sessions during tests and 33% of sessions during training. IOA was 97% (range, 94% to 100%) during tests and 100% during training.

Treatment Integrity

Treatment integrity data were obtained by having a second observer view videos of sessions and score the correct implementation of each trial conducted by scoring the correct implementation of a checklist of steps corresponding to the type of trial conducted (i.e., MTS, tact, or textual). A trial was considered correct if the experimenter correctly completed 100% of the steps on the checklist. Treatment integrity was calculated on a trial-by-trial basis by dividing the number of correctly implemented trials by the total number of trials and multiplying by 100.

For Gio, treatment integrity was collected for 37% of the trials during the pretest (due to recording equipment difficulties), 100% of trials during the posttest, and 33% of sessions during training. Treatment integrity was 97% (range, 95% to 98%) during testing sessions and 100% during training sessions. For Kiara, treatment integrity was collected for 100% of sessions during tests and 38% of sessions during training. Treatment integrity was 100% during both testing and training sessions. Finally, for Genie, treatment integrity was collected for 100% of sessions during tests and 33% of sessions during training. Treatment integrity was 99% (range, 98% to 100%) during tests and 98% (range, 89% to 100%) during training.

Procedures

A pretest-train-posttest design was used to evaluate the effects of conditional discrimination training and stimulus shaping on the emergence of novel stimulus relations. The order of the conditions was as follows: pre-experimental training, pretest, MTS training of the AB relation (if needed), MTS training via stimulus shaping of the AC relation, and posttest. A multiple stimulus without replacement (MSWO) preference assessment was conducted at the start of each session for pre-experimental training and MTS training sessions.

MSWO preference assessment. A MSWO preference assessment was conducted at the start of each training session to determine what stimuli may act as potential reinforcers for the participant that day. Five items were lined up horizontally in front of the participant. The experimenter then instructed the participant to choose the one he or she liked by stating, “pick the one you like.” The other items were removed, and the item chosen was recorded. For the next trial, the remaining items were moved over one spot from the left to right. This process was repeated until a hierarchy of preference was determined with the top three items or activities being available for token exchange at the end of each session.

Pre-experimental training. Prior to the pretest being conducted, each participant was trained to respond in the manner expected during MTS trials. Trial blocks consisted of nine trials with each sample stimulus presented three times, and the positive comparison stimulus was presented once in the left, middle, and right positions per stimulus. The order of trials and position of comparisons were preprogrammed and were presented in a quasi-random order with the following requirements: the same sample stimulus was presented no more than two consecutive trials and the positive comparison stimulus was presented in the same position no more than two consecutive trials.

A trial began by the experimenter presenting a barrier with a blank white card centered on it. If the participant emitted an observing response by touching the blank white card, the barrier was removed. If the participant did not emit the observing response, a LTM prompting hierarchy was implemented by first having the experimenter model touching the sample. If the participant responded incorrectly again, the participant was provided physical guidance to make an observing response. Once an observing response was made and the comparison stimuli were presented, the participant was instructed to touch a target comparison stimulus (e.g., "touch ball"). Correct, independent response received vocal praise and a token. Following incorrect responses, a LTM prompting hierarchy (i.e., gesture, physical guidance) was implemented. Correct, prompted responses received vocal praise only. The mastery criterion during pre-experimental training was one session with eight out of nine independent, correct responses for both the observing and MTS responses.

Pre- and posttest of emergent relations. Tests were conducted for all relations among stimuli (see Table 1). Four types of trials were included in the tests: auditory-visual MTS trials were conducted for AB and AC relations, visual-visual MTS trials were conducted for BC and CB relations, tact trials were conducted for BD relations, and textual trials were conducted for CD relations. Tests were conducted in 54-trial blocks with the four trial types mixed. A 3- to 4-min break was given after every 18 trials during pretests and after every 9 trials during posttests. The number of trials that were conducted prior to a break was decreased during posttests in order to reduce fatigue that seemed to occur during the pretest during the last three to five trials prior to a break in which participants asked when they could have a break or how many did they still had to do.

The order of trials was preprogrammed with each of the six relations for each of the three sets of stimuli conducted three times each. The positive comparison stimulus was placed in the left, middle, and right positions once per relation per stimulus. Trials were presented in a quasi-random order with the following exceptions: the same sample stimulus was not presented more than twice in a row and the positive comparison stimulus was presented no more than two times consecutively in the same position. During testing, no consequences were provided for correct or incorrect responses. A relation was determined to have previously been established if the participant responded correctly in eight out of nine trials during the pretest and to have emerged if the participant responded correctly in eight out of nine trials during the posttest.

During auditory-visual MTS trials, the participant was first presented a barrier sheet with a centered, blank white card. Once the participant emitted an observing response by touching the card, the barrier was removed and three comparison stimuli were presented in a horizontal line. The experimenter then provided the auditory sample stimulus, “touch (name of picture/word),” and the participant was expected to touch the positive comparison. Visual-visual MTS trials were identical to the auditory-visual MTS trials with the exception that the sample stimulus centered on the barrier was either text or a picture depending on the relation tested.

During tact trials, the participant was first presented with a barrier sheet with a centered, blank white card. Once the participant made an observing response, the barrier was removed and a single sample stimulus of a picture was presented. The experimenter then asked, “What is this?” and the participant was expected to state the name of the item in the picture. Textual trials were identical to tact trials with the exception that the sample stimulus presented was the written name of the item and the experimenter asked, “What does this say?”

Conditional discrimination training (AB). Participants were trained to select the picture of the object in the presence of the dictated name if they did not respond with eight out of nine correct, independent responses during the pretest. This relation was trained using a typical MTS procedure. Sessions consisted of nine-trial blocks with the sample stimuli presented three times each with the positive comparison stimulus presented in the left, middle, and right positions once per stimulus. Trials were preprogrammed and were presented in a quasi-random order with the following exceptions: the same sample stimulus was not presented more than twice in a row and the positive comparison stimulus was presented no more than two times consecutively in the same position.

A trial began by the experimenter presenting a barrier with a blank white card centered on it. Following an observing response from the participant, the barrier sheet was removed and three comparison stimuli in the form of pictures were presented horizontally on a trial sheet. The experimenter then provided the instruction to touch the target comparison stimulus (e.g., “touch cow”). Correct, independent responses received vocal praise and a token. Following incorrect responses, participants were given minimal feedback (i.e., “try again”) and a LTM prompting hierarchy was implemented with the experimenter first gesturing to the correct comparison stimulus. If the participant still responded incorrectly, the participant was given minimal feedback once more (i.e., “try again”) and given physical guidance to the correct comparison stimulus. Correct, prompted responses received vocal praise only. The mastery criterion during the AB MTS condition was three consecutive sessions with eight out of nine independent, correct responses.

Stimulus shaping (AC). Stimulus shaping consisted of three transformation stages between the picture and the text. Each transformation stage was slowly altered to more closely resemble the textual stimulus and look less like the picture (see Figure 3). This relation was trained using a typical MTS procedure. Sessions consisted of nine-trial blocks with the sample stimuli presented three times each with the positive comparison stimulus presented in the left, middle, and right positions once per stimulus. Trials were preprogrammed and were presented in a quasi-random order with the following exceptions: the same sample stimulus was not presented more than twice in a row and the positive comparison stimulus was presented no more than two times consecutively in the same position.

During each trial, the participant was first presented with a blank, white card centered on a barrier sheet and required to make an observing response. Once an observing response was made, the barrier was removed and three comparison stimuli in the form of the targeted transformation or text were presented horizontally on the trial sheet. The experimenter then provided the instruction to touch the target comparison stimulus (e.g., “touch rocket”). Correct, independent responses received vocal praise and a token. Immediately following incorrect responses, the same LTM prompting hierarchy as was used in the AB training condition was implemented. Correct, prompted responses received vocal praise only. The mastery criterion at the level of each transformation as well as with the final textual stimuli was eight out of nine correct, independent responses across three consecutive trial blocks.

Results

All three participants reached criteria for the emergence of all relations following training. Gio began with pre-experimental training and reached the mastery criterion after one session as he responded correctly in eight out of nine trials. Following this training, Gio was given the pretest (see Figure 4). The pretest indicated that two relations, AB and BD, were already established as Gio correctly responded to nine out of nine and eight out of nine trials respectively. Low responding was seen for the remaining relations. Gio responded correctly to four out of nine trials for the AC relation, zero trials for the CD relation, one out of nine trials for the BC relation, and four out of nine trials for the CB relation. As the AB relations was already established, this relation was not trained and Gio began with training on the AC relation (see Figure 5). Gio reached criterion for each of the first three transformation stages in three sessions each. When presented with the text, he responded below criterion during the first trial block (seven out of nine correct responses) but responded at criterion during the next three trial blocks meeting the mastery criterion. Following training, the posttest was given and Gio responded correctly to all trials for all six relations, demonstrating emergence of the four untrained relations (see Figure 4).

Kiara began with pre-experimental training and met the mastery criterion after one session as she responded correctly in eight out of nine trials. Following pre-experimental training, Kiara was given the pretest (See Figure 6). Pretest results indicated that two relations, AB and BD, were already established as she responded correctly in nine out of nine trials for both. Low responding was seen for the remaining relations. Kiara responded correctly to three out of nine trials for the AC relation, four out of nine trials for the CD relation, four out of nine trials for the BC relation, and two out of nine trials for the CB relation. As the AB and BD relations were already established and did not require training, Kiara began AC training (See Figure 7). Kiara reached mastery criterion for the first stage in the first three sessions. In the second transformation stage, Kiara responded at criterion for the first trial block, below criterion during the second trial block (seven out of nine correct responses) but then responded at criterion for the next three sessions reaching the mastery criterion. During the third transformation condition, she reached the mastery criterion in three sessions. When presented with the text, Kiara initially responded below criterion for two consecutive trial blocks then responded accurately during the following three trial blocks reaching criterion in five sessions. Following training, Kiara responded correctly on all trials for the AB, BD, AC, and CB relations and eight out of nine trials for the CD and BC relations, demonstrating emergence of the four untrained relations (See Figure 6).

Genie began with pre-experimental training and met the mastery criterion after one session as she responded correctly in eight out of nine trials. Following pre-experimental training, Genie was given the pretest (See Figure 8). The results of the pretest indicated that no relations were previously established including the AB and BD relation. Genie responded correctly to four out of nine trials for the AB relation, seven out of nine trials for the BD relation, three out of nine trials for the AC relation, zero trials for the CD relation, five out of nine trials for the BC relation, and two out of nine trials for the CB relation. Although Genie responded to five out of nine trials for the BC relation, it was hypothesized that this occurred at chance as she only responded correctly to two out of nine CB relation trials and to none of the CD relation trials which showed no consistent responding with the C stimulus. Genie began with AB training as she did not meet criterion during the pretest to ensure consistent responding before moving onto training of the AC relation (See Figure 9). She responded below criterion for the first trial block (five out of nine correct responses) but then responded at criterion for the next three sessions meeting mastery criterion. During the first transformation stage, Genie reached criterion in three sessions. During the second transformation stage, she responded below criterion for the first two trial blocks (seven out nine correct responses and six out of nine correct responses) then responded at criterion for the next three trial blocks reaching criterion in five sessions. During the third transformation stage and when presented with the text, Genie responded at criterion and reached mastery in three sessions for each condition. Following training, the posttest was given, but the emergence criterion was not met for the four untrained relations, although higher responding was seen than during the pretest for most relations. Genie responded correctly to nine out of nine trials for the AB and BD relations, seven out of nine trials for the AC relation, five out of nine trials for the CD relation, five out of nine trials for the BC relation, and eight out of nine trials for the CB relation. She returned to the textual AC condition for retraining as her low score for the AC relation was inconsistent with her original training performance. During the second AC training condition, she again responded at criterion and reached mastery in three sessions. During a second posttest, Genie responded correctly to all trials for five relations, AB, BD, AC, CD, and BC, and to eight out of nine trials for the CB relation indicating that there was emergence of all four untrained relations (see Figure 8).

Discussion

The current study evaluated the effects of conditional discrimination training and stimulus shaping on the emergence of novel stimulus relations across three typically developing preschool-aged children. All three participants demonstrated emergent relations; each participant learned to read, match, tact, and respond to the text accurately. Through utilization of MTS conditional discrimination training and stimulus shaping, stimulus equivalence occurred with minimal errors and frustration. Gio and Kiara demonstrated emergence of all untrained relations during their first posttest without any additional training. Genie also demonstrated emergence of all untrained relations but required a second posttest following retraining of a previously trained relation for this to be fully observed. It should be noted that Genie was also the youngest of the participants and was only 3-years-old at the time of the study which may have accounted for the initial failure on the equivalence test.

In addition to the emergence of stimulus equivalence, stimulus shaping was successful at establishing accurate responding to the AC relation with minimal errors. Gio maintained responding at or above criterion as the pictures were transformed into text throughout the condition with the exception of one trial block during the transformation to text in which he made two errors, one more than criterion allowed. Kiara maintained responding at criterion with the exception of one trial block during the second transformation in which she made two errors, one more than criterion allowed and two trial blocks during the transformation to text in which she made two and three errors in the first two trial blocks respectively. Genie also maintained responding at or above criterion throughout each stimulus shaping condition with the exception of two trial blocks during the second transformation. She initially made two and then three errors in the first two trial blocks but responded at or above criterion for the remaining stages.

The maintenance of response accuracy during training can be attributed to several factors. First, praise seemed to have served as a generalized conditioned reinforcer for correct responses in addition to tokens that, in turn, were exchanged for back-up reinforcers identified from a preference assessment each session. This was likely pertinent in increasing and maintaining responding during stimulus shaping when responses were at or below mastery criterion. Second, the combination of stimulus shaping and the LTM prompting hierarchy was effective in occasioning correct responses as also seen in Mosk and Bucher (1984). The use of the LTM prompting hierarchy occurred on only a small number of trials, and when needed, it was rare for more than a gesture to be given before a correct response was observed. This speaks to the efficacy of stimulus shaping as a useful method to fade prompts. It is also possible that the second level of the prompting hierarchy, which involved physical guidance, may have served as punishment for incorrect responses when they occurred. Trials that required the second level of the prompting hierarchy to evoke a correct response were only followed by another incorrect trial twice out of all trial blocks, once for Kiara and once for Genie. Additionally, stimulus shaping as a within stimulus prompt was likely responsible for accurate responding as well. The similarity across transformations can account for continued accurate responding with limited additional prompts needed to evoke correct responses. It is possible that some level of recognition occurred as each transformation resembled the previous one. Aside from Kiara experiencing a decrease (i.e., 6 correct responses) from the third transformation level to the text and Genie from the first transformation to the second, each participant maintained accurate responding across transformations.

The similarity between transformations may also account for the development of stimulus equivalence. While the picture and the text were never directly paired, the transformations between the stimuli may have resulted in the indirect pairing of these stimuli, particularly as they were both paired with the same vocal stimulus. Other factors may also account for the establishment of stimulus equivalence classes among the stimuli. As only listener responses were trained and participants were exposed to the auditory name for all stimuli, it is possible that bidirectional naming occurred. Bidirectional naming occurs when an individual has a generalized bidirectional speaker-listener repertoire in which responses only need to be trained in one repertoire (as a speaker or as a listener) for responses in the other repertoire to emerge (Miguel, 2016). For example, a child learns to reach for juice when given the dictated name "juice" and reinforcement is provided for doing so. If the child has a bidirectional naming repertoire, the child would engage in the speaker behavior of tacting juice upon seeing juice without direct training. Bidirectional naming may also be responsible for reading comprehension as an individual must be able to read the text (speaker behavior) and respond to it (listener behavior) simultaneously (Miguel, 2016). During visual-visual matching trials during posttests, participants read the text and selected the corresponding pictures further supporting this claim. During the current study, participants were exposed to the auditory name of each stimulus when instructed to "Touch (stimulus)" (i.e., listener behavior) and were not trained to tact or read the pictures or text; however, as demonstrated by responses during posttests, each participant learned to engage in speaker behavior to the target stimuli without reinforcement.

Accurate performance during both stimulus shaping and the posttests for equivalence may also have been due, in part, to the participant's own verbal behavior. Participants may have engaged in covert verbal behavior of the target response (i.e., rehearsal) or talking through what comparison stimulus to touch upon presentation of the transformation before engaging in an overt response. Although covert behavior is difficult to measure or observe, in this study participants could be seen moving their mouths without speaking before responding. The notion that each participant engaged in covert self-talk during the study can be supported by overt responses such "I already know this one" and "I knew it" before and after responses. Santos, Ma, and Miguel (2015) observed a similar finding in which it was possible that participants engaged in self-echoic behavior by rehearsing the sample stimulus at some covert level before engaging in an overt response. This is also consistent with the findings of Winsler and Neglieri (2003) in which the overt and covert verbal behavior of children ages 5 to 17 was examined during problem solving tasks. Approximately 60% of participants demonstrated or reported engaging in fully overt, partially overt/partially covert, or fully covert self-talk during tasks. Winsler and Neglieri (2003) also found that children ages 5 to 8 (children under 5 were not included in their study) were most likely to engage in overt self-talk during tasks. In the current study, the participants engaged in overt self-talk such as “that’s cow” or “oh rocket ship” before instructed to respond, as observed during auditory-visual matching tasks. This supports the theory that verbal behavior influenced or strengthened responses during training and posttest.

The results of this study add support for stimulus shaping as an effective procedure when examining stimulus equivalence via MTS. Previous research has shown that, in some cases, MTS alone falls short in evoking derived relations among stimuli, particularly ones that involve tact and intraverbal behavior (Carp & Petursdottir, 2015; Keintz et al., 2011). The results of the current study add practical and socially significant research on stimulus shaping. Previous research has seldom utilized stimulus shaping and its application has been limited thus far. In Mosk and Bucher (1984) and Schimoeller et al. (1979), stimulus shaping was used for motor-related tasks. In this study, auditory-visual matching tasks were trained with the aid of stimulus shaping. This opens up the tasks for which stimulus shaping could begin to be applied.

In addition, the results extend previous research and may help improve the efficacy for clinicians and teachers while minimizing frustration for learners by implementing stimulus shaping. Stimulus shaping may be an effective and practical tool to use not only with the typically developing population who are struggling in the school and/or home settings to read with comprehension, but also with individuals with disabilities that are more likely to experience difficulties in learning to read with comprehension. Participants showed minimal frustration (e.g., whining, unwillingness to participate, crying) during the study. One possibility for this was that each transformation stage shared features with the previous one. As only small changes were made to the pictures during progressing transformations, participants may have maintained accurate performance after reaching criterion for the previous transformation. Maintaining accurate performance allowed participants to contact reinforcement frequently, limiting frustration. This is demonstrated by each participant as they completed the study relatively quickly. Gio required 13 trials blocks to complete training, Kira required 16 trial blocks to complete training, and Genie required 21 trial blocks to complete training including the AB relation that was not previously established and an additional retraining of the final AC transformation. In addition, training was completed with near maximal performance in regards to the minimum trial blocks necessary to meet the mastery criteria (i.e., 12 for Gio and Kiara and 15 for Genie). Gio required one additional trial block to reach criterion during responses to text, and Kiara required four additional trial blocks to reach criteria during the second transformation and text. Genie had three trial blocks below criterion during training for the AB relation and the second transformation. Although performance was at criterion during the initial training, three additional trial blocks were conducted in order to retrain responses to text for Genie.

The results of the current study also replicate much of the previous research that has demonstrated that stimulus equivalence can emerge from training conditional discriminations via MTS (Grannan & Rehfeldt, 2012; Keintz et al., 2011; Lane & Critchfield, 1998; Miguel et al., 2009; Sidman et al., 1985). The results further support the efficacy of equivalence-based instruction not only to produce stimulus equivalence among stimuli but as a technology to save time and resources (Green et al., 1991; Lane & Critchfield, 1998; Sidman & Tailby, 1982; Zaine et al., 2014). Exponentially more relations among the stimuli emerged than were directly trained saving the time it would take to teach each relation individually. For Gio and Kiara, one relation was previously established and only one relation was trained, and for Genie, two relations were trained. This resulted in the emergence of an additional four relations with a total of six relations between the stimuli following training of just one or two. Not only were more relations established than directly trained but also a variety of response types emerged following training of just one. Training consisted of auditory-visual matching only but each participant demonstrated tacting, textual, and visual-visual responses during posttests. This exemplifies how the utility and efficiency of equivalence-based instruction could become an invaluable tool within school and home settings. As equivalence-based instruction is utilized as an educational technology, the ease with which the procedures can be applied within both clinical and educational settings adds an effective alternative tool to the teaching repertoire (Zaine et al., 2014). The addition of stimulus shaping adds benefit by saving time and minimizing frustration for students who have had difficulty learning.

While the results of this study are positive and provide support to MTS and stimulus shaping as effective procedures for teaching reading comprehension, there are several limitations to be discussed. First, faulty stimulus control could have occurred given the characteristics of the stimuli. Only three words were used, each consisting of a different first letter. It is possible that the first letter alone provided control over responses during trials involving text rather than the whole word. Given a more natural context for reading, if target words were preceded and followed by words with the same letter, discrimination and reading may not occur due to faulty stimulus control. Furthermore, the length of each word differed by three letters from the shortest word (cow) to the longest word (rocket). It is also possible that the physical size of the word depicted on the laminated card provided control over responses rather than the word itself or characteristics of the transformation. Additionally, stimuli ranged in sizes, potentially establishing stimulus control with some aspect of the card rather than the text or picture itself. Once again, if participants attended to a particular characteristic of the stimulus dimensions rather than the transformations and text, the stimulus control of the transformations and text may remain uncertain. Future research should ensure all stimuli are consistent size and include a larger number of words consisting of the same first letter and of the same length within the array in order to protect against faulty stimulus control.

Second, during pretests, breaks were given following every 18th trial while during posttests, breaks were given following every ninth trial. This was due to observed fatigue in the participants and to better resemble training trial blocks as they consisted of nine trials. It is unclear if the different number of trials required before a break was given may have had an effect. It is possible that lower performance may have been seen in pretests due to fatigue rather than not having the established relation. Future research should evaluate the most effective number of trials before a break is given during pretest and posttest to account for fatigue according to target population. This will allow for consistency across testing conditions and remove any confounds that may occur from the difference.

Lastly, no generalization or follow-up probes were conducted to determine if responses to text occurred under more natural conditions or if responses maintained over time. If reading comprehension does not generalize from the controlled conditions of the study to natural conditions under which reading would typically occur, then the social significance and effectiveness of the study to teach reading comprehension comes into question. Generalization and follow-up probes should be conducted during future research to evaluate if responses occur over time and under varying conditions.

In conclusion, with the percentage of the population whose reading skills are not up to par with their peers and curriculum by age 9 being at risk for lasting reading difficulties and dropping out of high school, it is important to identify an effective alternative method that can be used to teach reading comprehension at a young age. Additionally, teaching individuals to read with comprehension at a young age and maintain academic performance with their peers may allow for increased self-esteem and future academic success as well as job, career, and economic opportunities. Utilizing stimulus shaping and MTS to establish stimulus equivalence also provides the added incentive of efficient and expedited learning outcomes such as reading comprehension.

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Table 1

Relations Tested and Trained per Condition

Condition	Relations	Stimuli
Pretest and posttest	AB	Given vocal name, select picture
	AC	Given vocal name, select word
	BD	Given picture, state name (tact)
	CD	Given word, state name (textual)
	BC	Given picture, select word
	CB	Given word, select picture
Conditional discrimination training	AB	Given vocal name, select picture
Stimulus shaping	AC	Given vocal name, select word trained through three transformations from picture to word

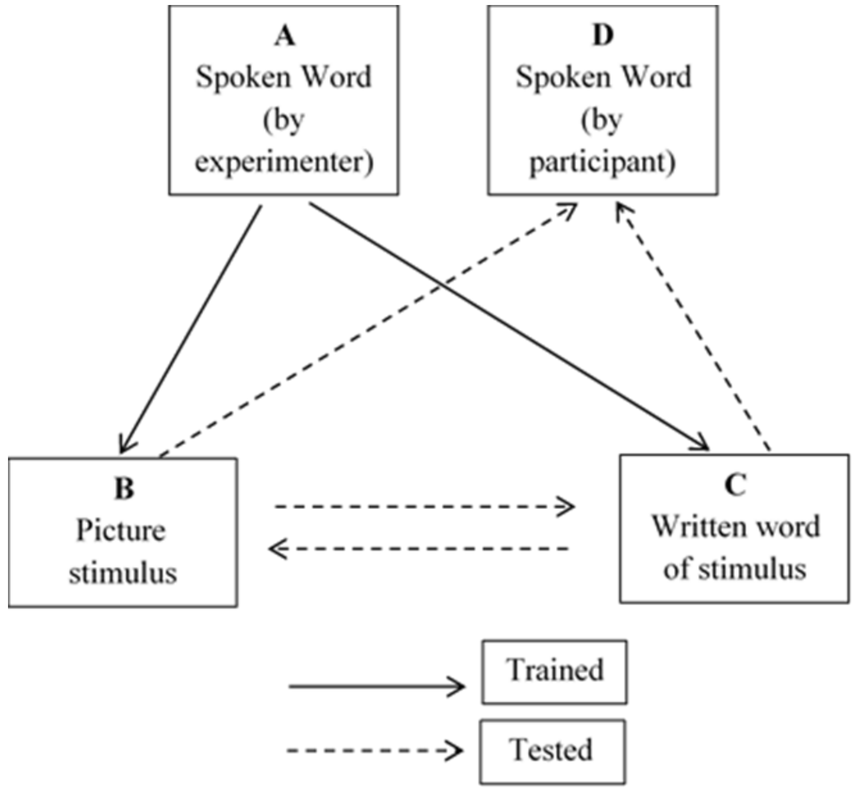

Figure 1. Relations trained and tested during the study.

Figure 2. Picture of tree, ball, and shoe used during pre-experimental training.

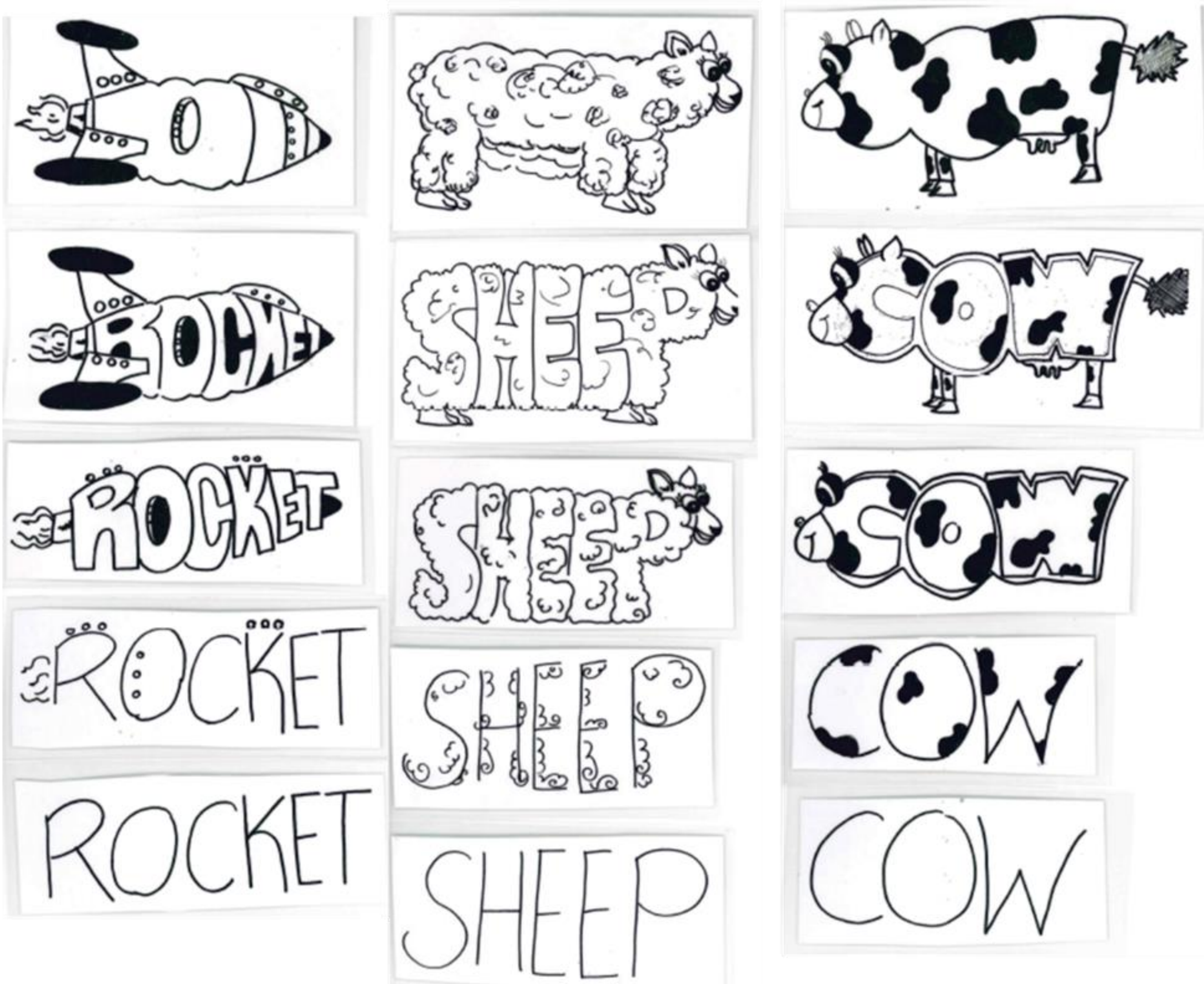

Figure 3. Stimulus transformations of rocket, sheep, and cow from pictures to text.

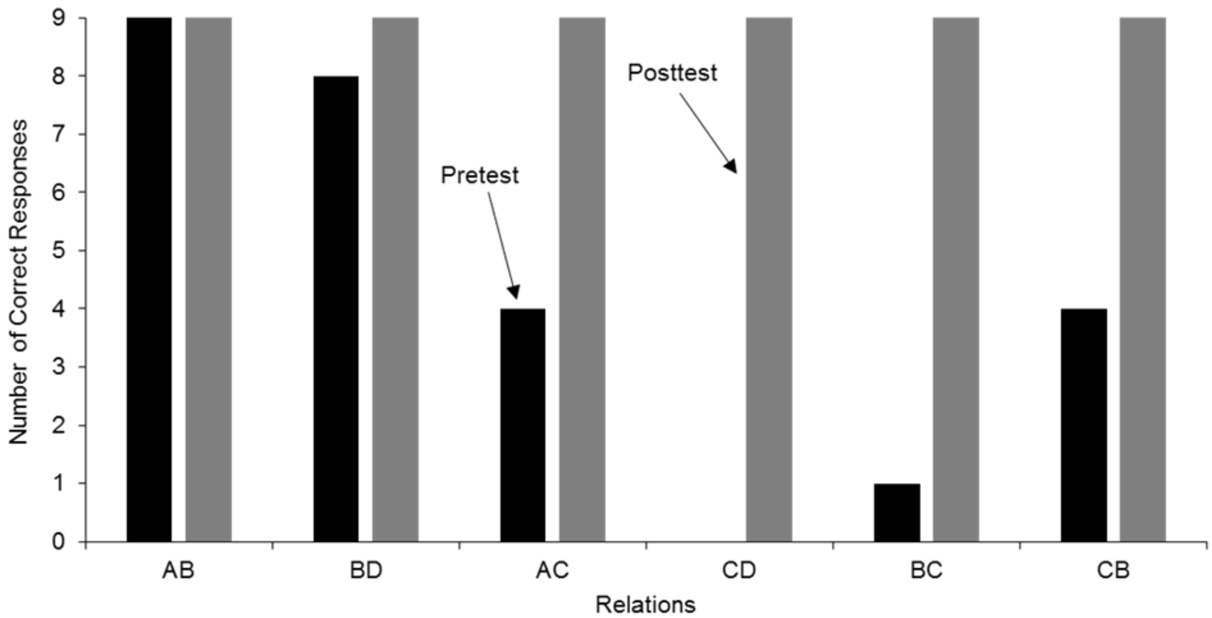

Figure 4. The number of correct responses per relation during the pre- and posttests for Gio.

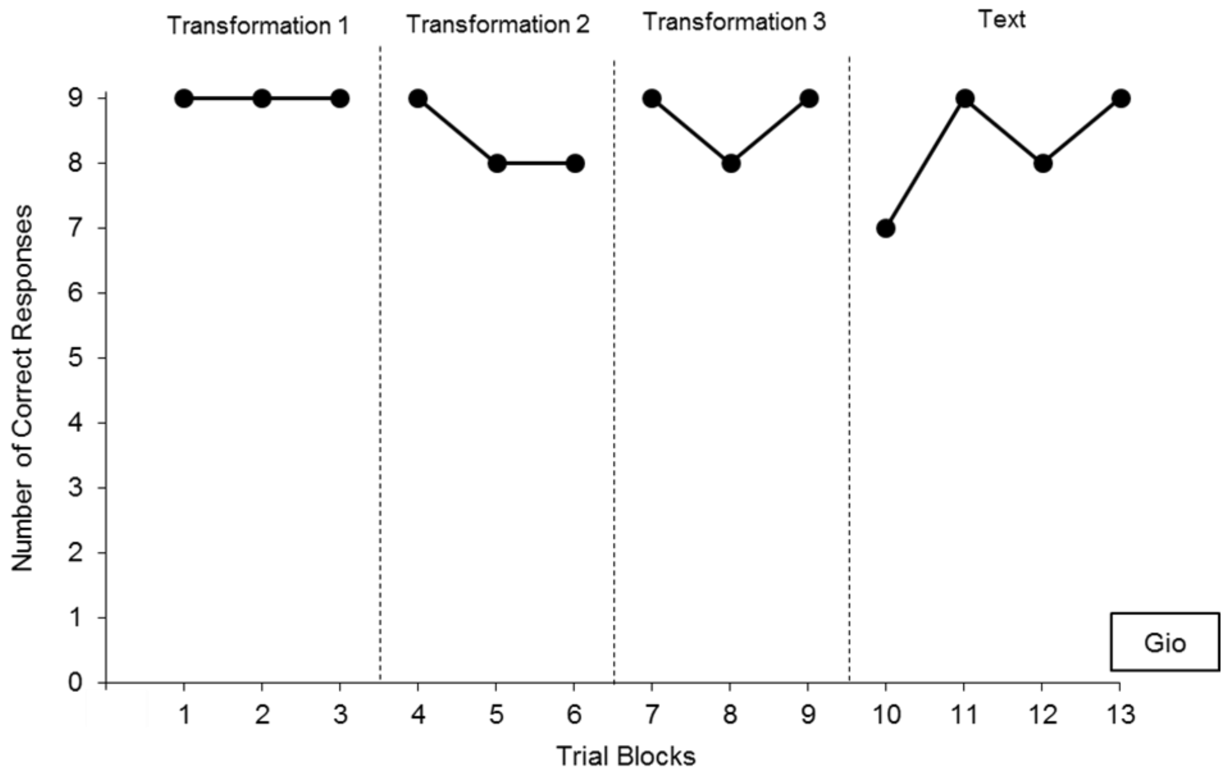

Figure 5. The number of correct responses per trial block during each stage of stimulus shape transformation and textual training for Gio.

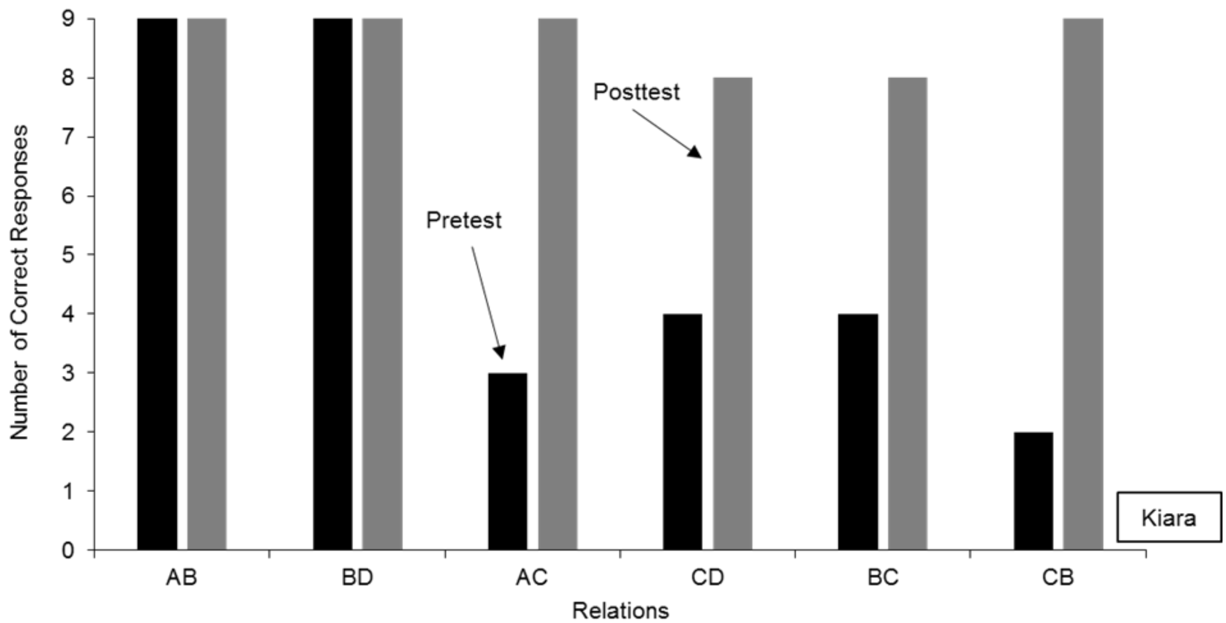

Figure 6. The number of correct responses per relation during the pre- and posttests for Kiara.

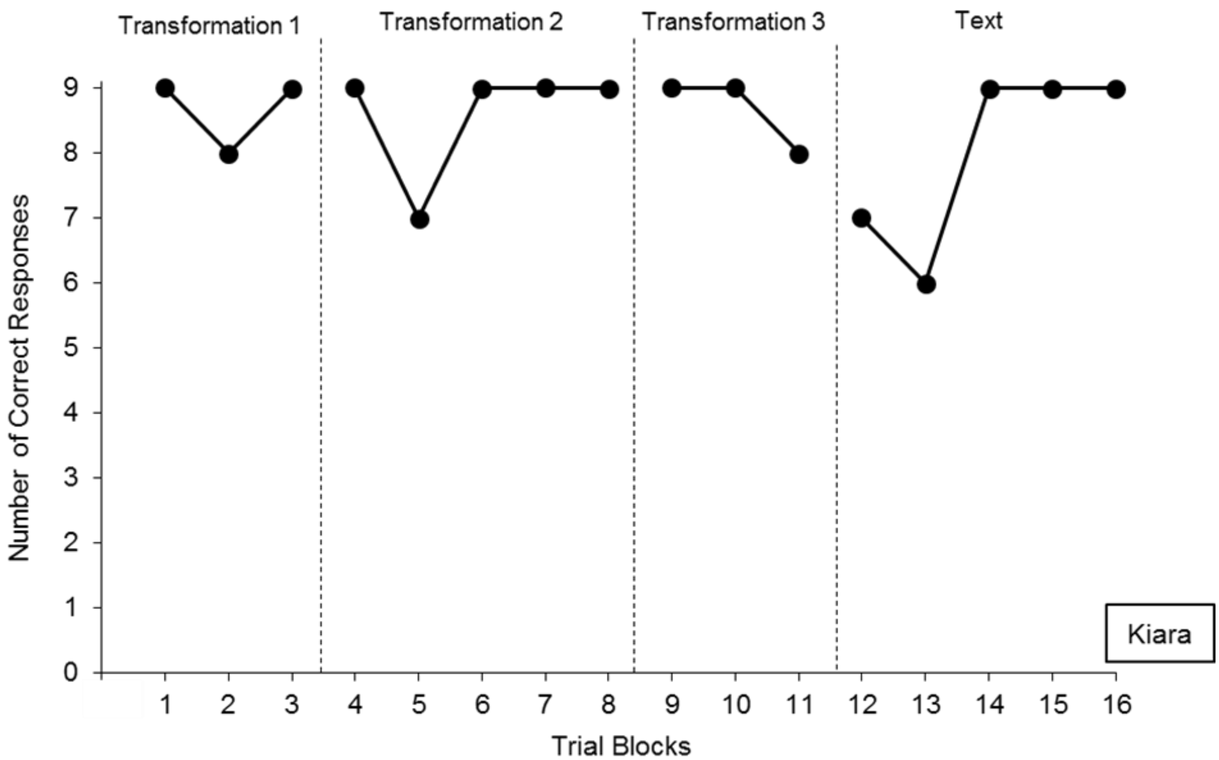

Figure 7. The number of correct responses per trial block during each stage of stimulus shape transformation and textual training for Kiara.

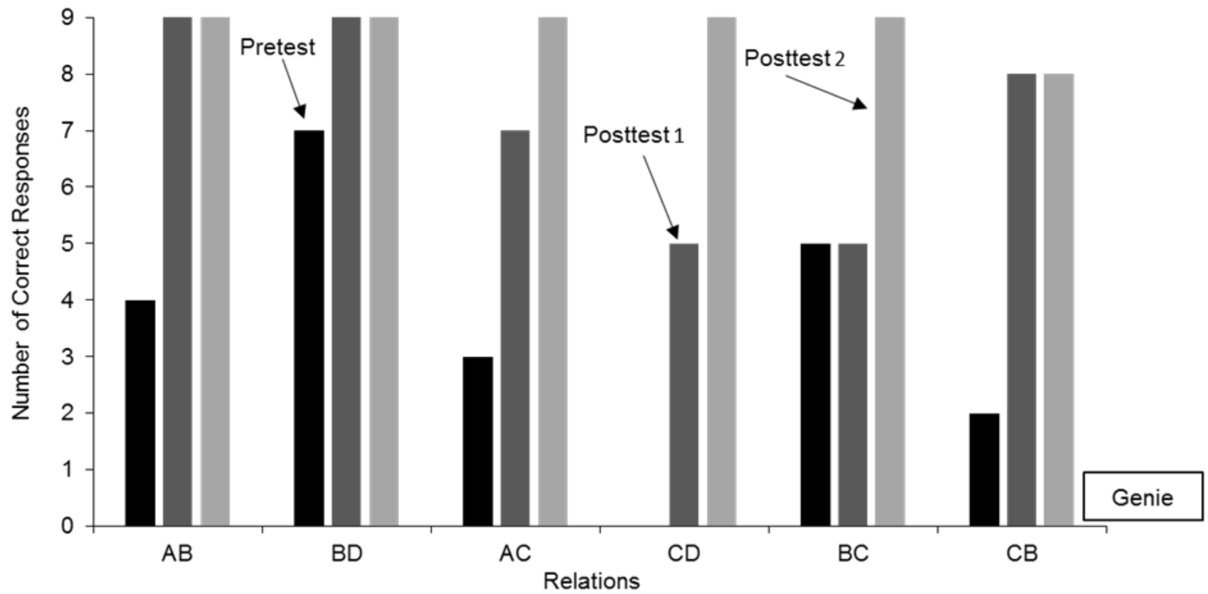

Figure 8. The number of correct responses per relation during the pre- and posttests for Genie.

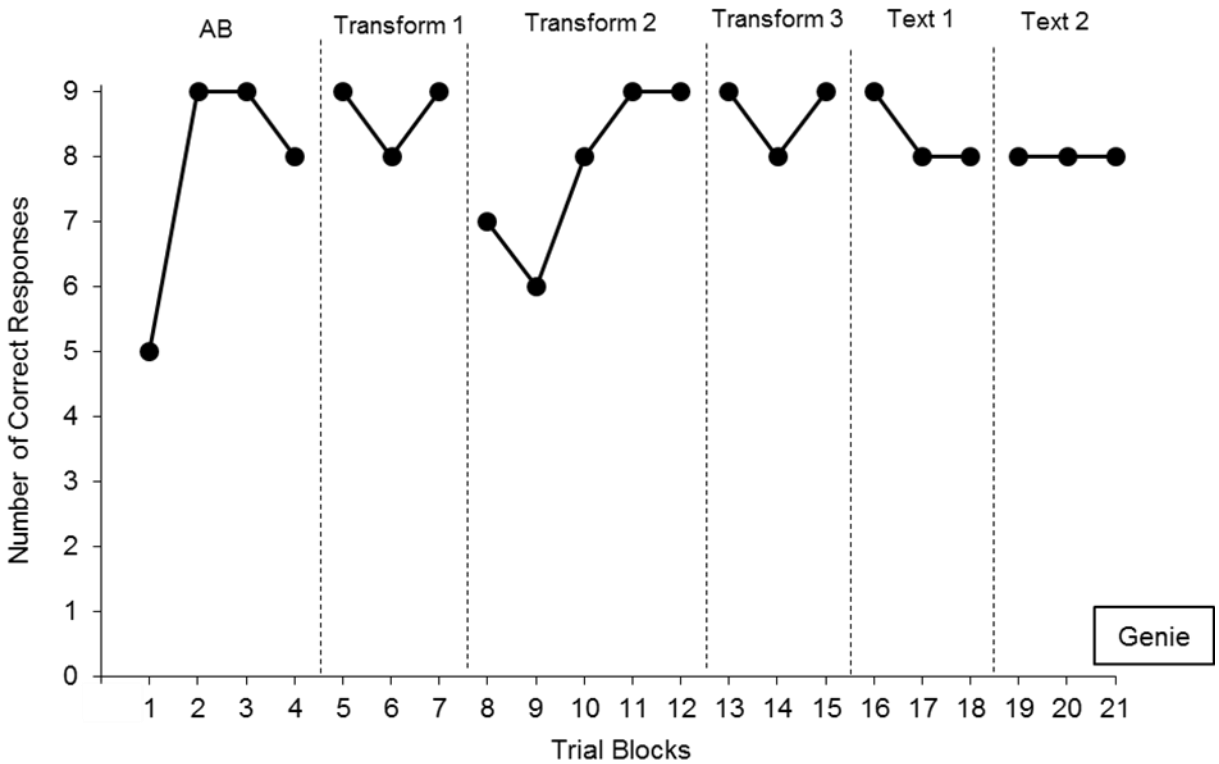

Figure 9. The number of correct responses per trial block during AB training, each stage of stimulus shape transformation, and textual training for Genie.