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Teaching tactual discrimination of braille characters to beginning braille readers

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TEACHING TACTUAL DISCRIMINATION OF BRAILLE CHARACTERS TO BEGINNING BRAILLE READERS

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ABSTRACT

We taught three children with visual impairments to make tactual discriminations of the braille alphabet within a matching-to-sample format. That is, we presented participants with a braille character as a sample stimulus and they were to select the matching stimulus from an array of three comparisons. In order to minimize participant errors, we arranged braille characters into training sets in which the target and non-target stimuli in the comparison arrays were initially maximally different in terms of the number of dots comprising each character. As participants mastered these discriminations, we then increased the similarity between target and non-target comparisons (i.e., an approximation of stimulus fading). All three participants' accuracy systematically increased following the introduction of this procedure.
Keywords: Braille, errorless learning, tactual discrimination, stimulus fading, visual impairments

INTRODUCTION

There is a growing concern that an insufficient number of students with visual impairments are learning to read braille (Johnson, 1996). The National Federation of the Blind (2009) reported that only 10% of school-age children with visual impairments in the United States use braille as their primary reading medium. This is in stark contrast to the 50% of school-age children with visual impairments that were reported to read braille in 1960 (American Federation for the Blind, 2008). There are multiple factors that may account for this decline in using braille.

Some have suggested that braille usage may be becoming obsolete because advances in technology have created additional mediums that translate printed information to auditory form (Aviv, 2010). For example, many popular novels are now available as audiobooks and computers can be equipped with text-to-speech technology. However, suggesting that visually impaired students should not be taught to read because they can listen to audiobooks seems as ethically questionable as it would be to suggest that sighted children should not be taught to read for the same reason. Even if these were reasonable solutions, listening devices and software are expensive and are not regularly available. Further, any text not linked to an audible program (e.g. signs on a restroom, grocery lists, and professional correspondence) would be inaccessible to a person with visual impairments who relied solely on auditory information.

Ryles (1996) suggested that early braille exposure may have long term effects on the lives of children with visual impairments. She surveyed 75 adults who were diagnosed as legally blind before age two, of which, half were braille readers and the other half were large-print readers. Unemployment rates were significantly lower for the braille-reader group (44%) compared to the print-reader group (77%). Furthermore, 42% of the braille-reader group were employed full time (40 or more hours per week) compared to 23% of the print-reader group, and 14% of the braille-reader group were employed part time compared to 3% of the print-reader group.

Standard English Braille is a tactually perceptible code representing letters, numbers, punctuation, contractions, and short form words (Olson, 1981). Each braille cell consists of a matrix of up to six dots across two columns and three rows each. The combined presence and absence of raised dots in these six locations creates a pattern; there is a one-to-one correspondence between each letter of the English alphabet and a braille character (see Figure 1). Braille characters are small; each dot is slightly over 1 mm in diameter and the distance between two adjacent dots in a cell is approximately 1.5 mm (Nolan and Kederis, 1969). The ball of the fingertip, which individuals use in braille reading, can detect differences between 2 and 3 mm thus allowing the fine discrimination of separate raised dots (Millar, 1997).

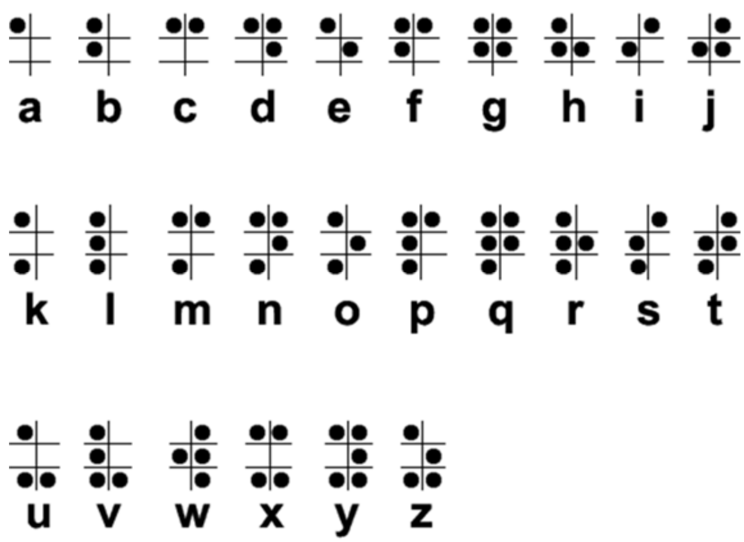

Figure 1. The braille alphabet. Raised dots are represented by a black circle within the 2x3 matrix of the braille cell.

The six-dot configuration unique to braille characters facilitates accurate character discrimination compared to other forms of tactual representations of letters (Loomis, 1981).

Loomis recruited sighted participants and taught them to label braille letters when presented visually so that participants were able to state the letter name of both braille and text letters. Following this training, participants tactually examined variations of embossed letters and provided the letter name. The embossed letters were either (a) standard braille letters, (b) raised shapes of print letters or (c) raised shapes of print letters but the shapes consisted of dots rather than solid lines. The standard braille letters resulted in the most accurate letter identification compared to raised shapes of printed letters. Braille patterns are simpler and require less than half as many dots (M = 3.2) than those required to represent print-shape letters (M = 8.6) which may explain the improved legibility of braille characters (Hollins, 1989).

There is a small body of research on how to teach braille reading. One of the earliest stages is to teach discrimination between individual braille characters. Tactual discriminations of braille characters present a challenge for novice readers (Millar, 1997). The reader must learn each unique pattern, which may vary from another pattern based upon the location of a single dot. For example, varying one dot in a character changes the letter F to the letter D (see Figure 1). Although it is a challenging skill, accurate discrimination is essential for braille reading. If the reader commits frequent errors related to the inability to discriminate between braille characters, reading cannot be effective nor efficient (Umsted, 1972).

Braille character recognition is emphasized because the perceptual unit of recognition in braille reading is the braille character (Nolan & Kederis, 1969). Unlike visual readers who may perceive 10 or more letter positions simultaneously, braille readers perceive one character at a time (McConkie, 1983). This letter-by-letter reading may explain why the average braille readers reads at an average rate of 90 words per minute; only one-third the rate at which the average sighted person reads print (Nolan & Kederis, 1969). When sighted readers are required to read print through a movable “window” so that only one letter at time is displayed; reading rates drop to approximately 100 words per minute, a rate approximating that of braille readers (Wallsten & Lambert, 1981). Advanced readers often use Grade 2 Braille, a system of contractions, which may increase reading speed by allowing readers to perceive whole words using fewer letters (Hollins, 1989).

One intervention for increasing braille-reading rate is additional instruction that focuses on accurate identification of braille characters. Nolan and Kederis (1969) provided instruction in character recognition of the 55 single braille characters that stand for letters or letter combinations for elementary-aged participants who had previous braille exposure but were not yet fluent. Instruction involved three different discrimination tasks during one 30 min session per day across 18 consecutive days. In one task, participants named the different characters within a set of three characters. In another task, participants named a sample character and found the matching comparison character. The third task consisted of participants naming and counting characters that were the same within a set of four characters. Participants' error rates in character identification decreased by 83%. In addition, oral reading error rates decreased by 28% and oral reading speeds increased by 15%.

Umsted (1972) provided a 15-day training program that emphasized tactual discrimination of braille contractions and short-form words to high-school students who had used braille as their primary reading medium for approximately three years. The training consisted of repeated practice and specific drill exercises of various symbols; however, a more in-depth procedural description was not provided. The training program resulted in improved silent reading rates, improved accuracy of oral reading rates, and decreased errors in braille character recognition.

The previously described studies provided remedial instruction to individuals with extensive braille experience; however, research has not fully addressed how to initiate braille instruction with novice learners. Resources on braille instruction suggest that beginning readers should discriminate large tactual differences prior to learning to distinguish between braille characters (Barraga, 1976; Olson, 1982). Olson suggested that instructors introduce stimuli along a continuum of tactual discriminations beginning with large, three-dimensional objects (e.g. blocks vs. balls) and finally progressing to small, three dimensional objects (i.e. Braille characters). More specifically, Barraga provided a sequence of skills a student should acquire prior to learning to discriminate between braille characters. A student should: (a) differentiate between salient characteristics of stimuli such as texture and temperature, (b) discriminate between various shapes, sizes, and weights of three-dimensional objects (c) label two-dimensional representations of geometric shapes, and finally (d) discriminate between braille characters. It is possible that teaching discriminations in this step-wise manner facilitates students responding to tactual properties of stimuli.

Unfortunately, resources on teaching tactual discriminations do not provide detailed information on how instructors should proceed with teaching tactual discrimination of braille characters. Guides for braille instructors emphasize the importance of tactual discriminations yet they often do not provide teachers with a method of teaching tactual discriminations of braille characters (Harley, Henderson, & Truan, 1979; Olson, 1981; Rex, Koenig, Scott, 1982; Wormsley & Baker, 1994). For example, the following excerpt is in *Guidelines and Games for Teaching Efficient Braille Reading*:

> Once the mechanical skills are mastered, the child is ready to sharpen his tactile perception and to recognize differences among braille configurations. There seems to be no 'right way' to introduce this phase of instruction. Some teachers introduce the braille alphabet first. Others introduce whole words in the beginning. (Olson, 1981, pg. 43)

The Mangold Developmental Program of Tactile Perception and Braille Letter Recognition is the sole program with empirical evidence for teaching tactual discriminations to early braille readers. The program provides 29 sequenced lessons utilizing precision teaching to teach tactual discriminations and braille letter recognition (Mangold, 1977). The program has the essential elements of precision-teaching in that it: (a) provides a measurable description of the skill to be mastered, (b) breaks each goal into small subskills, (c) sets a time-based mastery criterion for each step, (d) measures and graphs current performance, and (e) uses the measured performance as a means of assessing if instructive procedures need to be altered (Mangold, 1978).

Sally Mangold developed the program based upon the results of Mangold (1978) in which instructors taught participants to distinguish tactually between braille characters. Mangold presented participants with two braille characters and participants vocally stated whether the two characters were same or different. The initial comparison involved the presentation of letter D (a three-dot character) and the letter W (a four-dot character). The instructor continued to present additional comparisons until the student achieved mastery criterion of 90% accuracy.

Although the results of Mangold (1978) demonstrate effectiveness in teaching tactual discriminations, it may be possible to arrange instruction to make acquisition of these early braille discriminations more errorless and efficient for young learners acquiring braille.

Research suggests that the number and density of dots within each braille cell may be the most salient feature upon which to discriminate different braille characters (as opposed to the spatial arrangement or similarity to geographic shapes as suggested by Olson, 1981). For instance, Millar (1977) presented participants with outline-shape letters as a sample stimulus and braille characters as a comparison stimulus. Participants stated whether the pairs were the same or different. Millar produced outline-shape letters by connecting straight lines between the dots of the braille characters. Results of the evaluation indicated that neither participants' accuracy nor response time increased with the presentation of an outline-shape letter as the sample stimulus. These results suggested that individuals tend not to respond to the global pattern of braille characters.

Millar (1978) also evaluated if the dot locations within a braille character facilitated tactual discrimination. Experimenters presented slow and fast braille readers with two braille characters that were either the same or different. Experimenters created pairs that differed in one of three ways: (a) the location of one dot was changed by omitting one dot within a character, (b) the location of two dots was changed by omitting one dot and adding one dot in a different location within a character, or (c) the location of three dots was changed by omitting two dots in two locations and adding one in a different location within a character. Experimenters measured the latency to the participants' vocal statement of 'same' or 'different.' The number of changed features did not decrease the latency nor affect accuracy. However, results demonstrated a corresponding increase in latency to discrimination as the dot density of the characters increased.

Given that dot density may be the most salient feature associated with tactual discrimination of braille characters, braille-character discrimination may be facilitated by initially exposing learners to characters with increasingly gross differences in dot density and then systematically introduce increasingly similar letters (e.g., initiating discrimination training with comparisons with one and five dots and gradually introducing comparisons with two and five, three and five, four and five, five and five dots). This methodology, which gradually presents learners with increased complexity of characters and decreased dot differentials, is akin to stimulus fading and is one type of procedure common to the errorless-learning paradigm.

Errorless learning procedures encompass a variety of behavioral techniques such as stimulus shaping, stimulus fading, stimulus shape transformations, superimposition with stimulus shaping and delayed cue in order to train discriminations while minimizing incorrect responding (Lancioni and Smeet, 1986). Terrace (1963) demonstrated that one form of errorless learning, stimulus fading, produced shorter latencies to respond, increased response rates, and errorless performance when experimenters taught pigeons to discriminate between reinforcement and extinction periods.

Researchers extended these initial findings by using errorless training procedures with children and adults with and without disabilities to teach a variety of skills such as color discriminations, auditory discriminations, and reading clocks (for a review see Mueller, Palkovic, & Maynard, 2007). Researchers have also used errorless learning procedures to teach discriminations between printed text letters. Egeland and Winter (1974) taught discriminations between four sets of similar-letter pairs (e.g., R and P) to 64 preschool children. The researchers superimposed red highlight on the correct answer and gradually faded out the colored prompt. They found that recipients of errorless learning instruction made fewer errors than did participants receiving trial-and-error instruction.

Griffiths and Griffiths (1976) taught letter discriminations to six typically developing nursery school children. Similar to Egeland and Winter, the children receiving errorless learning acquired the discrimination with fewer total errors. In addition, all participants reported that they preferred the stimulus fading procedure to the trial-and-error procedure.

Stimulus fading has also been applied to learning braille letters presented visually (Fields, 1980). Fields presented college students with braille letters. Participants learned the letter names through (a) trial-and-error or (b) stimulus fading. When participants learned stimuli by stimulus fading, experimenters presented a compound stimulus consisting of the text letter superimposed on the braille letter. Experimenters gradually increased the focus of the braille letter contingent upon correct responding until only the braille letter was fully focused. After participants acquired the letters through both methods, participants learned a second set of braille letters by traditional, trial-and-error discrimination training. Participants who originally learned braille letters by fading learned the second set faster than did subjects who learned the second set by trial-and-error training.

No studies have used errorless learning techniques during tactual discrimination of braille characters. The purpose of the current study was to use the principles of stimulus fading to teach tactual discriminations between braille letters to beginning braille readers. Errorless methods are well suited to teach discriminations as these methods may capitalize upon the perceptual factor that tactual discrimination between braille characters are based - dot density differences. Given the paucity of research, there is a need for further evaluation in the area of braille discrimination.

METHOD

Participants

Three children with visual impairments participated in the evaluation. Nina was a 4-year-old girl diagnosed as blind; she attended a residential school for children with visual impairments and was in a special education classroom. Blaine was a 5-year-old boy diagnosed as legally blind and Mariah was a 4-year-old girl diagnosed as legally blind. Blaine and Mariah attended a public elementary school and were in a special education classroom. All three participants: (a) did not have any developmental or learning disabilities, (b) had already demonstrated proficiency in making gross three-dimensional discriminations, and (c) had demonstrated line tracking, except for Nina who received line-tracking instruction prior to participation. We defined line tracking as continuous movement of the index finger from left to right across a line of braille characters.

Settings and Materials

The evaluation took place in a quiet location in each participant's classroom. The instructor sat with each participant at a small table. Materials included braille characters printed using a Perkins Braillewriter on standard braille paper, a timer, toys (e.g. musical toys; trains), writing utensils, and data sheets.

For Blaine and Mariah who had low vision, the instructor placed braille stimuli under a five-sided box with a small opening. The instructor placed participants' hands in the small opening in the box to ensure that participants experienced braille letters only through touch during discrimination tasks.

Sessions occurred three to four days per week during a 1-hour block. The number of sessions per day varied depending upon the duration of each session (i.e., we conducted as many sessions as possible within 1 hour each day). We used a match-to-sample procedure to assess and teach tactual discriminations. The instructor initiated each trial by presenting the participant with a 2.5 cm x 20.3 cm strip of paper. The instructor used gentle physical guidance to place each participant's index finger on the sample stimulus and instructed participants, "Feel this one, now match."

The sample braille stimulus was embossed approximately 5 cm from the left edge of the paper and the three comparison stimuli were embossed in a horizontal line equidistant from each other (2.5 mm); the first comparison was 10 mm to the right of the sample stimulus. The instructor randomly assigned the position of the correct and incorrect comparison stimuli for each trial.

Dependent Variable and Interobserver Agreement

We defined a correct response as the participant selecting (touching) the correct comparison stimulus and vocalizing the selection (i.e., "this one") during sessions. We defined an incorrect response as a) selecting (touching) the incorrect comparison stimulus with or without vocalizing the selection or b) not responding within 5 s of the vocal prompt.

The instructor and data collectors were trained graduate students in school psychology. A second observer independently scored responses for 28% of sessions for Nina and Blaine, and 38% of sessions for Mariah. We defined agreement as both observers scoring the response as being correct or incorrect within each trial. We calculated interobserver agreement by dividing the number of agreements by the sum of the agreement and disagreements and converting the ratio to a percentage. Mean agreement was 97.7% for Nina (range, 83.3% to 100%), 97.9% for Blaine (range, 67% to 100%), and 96.5% for Mariah (range, 75% to 100%).

Experimental Design

The current evaluation employed a multiple-probe design (Cooper, Heron, & Heward, 2007). We first assessed accuracy of the terminal discrimination which was defined as selecting the correct comparison when there were an equal number of dots in the sample and comparison stimuli. Following baseline sessions, we sequentially provided instruction on subsets of letters (i.e., first letter pairs that differed by 4 dots). Following mastery of this skill (i.e., 100% accuracy) we conducted a baseline probe of the terminal skill set prior to teaching the next subset of letter pairs (see Table 1). We continued in this manner until performance under the terminal skill probe was 100% accurate.

Table 1. Instructional levels during tactual discrimination training.

Level	Dot differential	Sub-step	Number of dots
One	Four	1-a	1 and 5
Two	Three	2-a 2-b	1 and 4 2 and 5
Three	Two	3-a 3-b 3-c	1 and 3 2 and 4 3 and 5
Four	One	4-a 4-b 4-c 4-d	1 and 2 2 and 3 3 and 4 4 and 5
Five	Zero	5-a 5-b 5-c 5-d	2 and 2 3 and 3 4 and 4 5 and 5

Procedures

Probes. Each probe session consisted of 16 trials. The instructor randomly selected two comparison groups of stimuli from each of the four sub-steps of Level 5 (5a-d) and presented each comparison group twice. The instructor asked participants to indicate (by touching and vocalizing) which comparison stimulus matched the sample stimulus. The instructor did not deliver reinforcement or feedback.

Instruction. Instructional procedures were similar to probe conditions except for the number of trials and the presented stimuli, which varied in dot-density depending upon the phase of training. Additionally, the teacher provided instruction using a 5-s constant time delay prompting procedure. After the initial verbal prompt (i.e., "Feel this one, now match") was given, the instructor waited 5 s. If the participants emitted a correct response, the therapist provided praise and access to either a small, edible item (Mariah) or a token that was exchanged for access to preferred items at the end of the instructional period (Nina and Blaine). If the student did not engage in a correct response within 5 s, the instructor physically guided the participant to engage in the correct response. Specifically, the instructor gently guided the participant to touch all comparison stimuli and then placed the participant's finger on the correct comparison stimulus while stating, "This is the correct match."

The instructor proceeded with instruction according to the five levels that correspond with differences in dot density (see Table 1). Instruction began with Level 1 which had a maximum difference of four dots between the sample and comparison stimuli, Level 2 had a three-dot differential, Level 3 had a two-dot differential, Level 4 had a one-dot differential, and Level 5 had a zero-dot differential (no difference). Sub-steps that correspond with the presentation of increasingly complex braille configurations were within each major level. For example, Level 2 consisted of sub-steps 2-a (i.e. a comparison between one and four dot characters) and 2-b (i.e. a comparison of two and five dot characters). Thus, each step began with the least complex characters and increased in complexity.

We set mastery criterion at 100% correct responding for each training step. Participants experienced each letter pairing that produced a specified dot density differential twice. For example, a dot density differential of three was produced by pairing letters with a one-dot configuration (only the letter A) with letters with a four-dot configuration (G, N, P, R, T, V, W, X, and Z). Thus, the instructor randomly presented the following combinations twice: A-G; A-N; A-P; A-R; A-T; A-V; A-W; A-X; A-Z, so that all the possible letter pairings that generated a three-dot differential were presented twice. Thus, the number of trials within a session varied.

RESULTS

Participant One

We depict Nina's acquisition during instruction in Figure 2. Upon initial implementation of instruction, Nina's percentage of correct responding did not increase. Inspection of response patterns revealed that Nina demonstrated a position bias; that is, she consistently chose the comparison stimulus in the first position in the array. To resolve this error, the instructor provided a simple discrimination in which there was only one comparison stimulus (that matched the sample stimulus) and the comparison stimulus varied in location. After correct responses occurred on at least 90% of trials (noted as Step .5a in Figure 2), the instructor reintroduced a conditional discrimination by including an additional comparison stimulus; thus, creating a two-comparison array. After correct responses occurred on at least 90% of trials with a two-comparison array (noted as level .5b in Figure 2), the programmed instruction resumed with the standard level 1a (see session #14 in Figure 2) which consisted of a three-comparison array. Nina made 40 errors during the first level of instruction (see Table 2). Following implementation of this procedure, Nina no longer demonstrated a position bias and her level of correct responding increased.

During instruction, Nina's school closed for a one-month period. Upon Nina's return, the instructor provided booster sessions to ensure that the discrimination skill was maintained. Four booster sessions were provided: three sessions for 1a and one session for 2a (data not depicted). Nina's level of correct responding quickly returned to prior levels, and instruction was resumed. Nina made 7 errors during Level Two of instruction (see Table 2). The instructor conducted a terminal probe following completion of Level Two and Nina's correct responding was 69%, below mastery crieterion. Thus, the instructor resumed with the third level of instruction.

During the third level of instruction, Nina made six errors (see Table 2). After Nina achieved mastery criterion for step 3c, the instructor conducted a terminal probe and Nina's accuracy was at 100% (Figure 5; top panel). No additional training was necessary. Nina required 31 instructional sessions (including booster sessions) before reaching 100% accuracy on the terminal probe.

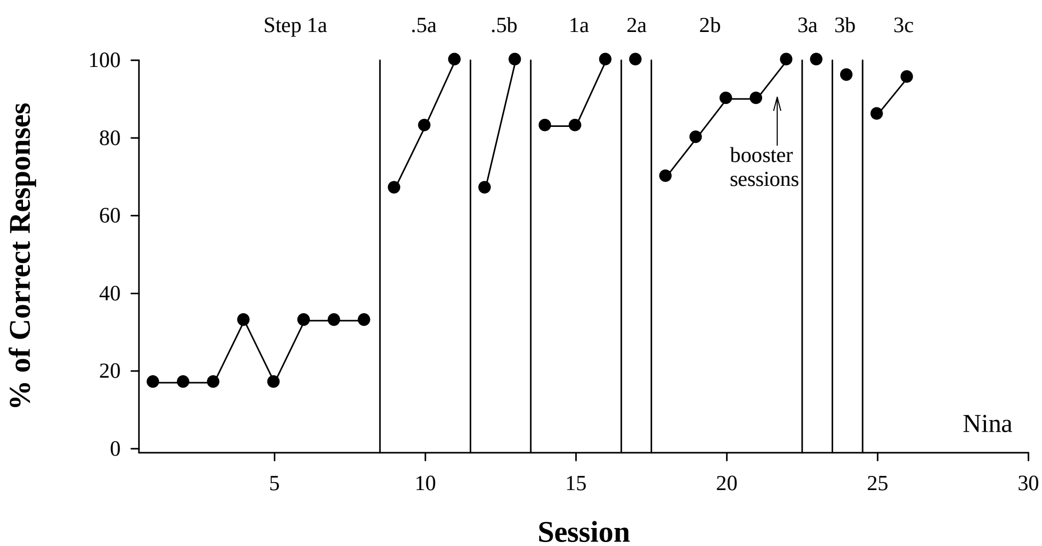

Figure 2. Percentage of correct responses during instruction for Nina.

Table 2. Number of errors at each level per participant.

Level	Dot differential	Nina	Blaine	Mariah
One	Four	40	20	37
Two	Three	7	20	10
Three	Two	6	69	276
Four	One	N/A	161	N/A
Five	Zero	N/A	N/A	N/A

Participant Two

Blaine's acquisition during instruction is depicted in Figure 3. Blaine showed a similar pattern to Nina in that accurate responding did not increase during step 1a. We introduced the modified instructional procedures, steps .5a and .5b, as we did for Nina. Blaine's level of correct responding was high during this modified procedure but he returned to making errors upon the resumption of training with step 1a. Closer inspection of the data revealed that Blaine was having difficulty distinguishing between the sample (letter A) and comparison stimuli (letters Q and Y). Rather than matching to the sample, it appeared that Blaine was matching the similar comparison stimuli. Therefore, the instructor implemented a "hand blocking" procedure where the instructor placed Blaine's left hand on the sample stimulus and "blocked" his left hand from scanning the comparison stimuli. Blaine scanned the comparison stimuli with his right hand. The use of the blocking procedure was quickly faded.

Following the use of the blocking procedure, Blaine was able to benefit from the matching-to-sample procedure as indicated by his increased accuracy within each step. Blaine's number of error responses was 29 for Level 1, 20 for Level 2, 69 for Level 3, and 161 for Level 4 (see Table 2). The instructor conducted a terminal probe following mastery of step 3c and percentage of correct responding increased to 84%. Blaine resumed training at Level 4; however, the school year ended and we were unable to collect any further data. Blaine received 56 instructional sessions.

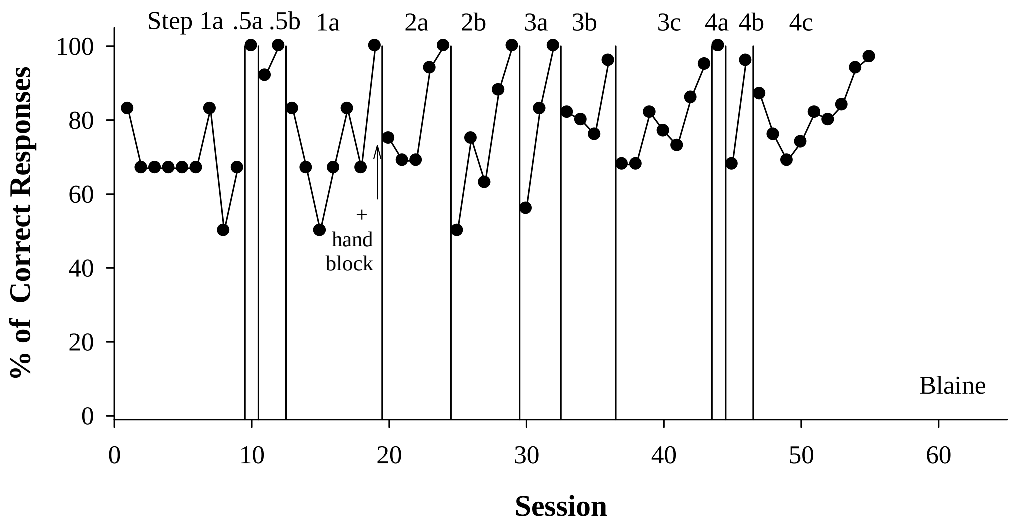

Figure 3. Percentage of correct responses during instruction for Blaine.

Participant Three

We depict Mariah's acquisition in Figure 4. Mariah also demonstrated an error pattern during her initial exposure to the instruction in step 1a. In step 1a, there are three potential sample stimuli (A, Q, and Y). Mariah was consistently making errors when the sample was A (the one-dot character). It is possible Mariah was not matching to the sample but rather selecting the comparison with a higher dot density and obtaining reinforcement on approximately one-third of the trials. Therefore, we modified the instructional procedure to where the character, A, was presented 4 times within a session while the two other characters with five-dot configurations (Q and Y) were only presented once during a session. Results indicate that this modified instructional phase was sufficient to increase correct responding to mastery levels. Instruction resumed and correct responding increased to mastery levels for each level of training. The instructor conducted terminal probes after each level was mastered. After completion of Level 3, Mariah's percentage of correct responding was 100% during the terminal probe (see Figure 2; bottom panel). We conducted additional probes at this terminal value and responding decreased slightly to 88% for two sessions and increased to 94% during the last session. Mariah's number of error responses was 37 for Level 1, 10 for Level 2, and 126 for Level 3 (see Table 2). Mariah required 52 instructional sessions before reaching 100% accuracy on the terminal probe.

We depict the evaluation results for all participants in Figure 5. For all participants, correct responding was near chance levels (33%) during baseline probe conditions. The instructor systematically provided instruction and the results demonstrate increased correct discrimination following each instructional level. Nina and Mariah's accuracy during terminal probes reached mastery criterion (100%) following three levels of instruction; additional instruction was not required. Blaine's accuracy approached mastery criterion (88%) following the first three levels. Following instruction, correct responding increased to mastery or near-mastery level during terminal probes for all participants.

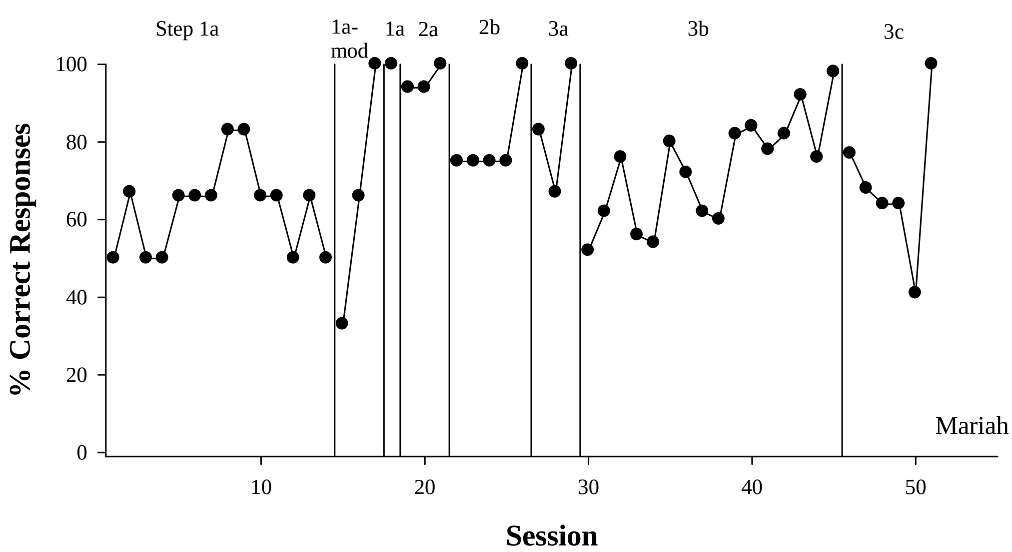

Figure 4. Percentage of correct responses during instruction for Mariah.

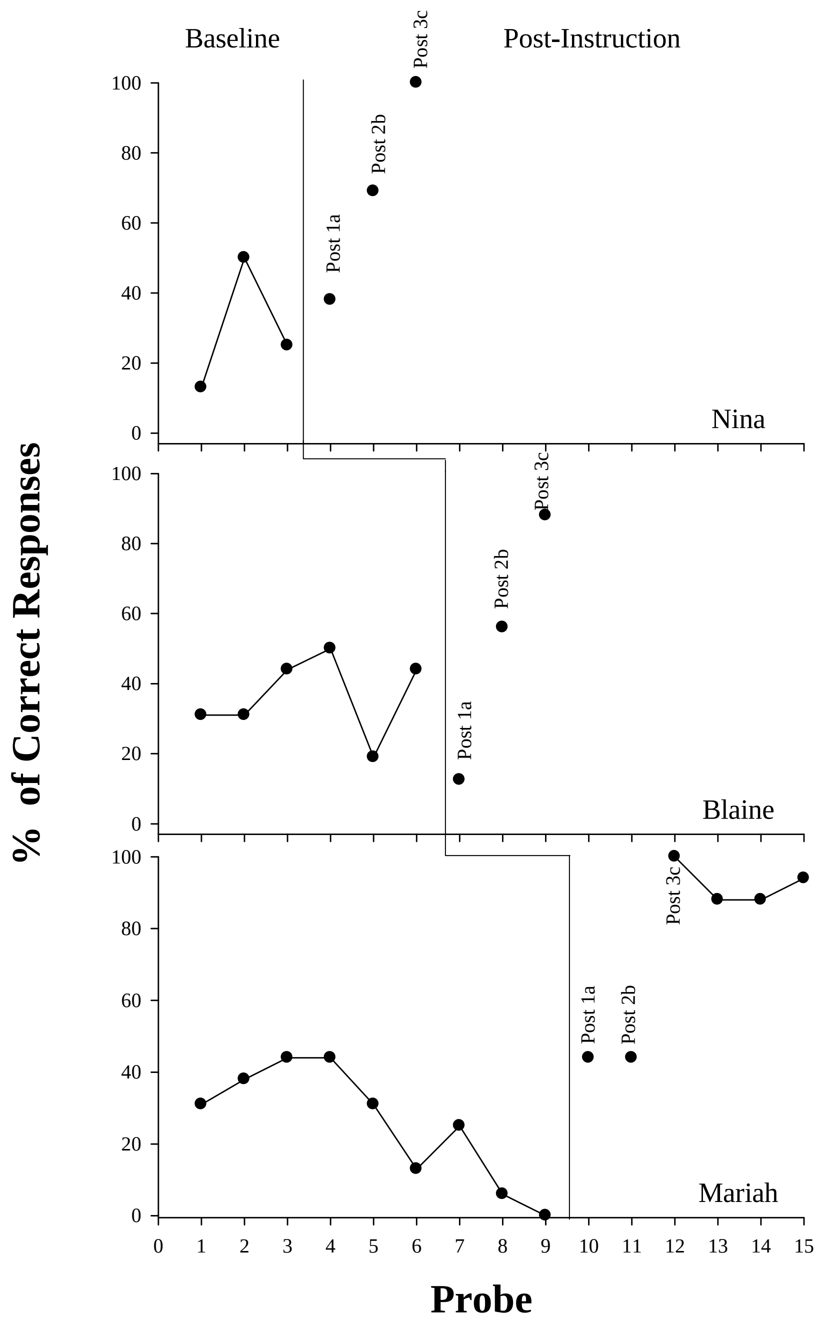

Figure 5.Percentage of correct responding for all participants.

DISCUSSION

Tactual discrimination of braille characters is a critical skill in braille reading. The purpose of the current evaluation was to examine a novel procedure for teaching tactual discrimination of braille characters based upon a technique in the errorless learning paradigm, stimulus fading.

The results of the present evaluation provide support for using a methodology based upon errorless learning to tactual discrimination of braille characters to beginning braille readers. The three participants did not successfully discriminate between braille characters prior to intervention. Participants increased their accuracy in the tactual discrimination of braille characters after intervention. Two of the three participants, Nina and Mariah, acquired the skill of tactual discrimination with 100% accuracy after progressing through the first three levels of instruction. For these two participants, continued instruction was unnecessary. One participant, Blaine, increased his accuracy to 84% after completing the first three levels. Unfortunately, Blaine discontinued school unexpectedly and we were unable to continue the intervention.

The current study extends the literature on instruction for individuals with visual impairments by providing an effective technique for teaching tactual discriminations, a necessary process in learning to read braille. It is also the first study to use a single-subject design during tactual discrimination learning, which demonstrates individual student performance.

The current procedure is also the first evaluation to use the principles of errorless learning to teach tactual discriminations of braille characters. The goal of errorless learning is to reduce the likelihood of making incorrect responses. Although the current results demonstrate a useful training method for establishing tactual discriminations, participants' acquisition of tactual discriminations indicate this was not an errorless procedure. Several factors may account for this.

One reason is stimulus fading requires an exaggeration of some dimension of the relevant stimulus to help an individual make the correct response. This exaggerated feature is faded over time. For example, Fields (1980) superimposed printed letters over braille letters and gradually faded out the printed letter until participants responded only to the relevant stimulus, the visual presentation of the braille letter. Our procedure attempted to exaggerate the dot density differential between braille characters and fade out the difference until participants were able to respond to characters when there were no differences in the number of dots. Accordingly, individuals' first exposure to training should have resulted in initial correct responding. However, individuals did not respond correctly to the first exposure of training as evidenced by participants responding in step 1a. A possible explanation is that the dot differential was not salient enough to produce accurate tactual discriminations. Future research may consider other techniques to make the initial discrimination more salient (e.g., enlarging the target stimuli or offsetting its location in the stimulus array).

An additional reason that initial exposure did not facilitate accurate discrimination is possibly because of faulty stimulus control. Error patterns varied across participants with Nina demonstrating a position bias, and Blaine and Mariah demonstrating faulty stimulus biases. This error pattern of forming a bias is common in matching-to-sample procedures and was likely maintained by a variable schedule of reinforcement associated with that type of error pattern (Kangas & Branch, 2008) That is, participants' have a probability of responding correctly on 33% of trails based upon chance alone (as there are three comparison stimuli). Reinforcement of these adventitiously correct responses may have been sufficient to maintain these errors in responding. Thus, instructors should take care when using any matching-to-sample procedure.

Instructors should actively look for any biases in responding that may occur so that a correction procedure can be implemented to eliminate faulty responding.

One potential improvement upon the current methodology would be to add an additional prompt to the prompting sequence used in the current evaluation. A 5 s constant time delay was utilized which inserted a fixed interval of 5 s between the delivery of the instruction or target stimulus and the prompt. A modification would be to incorporate a 0 s time delay for the first two training sessions followed by a 5 s delay implemented for all subsequent trials. It is possible that the initial use of a 0 s delay would facilitate acquisition by providing participants with a model of the correct response on initial learning trails. Future research may consider combining this modification when teaching tactual discriminations.

The current investigation did not compare the effectiveness of the current technique with other techniques such as the precision teaching method by Mangold (1978). It is difficult to compare the relative effectiveness or efficiency of these procedures, as there are substantial differences between the two studies. First, the Mangold evaluation does not report individual data so it is not possible to compare the number of trials required to reach mastery criterion. Second, the task itself differed; the Mangold study presented a sample and a comparison stimulus and students were required to make same-different judgments. The current evaluation presented a sample and three comparison stimuli and students were required to match the correct comparison stimulus to the sample. Finally, and perhaps most importantly, the participant characteristics were different. Half of the participants in the Mangold evaluation were remedial braille readers. Of the remaining half of the participants who were beginning braille readers, the participant age was higher (age range, 5-15 years) compared to the participants in the current evaluation (age range, 4-5 years of age).

Participants in this study were beginning braille readers who will continue to receive braille instruction within the general education setting. Additional research is needed to identify effective, evidence-based procedures for not only tactual discrimination of braille characters but for braille curriculum as a whole. Instruction for children with visual impairments is "more often than not based on tradition, superstition, anecdote, and common sense rather than scientific evidence" (Ferrell, 2006, p. 42). We hope the results of the current investigation provide a segment of scientific evidence in the field of braille literacy instruction.

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