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TEACHING LEVEL-1 BRAILLE READING SKILLS WITHIN A STIMULUS EQUIVALENCE PARADIGM TO CHILDREN WITH PROGRESSIVE VISUAL IMPAIRMENTS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Arts

in

The Department of Psychology

by
Karen A. Toussaint
B.S., Louisiana State University, 2003
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ABSTRACT

Degenerative visual impairments refer to conditions that result in the progressive loss of vision; several of these conditions have their onset during childhood. Nearly 3% of the school-aged population will experience vision loss that will require specialized support, yet there has been little attempt to systematically evaluate braille-instruction programs. The current study evaluated an instructive procedure for teaching early braille-reading skills with four school-aged children with degenerative visual impairments. Following a series of pretests, braille instruction involved providing a sample braille letter and teaching the selection of the corresponding printed text letter from a comparison array. Concomitant with increases in the accuracy of this skill, we assessed and captured the formation of equivalence classes through tests of symmetry and transitivity between the text letters, the corresponding braille letter, and their spoken name.

INTRODUCTION

Degenerative visual impairments refer to conditions that result in progressive vision loss over time. Certain conditions, such as glaucoma and degenerative myopia, have an onset early in childhood with vision worsening over time. It is estimated that approximately 3% of all school-aged children will experience a vision loss that will require specialized support (Gargiulo, 2005). Individuals who are identified with a degenerative visual impairment may benefit from braille instruction prior to losing their functional sight in that relations can be established between braille and other symbols existent in their repertoire (i.e., letters and numerals; Hall & Newman, 1987).

Braille is a system that enables individuals to read and write through touch. The braille system is coded so that each character is represented by an arrangement of six raised and lowered dots within a matrix of two columns and three rows. Each letter of the English alphabet is represented by a unique dot configuration. Braille characters are relatively small with each dot slightly over 1 mm in diameter and 1.5 mm between the midpoints of two adjacent dots. These small patterns differ only by the presence or absence of dots, making braille alphabet learning difficult (Millar, 1978).

One of the earliest stages of braille reading is correctly labeling individual characters (commonly referred to as Grade-1 braille). Difficulty in this stage impedes learning more complex braille-reading skills, such as producing letter sounds (Hampshire, 1975), which combined are considered a key component of reading acquisition (National Institute of Child Health and Human Development, 2000). Despite the need for braille letter naming as a precursor for braille reading, limited research exists on effective methods for teaching this skill.

Braille Letter Instruction

We have identified only two studies that have evaluated procedures for teaching braille-letter identification. Both studies share the approach of establishing a novel relation between the tactile stimulus (i.e., a braille symbol) and an auditory/vocal stimulus (i.e., a spoken letter). Mangold (1978) taught congenitally blind students to vocalize letter names upon feeling the tactile braille stimulus. Crawford and Elliott (2007) sang songs to low-vision braille learners as they tactilely contacted the braille symbols (e.g., as students placed their finger over the braille "P," the experimenter sang "p is in the alphabet, /p/ /p/ /p/" three times) and prompted the students to repeat this song.

While both of these approaches have been shown to be effective in establishing early braille-letter naming, teaching the relation between the braille symbol and a visual stimulus (i.e., a printed text), as opposed to the spoken letter, may benefit for learners with some level of vision. First, the presentation of visual stimuli will allow for a motor-selection response. By requiring a motor response, teachers or therapists ensure that they will be able to prompt correct responses to facilitate learning (as opposed to vocal responses in Mangold, 1978 and Crawford & Elliott, 2007). Second, visual discriminative stimuli may be presented continuously, while spoken discriminative stimuli are typically presented briefly. That is, a visual stimulus is presented throughout a teaching trial while a spoken stimulus is presented at the onset of the trial but is absent when a learner is making a selection response. Continuous stimulus presentation has been shown to enhance the development of stimulus control (Schaal & Branch, 1988). Third, variability in terms of the volume, pitch, and tone in the presentation of spoken stimuli may be disruptive without the use of mechanical equipment relative to a printed symbol, which is represented identically across trials (Serna, Stoddard, & McIlvane, 1992; Stoddard & McIlvane,

1989). Fourth, the inclusion of a visual stimulus may result in the emergence of stimulus equivalence relationships between the visual, tactile, and auditory stimuli.

Stimulus Equivalence

Stimulus equivalence is a description of a complex transfer of stimulus control between stimuli. Three relations must be present between stimuli to demonstrate the emergence of an equivalence class: reflexivity, symmetry, and transitivity (Sidman & Tailby, 1982). Reflexive relations are demonstrated when each member of the stimulus class can be matched to itself. For instance, an individual would select the printed word “dog” from an array of comparison stimuli when presented with an identical sample stimulus, the printed word “dog,” would select a picture of a dog when presented with a picture of a dog, and would be able to say the word “dog” upon hearing the spoken word “dog.” Symmetric relations are demonstrated when bidirectionality exists between two stimuli. For instance, if one is taught to select the printed word “dog” when shown a picture of a dog, symmetry would be demonstrated should they then be able to select a picture of a dog when shown the printed word “dog”. Transitive relations are demonstrated when uninstructed conditional relations emerge in the presence of novel discriminative stimuli. Given the previous example, following instruction to select the printed word “dog” when shown a picture of a dog and to say the word “dog” when presented a picture of a dog, a transitive relation would be demonstrated if the individual could then select the printed word “dog” when presented with the spoken word “dog” and when the individual could speak the word “dog” upon seeing the printed word “dog”.

From a teaching perspective, stimulus equivalence technology may be particularly useful given its efficiency, namely, teaching a few relations between stimuli enter into an equivalence class and result in the emergence of a number of uninstructed relations. Stimulus equivalence

procedures have been demonstrated to be successful at teaching a variety of complex skills such as reading (de Rose, de Souza, & Hanna, 1996; Connell & Witt, 2004), geography (LeBlanc, Miguel, Cummings, Goldsmith, & Carr, 2003; Hall, DeBernardis & Reiss, 2006), statistical inference and decision making (Fienup & Critchfield, in press; Fienup, Critchfield, & Covery, in press), and emotion recognition (Guercio, Podoleski-Schroeder, Rehfeldt, 2004). For example, Lynch & Cuvo (1995) taught fifth and sixth-grade students displaying difficulties in mathematics to match pictorial representations of fractions to fraction ratios and also to match decimals to pictorial representations of fractions in an elementary school setting. Students were then able to match printed decimals to printed fraction ratios and also to match ratios to decimals without additional instruction.

No studies have examined using stimulus equivalence technology during braille instruction to date. The purpose of the current study was two-fold. First, we conducted a preliminary evaluation of a teaching procedure in which students were taught to select printed text letters when presented with braille sample stimuli in a matching-to-sample task. Second, we assessed the emergence of an equivalence class between braille, printed, and spoken letters as a result of this instruction with four children with degenerative visual impairments.

METHOD

Participants and Setting

Four children with degenerative visual impairments, nominated by the director of a state school for children with visual impairments, participated. Fred was a 7-year-old boy diagnosed with high myopia. He had received one year of classroom-based braille instruction prior to participation in the study. Jeremy was a 12-year-old boy diagnosed with a hypoplastic optic nerve in his left eye and neurofibromatosis. Prior to participation, Jeremy had received three years of classroom-based braille instruction. Danielle was a 9-year-old girl diagnosed with congenital glaucoma and congenital nystagmus. She had received two years of classroom-based braille instruction. Cole was a 7-year-old boy diagnosed with retinopathy of prematurity. He had received one year of classroom-based braille instruction. The inclusion criteria were that students were of typical cognitive development and demonstrated text-letter identification, identity matching, and braille readiness skills as assessed via a series of pre-tests. Sessions were conducted in an unoccupied common room in a dormitory on the school's campus.

Materials

The 26 English alphabetic letters printed in 72-point Times New Roman font were used as visual stimuli. Braille letters printed using a Perkins Braillewriter on 26 small cards of standard braille paper were used as tactile stimuli. All braille letters were presented under identical cardboard boxes with a small opening for participants' hands to be placed through. This ensured that participants only experienced braille letters through touch (i.e., they could not see the symbols). The experimenter read aloud the appropriate letter names in a uniform tone and volume level during the presentation of auditory stimuli.

Measurement and Inter-observer Agreement

A correct response was defined as the participant selecting (touching) the correct comparison stimulus, and incorrect responding was defined as selecting any of the other comparison stimuli throughout all pre-test, probe, and instructional sessions. One or two independent observers collected data on a trial-by-trail basis with a second observer present during 63% of sessions for Fred, 57% of sessions for Jeremy, 40% of sessions for Danielle, and 58% of sessions for Cole across all assessments to provide a measure of inter-observer agreement (IOA). We calculated agreement scores by comparing observers' records on a trial-by-trial basis. Each trial in which both observers coded a correct response or both coded an incorrect response was scored as an agreement. All other trials were scored as a disagreement. Percentage of agreement was calculated by dividing the number of trials in agreement by the total number of trials and then multiplying the quotient by 100% resulting in a mean agreement score of 99.4% (range 89% to 100%) for Fred, 98.5% (range 75% to 100%) for Jeremy, 99.8% (range 93% to 100%) for Danielle, and 99.7% (range 90% to 100%) for Cole.

Pretest Procedures

We conducted a number of pretests to ensure students demonstrated certain prerequisite skills for this instructional program and to eliminate any previously learned relations from our instructional sets. One aspect of our instructional procedures capitalizes upon an existent relation between text letters and their spoken or heard counterparts to enter into an equivalence class. Therefore, our first pretest was conducted to ensure students could correctly select a text letter upon hearing its auditory counterpart and could vocally state the name of a letter upon seeing its text symbol. Text-to-vocal sessions consisted of 26 trials (i.e., 1 trial for each letter of the alphabet) in which the participant was presented with a text letter and was asked to name it.

Auditory-to-text sessions were similar except that the teacher spoke the name of each letter and asked the participant to select the correct letter from an array of three text letters. Letter presentation order was randomized for each session. Students who obtained 100% accuracy for both text-to-vocal and auditory-to-text relations continued in the study. Students whose performance exceeded 85% participated in a brief skill instructional procedure until they met 100% accuracy for two sessions. Students with less than 85% accuracy were excluded from this study as not demonstrating the necessary prerequisite skill. They continued to receive the standard braille instruction offered by their school.

Next, we conducted a series of identity matching tasks to ensure that students could match braille, text, and auditory/vocal letters to themselves. Each child was presented with a braille, text, or auditory sample stimulus and prompted to select the identical comparison from an array of three stimuli. Each 26-trial session (i.e., each letter presented 1 time) consisted of only braille, text, or auditory stimuli (i.e., a minimum of 3 identity matching sessions were conducted). Students were required to demonstrate 100% accuracy in each session to advance in the study; students who did not demonstrate 100% accuracy received additional instruction, which was only required for the braille-to-braille identity matching task.

For braille-to-braille identity matching, we conducted an additional daily probe session to ascertain mastered and non-mastered letters. Each letter was presented once as a sample, and the student was prompted to “Find the same,” from a randomly arranged comparison array of three letters. The experimenter (first author) did not provide feedback, nor did she name letters during this probe. Letters that were not correctly matched during this probe entered into a teaching set. The experimenter re-presented these letters in a similar identity-matching arrangement except that correct responding was praised and incorrect responding resulted in a vocal prompt to

immediately re-touch the sample and then the correct comparison stimulus twice. The instructional session ended when the participant correctly identified all letters in the instructional set three times. Instructional sessions were repeated daily until the participant achieved 100% accuracy during the initial probe session.

We conducted a final pretest to determine any existent relations between braille, text, and spoken letters. Four relations were assessed, the braille-to-text relation, the text-to-braille relation, the auditory-to-braille relation, and the braille-to-vocal relation. Each relation was assessed separately, with three tests of each relation. Sessions were similar to those of previous pretests except that during *braille-to-text relation* sessions, braille letters served as the sample stimulus and text letters served as the comparisons, during *text-to-braille relation* sessions, text letters served as the sample stimulus and braille letters served as the comparisons, during *auditory-to-braille relation* sessions, the spoken letter name served as the sample and braille stimuli served as the comparison, and during *braille-to-vocal relation* sessions, braille stimuli served as the sample stimulus and the participant was required to vocalize the correct letter name. No consequences were provided for correct or incorrect responding. The results of these pretests were evaluated on a letter-by-letter basis. Any letter which was selected correctly during 100% of trials during the braille-to-text session (i.e., the would-be directly instructed relation) or 100% of trials in 2 of the other 3 relations was excluded from further assessment and instruction. All other letters were randomly assigned into letter sets. This resulted in four sets of five letters and one set of six letters for Fred, two sets of four letters for Jeremy, one set of four letters and one set of five letters for Danielle, and one set of five letters for Cole. Individual letter set assignments are presented in the table below.

Table 1.
Letter Set Assignments for Each Participant

Participant Letter Sets	Included Letters
Fred	
1	A, O, P, Q, V, X
2	E, G, K, L, N
3	H, J, R, U, Z
4	B, I, M, W, Y
5	C, F, P, S, T
Jeremy	
1	F, H, J, M
2	I, N, R, Z
Danielle	
1	E, I, S, W
2	D, H, N, T, Y
Cole	D, H, J, N, O

Instruction and Evaluation Procedures Overview

We conducted a novel baseline for each of the four (braille-to-text, text-to-braille, auditory-to-braille and braille-to-spoken) relations in which only those letters included in the instructional sets were presented as sample and comparison stimuli. Comparison stimuli were randomly drawn from all braille letters for Fred and from within the same letter set as the sample stimulus for Jeremy, Danielle, and Cole. Following a minimum of three baseline sessions for each relation, instruction was provided for the braille-to-text relation for one letter set. Once responding met mastery criteria for the letter set, additional probes of each relation with each letter set were conducted to a) determine the direct effects of instruction on the braille-to-text relation and b) assess the emergence of uninstructed symmetric (text-to-braille) and transitive (auditory-to-braille and braille-to-spoken) relations. Booster sessions for mastered letter sets were conducted between each series of probes for emergent relations to ensure that the directly

instructed relation was at strength prior to this test. Following post-instruction probes, the instruction was then implemented in the next letter set conforming to a multiple-probe design (with the exception of Cole for whom only one letter set was included; see Figure 1 for a flow-chart of assessment and instruction steps).

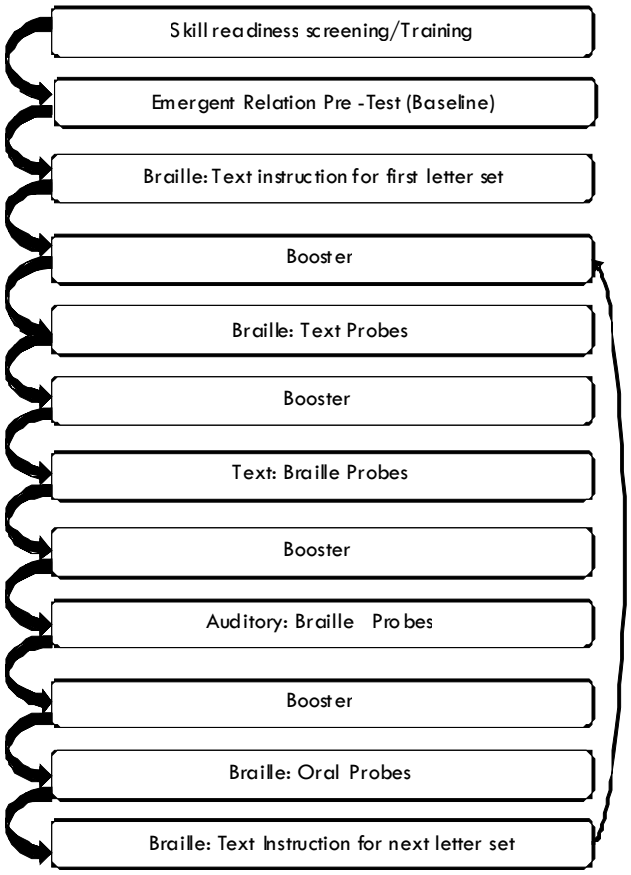


Figure 1. Flow chart of phases each participant experienced.

Probe Session Procedures

We conducted probe sessions for each of the four relations individually for each letter included in the training sets in a manner similar to those in the baseline procedure described above. Letter presentation order was randomized within each session. Following completion of

an instructional phase, relations were always probed in the following order: braille-to-text, text-to-braille, auditory-to-braille, and braille-to-vocal.

Instructional Procedures

Braille-to-text instructional sessions were similar to those of the braille-to-text pretest except that (a) each letter in the instructional group was presented twice each session, (b) a three-step prompting procedure (i.e., vocal, model, physical prompting with 3 to 5 s between prompts) was implemented to teach the student to select the correct comparison stimulus with the least amount of assistance, and (c) correct responses resulted in brief praise and delivery of a token exchangeable for 30 s access to participants' choice of a leisure activity at the conclusion of the day's sessions. The letter set was considered mastered following two consecutive sessions with correct responding at or above 90% of trials.

We made an additional modification during Jeremy's instructional sessions because he failed to meet mastery criterion following repeated exposure to the aforementioned instruction. Instead, we initially presented a single braille sample across consecutive trials until it reached mastery criterion (similar to the "blocking" or "chunking" procedure described by Williams, Perez-Gonzalez, & Queiroz, 2005). Then we added and alternated one additional sample letter from the letter set until mastery criterion was reached. Letters from within a set were sequentially introduced as samples until Jeremy reached mastery criterion with all letters of the set being presented twice within a session.

Booster Session Procedures

Booster sessions were identical to braille-to-text instructional sessions and, again were conducted prior to each emergent-relation probe to ensure this instructed relation was at full strength due to the duration of time between instruction and some probes (a single probe

typically occupied a full day's experimental time, so it may have been several days between the completion of instruction and the final probe test).

RESULTS

Participant One

Fred's evaluation results are shown in Figure 2. All 26 letters were included in Fred's evaluation and were divided into five letter sets. Data for Fred's directly instructed braille-to-text relation are shown in the left column of Figure 2. Correct responding levels were low for letter sets 1, 2, 3, and 4 prior to instruction (*Ms* = 29%, 28%, 40%, and 40%, respectively). Braille-to-text instruction was then systematically introduced across these letter sets in accordance with a multiple probe design and mastery criterion were achieved following 6, 9, 7, and 2 instructional sessions for letter sets 1, 2, 3, and 4, respectively (data not shown in figure). The acquisition of this skill was shown to maintain during post training probes in each set (*Ms* = 98%, 100%, 100%, and 100% correct, respectively). Correct responding steadily increased to mastery criteria in the absence of direct instruction for letter set 5; therefore, instruction was not implemented with this letter set.

Data for Fred's emergent symmetric text-to-braille relation are shown in the second column of Figure 2. Correct responding was initially low during baseline for letter sets 1, 2, 3, and 4 (*Ms* = 41%, 28%, 40%, and 40%, respectively). Correct responding emerged to very high levels in each of these letter sets following the previously discussed braille-to-text instruction (*Ms* = 95%, 100%, 100%, and 100%, respectively). Similar to the braille-to-text relation, a gradual increase was observed with Fred's letter set 5.

Data for Fred's emergent transitive auditory-to-braille relation are shown in the third column of Figure 2. Correct responding was low during baseline for the first four letter sets (*Ms* = 46%, 28%, 40%, and 49%, respectively) but increased and maintained following receiving

instruction for the braille-to-text relation (*Ms* = 91%, 87%, 76%, and 90%, respectively) during post-instruction probes. Again, a steady increase was observed for letter set 5.

Data for Fred's emergent transitive braille-to-vocal relation are shown in the fourth column of Figure 2. Again, correct responding was low during baseline for each of the first four letter sets (*Ms* =30%, 0%, 9% and 9%, respectively) but increased to and maintained at high levels following the braille-to-text instruction (*Ms* =92%, 100%, 85%, and 100%, respectively). A temporally corresponding increase in correct responding was also observed with letter set 5.

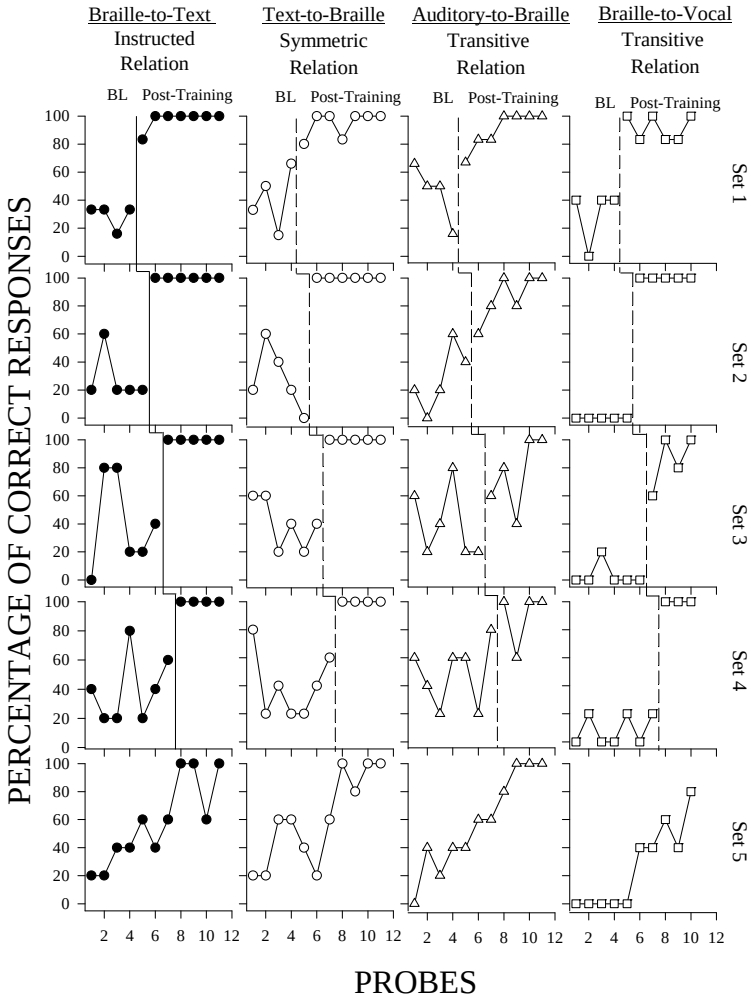


Figure 2. Evaluation results for Fred. The trained relation (braille-to-text) is shown in the far left column with the emergent symmetric (text-to-braille) and transitive (auditory-to-braille; braille-to-vocal) relations in the three right columns.

Participant Two

Jeremy's results are shown in Figure 3. Eight letters were included in Jeremy's evaluation and were divided into two letter sets. Data for Jeremy's directly instructed braille-to-text relation are shown in the left column of Figure 3. Mean correct responding was 33% and 62% for letter sets 1 and 2, respectively. Both letter sets met acquisition mastery criterion following 28 and 9 instructional sessions, respectively (data not shown in figure) and maintained at high levels during post-instruction probes (*Ms* = 100% and 94%, respectively). Data for Jeremy's emergent text-to-braille relation are shown in the second column of Figure 3. Mean correct responding was 33% and 64% for letter sets 1 and 2, respectively, which increased to 95% and 100% following braille-to-text instruction. Data for Jeremy's emergent auditory-to-braille (transitive) relation are shown in the third column of Figure 3. Mean correct responding was 42% and 56% for letter sets 1 and 2, respectively, and increased to 95% and 100% following braille-to-text training. Data for Jeremy's emergent braille-to-vocal (transitive) relation are shown in the fourth column of Figure 3. Correct responding was low for both letter sets 1 and 2 during baseline (*Ms* = 30% and 38%, respectively) and increased and maintained to high levels following the braille-to-text instruction (*Ms* = 100% and 100%).

Participant Three

Danielle's results are shown in Figure 4. Nine letters were included in Danielle's evaluation and were divided into two letter sets. Data for Danielle's braille-to-text (directly trained) relation are shown in the first column of Figure 4. Mean correct responding was 17% and 64% for letter sets 1 and 2, respectively. These letter sets met mastery criterion after 9 and 3 instructional sessions (data not shown in Figure) and both maintained at 100% accuracy during subsequent test probes. Data for Danielle's text-to-braille (symmetric) relation are shown in the

second column of Figure 4. Mean correct responding was 25% for set 1 and 68% for set 2 during baseline and increased to high levels (*Ms* = 100% and 95%) after braille-to-text instruction. Data for Danielle's auditory-to-braille (transitive) relation are shown in the third column of Figure 4. Mean correct responding was 13% and 76% for letter sets 1 and 2, respectively during baseline and increased to 96% and 100% post-instruction. Data for Danielle's braille-to-vocal relation are shown in the fourth column of Figure 4. Correct responding was low in both letter sets (*Ms* =17% and 28%) during baseline and increased to 96% and 90% during post-instruction probes

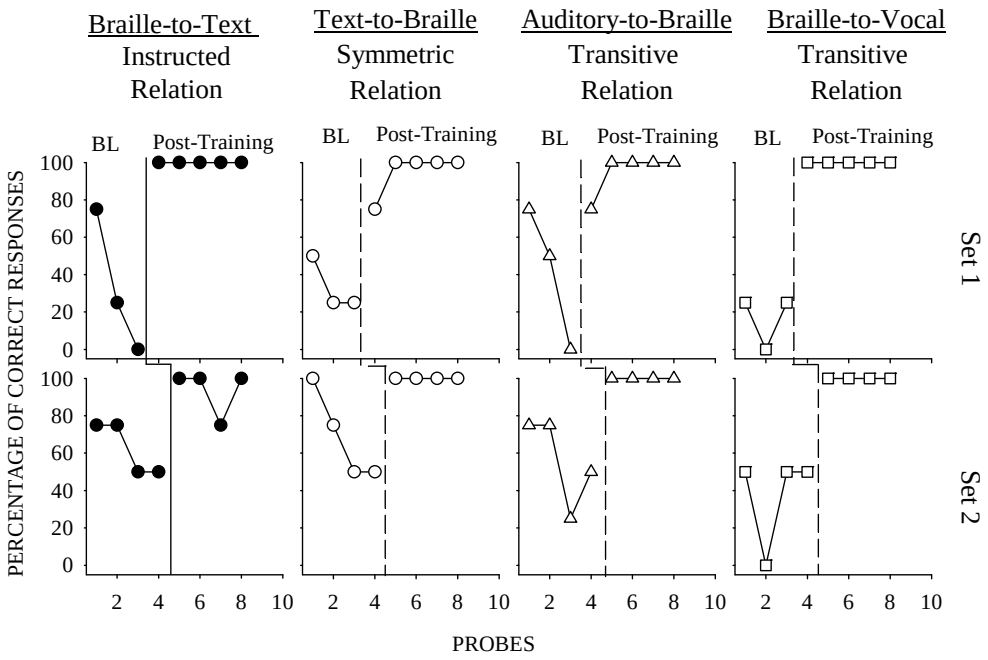


Figure 3. Evaluation results for Jeremy. The trained relation (braille-to-text) is shown in the far left column with the emergent symmetric (text-to-braille) and Transitive (auditory-to-braille; braille-to-vocal) relations in the three right columns.

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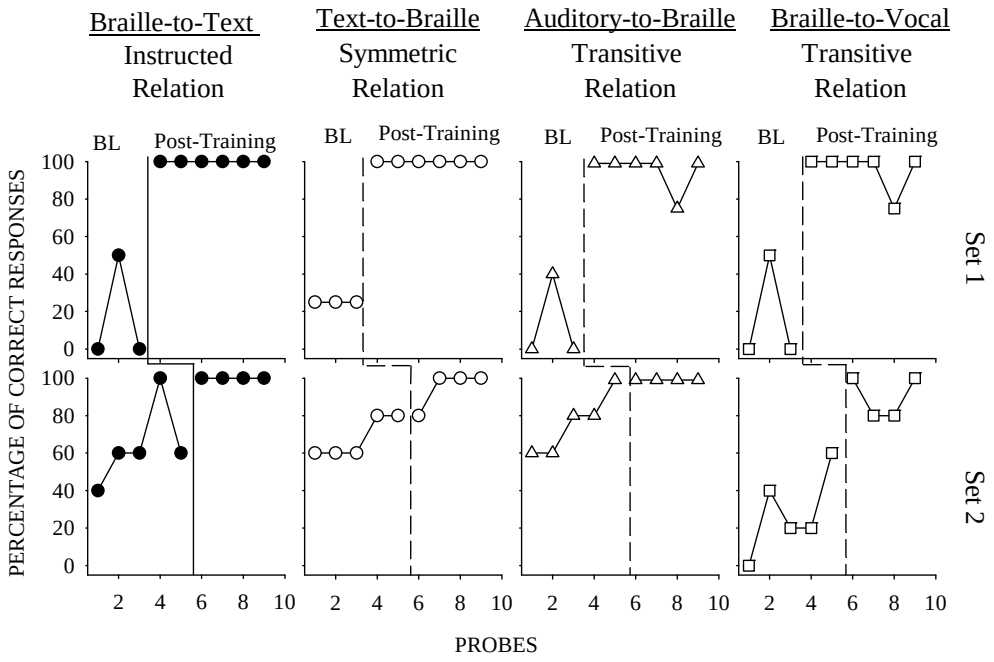


Figure 4. Evaluation results for Danielle. The trained relation (braille-to-text) is shown in the far left column with the emergent symmetric (text-to-braille) and Transitive (auditory-to-braille; braille-to-vocal) relations in the three right columns.

Participant Four

Cole's results are shown in Figure 5. One set of five letters was included in Cole's evaluation (presented in Table). Data for the braille-to-text (directly instructed) relation are shown in the first panel of Figure 5. Mean correct responding was 67% during baseline. This relation met mastery criteria after 5 instruction sessions (data not included in figure) and correct responding maintained at high levels (M = 93%) during post-instruction probes. Data for the text-to-braille (symmetric) relation for Cole are shown in the second panel of Figure 5. Mean correct responding was 73% prior to braille-to-text instruction and increased to 98% following this instruction. Data for the auditory-to-braille (transitive) relation are shown in the third panel of Figure 5. Mean correct responding was 77% during baseline and increased to 95% during post-instruction probes. Data for the braille-to-vocal relation is shown in the fourth panel of

Figure 5. Mean correct responding was 57% during baseline and increased to 100% during post-instruction probes.

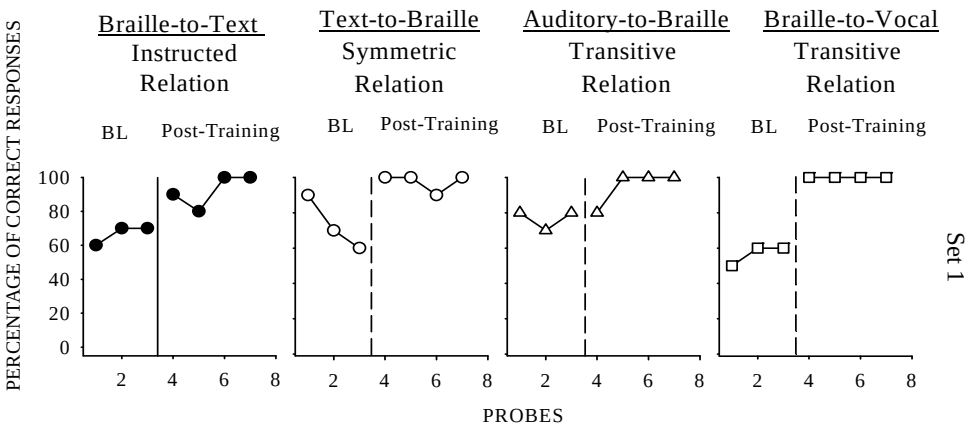


Figure 5. Evaluation results for Cole. The trained relation (braille-to-text) is shown in the far left panel with the emergent symmetric (text-to-braille) and transitive (auditory-to-braille; braille-to-vocal) relations in the three right panels.

DISCUSSION

In the current study, four children with degenerative visual impairments were taught braille-letter-identification skills in which they selected a text letter when given a braille sample. The acquisition of this skill entered into an equivalence class relationship with a number of prerequisite skills (e.g., text letter naming) and resulted in the emergence of important symmetric (i.e., selecting braille letters given a text sample) and transitive (selecting braille letters given an auditory letter name and vocally naming braille letters) relations for each participant. These results extend the literature related to braille instruction considerably by providing a systematic approach to teaching Grade-1 braille specifically targeted at individuals with existing sight and reading skills. This is the only study of which we are aware that specifically targeted this population by including visual stimuli into the instructional milieu.

This study differed from previous research in a number of important ways. First, this is the first study of which we are aware which assessed the emergence of equivalence relationships between previously learned spoken and text letters and novel braille letters. These results suggest that instruction based upon these relations may efficiently develop the prerequisites necessary for more comprehensive braille instruction (i.e., those involving phonemes and the combination of letters into words and sentences).

Second, this study differed in that instruction focused upon the relation between visual and tactile stimuli rather than tactile and auditory/spoken stimuli. Although we did not specifically target the braille-to-vocal relation (as was the case in Mangold, 1978), or the auditory-to-braille relation (as was the case in Crawford & Elliott, 2007), these relationships did emerge following our braille-to-text instruction. Thus, our instructional procedures should be considered at least as effective in establishing these relations as previously described

instructional procedures even though they were not the direct targets of our instruction, and at best superior in that *all* of these relations were acquired. Although teaching any combination of these relations may result in the formation of equivalence relationships, we believe teaching the braille-to-text relation may have particular benefits to learners.

We chose to teach the braille-to-text relation (a) to ensure that the required response (i.e. touching a text letter) was one that could be physically prompted and (b) to allow the comparison stimulus to be presented continuously. Physical prompting was never necessary in the current study, thus the benefit of this procedure was not realized. The current data support the latter assertion regarding the use of continuous relative to brief sample stimuli. Specifically, we observed the lowest levels of post-instruction correct responding during the auditory-to-braille probes (in Fred's data most notably) in which a brief vocal statement served as a sample stimulus relative to the other relations which involved a continuous braille or text sample. Thus, the presentation of brief sample stimuli may have weakened stimulus control. Despite the potential advantages of teaching the braille-to-text relation, other advantages for initiating instruction with one of the other relations may exist. Specifically, Stromer, McIlvane and Serna (1993) suggested that equivalence class formation may be facilitated by labeling sample stimuli; thus, stimulus class formation may have formed more readily by teaching the braille-to-vocal relation. Additional research is needed to directly compare the efficiency of braille learning depending upon the initial relation taught.

Braille-to-braille identity matching was included as one of our prerequisite skills to ensure participants were capable of making the tactile discriminations necessary for braille reading. Most people have limited experience making such fine tactile discriminations so it is not surprising that each of our participants required instruction to develop this skill. While our

identity-matching instruction accomplished this goal, we believe that a more systematic investigation of procedures to teach braille-to-braille identity matching is warranted. For instance, we are beginning to develop a programmed sequence in which comparison-stimulus combinations are initially very distinct from the target stimulus (e.g., 1-dot characters vs. 5-dot characters) and then made progressively more similar by decreasing the comparison density difference across learning trails.

We also would like to make a note about Fred's increased accuracy with letter set 5 despite the absence of direct instruction for these letters. Such a pattern is somewhat troubling in that it violates the logic of the multiple probe design (i.e., behavior change should be observed when and only when the independent variable has been implemented). It is apparent that learning occurred for the members of letter set 5 corresponding to the completion of training with the previous four letter sets (i.e., increases were observed across all assessed relations). Rather than interpret these data as a source of uncontrolled or confounding influence, we believe this learning resulted as an artifact of our procedures. That is, during braille-to-text probes, we randomly selected comparison stimuli from *any* of the five letter sets. Following completion of training for the first four letter sets, there was roughly an 80% probability that when a novel sample stimulus was presented during the probes for letter set 5, the other two comparison stimuli had already been acquired, and thus the correct comparison could be easily identified through exclusion. Repeated exposure to this exclusion arrangement could explain the acquisition of skills related to letter set 5, including each of the emergent relations. Although this outcome is exceedingly desirable from a practical standpoint (i.e., uninstructed learning), we would recommend researchers either (a) control for this confound in future evaluations, perhaps by drawing comparison stimuli from within, as opposed to across, training sets such that all

comparison stimuli would be equally novel with the sample stimulus (which we did for the 3 children whose participation followed Fred) or (b) systematically demonstrate the impact of exclusion learning either within or across participants (e.g., McIlvane & Stoddard, 1981).

Letter identification is only the first step in braille reading. Participants of this study were by no means fluent braille readers at the conclusion of this study. We intend to evaluate a similar stimulus equivalence based teaching procedure in which letter sounds (i.e., phonemes) are included in the equivalence relations. Additional instruction would then be necessary to expand reading repertoires from simple phonemes to full words. Stimulus equivalence based instruction may also be used to efficiently teach individuals to recombine learned syllables into novel words (Melchiohri, de Souza, & de Rose, 2000). The development of such a comprehensive curriculum is an important goal for the future.

It is also worth noting that these instructional procedures were carried out by an experimenter with greater training and experience with behavior analytic principles and direct instruction than would be typical of a braille instructor. The utility of these teaching procedures will ultimately be determined by the extent to which individuals with limited behavior-analytic training will be able to successfully implement these procedures and thus needs to be assessed.

Despite the questions yet to be resolved, we are enthusiastic regarding the utility of these teaching procedures in helping children who will lose their sight in acquiring braille-reading skills prior to further visual deterioration. These procedures are likely not relegated to this population as the necessary prerequisite skills appear to be (a) the ability to make tactile discriminations between braille letters and (b) a preexisting text reading repertoire. For example, age related macular degeneration is the number one cause of vision loss, and the number of adults with eye-related diseases is expected to double within the next three decades (Prevent

Blindness America 2008). Using stimulus equivalence procedures while there is still a functional level of sight may aide in preparing these individuals who will need to learn braille for continued literacy, and thus have utility for adult populations at risk for vision loss as well.

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