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Teaching Braille Letters, Numbers, Punctuation, and Contractions to Sighted Individuals

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TEACHING BRAILLE LETTERS, NUMBERS, PUNCTUATION, AND CONTRACTIONS TO SIGHTED INDIVIDUALS

by

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ABSTRACT
TEACHING BRAILLE LETTERS, NUMBERS, PUNCTUATION, AND CONTRACTIONS TO SIGHTED INDIVIDUALS

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Sighted teachers who can read braille visually can provide better instruction and feedback to students with visual impairments who are learning to read braille tactually. Due to the overwhelmingly low ratio of certified braille instructors to children with visual impairments, instruction in visual braille is socially relevant and would greatly improve literacy instruction for children with visual impairments. We conducted a study that used the principles of behavior analysis to teach visual braille reading to sighted teachers. The computer-based teaching program employed a matching-to-sample approach in which participants selected the correct answer from an array. Four undergraduate participants completed the visual braille training program. Participants responded at mastery levels immediately following training, but correct responding decreased during maintenance probes. In addition, participants were able to identify some braille characters when provided a passage written in braille, but they were not able to fluently read braille.

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Introduction

According to the American Printing House for the Blind's 2011 Annual Report, there are 58,939 registered legally blind individuals under age 21 in the United States. The Individuals with Disabilities Education Act (IDEA) defines visual impairment as "impairment in vision that, even with correction, adversely affects a child's educational performance. The term includes both partial sight and blindness" (U.S. Department of Education, 2004). Literacy is an integral aspect of education, yet only 9% of legally blind students under age 21 are registered as braille readers (American Printing House for the Blind, 2011). Adults with limited literacy proficiency are more likely to be unemployed than adults with more advanced literacy proficiency (Kirsch, Jungeblut, Jenkins, & Kolstad, 2002).

The braille code is a system that facilitates the development of literacy in individuals with visual impairments by allowing these individuals to read through touch rather than sight. This code consists of raised dots arranged in a cell that contains six possible dot positions. Braille can take two different forms: uncontracted or contracted. Uncontracted English braille (referred to as uncontracted braille from this point) consists of a point-to-point correspondence between print letters, numbers, and punctuation and their braille counterparts (see Figures 1 and 2). Contracted braille includes all of the characters of uncontracted braille as well as 186 contractions for common words (see Figures 3, 4, and 5) and letter combinations (see Figure 6). As most braille reading material is printed in contracted braille, it is necessary for braille readers to learn contracted braille (American Foundation for the Blind, 2013).

One reason for limited braille literacy is a dearth of qualified braille instructors (National Federation of the Blind, 2013). Qualification standards for braille literacy are set by the National Certification in Literacy for the Blind (NCLB; National Blindness Professional Certification Board [NBPCB], 2013). In order to receive the NCLB, an individual must pass an examination demonstrating proficiency in writing braille using a braille writer, writing braille using a slate and stylus, proofreading written braille, and answering multiple choice questions regarding correct braille usage and rules. The examination consists of letters and numbers (1%), contractions (68%), common punctuation and composition (26%), and formatting (5%; National Certification in Literary Braille Candidate Manual, 2010). Approximately 200 individuals in the United States have obtained the NCLB, and there are several states in which no teachers have this certification (NBPCB, 2013). Due to the lack of certified instructors, literacy instruction for visually impaired students frequently becomes the responsibility of lesser qualified teachers (National Federation of the Blind, 2013). Developing readily accessible instructional programs to equip teachers with the skills necessary to provide braille instruction is important, but little research has addressed this issue.

The most rudimentary skill required from teachers is the ability to identify braille characters and their relation to print. Scheithauer and Tiger (2012) developed a computerized-instruction program to teach four college students the relations between braille and print letters. The 26 letters of the print alphabet were divided randomly into five letter sets with five or six letters in each set. During teaching sessions, the program presented a braille character and five or six comparisons within a multiple choice format and provided immediate feedback for correct and incorrect answers. Learners' progression through the program was sequenced such that participants were required to master one letter set prior to advancing to the next set. Learners completed the entire program in a mean of 24 min; they were then post-tested on their ability to read an uncontracted braille passage. Participants demonstrated emergent braille reading during these post-tests as well as during a 1- to 2-week maintenance assessment. Scheithauer, Tiger, and Miller (2013) replicated these procedures with a larger sample of 84 college students and found near identical results. Although promising in developing braille reading repertoires for teachers, these studies were limited in a number of important ways. Most notably, Scheithauer et. al only trained point-to-point correspondence between English letters and their braille counterparts; they did not include numbers, punctuation, symbols, or contractions in their training program. Additionally, the program was developed within PracticeMill (Peladeau, 2000) software, which requires users to (a) have a copy of the software, which is no longer commercially produced, (b) a PC computer that runs on Microsoft Windows XP operating system or earlier, and (c) to manually enter the programmed stimuli for each teaching computer. Thus, although the program developed by Scheithauer et al. was effective at teaching uncontracted braille, its utility was limited in scope and portability.

The purpose of the current study is to extend the studies conducted by Scheithauer et. al (2012, 2013) by teaching not only letter identification, but also numbers, punctuation, symbols, and contractions for common words and letter combinations. Further, this stand-alone version of the program (called the Visual Braille Trainer, or VBT) was written in Java and will be compatible with new operating systems as they are released and adopted.

Method

Participants and Setting

Four sighted undergraduate students participated in this study; each participant received monetary compensation for participation and three participants who were enrolled in Psychology courses received course credit. We recruited undergraduate participants because they are demographically similar to the teachers who would use this software to learn braille. One of our inclusion criteria was that participants be sighted because we taught them to read braille visually, not tactually. We solicited participants through the University's online portal, which provided a brief description of the study, the time requirements, and the available compensation. We provided compensation in the form of course credit, $10 per session attended, and a $25 bonus for completing the study. Students scheduled their participation in training sessions on one to three days per week for two to four weeks (*M* = 19.75 days) and one maintenance session, which occurred 2 to 3 weeks (*M* = 17.5 days) after the final training session. Participants completed training in otherwise unoccupied offices on a college campus. Minimally, each office had a table, a chair, and a desktop computer. The computer was equipped with Microsoft Windows 7 and the VBT software.

Response Measurement and Reliability

Prior to conducting this study, the experimenter pilot tested each VBT module to ensure the accuracy of its functioning. The VBT automatically recorded participants' responding during probe and training sessions and reported these measures on a trial-by-trial basis in a .csv (spreadsheet) file (see Figure 8 for a sample data file). On each trial, the output provided (a) the correct response, (b) the participant's response, (c) whether the response was correct or incorrect, (d) the number of times a stimulus had been presented, (e) the response latency between the presentation of stimuli and selection of response measured in s, (f) the total number of questions correct, (g) the total number of questions answered, (h) the overall percentage correct (f/g*100%), and (i) the percentage correct during the last 15 presentations (this measure was used to determine mastery criteria). Following probe sessions, using these outputs, the experimenter grouped stimuli by module and calculated the percentage correct for each module by dividing the number of correct responses from that module by five (i.e., total presentations from the module) and multiplying by 100.

Both print and braille reading probes were scored manually by trained observers. During the print Oral Reading Fluency (ORF) probe, the observers scored an identical passage on a separate sheet while the participant read the passage. When the participant began reading, the observer started a timer; after 1 min the timer beeped and the experimenter marked the last word the participant read with a bracket. Words read correctly were left alone; words read incorrectly were struck through. The experimenter then counted the total number of words read and recorded this number on the data sheet. For three of the four participants (Sandra, Matthew, and Heidi), the experimenter used a webcam to digitally record the participants reading the passage. A second observer scored the video recording independently during 75% of ORF probes. Observers' records were compared by dividing the smaller number of words read aloud by the larger number and converting this fraction into a percentage. Agreement was 100% across reliability assessments.

For braille reading probes, the experimenter created a scoring sheet for passages in which each utterance was broken down into scorable units. For instance, presented with the braille equivalent of “**THE”**, the target responses would have been stating (a) bold, (b) capital, and (c) the; these were scored as three separate items. Each item was scored as either correct (+) or incorrect (-); skipped items were scored as incorrect. The last item attempted before the expiration of the session or a statement from the participant of completion was noted with a bracket. One observer scored these sessions live and a second observer scored 87.5% of these sessions via a video-recording. Observers’ records were compared on an item-by-item basis. Agreement was calculated by dividing the total number of items with agreement by the number of items attempted and multiplying by 100%. Agreement was 98.7% (range: 94-100%) across reliability assessments.

Procedures

When participants arrived for their first session, the experimenter briefed participants on the purpose and procedures of the experiment prior to obtaining written consent. Participants then completed several pretests before beginning braille training. First, we administered a print-reading fluency test to ensure participants were fluent readers. The experimenter prompted participants to read a sixth grade passage from the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) reading assessment. We chose this assessment tool because it is norm referenced and widely used. This assessment required participants to read a passage aloud for 1 min. According to the DIBELS benchmarks for the end of 6^{th} grade (the norm level provided), a student who reads 125 words in one min at the end of sixth grade is considered low-risk for literacy problems

(University of Oregon Center on Teaching and Learning, 2012); we therefore selected 125 wpm as our minimum fluency for inclusion.

Next, we conducted a baseline probe of printed-braille reading; the experimenter provided participants with a braille passage to determine if participants could read braille visually (see Figure 9). This passage was considered the terminal probe for the study and includes stimuli from all six training sessions. We used a passage that is similar to those used in a braille instructor certification exam. The experimenter asked participants to read as much of the passage as they could, or to tell the experimenter that they could not read any of the passage. Participants who read any portion of the braille passage would have been excluded from the study.

We then conducted a braille-stimuli identification probe; this pretest was administered within the VBT and consisted of 30 trials. On each trial, the VBT presented a braille character and an array of five or six printed characters in a multiple choice format. For each probe session, the program randomly selected five characters from each of the six training modules (i.e., five letters; five numbers, symbols, or punctuation marks; five whole-word contractions from group A; five whole-word contractions from group B; five whole-word contractions from group C; and five letter combination contractions). The comparison stimuli on each trial were selected randomly from the same training modules, such that letters were presented with other letters only as comparisons. Participants completed each trial by clicking on a radio button next to the selected comparison. A dialogue box appeared indicating that the response was scored and the participant clicked "ok" to continue to the next braille stimulus. The VBT recorded selections, but did not provide any feedback during these pretests. This pretest served as a baseline upon which we evaluated the effects of the computer based training in a concurrent multiple probe design across training sets. When participants completed all pretests (i.e., DIBELS ORF, braille reading probe, stimulus identification probe), they began braille training.

Braille Training

The experiment was conducted across a total of 7 days; the first 6 days followed a similar schedule. Upon arrival, the participant first completed the braille-stimuli identification probe described above. After this, participants experienced computer-based instruction for a training module; a different training module was targeted each day. Each training module was divided into smaller subsets of stimuli, and each braille stimulus within the targeted subset was presented on three trials within each session (e.g., five targeted stimuli would result in a 15-trial session). On each trial the program presented a braille sample stimulus and five or six comparisons in a multiple-choice format (these comparisons were always drawn from the same training subset as the sample stimulus). When a participant selected the correct stimulus by clicking on a radio button adjacent to that stimulus, a dialogue box appeared indicating the answer was correct. Selecting an incorrect stimulus resulted in a dialogue box indicating the selection was incorrect and providing the participant with the correct response. The program then presented an error correction trial in which the same stimulus was again presented as a sample; the participant was required to select the correct option before moving on to the next stimulus presentation. These error correction trials were not included in the data analysis.

When a participant answered correctly on 90% or more trials within a session, the program introduced the next subset in the subsequent session. Each time a new subset was presented, the program also included one probe trial of each previously mastered stimulus within that training unit; the multiple-choice options during these probes were the other stimuli from that particular mastered subset. When the participant met mastery criteria for all subsets within the module, participants again completed the braille-stimuli identification probe. This allowed repeated measurements of performance prior to and following training of each module.

Letter training (Module 1). The letter training module taught the relations between the 26 letters of the alphabet and their corresponding braille characters. These 26 stimuli were divided into five subsets consisting of five or six stimuli (see Figure 1). We created subsets based on the visual similarity among the braille characters to facilitate discrimination.

Number, symbol, and punctuation training (Module 2). This training module consisted of 41 braille number, symbol, and punctuation mark stimuli. These stimuli were divided into eight subsets, which each contained four, five, or six braille stimuli. Two subsets contained only numbers and the other six subsets contained punctuation and braille symbols (see Figure 2). We also created the number, symbol, and punctuation subsets based on visual similarity among braille characters to facilitate discrimination.

Whole-word contraction training A to C (Modules 3 to 5). The whole-word contraction training consisted of 149 whole-word contractions. We divided the contractions into three modules due to the large number of relations to be taught. Whole-word contraction module A consisted of 51 words divided into nine subsets, each containing five or six stimulus pairs (see Figure 3). Whole-word contraction module B consisted of 53 words divided into nine subsets, each containing five or six stimulus pairs (see Figure 4). Whole-word contraction module C consisted of 45 words divided into eight subsets, each containing five or six stimulus pairs (see Figure 5). Subsets contained contractions that are made up of the same number of braille characters to prevent participants' behavior from coming under faulty stimulus control (e.g., choosing the answer based on the number of braille characters rather than dot location).

Letter-combination contraction training (Module 6). There are 37 letter combination contractions, which we divided into seven subsets. Each subset contains four, five, or six stimulus pairs (see Figure 6). Subsets contained contractions that were made up of the same number of braille characters to prevent participants' behavior from coming under control of the wrong stimuli (e.g., choosing the answer based on the number of braille characters rather than dot location). After completing the stimulus identification probe at the end of module 6, the participant completed the braille passage reading probe.

Follow-Up Probe

Participants returned for a follow-up probe 2 to 3 weeks (*M* = 17.5 days) after their final training session (i.e., Module 6). This follow-up session consisted of completing the stimulus identification probe (described above) and the braille-passage reading probe.

Results

Pre-Tests

All four participants read at least 125 words in 1 min during the print ORF task (*M* = 197.3 words, range: 186-213 words) and read zero units on the braille reading probe.

Braille Training and Stimulus Identification Probes

Sally completed all training modules during a 16-day period. Figure 10 shows the results for Sally's stimulus identification probes for all six modules; each data point represents Sally's responding to five randomly drawn stimuli from a particular module.

Prior to training on the letters module (top panel of Figure 3), Sally responded correctly on 0% of probe trials. Sally completed training on the letter training module in 11 min 57 s. Immediately after completing training on this module, Sally's responding increased to 100% (first data point to the right of the solid phase line). On subsequent post-training probes, responding maintained at high levels (*M* = 88.0%, range: 80-100%). When Sally completed the follow-up probe, which occurred 31 days after initial letter training, Sally responded correctly on 100% of trials.

During pre-training probes of the numbers, symbols, and punctuation module Sally responded correctly on 13.3% (range: 0-20%) of trials (second panel of Figure 10). She completed training on this module in 31 min 11 s. Immediately after completing the training module, Sally's correct responding increased to 100%. Sally responded correctly on 52.5% of trials (range: 0-80%) on post-training probes and on 40.0% of trials on the follow-up probe, which occurred 30 days after initial training on this module.

Sally responded correctly on 40.0% (range: 0-80%) of pre-training trials for the Whole-Word Contractions A module (third panel of Figure 10) and she completed training on this module in 38 min 25 s. Immediately following training on this module, Sally's correct responding increased to 100%. During post-training probes, Sally responded correctly on 76.7% of trials (range: 60-80%); correct responding on the follow-up probe, conducted 24 days after initial training on this module, occurred during 80.0% of trials.

Prior to training on the Whole-Word Contractions B module, Sally responded correctly on 57.1% (range: 20-100%) of trials (fourth panel of Figure 10). While Sally was completing training on this module, a program glitch caused the program to cease to deliver new training stimuli after Sally had mastered several subsets. The programmer rectified the issue and Sally returned several days later to re-train on this module. We were unable to re-commence training where Sally had left off, so she completed extra training on the first few subsets of this module; we were therefore unable to determine how much time she spent training on the Whole-Word Contractions B module. Responding immediately increased to 100% post-training, and maintained at 100% for all four post-training maintenance probes. The follow-up probe was conducted 21 days after initial training on this module, and Sally responded correctly on 80.0% of trials.

Sally responded correctly on 62.2% (range: 0-100%) of probe trials prior to completing training on the Whole-Word Contractions C module (fifth panel of Figure 10). She completed training on this module in 22 min 30 s. Immediately after completing training on this module, Sally's correct responding increased to 100%. Correct responding maintained at 100% during the two maintenance probes and during the follow-up probe, which was conducted 17 days after initial Whole-Word Contractions C training.

Sally responded correctly on 45.5% (range: 0-80%) of trials during pre-training Common Letter Combinations probes (bottom panel of Figure 10). She completed training on this module in 17 min 15 s. Immediately after completing training on this module, Sally responded correctly on 100% of trials. When she completed the follow-up probe 16 days later, Sally responded correctly on 40.0% of trials.

Figure 11 shows stimulus identification probe data for Sandra; she completed training on all modules across 15 days. On the pre-training probe, Sandra responded correctly on 0% of letter trials (top panel of Figure 4). She completed letter training in 9 min 37 s. Immediately after completing training on this module, Sandra responded correctly on 100% of trials. Correct responding remained high (*M* = 96.0%, range: 80-

100%) during post-training probes and occurred on 100% of trials during the 35-day post-training follow-up probe.

Prior to completing training on the numbers, symbols, and punctuation module, Sandra responded correctly on 26.7% (range: 20-40%) of trials from this module (second panel of Figure 11). She completed training on this module in 20 min. Immediately following training, Sandra responded correctly on 80.0% of trials, and this level of responding maintained during the eight post-training probes (*M* = 82.5%, range: 60-100%). Sandra responded correctly on 80.0% of trials during the post-training probe, which she completed 33 days after initial training on this module.

Before training on the Whole-Word Contractions A module, Sandra responded correctly on 48.0% (range: 0-80%) of trials (third panel of Figure 11). She completed training on this module in 30 min 24 s; upon completing this module, correct responding increased to 100%. During post-training maintenance probes, Sandra responded correctly on 86.7% (range: 80-100%) of trials. She responded correctly during 60.0% of trials during the 31-day post-training follow-up probe.

Prior to completing the Whole-Word Contractions B training module, Sandra responded correctly on 60.0% (range: 40-100%) of trials (fourth panel of Figure 4). She completed training on this module in 31 min 26 s. Immediately after completing training on this module, Sandra's correct responding increased to 100% (first data point to the right of the solid phase line). Correct responding maintained at mastery levels (m = 90.0%, range: 80-100%) on post-training probes, and occurred on 80.0% of trials during the 28-day post-training follow-up probe.

During pre-training Whole Word Contractions C probes, Sandra responded correctly on 75.6% (range: 20-100%) of trials (fifth panel of Figure 11); she completed training on this module in 20 min 8 s. Immediately after completing training on this module, Sandra responded correctly on 80.0% of trials. During both post-training maintenance probes and during the follow-up probe, which occurred 26 days after initial training on this module, Sandra responded correctly on 100% of trials.

Sandra responded correctly on 49.1% (range 0-100%) of pre-training letter combination trials (bottom panel of Figure 11). She completed training on this module in 16 min 20 s. Immediately after completing training on this module, Sandra responded correctly on 100% of trials. During the follow-up probe, which occurred 21 days after the initial letter combination training, Sandra responded correctly on 60.0% of trials.

Matthew completed all six training modules during a 22-day period. He responded correctly on 20.0% of letter trials during the pre-training probe (see Figure 12, top panel). He completed training on this module in 7 min 20 s; immediately after completing the letter training module, Matthew's correct responding increased to 100%. During post-training maintenance probes, correct responding occurred on 78.0% (range: 40-100%) of trials. When Matthew completed the follow-up probe 42 days after completing the letter training module, he responded correctly on 100% of trials.

Prior to completing training on the numbers, symbols, and punctuation module, Matthew responded correctly on 40.0% (range: 20-60%) of trials (second panel of Figure 12). Matthew completed training on this module in 18 min 23 s. During the probe conducted immediately after numbers, symbols, and punctuation training, Matthew responded correctly on 100% of trials. Correct responding decreased to 57.5% (range: 40-

100%) on post-training maintenance probes. During the follow-up probe, which occurred 35 days after training on this module, Matthew responded correctly on 40.0% of trials.

During pre-training probes of the Whole-Word Contractions A module, Matthew responded correctly on 48.0% (range: 20-80%) of trials (third panel of Figure 12). Matthew completed training on this module in 24 min 52 s. When he completed the probe immediately following training on this module, correct responding increased to 80.0%. Correct responding during post-training maintenance probes decreased to 56.7% (20-100%); however, when Matthew completed the follow-up probe 34 days after training on this module, he responded correctly on 100% of trials.

Prior to training on the Whole-Word Contractions B module, Matthew responded correctly on 60.0% (range: 20-100%) of trials (panel 4 of Figure 12). He completed training on this module in 34 min 12 s. Immediately after completing training on this unit, Matthew responded correctly on 80.0% of trials. Correct responding maintained at 80.0% (range: 60-100%) during post-training maintenance probes and also occurred on 80.0% of trials during the follow-up probe, conducted 27 days after training on this module.

During pre-training Whole-Word Contractions C probes, Matthew responded correctly on 64.4% (range: 20-100%) of trials (fifth panel of Figure 12). He completed training on this module in 23 min 52 s. Immediately after completing training on this module, Matthew responded correctly on 100% of trials. During post-training maintenance probes, correct responding occurred on 80% of trials. Matthew responded correctly on 100% of trials when he completed the follow-up probe 21 days after training on this module.

Matthew responded correctly on 50.9% (range: 20-100%) of pre-training trials for the letter combinations module (bottom panel of Figure 12); he then completed training on this module in 23 min 35 s. Immediately following letter combination training, Matthew's correct responding increased to 100%. Correct responding on the follow-up probe, conducted 14 days after initial training on this module, occurred during 60.0% of trials.

Figure 13 displays data for Heidi's responding on stimulus identification probes. Before completing letter training, Heidi responded correctly on 40.0% of letter trials (top panel of Figure 13). She completed training on this module in 8 min 52 s; immediately post-training, correct responding increased to 100%. During post-training maintenance probes Heidi responded correctly on 80.0% (40-100%) of trials. During the follow-up probe, which occurred 35 days after initial letter training, Heidi responded correctly on 40.0% of trials.

Prior to completing training on the numbers, symbols, and punctuation module, Heidi responded correctly on 26.7% (range: 0-40%) of trials (second panel of Figure 13). She completed training on this module in 17 min 16 s; immediately after completing training, her responding increased to 80.0%. During post-training maintenance probes, Heidi responded correctly on 42.5% (range: 20-80%) of trials. When she completed the follow-up probe, 32 days after training on this module, Heidi's correct responding decreased to 0%.

Heidi responded correctly on 36.0% (range: 0-80%) of pre-training probes from the Whole-Word Contractions A module (third panel of Figure 13). She completed training on this module in 28 min 2 s. Immediately after completing training on this module, Heidi's correct responding increased to 100%. During post-training maintenance probes, Heidi responded correctly on 53.3% (range: 0-100%). When she completed the follow-up probe 27 days after training on this module, Heidi responded correctly on 40.0% of trials.

Prior to completing Whole-Word Contractions B training, Heidi responded correctly on 37.1% (range: 0-80%) of trials (fourth of Figure 13). She completed training on this module in 28 min 43 s. When she had completed training, Heidi’s correct responding increased to 100%. During post-training maintenance probes, correct responding decreased to 60.0% (range: 20-80%), but when Heidi returned 25 days after training on this unit she responded correctly on 100% of trials.

During pre-training Whole-Word Contractions C probes, Heidi responded correctly on 51.1% (range: 40-80%) of trials (fifth panel of Figure 13). She completed training on this module in 22 min 57 s. Immediately after completing training on this module, correct responding increased to 100%. Heidi responded correctly on 90.0% (range: 80-100%) of trials during post-training maintenance probes. During the follow-up probe, 21 days after Heidi completed Whole-word Contractions C training, she responded correctly on 60.0% of trials.

During pre-training probes of the Common Letter Combinations module Heidi responded correctly on 43.6% (range: 0-80%) of trials (bottom panel of Figure 13). She completed letter combination training in 13 min 3 s. Immediately after completing the training module, Heidi’s correct responding increased to 100%. Heidi responded correctly on 60.0% of trials during the follow-up probe, which occurred 18 days after initial training on this module.

Participants' individual training completion times and means for each module are presented in Figure 14. On average, participants completed training on the letter training module in 9 min 27 s (range: 7 min 20 s to 11 min 57 s); the numbers, symbols, and punctuation module in 21 min 35 s (range: 17 min 16 s to 31 min 11 s); the whole-word contractions A module in 30 min 26 s (range: 24 min 52 s to 38 min 25 s); the whole-word contractions B module in 31 min 27 s (n= 3 participants, range: 28 min 43 s to 34 min 12 s); the whole-word contractions C module in 22 min 22 s (range: 20 min 8 s to 23 min 52 s); and the letter combinations module in 17 min 33 s (range: 13 min 3 s to 23 min 35 s). The three participants for whom we have time-to-completion data for all six modules completed the six training modules in 2 hr 6 min 21 s (range: 1 hr 58 min 53 s to 2 hr 12 min 14 s).

Training on each of the six modules produced immediate effects on performance on probes, although these effects did not maintain for all participants (see Figure 15 for a summary figure). Before training on the letters module, participants responded correctly on few trials (*M* = 15.0%, range: 0-40%), and after training on this module all participants responded correctly on 100% of trials. During the post-training maintenance probes participants responded correctly on 85.5% (range: 78-96%) of trials. When participants completed the follow-up probe, they responded correctly on 85.0% (range 40-100%) of trials. We conducted a paired samples t-test and found that there were significant differences in responding on letter probes from baseline to the immediate probe; $t(3) = -8.873$, $p = .003$ and from baseline to the maintenance probes; $t(3) = -5.403$, $p = .012$. There were no significant differences in responding between baseline and follow-up probes; $t(3) = -2.941$, $p = .060$.

Correct responding on numbers, symbols, and punctuation probes occurred on 23.3% (range: 0-40%) of pre-training trials and increased to 90.0% (range: 80-100%) immediately after training. Participants responded correctly on 58.8% (range: 42.5-82.5%) of post-training maintenance trials and on 40% (range: 0-80%) of follow-up trials. We conducted a paired samples t-test and found that there were significant differences in responding on letter probes from baseline to the immediate probe; $t(3) = -6.322$, $p = .008$. There were neither significant differences in responding between baseline to the maintenance probes; $t(3) = -2.035$, $p = .135$, nor between baseline and follow-up probes; $t(3) = -.663$, $p = .555$.

Before participants completed training on the Whole-Word Contractions A module, they responded correctly on 43.7% of trials (range: 36-48%). Immediately after training, responding increased to 95.0% (range: 80-100%). Responding decreased to 68.4% (range: 53.3-86.7%) and maintained at 70.0% (range: 40-100%) during the follow-up probe. We conducted a paired samples t-test and found that there were significant differences in responding on Whole-Word Contractions A probes from baseline to the immediate probe; $t(3) = -7.305$, $p = .005$ and from baseline to the maintenance probes; $t(3) = -3.572$, $p = .038$. There were no significant differences in responding between baseline and follow-up probes; $t(3) = -2.377$, $p = .098$.

When participants completed pre-training probes from the Whole-Word Contractions B they responded correctly on 53.6% of trials (range: 37.1-60%). Responding immediately increased to 95.0% (range: 80-100%) after participants completed Whole-Word Contractions B training, and maintained at 82.5% (range: 60-100%) and 90.0% (80-100%) during post-training maintenance and follow-up, respectively. We conducted a paired samples t-test and found that there were significant differences in responding on letter probes from baseline to the immediate probe; $t(3) = -4.723$, $p = .018$, from baseline to the maintenance probes; $t(3) = -5.673$, $p = .011$, and from baseline to follow-up probes; $t(3) = -3.526$, $p = .039$.

Prior to completing training on the Whole-Word Contractions C module participants responded correctly on 63.3% (range: 51.1-75.6%) of trials. During probes conducted immediately post-training, participants responded correctly on 95.0% (range: 80-100%) of trials. This high percentage of correct responding maintained during maintenance probes (M = 92.5%, range: 80-100%) and during follow-up probes (M = 90.0%, range: 60-100%). We conducted a paired samples t-test and found that there were significant differences in responding on letter probes from baseline to the immediate probe; $t(3) = -3.318$, $p = .045$, from baseline to the maintenance probes; $t(3) = -5.212$, $p = .014$, and from baseline to follow-up probes; $t(3) = -4.035$, $p = .027$.

Participants responded correctly on 47.3% (range: 43.6-50.9%) of pre-training common letter combination probes. Immediately after they completed training, all participants responded correctly on 100% of trials; however, these training effects did not maintain during follow-up probes (M = 55%, range: 40-60%). We conducted a paired samples t-test and found that there were significant differences in responding on letter probes from baseline to the immediate probe; $t(3) = -31.733$, $p = .000$. There were no significant differences between responding on letter probes from baseline to follow-up; $t(3) = -1.653$, $p = .197$.

Braille Reading Probes

Participants completed braille reading probes immediately after training on the final module (i.e., common letter combinations) and during the follow-up session. During the immediate post-training probe Sally, Sandra, Matthew, and Heidi correctly identified four, five, five, and three items, respectively (see Figure 15). When they returned for the follow-up probe, Sally, Sandra, Matthew, and Heidi correctly identified seven, four, eleven, and one items, respectively.

Discussion

The current study evaluated the efficacy of the VBT software at teaching relations between braille stimuli (presented visually) and their print counterparts. This study extended previous research in a number of important ways. First, the current software was written as a stand-alone program that could be downloaded on any personal computing device and used to learn basic print-to-braille relations. Second, the current software targeted many additional relations beyond those of previous research. Scheithauer and Tiger (2012) and Scheithauer et al. (2013) both targeted 26 print-to-braille relations (letters); the current program targeted a total of 251 relations including letters, numbers, punctuations, symbols, and contractions.

The outcomes pertaining to the training of letters were similar to those of Scheithauer et al. (2012, 2013) in that all participants met mastery criterion given exposure to computerized instruction, but it is worth noting that mastery criterion were met more rapidly in the current study than in both prior reports. The mean training times were 24 and 27 min for the four and 81 participants in Scheithauer and Tiger (2012) and Scheithauer et al. (2013), respectively. By contrast, letter training in the current study averaged only 9 min 27 s. It is unclear if these differences are due to individual participant differences or due to the new program. The new program was intentionally designed to place the comparisons closer to the sample stimulus on screen to minimize scanning time; however, additional comparisons will be necessary to determine if this ergonomic change was responsible for the reduced training time.

The VBT software also produced improved responding on probes for the remaining five modules, not surprisingly with the highest levels of accuracy occurring just following the completion of training. Correct responding did decrease for all participants in probes more distant from training and during follow up, most notably in Matthew's and Heidi's evaluations. These data indicate that meeting mastery criterion alone was not sufficient to develop these relations at sufficient strength to persist over time. One potential solution would be to increase the stringency of the mastery criterion to create additional stimulus-stimulus pairings. An alternative approach would be to program more incremental rehearsal of previously mastered relations. Within each training module, participants experienced rehearsal of previously mastered subunits within that module, but there was no further rehearsal of previously mastered modules. We omitted this incremental rehearsal due to the large number of relations being targeted; however, the data clearly show that additional rehearsal is needed to promote maintenance. Future research will be necessary to identify the levels of rehearsal that will be needed.

One interesting outcome observed was an increasing trend in correct responding and high levels of variability in the four contractions modules pre-training (the lower four panels for each participant). These increasing trends provide a challenge for demonstrating functional control of the training program within a multiple baseline (although those trends were replicated for three of the four participants), but at the same time suggest collateral effects of the training program. That is, increases were noted in these four modules following completion of Module 1 (letters) training. Upon learning the letter relations, participants were likely able to improve their accuracy in selecting contractions (e.g., selecting the option that started with a recognized first letter). It is worth noting that no collateral increases were observed in number and punctuations for which there is no content overlap with letters. From an experimental design perspective, future research should either (a) conduct additional pre-training baseline probes to determine if the Module 1 training was responsible for the observed increases in contractions or (b) use a typed-response format (similar to Scheithauer et al., 2013) during pretests and posttests to minimize accurate guessing based upon component letters.

In addition to the direct effects of training these relations, we also assessed and captured the untrained emergence of some braille reading. In each case, participants' braille reading increased during post-training and follow-up probes relative to pre-training probes, but these post training scores did not approach fluency levels. These results are similar to those reported by Scheithauer et al. (2012, 2013) but differed in important ways. The reading passage provided to participants in both Scheithauer papers was transcribed in uncontracted braille. That is, each word was transcribed using a point-to-point correspondence between each letter of the print word and the braille character, and punctuation marks were left as regular print. In the current study, the reading passage included contractions, letters, numbers, symbols, and punctuation, and was transcribed entirely in braille. Thus, the current passage provided a more rigorous test of braille reading and was more analogous to the terminal performance braille teachers will need to master.

Despite the rigorousness of the braille assessment, the low reading levels post training are troubling and highlight the need for additional research. It is not entirely surprising that reading scores were low considering many of the composite trained relations did not maintain at mastery levels, so promoting maintenance of the trained relations seems an obvious first step in addressing the lack of untrained emergence. In addition, it would likely be helpful to provide participants with direct training to combine the individually trained elements. For instance, this iteration of the VBT taught participants to select "italics" when presented with the symbol for italics (i.e., ⠨) and to select "the" when presented with the braille contraction for "the" (i.e.,⠮), but they never saw the stimulus, *the* (i.e.,⠨⠮). Similarly, they learned the braille equivalents for "m" (i.e., ⠍), "o" (i.e.,⠕), and the contraction "-st" (i.e.,⠌), but never the combination of the three for "most" (i.e.,⠍⠕⠌). We are currently developing additional training modules to teach a subset of these combined relations and assessing recombinative generalization across items (e.g., Mahon, Lyddy, Barnes-Holmes, 2010).

This study provided a preliminary evaluation of a computerized program to teach Visual Braille Reading to sighted adults. The initial effects were promising in that all of the targeted relations were mastered, but additional work is necessary to ensure these repertoires maintain and are generalized to normative braille text. Several of these projects are now under development in our lab for what we hope can be a comprehensive introduction to braille for teachers who find themselves responsible for braille education.

Letter Identification									
Subset 1		Subset 2		Subset 3		Subset 4		Subset 5	
a	⠁	k	⠅	n	⠝	w	⠺	j	⠚
b	⠃	l	⠇	s	⠎	r	⠗	h	⠓
c	⠉	u	⠥	t	⠞	o	⠕	f	⠋
e	⠑	v	⠧	z	⠵	p	⠏	d	⠙
i	⠊	x	⠭	y	⠽	q	⠟	m	⠍
						g	⠛		

Figure 1. Letter stimulus identification pairs.

Numbers, Symbols, and Punctuation Identification							
Subset 1		Subset 2		Subset 4		Subset 8	
1	⠼⠁	4	⠼⠙	!	⠖	®	⠘⠗
2	⠼⠃	6	⠼⠋	(or)	⠶	™	⠘⠞
3	⠼⠉	7	⠼⠛	“ or ?	⠦	©	⠘⠉
5	⠼⠑	8	⠼⠓	. Period	⠲	/	⠸⠌
9	⠼⠊	0	⠼⠚	”	⠴	#	⠸⠹
Subset 3		Subset 5		Subset 6		Subset 7	
’	⠄	Letter Sign	⠰	Termination Sign	⠠⠄	]	⠶⠄
*	⠔⠔	Capital Sign	⠠	Double Italics Sign	⠨⠨	[	⠠⠶
;	⠆	Number Sign	⠼			%	⠈⠒⠏
:	⠒	Italic Sign or Decimal Point	⠨	Double Capital Sign	⠠⠠	@	⠈⠁
-	⠤					¢	⠈⠉
,	⠂	$	⠲	°	⠙⠛	&	⠈⠯

Figure 2. Numbers, symbols, and punctuation identification stimulus pairs.

Whole-Word Contractions A Identification									
Subset 1		Subset 2		Subset 3		Subset 4		Subset 5	
us	⠥	was	⠴	still	⠌	by	⠴	this	⠹
more	⠍	just	⠚	in	⠔	be	⠆	were	⠶
like	⠇	from	⠋	child	⠡	but	⠃	go	⠛
to	⠖	so	⠎	enough	⠢	do	⠙	not	⠝
which	⠱	have	⠓	every	⠑	knowledge	⠅	out	⠳
shall	⠩	his	⠦					rather	⠗
Subset 6		Subset 7		Subset 8		Subset 9			
that	⠞	with	⠾	ever	⠐⠑	beneath	⠆⠝		
it	⠭	you	⠽	character	⠐⠡	beyond	⠆⠽		
as	⠵	and	⠯	know	⠐⠅	because	⠆⠉		
very	⠧	quite	⠟	about	⠁⠃	blind	⠃⠇		
will	⠺	of	⠷	according	⠁⠉	beside	⠆⠎		
people	⠏	for	⠿			between	⠆⠞		

Figure 3. Whole-word contraction A identification stimulus pairs.

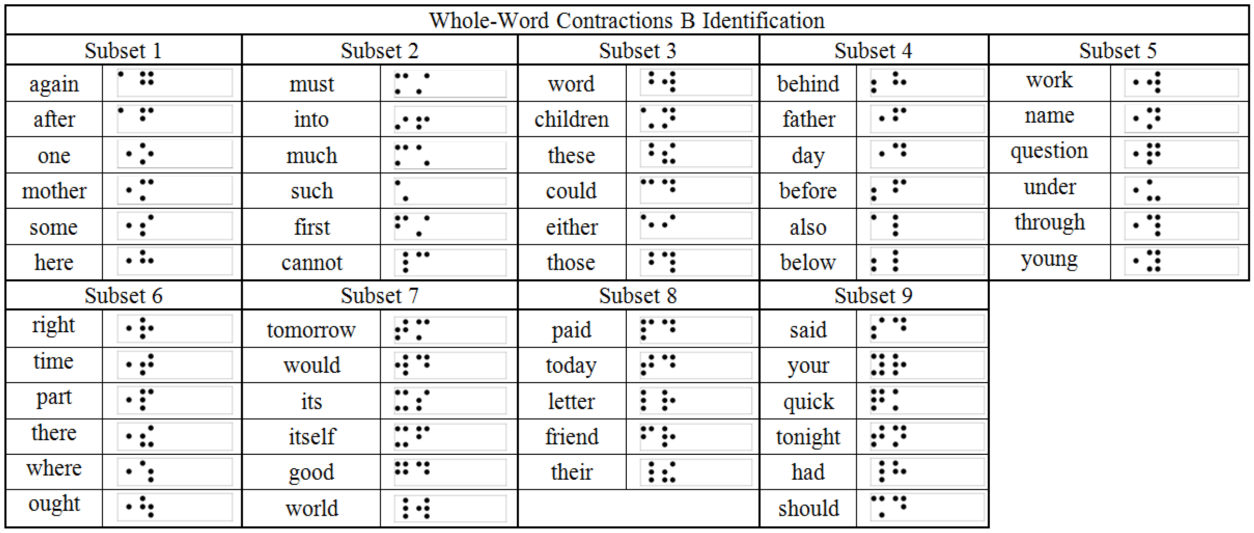
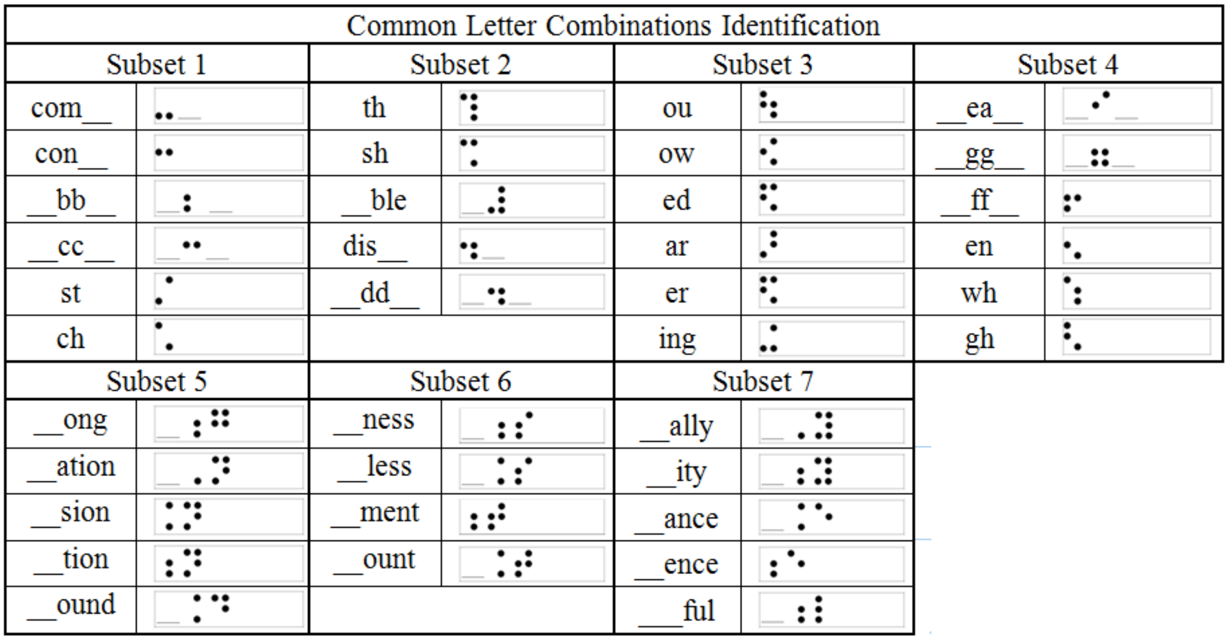


Figure 4. Whole-word contractions B stimulus pairs.

Whole-Word Contractions C Identification							
Subset 1		Subset 2		Subset 3		Subset 4	
whose		although		afternoon		thyself	
him		altogether		together		oneself	
upon		almost		above		myself	
many		always		across		yourself	
spirit		already		afterward		himself	
little				against		herself	
Subset 5		Subset 6		Subset 7		Subset 8	
immediate		receive		perceive		deceiving	
declare		o’clock		themselves		yourselves	
perhaps		great		receiving		ourselves	
braille		rejoice		perceiving		declaring	
neither		deceive		rejoicing		conceiving	
necessary		conceive					

Figure 5. Whole-word contractions C stimulus pairs.



Common Letter Combinations Identification							
Subset 1		Subset 2		Subset 3		Subset 4	
com__		th		ou		__ea__	
con__		sh		ow		__gg__	
__bb__		__ble		ed		__ff__	
__cc__		dis__		ar		en	
st		__dd__		er		wh	
ch				ing		gh	
Subset 5		Subset 6		Subset 7			
__ong		__ness		__ally			
__ation		__less		__ity			
__sion		__ment		__ance			
__tion		__ount		__ence			
__ound				___ful			

Figure 6. Common letter combination identification stimulus pairs.

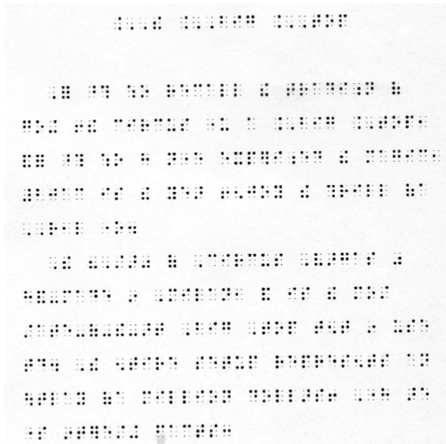
Module	Sally	Sandra	Matthew	Heidi	Mean
1	11 min 57 s	9 min 37 s	7 min 20 s	8 min 52 s	9 min 27 s
2	31 min 11 s	20 min	18 min 23 s	17 min 16 s	21 min 35 s
3	38 min 25 s	30 min 24 s	24 min 52 s	28 min 2 s	30 min 26 s
4	--	31 min 26 s	34 min 12 s	28 min 43 s	31 m in 27 s
5	22 min 30 s	20 min 8 s	23 min 52 s	22 min 57 s	22 min 22 s
6	17 min 15 s	16 min 20 s	23 min 35 s	13 min 3 s	17 min 33 s
Total	1 hr 51 min 18 s	2 hr 7 min 55 s	2 hr 12 min 14 s	1 hr 58 min 53 s	Mean time to complete all training: 2 hr 12 min 33 s

Figure 7. Training time summary by module and participant.

	A	B	C	D	E	F	G	H	I	J	K
2				Baseline Probe							
3	Current Tab	Test Typ	Correct Answer	Respondent Answer	Result	Presentation Count	Response Time - Seconds	Total Questions Correct	Total Questons Answered	Percentage Correct (Over All)	Percent Correct of Last 15 Presentations (Last Group Added Only
4	User Reset										
5	All	Baseline	1	5	Incorrect	1	5.888	0	1	0	0
6	All	Baseline	great	o'clock	Incorrect	1	1.758	0	2	0	0
7	All	Baseline	/	®	Incorrect	1	3.381	0	3	0	0
8	All	Baseline	Double Italic Sign	Termination Sign	Incorrect	1	1.405	0	4	0	0
9	All	Baseline	word	those	Incorrect	1	1.653	0	5	0	0
10	All	Baseline	ourselves	conceiving	Incorrect	1	3.701	0	6	0	0
11	All	Baseline	ever	about	Incorrect	1	1.446	0	7	0	0
12	All	Baseline	__cc__	con__	Incorrect	1	1.437	0	8	0	0
13	All	Baseline	little	spirit	Incorrect	1	1.509	0	9	0	0
14	All	Baseline	__ation	__ong	Incorrect	1	1.373	0	10	0	0
15	All	Baseline	k	u	Incorrect	1	1.854	0	11	0	0
16	All	Baseline	himself	oneself	Incorrect	1	1.237	0	12	0	0
17	All	Baseline	through	question	Incorrect	1	1.166	0	13	0	0
18	All	Baseline	father	behind	Incorrect	1	1.516	0	14	0	0
19	All	Baseline	st	st	Correct	1	2.046	1	15	6.666666667	6.666666667
20	All	Baseline	n	s	Incorrect	1	1.477	1	16	6.25	6.666666667
21	All	Baseline	like	like	Correct	1	1.204	2	17	11.76470588	13.33333333
22	All	Baseline	altogether	almost	Incorrect	1	2.757	2	18	11.11111111	13.33333333
23	All	Baseline	would	would	Correct	1	3.381	3	19	15.78947368	20
24	All	Baseline	7	4	Incorrect	1	1.373	3	20	15	20
25	All	Baseline	ing	ow	Incorrect	1	1.653	3	21	14.28571429	20
26	All	Baseline	Number Sign	Number Sign	Correct	1	1.798	4	22	18.18181818	26.66666667
27	All	Baseline	have	just	Incorrect	1	1.406	4	23	17.39130435	26.66666667
28	All	Baseline	which	shall	Incorrect	1	1.358	4	24	16.66666667	26.66666667
29	All	Baseline	q	g	Incorrect	1	1.11	4	25	16	26.66666667
30	All	Baseline	had	quick	Incorrect	1	3.645	4	26	15.38461538	26.66666667
31	All	Baseline	out	go	Incorrect	1	2.789	4	27	14.81481481	26.66666667
32	All	Baseline	w	p	Incorrect	1	1.246	4	28	14.28571429	26.66666667
33	All	Baseline	s	t	Incorrect	1	3.334	4	29	13.79310345	26.66666667
34	All	Baseline	__ment	__ness	Incorrect	1	1.558	4	30	13.33333333	20
35	User Reset										

Baseline Probe

Figure 8. Sample data file produced by Visual Braille Trainer during the baseline pre-training probe for one participant.



THE BIG TOP

For those who recall the tradition of going to the circus under a *Big Top*, and for those who have never experienced the magic, 2013 is the year to enjoy the thrill of a REAL one.

The “Star” of Circus Vargas was hand-made in Milan, and is the most state-of-the-art Big Top tent in use today. The entire setup represents an outlay of a million dollars! Here are some interesting facts:

Figure 9. Sample braille passage (left) and English text transcription (right).

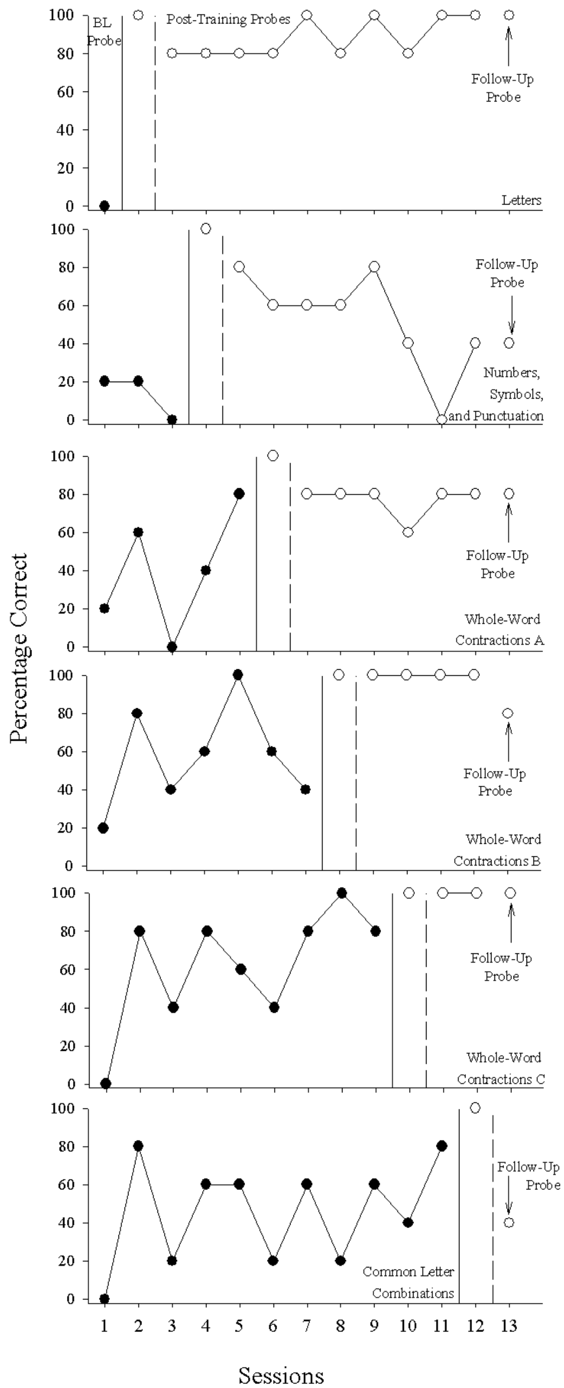


Figure 10. Results from Sally's stimulus identification probes for letters; numbers, symbols, and punctuation; whole-word contractions A; whole-words contractions B; whole-word contractions C; and common letter combinations modules.

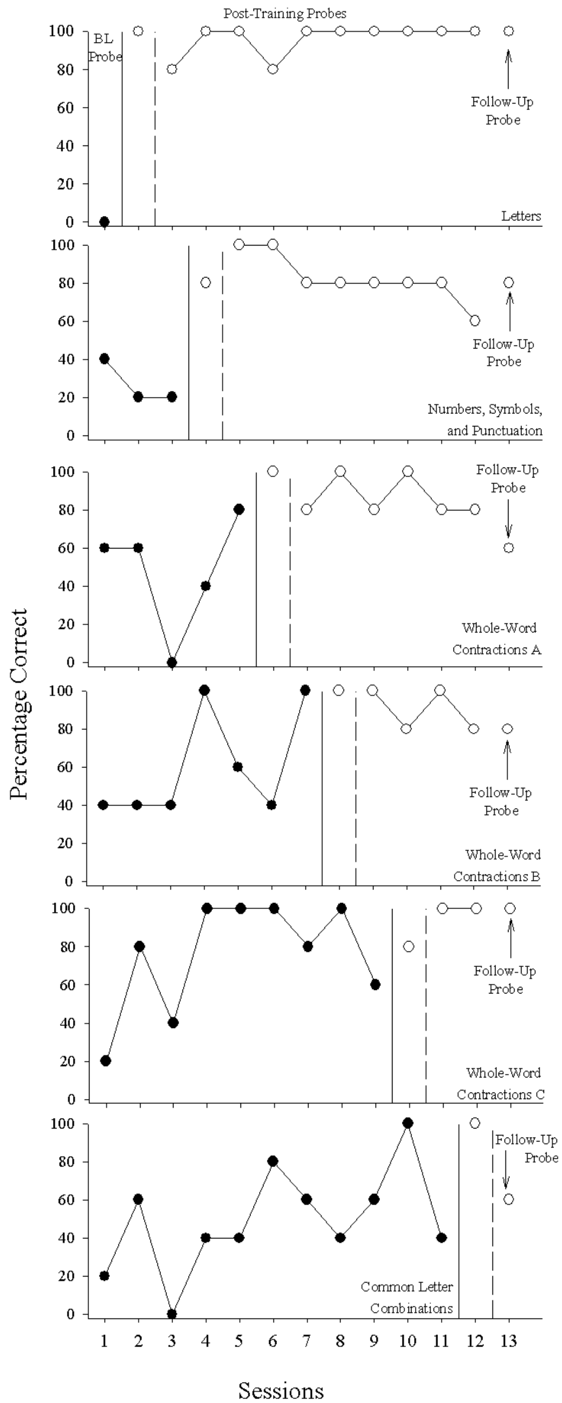


Figure 11. Results from Sandra's stimulus identification probes for letters; numbers, symbols, and punctuation; whole-word contractions A; whole-words contractions B; whole-word contractions C; and common letter combinations modules.

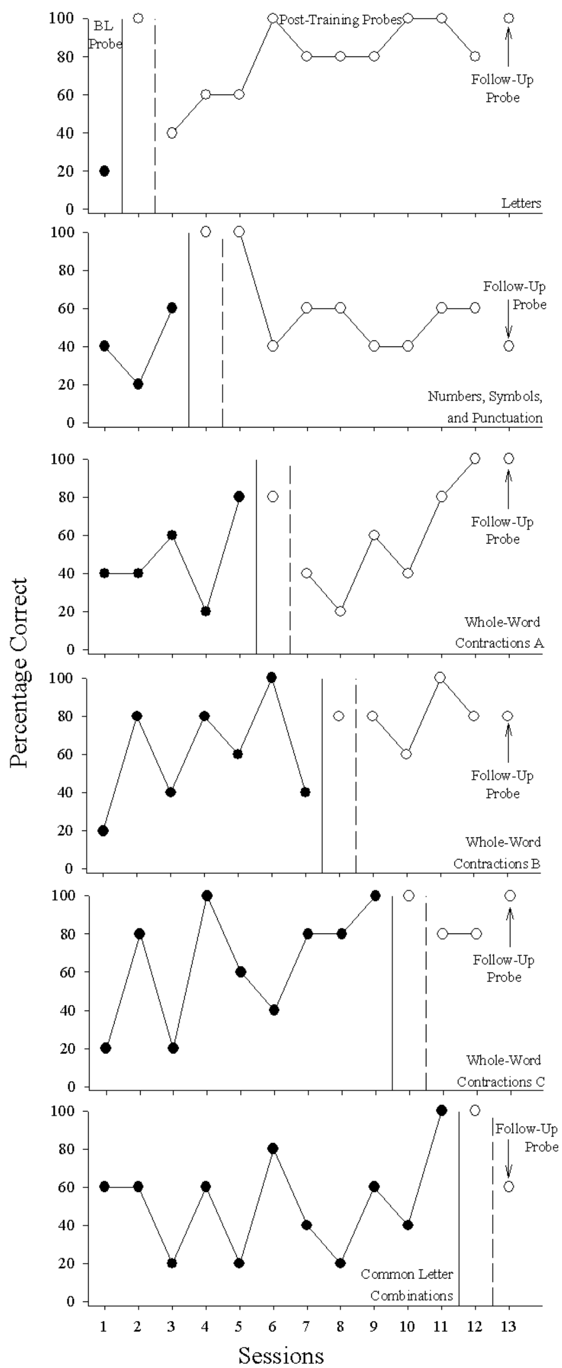


Figure 12. Results from Matthew's stimulus identification probes for letters; numbers, symbols, and punctuation; whole-word contractions A; whole-words contractions B; whole-word contractions C; and common letter combinations modules.

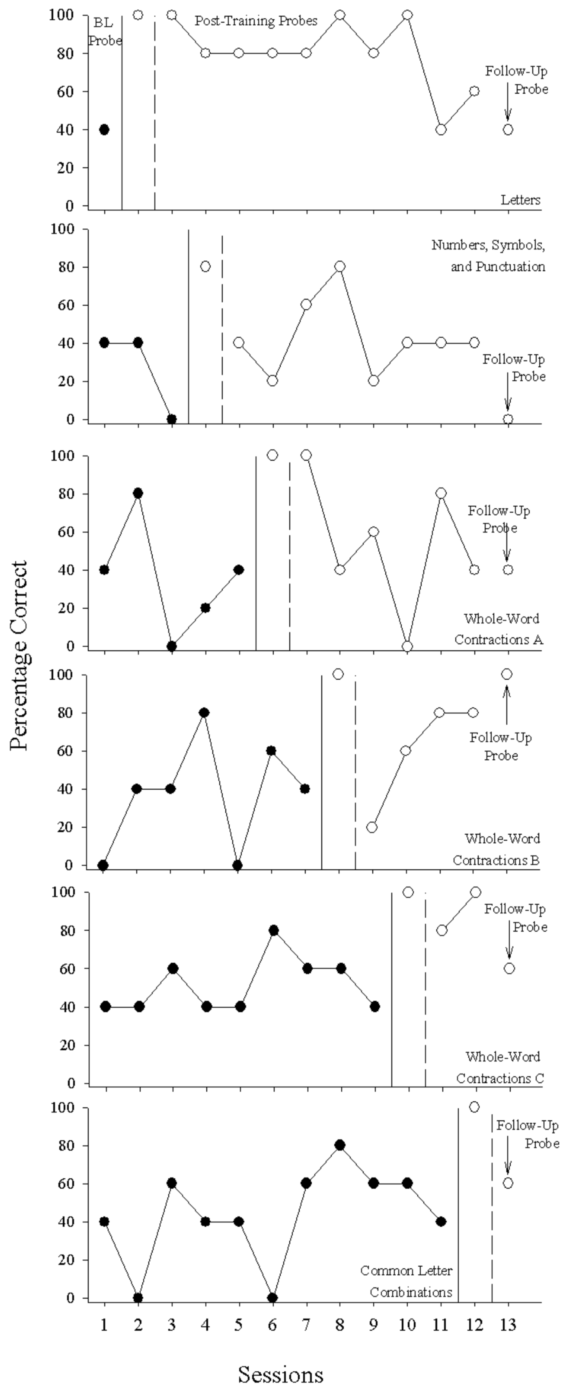


Figure 13. Results from Heidi's stimulus identification probes for letters; numbers, symbols, and punctuation; whole-word contractions A; whole-words contractions B; whole-word contractions C; and common letter combinations modules.

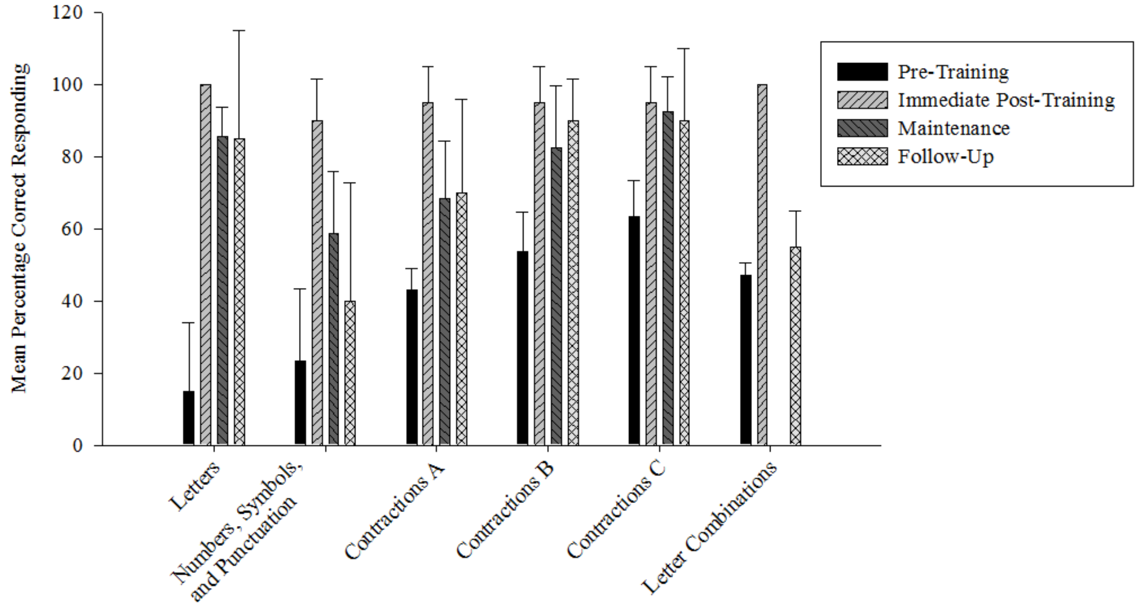


Figure 14. Mean percentage correct responding for each module, averaged across participants; error bars represent standard deviation. Participants responded correctly at high rates immediately following training on each module, but these training effects did not maintain at high levels during maintenance and follow-up probes. (Note: No post-training maintenance probes were conducted for the letters combination module because this was the last training module participants completed.)

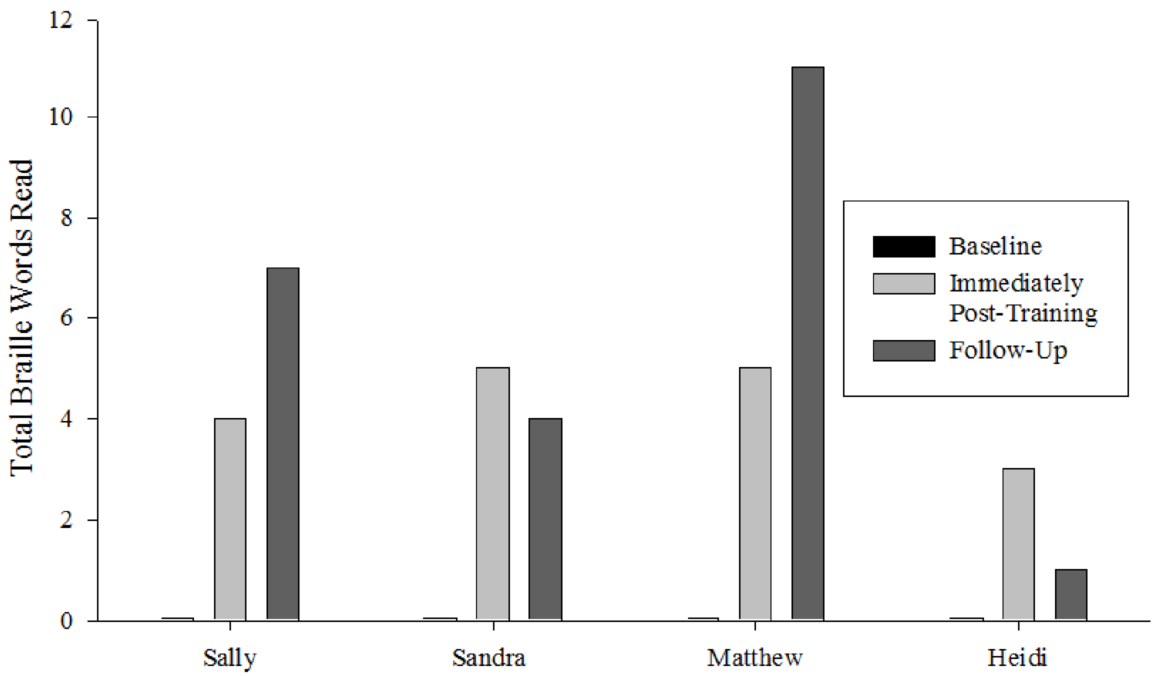


Figure 15. Baseline, immediately post-training, and follow-up braille reading probes for all four participants. No participants were able to identify any braille characters during the baseline probe; all participants were able to identify at least one character during post-training probes.

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