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Teaching Sighted Students to Read Braille Visually

Brittany C. Putnam
University of Wisconsin-Milwaukee

TEACHING SIGHTED STUDENTS TO READ BRAILLE VISUALLY

by

Brittany C. Putnam

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ABSTRACT
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Brittany C. Putnam

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For many visually impaired children in public schools, braille instruction is not an educational priority included in the Individualized Education Program (IEP). This issue is likely the result of a lack of accessible and effective braille training for regular and special education teachers. Prior studies have assessed the efficacy of computer software to teach sighted individuals braille-to-print relations. Although the results from these studies are promising, there are several limitations that should be addressed. The purpose of this study was to extend previous research by developing and testing a computer-based program to teach visual contracted braille to sighted individuals. We assessed the effects of this training program on promoting generalization to braille-to-print and print-to-braille construction responses, braille reading, and braille-to-print transcription.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Introduction

Teaching Sighted Students to Read Braille Visually

The cornerstone of the 2004 Individuals with Disabilities Education Act (IDEA) is the requirement that all children between the ages of 3 and 21, regardless of disability, be provided a free and appropriate public education (IDEA, 2004). Visual impairment, including blindness and partial blindness, that interferes with a child's education qualifies that child for special education and related services under the IDEA (2004). In a June 2013 "Dear Colleague" letter, the United States Department of Education's Office of Special Education and Rehabilitative Services reiterated the requirement that school districts provide braille instruction when it is determined that a particular student will benefit from such instruction, and Individualized Education Program (IEP) teams must conduct comprehensive tests prior to determining that a student will not benefit from braille instruction (Musgrove & Yudin, 2013). Despite the mandate for braille instruction, few children with visual impairments are actually being taught braille, with as few as 8.5% of visually impaired students using braille as their primary reading medium (United States Department of Education, Office of Special Education and Rehabilitative Services, 2013; American Printing House for the Blind, 2014).

One reason for limited braille literacy among visually impaired individuals is a lack of braille competency among regular and special education teachers; put simply, most schools do not have a teacher who is trained to provide braille instruction. In fact, only 152 individuals in the United States hold the National Certification in Literary Braille (NCLB), conferred by the National Blindness Professional Certification Board (NBPCB, n.d.) whereas there are 98,817 US public schools (National Center for Education Statistics, n.d.). Although schools that specifically serve children with visual impairments do exist, a minority of children with visual impairment attend these schools (American Printing House for the Blind, 2014); rather, the majority of children attend their home school districts. As a result, schools either omit braille instruction for their visually impaired students or place the responsibility for braille instruction on an overburdened or underqualified teacher (National Federation of the Blind, 2013). Although the long-term goal would be to ensure a qualified teacher is available at each school, a more immediate goal may be to equip local teachers with some of the skills necessary to teach braille reading to visually impaired children.

The most rudimentary skill for teachers would be to read braille themselves. Unlike their visually impaired students who read braille tactually, sighted teachers read braille visually so that they can provide appropriate prompting and feedback to their students. Braille is not considered a separate language from printed English, but rather a code in which English text can be transcribed. However, the code does not share a perfect point-to-point relation with printed English. Although each individual letter can be transcribed using braille, the code also utilizes a large number of contractions in which one or a few characters can substitute for whole words or for elements within words. In addition to the 26 letters of the English alphabet, contracted braille includes over 250 additional stimuli to account for these contractions and punctuation symbols. We can analyze the skill of reading braille and translating to printed English as a verbal operant according to Skinner’s analysis of verbal behavior.

Skinner (1957) described five basic verbal operants: Mand, tact, intraverbal, echoic, and textual. Two of these verbal operants, intraverbals and textuals, are immediately relevant to the discussion of the behaviors in which a braille instructor would need to engage. An intraverbal is a verbal operant in which a verbal discriminative stimulus evokes a response, but the response has no point-to-point correspondence with the verbal stimulus (p.71). Skinner also indicated that formal similarity is not a requirement here, so it is possible to discuss vocal and written stimuli as well as vocal and written responses within this context. An example of an intraverbal as it relates to braille instruction would be seeing the braille contraction for the word *the* (⠮) and writing the printed English word *the*. In this case, the braille stimulus is the verbal stimulus that evokes the printed English response. Because the braille stimulus has no point-to-point correspondence with the printed English response, engaging in this verbal behavior would be considered an intraverbal. The reverse of this relation (i.e., seeing a printed English stimulus and producing the braille stimulus) can be categorized in the same way. Thus, the presentation of a printed braille stimulus should occasion the production of a printed English response, and the presentation of a printed English stimulus should occasion the production of a printed braille response.

Braille instructors must be able to engage in textual responding. A textual response is a verbal operant that is evoked by a non-auditory verbal discriminative stimulus with which the response has no formal similarity (Skinner, 1957; pp. 65-69). An example of textual behavior would be reading aloud in the presence of printed text. However, Michael (1982) argued that this term can be problematic because it seems to exclude some forms of verbal behavior, specifically verbal behavior related to stimuli that stand for other stimuli (e.g., Morse Code). He instead proposed a new verbal operant to take the place of textual behavior, which he called codic behavior. Michael defined codic as a verbal operant controlled by a verbal stimulus "with which it has point-to-point correspondence, but where there is NO *formal similarity* between stimulus and response product" (Michael, 1982, p. 3). For example, if the stimulus is printed, then the response is spoken (i.e., textual behavior) and if the stimulus is spoken, then the response is written (i.e., taking dictation). The major difference between Skinner's definition of textual and Michael's definition of codic is that Skinner specifically states that the stimulus is non-auditory verbal behavior, whereas Michael does not specify the form of the verbal operant. As a result, the definition is more inclusive and provides a common description for behavior that has point-to-point correspondence but no formal similarity with the stimulus that controls it. Another way in which this new verbal operant is more inclusive is that it account for stimuli and responses that are codes (i.e., stand for something else). This change in terminology is useful in discussions of oral braille reading because it accounts for the "codic" nature of the braille code.

Intraverbal and codic behavior with regards to braille stimuli and responses are complex behaviors that require the reader to first master a large number of braille-to-print relations. Breaking complex behaviors down into their component parts and teaching those parts to mastery sequentially is an empirically supported method for developing successful instructional programming (Saunders, 2011). In teaching visual braille reading, this entails teaching the visual discriminations among different braille stimuli. Another important aspect of teaching complex repertoires is programming a gradual progression through the subject matter (Holland, 1960). This can be done with visual braille instruction by systematically creating learning sets in such a way that the learner will master the simplest relations first (i.e., letter discrimination), more complex relations next (i.e., contractions that have no point-to-point correspondence with printed English words or letter combinations), and the most complex task last (i.e., reading full sentences written in braille). Further, research indicates that it is possible to design discrimination training in a way that promotes better discrimination among stimuli. Several studies have manipulated the visual similarity of letters and letter-like stimuli when creating training materials and assessed the effects of this manipulation on posttest letter discrimination (e.g., Nelson & Wein, 1974; Tawney, 1972). These authors created arrays for matching-to-sample tasks that contained stimuli that were either visually similar to or different from the sample stimulus. The results of both studies show that children performed better on posttest letter discrimination when training required discrimination among stimuli that were more visually similar than stimuli that were not visually similar.

When the probability of a particular behavior occurring is increased in the presence of a particular antecedent stimulus, that stimulus is said to have stimulus control over the behavior (Miltenberger, 2012). In the example of braille character identification, the behavior of selecting the letter "a" comes under control of the braille stimulus "⠁". According to some researchers, simply being able to engage in discriminated responding does not indicate mastery of stimuli. Binder (1996) says that true mastery occurs, "When a combination of accuracy plus speed of performance optimizes these outcomes with respect to a specific behavior class" (p. 165). Many people, including Binder, call this combination of accuracy and speed behavioral fluency. Bucklin, Dickinson, and Brethower (2000) compared fluency training with training for accuracy only and assessed the effects of performance on a stimulus equivalence task. These authors found that participants who trained to fluency responded correctly at higher rates both immediately after training and during follow-up tests than did participants who trained to accuracy. It is possible to conceptualize fluency as a measure of stimulus control, in that better stimulus control may result in quicker, more accurate responding (i.e., short response latency, high percentage correct); thus, these results indicate that implementing training procedures that require fluent responding may improve both stimulus control and maintenance.

A number of recent studies have begun to develop and evaluate programs to teach braille-to-print stimulus relations systematically. Scheithauer and Tiger (2012) developed a computer-based program to teach the relations between the 26 letters of the English alphabet and their braille counterparts to four undergraduate students. The experimenters segmented the alphabet into five learning sets of five or six letters and taught each letter set to mastery sequentially. This involved presenting a braille character visually along with a multiple-choice comparison array. Participants responded by selecting a comparison and receiving feedback on whether or not their responses were correct. Following a mean training of 38 min, participants completed a post-training test and correctly identified each letter of the braille alphabet. Scheithauer, Tiger, and Miller (2013) conducted a follow-up study with 81 undergraduate students and found similar results.

Putnam and Tiger (in press) extended this research by developing and evaluating a program that taught not only braille letters, but also numbers, punctuation, symbols, composition signs, and contractions for common words and letter combinations. In this study, braille stimuli were presented as samples, and the participants were taught to select printed-English counterparts from a multiple-choice array. Similar to previous studies, the experimenters divided braille stimuli into small training sets and taught each set to mastery prior to initiating the next training set. In order for participants to master one training set and move on to the next, the participant was required to respond correctly on 90% of the previous 15 trials. The experimenters arranged these training sets according to visual similarity to facilitate post-training discrimination among stimuli (Nelson & Wein, 1974; Tawney, 1972). Engaging in a selection response forced participants to behave with regards to the training stimuli, and participants received immediate feedback for both correct responding and incorrect responding. All participants met mastery criteria on each of the six training modules.

The skill of selecting a printed-text stimulus given a braille sample was targeted due to its simplicity of programming and for participant interaction with the computer program. However, this particular skill bears minimal similarity to any of the skills needed by a braille instructor. Instructors will need to see braille and transcribe it to print, to transcribe print to braille, and to read braille visually. Computer-based training using the matching-to-sample arrangement is valuable only to the extent that it produces generalized repertoires among the learners; however, only some of these repertoires have been systematically examined in prior research and the outcomes have not proven socially significant at this point. For instance, in Putnam and Tiger (in press) the experimenters assessed the extent to which completing this training resulted in braille reading by having participants attempt to read a passage transcribed in braille. Reading increased after training, but the rates were substantially below what one would consider fluent. The generation of transcription skills has not been assessed at all at this point.

The purpose of the current study was to extend the Putnam and Tiger (in press) study in several ways. First, we specifically assessed the untrained emergence of braille-to-print character transcription, braille-to-print sentence transcription, print-to-braille transcription, and braille reading following exposure to the match-to-sample training. Second, we made a number of modifications to the teaching program of Putnam and Tiger to enhance the likelihood of this generalization occurring. First, we included more stringent mastery criteria during the training program to ensure the strength of trained relations. Specifically, participants were required to respond accurately and with a short response latency (i.e., 3 s) in order to meet mastery criteria. Second, we developed additional training modules a) to provide incremental rehearsal of previously mastered material and b) to provide direct training on the combination of braille stimuli into words and other meaningful units.

Method

Participants and Setting

The participants in this study were five sighted undergraduate students. Andy was a 19 year old Caucasian male, Sophie was a 21 year old Caucasian female, Callie was a 20 year old Caucasian female, Julie was a 21 year old Caucasian female, and Lexie was a 21 year old African American female. Lexie withdrew from the study voluntarily after appointment 2 due to reasons unrelated to this study; data from appointments 1 and 2 are reported below. The remaining four participants completed the study in its entirety, attending all 11 appointments. We selected undergraduates as participants because they are demographically similar to the teachers who would use this software to learn braille. Our inclusion criteria were that participants be fluent English readers (could read at a high school reading level) and be unable to read braille at the onset of our study (we assessed these skills as part of our pretesting procedures during the initial appointment). All participants met the inclusionary criteria (data presented below).

We recruited participants using the University's online study-participation portal. Participants scheduled their first appointment via the online portal and scheduled all subsequent appointments with the first author. Participants attended two to six appointments per week until they completed all 11 scheduled appointments. We divided the training across several days to mitigate the effects of fatigue that may have resulted if participants learned all 378 braille-to-print relations at one time. Due to scheduling constraints, one participant attended up to two appointments in one day.

We compensated participants in the form of gift cards and extra credit (if they were enrolled in a Psychology course that offered extra credit). Compensation consisted of $10 per appointment attended and a $25 bonus for attending all scheduled appointments, for a total of $135 per participant. We provided gift cards at the end of each training appointment; participants received two gift cards during their final appointment. Appointments ranged from 1 hr to 1.5 hr. Three of the four participants who completed the study received extra credit for participation. Julie, Andy, and Callie earned 12.5, 13.5, and 12 hr of extra credit, respectively. Lexie earned 2 hr of extra credit and two $10 gift cards for the appointments she attended.

We conducted this study in an otherwise unoccupied office furnished with a desktop computer, a desk, and a chair. The computer was equipped with the Microsoft Windows 7 operating system and the Visual Braille Trainer 2.0 (VBT).

Assessments and Measurements

Print oral reading fluency. When participants arrived for their initial appointment, we briefed them and obtained written consent prior to administering several pretests. Pretests included the WIAT (Wechsler Individual Achievement Test) oral reading fluency (ORF) subtest, two braille reading probes, and two baseline braille construction probes (See Table 1 for a list of assessments and when they were administered). The purpose of the WIAT ORF, which consisted of one passage written at a grades 7-8 reading level and one passage written at a grades 9-12 reading level, was to ensure that participants could read fluently at a high school reading level. Reading fluency is an important prerequisite skill for this training program because participants were required to read both printed English items and braille passages. We scored this subtest using the Pearson Inc. scoring software. We selected this subtest because it is a normed assessment that provided information about participants' reading fluency. We selected a high school reading level as a cutoff for our participants because we determined through several online readability analyses that the braille passage participants were expected to read at the end of the training was written at a high school reading level. Any participants who were unable to meet our criterion would have been excluded from the study; this did not occur. This assessment was administered only during the first appointment, prior to the initiation of the training program.

To score participant responding during the print-reading probes, the primary observer followed on a separate scoring version of the passage, recording addition errors and other errors (defined in the WIAT administration materials) while participants read the passages. When the participant began reading, the experimenter started a stopwatch and then stopped the stopwatch when the participant read the last word; she recorded the time on a data sheet. We video-recorded 90% of WIAT Oral Reading Fluency (ORF) administrations for reliability scoring. A second, independent observer scored from these videos to determine interobserver agreement (IOA). We calculated IOA by dividing the number of agreements (words both observers scored as read correctly or incorrectly) by the number of agreements plus disagreements and multiplying by 100; IOA for the WIAT ORF across all five participants was 99.8% (range: 99.4-100%).

Braille oral reading fluency. Next we administered an oral braille-reading test in which participants received a passage written entirely in braille (see Appendix B); they had 5 min to read as much of the passage as they could, or they could tell the experimenter they could not read any part of the passage. Any participants who were able to read any part of the passage would have been disqualified from this study; however, this never occurred. We administered this test again during the final appointment, after participants had mastered all training modules, to assess the effects of the VBT on braille reading. This task allowed us to assess the extent to which the VBT resulted in reading of directly trained relations as well as generalization to untrained combinations of braille stimuli.

For this probe, the experimenter created a scoring guide (see Appendix A for an example) on which each component of the passage was broken down into scorable units. For example, if the braille characters for *THE* (⠨⠠⠠⠮) were presented, the participant should say a) “single italics”, b) “double capital”, and c) “the”. In this example, the participant would need to say the components in the order they are presented here due to the order of the braille characters. The primary observer followed along on the scoring guide and wrote the participants’ utterances in the right-hand column. If the participant read a word incorrectly, that incorrect word was recorded on the scoring sheet; likewise, if the participant read a word correctly, that correct word was recorded. If the participant said "skip," the observer also wrote the word "skip." Correct items were scored with a (+) and incorrect items were scored with a (-); skipped items were considered incorrect responses. Participants had 5 min to read as many braille words as possible; when the timer beeped, participants stopped reading. The experimenter informed participants that if they could not read the passage that they should indicate this by saying, "I cannot read any part of this passage." With participants' consent, we video recorded the braille oral-reading probes conducted during the first and the final appointments. A second observer independently scored this probe from the video-recording. During the pre-training probe, all five participants indicated they could not read the passage (IOA = 100%). During post-training probes all participants were able to read some of the passage; IOA was 100% on all four participants' post-training probes.

Braille transcription. The second braille reading test, (which we will call the braille-transcription probe) consisted of 15 sentences written in braille (see Appendix C). We allowed participants as much time as they need to transcribe each of the 15 sentences from braille into English print; all participants indicated they could not read any of the sentences during the first appointment. If participants had been able to read any part of the braille passage or transcribe any of the sentences they would have been excluded from the study. As with the oral braille-reading test, we re-administered the braille-transcription probe during the final appointment. This probe allowed us to assess the extent to which character identification generalized to braille reading following training with the VBT.

During the first appointment, the experimenter video-recorded participant responding for all five participants. A second observer reviewed these videos; both observers agreed that none of the participants were able to transcribe the braille sentences (IOA = 100%). Participants' written responses on the final transcription probe served as a permanent product from which the research team calculated accuracy and IOA. The experimenter created a scoring sheet for this task similar to the one described above (oral braille-reading probe). Each item was scored as either correct (+) or incorrect (-); skipped items were scored as incorrect. The experimenter then calculated percentage correct for the entire worksheet by dividing the total number of items participants transcribed correctly by the total number of items on the worksheet. A second observer scored 75% of the transcription probes. We calculated IOA by dividing the smaller number of items transcribed correctly by the larger number of items transcribed correctly and multiplying by 100%. IOA for Andy, Sophie, and Callie's transcription probes was 97.5%, 99.8%, and 99.6%, respectively.

Braille-to-print construction probe. The next pretest was a baseline probe of the braille-to-print relations that would be targeted during braille training. This probe was a paper-and-pencil construction probe, or a probe in which the participant received no prompts beyond the sample stimulus (braille character) (see Appendix D). Participants saw the braille characters in the left column of the worksheet and produced the printed English equivalent in the blank provided in the right column. This probe consisted of 50 braille-to-print relations, five stimuli drawn randomly from each of the 10 training modules. Participants completed a braille-to-print construction probe twice during each appointment, once before braille training and once after braille training.

There were 10 unique versions of this probe; we randomly selected the probes participants received pre- and post-training. The purpose of this probe was to assess the extent to which relations learned using the computer-based matching-to-sample training program would generalize to a paper-and-pencil construction response.

The experimenter scored each of these probes and determined the overall percentage correct as well as the percentage of items correct from each of the 10 modules. A second, independent, observer scored the permanent products of these probes. Any discrepancies in scoring were verified by the first author and verified errors were corrected. On the braille-to-print construction probes this occurred on 0.1% (1 out of 1050 trials), 0.0%, 0.2% (2 out of 1050 trials), 0.1% (1 out of 1050 trials), and 0.5% (1 out of 200 trials) of trials for each participant.

Print-to-braille construction probe. The final pretest was a baseline probe that assessed whether participants could produce braille stimuli. Participants learned braille-to-print relations using the VBT; this probe tested whether they could produce braille characters given no additional prompts beyond the English print. Participants received a worksheet that contained printed English in the left column and light-colored braille grids in the right column (see Appendix E). There were a total of 20 stimuli on each worksheet, two from each of the 10 modules. We instructed participants to darken the braille grids so they matched the braille equivalent of the English print provided. As with the braille-to-print probe, participants completed the print-to-braille probe twice during each appointment (once before braille training and once after braille training). There were 10 unique versions of this probe, and the print-to-braille probe was administered in the same manner as the braille-to-print probe was administered. The purpose of this probe was to assess the extent to which participants were able to produce braille with no direct training in this skill. Teachers who would be using this training software would be expected to not only read braille, but also write braille. If individuals are able to produce braille following computer-based braille-to-print instruction, it may be possible for teachers to use the VBT to learn both reading and writing skills.

The first author scored each print-to-braille probe and determined the overall percentage correct on probes from all 10 modules. A second observer re-scored each probe. The first author assessed any discrepancies in scoring and fixed verified errors in the data. On the print-to-braille construction probes this occurred on 1.0% (4 out of 420 trials), 0.5% (2 out of 420 trials), 0.0%, 0.2% (1 out of 420 trials), and 0.0% of trials for each participant.

When participants completed all pretests (i.e., WIAT ORF, oral braille reading, braille-to-print transcription, braille-to-print construction probe, and print-to-braille construction probe) they began braille training.

Computer-Based Training Procedures

Participants completed their braille training using the computer-based VBT 2.0; during each appointment the program presented a new training module. Each module was broken up into smaller subsets of four to six stimuli. When participants began braille training, the program presented a sample braille stimulus and an array of response options from the same subset as the sample stimulus (i.e., if the sample stimulus was a letter from the first subset of Module 1, the array contained only letters from the first subset of Module 1) . To select a stimulus the participant clicked the radio button adjacent to that stimulus. If the participant selected the correct response, a dialogue box appeared indicating that the response was correct. If the participant selected an incorrect response, a different dialogue box appeared indicating that the response was incorrect; this dialogue box also provided the correct response. When an incorrect response was selected, the program re-presented the same stimulus until the participant responded correctly. In addition, if the participant selected the correct response after a latency greater than 3 s, the program re-presented the same stimulus until the participant responded correctly. These error correction trials did not count toward the participant's percentage correct.

The program presented each braille stimulus within a subset on at least three trials, until the participant met the mastery criterion of 90% correct responding (correct responding required that the correct response be selected within 3 s of the onset of the trial) on the last 15 trials. Once a participant mastered one subset, the program began presenting the next subset. Subsequent subsets were presented in the same manner as the first subset, except that the program also included one presentation of each stimulus from previously mastered subsets within a module. Response arrays for these rehearsal trials consisted of stimuli from the same subset as the sample stimulus. This allowed for incremental rehearsal of previously mastered relations. We created subsets based on visual similarity among characters and the number of braille characters in each word in order to facilitate discrimination (Nelson & Wein, 1974; Tawney, 1972). The combination modules (Modules 2, 5, 8, and 10) provided participants with exposure to these stimuli being combined into meaningful units and provided additional rehearsal of previously mastered relations. We selected stimuli for the combination modules from several braille-training sources, including the terminal braille oral reading fluency assessment.

Letter training (Module 1) consisted of the relations between the 26 letters of the printed English alphabet and their braille counterparts. These 26 stimuli were divided into five subsets consisting of five or six stimuli (see Appendix F).

The *combination of letters into words* module (Module 2) consisted of 30 braille words written without contractions. The braille characters that made up these words have point-to-point correspondence with the printed English letters of which they are composed. These 30 stimuli were divided into six subsets consisting of five stimuli each (see Appendix G). Each of the 26 previously trained letter relations were represented in this module.

The *Contractions 1* module (Module 3) consisted of 37 braille contractions of common letter combinations. These 37 contractions were divided into seven subsets of four to six stimuli (see Appendix H).

The *Contractions 2* module (Module 4) consisted of 54 braille contractions for common words. These 54 contractions were divided into nine subsets of six stimuli (see Appendix I).

Combination of letters and contractions into words (Module 5) consisted of 30 braille words with contractions. The braille characters that made up the words have point-to-point correspondence with letters from Module 1, letter combination contractions from Module 3, and/or word contractions from Module 4. These 30 stimuli were divided into six subsets of five stimuli (see Appendix J).

The *Contractions 3* module (Module 6) consisted of 53 braille contractions for common words. We divided these 53 contractions into nine subsets of five or six stimuli (see Appendix K).

The *Numbers, punctuation, symbols, and composition signs* module (Module 7) consisted of 42 numbers, punctuation, symbols, and composition signs. We divided these 42 stimuli into eight subsets of five or six stimuli (see Appendix L).

The next module, *combination of letters, contractions, numbers, punctuation, symbols, and composition signs (*Module 8), consisted of 30 combinations of words, numbers, punctuation, symbols, and composition signs. These 30 stimuli were divided into six subsets of five stimuli (see Appendix M).

Contractions 4 (Module 9) consisted of 46 contractions for common words. We divided these 46 stimuli into eight subsets of five or six stimuli (see Appendix N).

The *combination of previously learned characters into short sentences and phrases* module (Module 10) consisted of 30 short sentences and phrases. These 30 stimuli were divided into six subsets of five stimuli (see Appendix O).

Results

Pre-Tests

The first pre-test we conducted was the WIAT ORF subtest. Using the computerized scoring program that accompanies the WIAT, we determined that Andy, Sophie, Julie, and Lexie's grade equivalent reading levels were greater than 12.9 (i.e., the end of high school). Callie's grade equivalent reading level was 10.7. Next we administered the oral braille reading probe (see Figure 11) and the braille transcription probe (see Figure 12). All participants indicated they could neither read the braille passage nor transcribe the braille sentences into printed English. Finally, we administered the pre-training braille-to-print and print-to-braille construction probes. All participants indicated they could neither read nor produce braille on these worksheets.

The first data point on each panel of the participants' braille-to-print graphs and print-to-braille graphs indicate that no correct responding occurred on the initial pre-training probe (see below for detailed descriptions of each participant's data).

Braille Training

All participants met mastery criteria for the modules on which they initiated training. Julie, Sophie, Andy, and Callie completed all ten training modules, demonstrating mastery performance of a total of 378 braille-to-print relations within a matching to sample format. Lexie completed Modules 1 and 2, mastering total of 56 braille-to-print relations (her data were not included when calculating the time or trials to mastery means). On average, participants mastered all 10 training modules in 4 hr 45 min 33 s (range: 4 hr 24 min 39 s to 5 hr 3 min 46 s; see Table 2 for individual participants' training times on each training module). Table 3 shows the number of trials to mastery for each participant during each module. On average, participants mastered the 378 braille-to-print relations after responding on 4,737 trials (range: 3,729 to 5,235 trials; see Table 3 for trials to mastery for individual participants and modules). Andy completed training on the VBT across 29 calendar days (there was a 1 week gap between appointments five and six due to spring break), Julie, Sophie, and Callie completed training across14, 16, and 22 calendar days, respectively. Lexie completed only the first two training modules before withdrawing from the study.

Braille-to-Print Construction Probes

Figures 1 through 5 show individual subjects' performance on the braille-to-print construction probes that we administered before and after each training module. Rather than recount each data path, we will instead summarize the patterns across modules.

These summary data are presented in in Figure 6. All participants responded at zero levels prior to training in Module 1 and engaged in high levels of correct responding post training (*M* = 86%, range: 75-96%). This training also resulted in some increases in Module 2 performance for each of the 5 participants. Following Module 2 training, all participants responded at near 100% levels (*M* = 95.6%, range: 88.9-100%). No participant identified any of the contractions targeted in Module 3 during baseline; post-training performance was more variable both within and across participants (*M* = 38.6%, range: 17.4-47.1%). Julie and Sophie correctly produced print given braille contractions on about 40% of trials; however, responding was lower for Andy and at near zero levels for Callie. The results for Module 4 were similar, although correct responding was somewhat higher for all participants (*M* = 38.6%, range: 17.0-57.1%). There was some evidence of generative responding in the pre-training phase for Module 5 (*M* = 10%, range: 0-20%) and all four participants improved notably after completing Module 5 training (*M* = 65%, range: 40-85%). Pre-training probes of Module 6 stimuli resulted in very little correct responding (*M* = 2.3%, range: 0-5.5%); correct responding improved on post-training probes across participants (*M* = 30%, range: 16-48%), but was variable both within and across participants. Participants did not identify any of the Module 7 stimuli during pre-training probes. Responding on post-training probes was variable within and across participants, but elevated when compared with baseline responding (*M* = 43%, range: 22.5-67%). We saw similar responding on pre- (*M* = 3.7%, range: 2.7-5.3%) and post-training (*M* = 45.9%, range: 26.7-66.7%) probes of stimuli from Module 8. Participants correctly identified Module 9 stimuli on 3.3% (range: 0-5.9%) of pre-training trials; correct responding increased to 63.8% (range: 40-80%) across participants. We saw some evidence of generative responding during pre-training probes of Module 10 stimuli (*M* = 14%, range: 4.2-24.2%). Post-training, Andy and Callie engaged in low levels of correct responding and Julie and Sophie engaged in high levels of correct responding. The post-training mean across participants was 55% (range: 30-80%) correct.

Print-to-Braille Construction Probes

Individual participant responding for pre- and post-training print-to-braille construction probes are presented in Figures 7, 8, 9, 10, and 11. Instead of presenting each data path individually, we will provide summary data for responding across participants on pre- and post-training probes of stimuli from each module. No participant correctly produced braille stimuli prior to completing Module 1 training; during post-training probes, correct responding was high across participants (*M* = 91.6%, range: 83.3-100%). Pre-training probes of Module 2 stimuli resulted in generative responding for all participants except Andy (*M* = 33.3%, range: 0-66.7%). On post-training probes, Julie and Sophie consistently produced correct braille stimuli across probes; Andy and Callie engaged in variable levels of correct responding. Overall, participants correctly produced 85% of braille stimuli (range: 58.3-100%). Pre-training probes of Module 3 and 4 stimuli resulted in no correct responding; post-training probes for both modules resulted in variable levels of correct responding across participants (Module 3 *M* = 35.9%, range: 9.4-56.3%; Module 4 *M* = 35.7%, range 10.7-60.7%). On pre-training probes of stimuli from Module 5, Sophie was the only participant who correctly produced braille stimuli. Across participants these probes resulted in 2.8% (range: 0-11.1%) correct responding. Post-training probes of Module 5 stimuli resulted in 15.6% (range: 0-33.3%) correct responding. We saw similar results on pre- (*M* = 1.1%, range: 0-4.5%) and post- (*M* = 22.5%, range: 10-35%) training probes of stimuli from Module 6. When participants completed pre-training probes of stimuli from Module 7, only Andy correctly produced any braille stimuli (*M* = 1.9%, range: 0-7.7%). Post-training probes resulted in variable levels of correct responding across participants (*M* = 51.6%, range: 25-81.3%). All participants correctly produced some Module 8 braille stimuli on pre-training probes (*M* = 5.8%, range: 3.3-10%); correct responding increased for all participants except Callie on post-training probes (*M* = 32.1%, range: 3.3-50%). Participants did not correctly produce any Module 9 braille stimuli during pre-training probes; post-training probes resulted in high levels of correct responding for Andy, moderate levels of correct responding for Julie and Sophie, and no correct responding for Callie (*M* = 34.3%, range: 0-62%). Pre-training probes of stimuli from Module 10 resulted in some correct responding across participants (*M* = 7.9%, range: 2.6-15.8%). Post-training probes resulted in low and variable levels of correct responding across participants (*M* = 18.8%, range: 0-25%).

Oral Braille Reading Probe

Figure 13 depicts data from the oral braille reading probe for all five participants. Black bars represent number of items read during the pre-training probe, and gray bars represent the number of items read during the post-training probe. All participants were unable to read any of the braille passage prior to beginning training on the VBT. The four participants who completed the training program were all able to read correctly some items on the oral braille reading probe. Julie read correctly 55 items, Sophie read correctly 29 items, Andy read correctly 28 items, and Callie read correctly 16 items.

Lexie did not complete the terminal braille reading probe due to voluntary withdrawal from the study after appointment 2.

Braille Transcription Probe

Data from the braille transcription probe are shown in Figure 14. Black bars depict pre-training data and gray bars depict post-training data. Data are presented as the percentage of scorable units participants correctly transcribed from a 15 sentence worksheet. Pre-training probes resulted in no correct identification of braille characters; post-training probes resulted in all four participants who completed the study correctly transcribing a high percentage of scorable units. Julie correctly transcribed 96.9% of the items in 42 min 25 s, Sophie correctly transcribed 90.1% of the items in 50 min 43 s, Andy correctly transcribed 73.9% of the items in 56 min 21 s, and Callie correctly transcribed 76.4% of the items in 42 min 18 s, and. Lexie did not complete the post-training transcription probe.

Discussion

The current study evaluated the efficacy of a computer-based training to teach matching of print to braille characters within a matching-to-sample (MTS) format and assessed the extent to which this MTS training resulted in generalization of performance to important braille repertoires. Four out of the five participants we recruited for this study completed the entire training program meeting mastery of a total of 378 braille-to-print relations with a mean training time of 4 hours and 45 min, thus demonstrating the efficacy and efficiency of the program in terms of teaching the match-to-sample performance. In addition, we assessed the generative effects of this instruction on a number of important braille reading skills (construction of a print letter given a braille character, construction of a braille character given a print character, transcribing braille sentences into print sentences, and reading aloud given a braille text) and in doing so extended previous research.

First, we examined the emergence of braille-to-print constructed responding. This task was similar to the training program in that participants responded to a braille sample stimulus, but participants printed their response rather than selecting the stimulus from a multiple-choice array. The emergence of this skill can be considered an instance of induction, or response generalization, in that a novel response (printing) emerged in the presence of the stimuli present during training (braille characters). This skill emerged across all modules and all participants at varying levels (nearly 100% of trials in Modules 1 and 2 to 30% for Module 3), despite this skill never being directly trained.

Next we assessed the emergence of print-to-braille construction. This skill is an important requirement for braille instructors; that is teachers are often required to create their own braille materials for their students. These results indicated that this training did result in generative braille production at varying levels. In particular, Modules 1 and 2 were associated with the highest levels of braille production (likely not coincidently correlated with braille-to-print relation responding) with lower levels occurring for contractions modules. This finding is particularly unique; prior research on matching-to-sample teaching of braille relations (Putnam & Tiger, in press; Scheithauer & Tiger, 2012) has not assessed the emergence of this relation. Despite variable levels of correct responding on the print-to-braille probes, these data indicate that participants are able to emit this untrained behavior (i.e., producing a braille stimulus given a printed-English stimulus) without direct training.

We also assessed the emergence of braille reading, that is, engaging in vocal responses in the presence of braille text. This relation has been assessed given previous MTS research, but the authors noted the limited generative responding in these assessments. We included a number of modifications of our training program to promote this generative response. First, we attempted to ensure greater retention of trained relations by requiring responding to occur fluently during training (i.e., responding within 3 s of stimulus presentation). Second, we included "combination training" modules in which previously taught letters and contractions were combined to form words and sentences as they would appear in a reading passage (note that the passage included combinations of letters and contractions that were not directly trained). Each of our participants was able to read some of the braille text following the training. Although the additive effects of those features noted above were not specifically manipulated, it is worth noting that the number of items read in the current study was substantively higher in the current study than those reported in Putnam & Tiger (in press). Participants in that study read a mean of 4.3 words (range: 3-5 words) immediately after completing training on the VBT and a mean of 5.8 words (range: 1-11 words) during a follow-up appointment 2 to 3 weeks after the final training appointment.

Finally, we assessed the emergence of transcription from complete braille sentences to printed English; this assessment was novel to this study. The 15 targeted sentences were comprised of both braille characters that appeared in the training program and novel combinations of braille characters that participants had not seen before. Although participants learned to select some printed-English sentences and phrases given their braille counterparts during Module 10 training, the sentences involved in this task were more complex and consisted of more braille characters. Impressively, all participants transcribed the target sentences with high levels of accuracy (*M* = 84.3%, range: 73.9 - 96.9%).

The behavioral processes accounting for the emergence of these generative repertoires deserves some comment. That is, we typically consider the emergence of a trained response occurring the presence of novel stimuli as an example of stimulus generalization, and the emergence of novel responses as induction. In the present study, we saw several instances of induction. Specifically, participants learned to select a printed-English stimulus from an array given a braille stimulus, but produced printed-English stimuli given braille stimuli, produced braille stimuli given printed-English stimuli, and produced an auditory response given braille stimuli. This emergence of novel responses is important because it indicates that teaching one or only a few behaviors can result in learners engaging in other, untaught, requisite behaviors. For teachers learning braille this is especially important because being a braille instructor for visually impaired students requires engaging with braille in many different ways (e.g., providing corrective feedback when students are learning, reading braille that a student has produced, producing braille materials for students to use). These results indicate that these are indeed distinct repertoires, but careful programming of trained relations can result in the untrained emergence of other important behaviors. It is clearly more efficient to teach a subset of responses to promote generalization than it would be to individual teach each relation.

One approach to understanding these relations would be to interpret the results in terms of stimulus equivalence. Equivalence describes the process by which distinct stimuli become functionally equivalent, or serve to occasion the same responses. For instance, the written word, "ball," a picture of a ball, and a three dimensional ball would all occasion the response "ball." Thus, we could describe these stimuli as equivalent. According to Dinsmoor (1995) stimuli that belong to the same equivalence class occasion the same response; we can therefore say that they have the same meaning. Sidman (1994) suggested in order for us to say that an equivalence relation exists, we must be able to demonstrate reflexivity (A = A), symmetry (if A = B, then B =A), and transitivity (if A = B and B = C, then A = C). Through numerous studies, Sidman and colleagues trained and tested relations using what they called a conditional discrimination procedure. In the present study, we taught participants to select from an array the correct printed-English stimulus when presented with a braille stimulus. After participants mastered these relations, we tested how participants behaved with regards to the stimuli. Specifically, participants came into the lab with the repertoires of saying "a" in the presence of the printed letter "a" and of writing "a" when presented with the auditory stimulus "a". We taught the relation between the braille character "⠁" and the printed-English letter "a" and saw the emergence of written braille and the ability to say "a" in the presence of the braille character "⠁". This is similar to the equivalence relation transitivity; thus, we could interpret our results of having capitalized on the existing relations between print letters, writing, and vocal speech and that by associating the braille letter with the print letter, we simply entered the braille stimulus into an already existing stimulus class. However, our procedures depart from the typical stimulus equivalence literature because we required different response modalities (i.e., typically equivalence requires identical responses to novel stimuli whereas our preparation involved novel responses in the presence of novel stimuli), so this study is not a perfect analogue to the equivalence paradigm.

Another possible explanation is the naming account provided by Lowe and Horne (1996). In this paper, the authors define naming as “a higher order bidirectional behavior relation that (a) combines conventional speaker and listener behavior within the individual, (b) does not require reinforcement of both speaker and listener behavior for each new name to be established, and (c) relates to classes of objects and events” (p. 207). Naming occurs in two different contexts, what Horne and Lowe call *social speech* and *inner speech*. In the present study, inner speech may be particularly relevant. Naming occurs when an individual sees a stimulus, emits a name (either as overt or covert verbal behavior), hears the name, and orients to any other stimuli in that stimulus class. Participants in our study may have engaged in this series of behaviors during discrimination training (i.e., see “⠁”, engage in the covert verbal response “a”, hear oneself say “a”, and orient to the braille stimulus in the array that is “a”). Once a participant met mastery on the VBT, he or she would then complete the braille-to-print construction probe. In this context, the participant would engage in the same behaviors, except that the terminal behavior would be writing the letter “a” rather than selecting it from an array. The braille stimulus “⠁” and the printed-English stimulus “a” both occasion the same name, thus we have established stimulus equivalence. This account may better explain the results we found with regards to training with a selection response and testing with a construction response (i.e., training and testing using different response modalities).

From a more practical perspective, our study offers a number of interesting findings. First, not all participants performed equally well on the training and generative responding assessments. In particular, Callie tended to score the lowest during generative assessments. We can only speculate on the causes of this performance, but it is notable that Callie scored somewhat lower on the WIAT ORF subtest of reading fluency than the other subjects (Grade Level Equivalent of 10.7 relative to 12.9 or higher). In makes intuitive sense that a robust print-reading repertoire would facilitate the generalization from print to braille targeted in this study; future research will be needed to evaluate the impact of reading levels on acquisition and to identify the minimal reading abilities necessary to master similar training programs.

Second, each assessment of generative responding identified that exposure to the matching-to-sample program resulted in emergent braille behavior that is similar to that which teachers would need to engage in as part of braille instruction. Although this emergence speaks to the power of this fairly brief teaching program, it is important to note that few of the generative performances occurred at expert levels (i.e., near 100% accuracy or at the speed a fluent braille reader). Additional intervention (direct training and reinforcement) would be necessary to bring these repertoires to expert levels, but the use of the VBT 2.0 program established a foundation on which this instruction could progress.

Several adjustments could be made to the training program in order to improve generalization and maintenance. First, we programmed additional incremental rehearsal of previously mastered stimuli within each module and by targeting combination modules, but additional rehearsal may be beneficial. One of the limitations of recruiting undergraduate students to participate is that we were limited in the number of appointments for each individual and thus had to follow a scheduled structure in presenting modules. However, in practice if responding from the MTS did not result in generalization, we would likely either (a) provide additional training trials for the targeted relation and/or (b) directly train the generalized repertoire. Evaluations with actual teachers should allow greater responsiveness to individual learning patterns.

Despite the structured pace of the current preparation, we were able to identify some consistencies in participant performance. First, all participants performed well in the letters and combination of letters into words modules (Modules 1 and 2); however, performance was consistently lower in tests of contractions, for example. It is possible that these training modules targeted too many stimulus relations at once. There was a relation between number of items per module and maintenance of correct responding. For example, Modules 3, 4, and 6 resulted in the lowest levels of post-training correct responding and they contained 37, 54, and 53 items, respectively relative to Modules 1 and 2, which contained 26 and 30 items, respectively. Thus further dividing the modules may improve performance.

The selection of the MTS training from braille to print was based upon previous research in the area (most notably Toussaint & Tiger, 2010) and the stimulus-equivalence paradigm. However, targeting an alternative initial skill could result in greater generative learning. For instance, in the context of teaching discriminated requesting to children with autism, Gutierrez et al. (2007) compared the development of discriminated responding for different preferred stimuli when requests were taught using a selection response (e.g., selecting one card from an array of pictures) relative to a signed response.

The defining characteristic between these response modalities is that each response was identical in form using the selection response whereas each response is topographically unique using the signed response. In this study, children with autism were more likely to engage in discriminated responses using signed language. In the teaching of braille, perhaps discriminated responding would be more likely to generalize across response modalities if we targeted a construction response during training in lieu of a selection response. Scheithauer, Tiger, and Miller (2013) compared teaching identification of braille letters using either a selection response relative to a keyed response. However, keying a response is essentially a selection response from a large array of available keys. Perhaps requiring learners to produce braille characters (similar to our print-to-braille probes) during training would result in more robust generalization (this would require participants to attend to all features of the braille characters). Future studies could compare the efficacy of print-to-braille instruction (i.e., see printed-English stimulus, produce braille stimulus) with the efficacy of braille-to-print instruction (i.e., see braille stimulus, produce printed-English stimulus.

Future studies in this area could also systematically assess the differences between training to fluency and training to accuracy. In the present study, we incorporated a fluency criterion into our training program, but it would be useful to assess the effects of this additional mastery criterion on training time, trials to mastery, post-training correct responding, and maintenance over time. Another interesting manipulation for future research would be to assess the effects of training on participants' braille reading when the test stimuli are actually paper-colored raised dots rather than black ink stimuli. Finally, we did not provide our participants with any background on braille, information regarding braille usage rules, or explanation of contractions. Individuals who are interested in becoming teachers of students with visual impairments may have some of this knowledge and be motivated to learn braille, thus these individuals would be ideal candidates for participation in future studies.

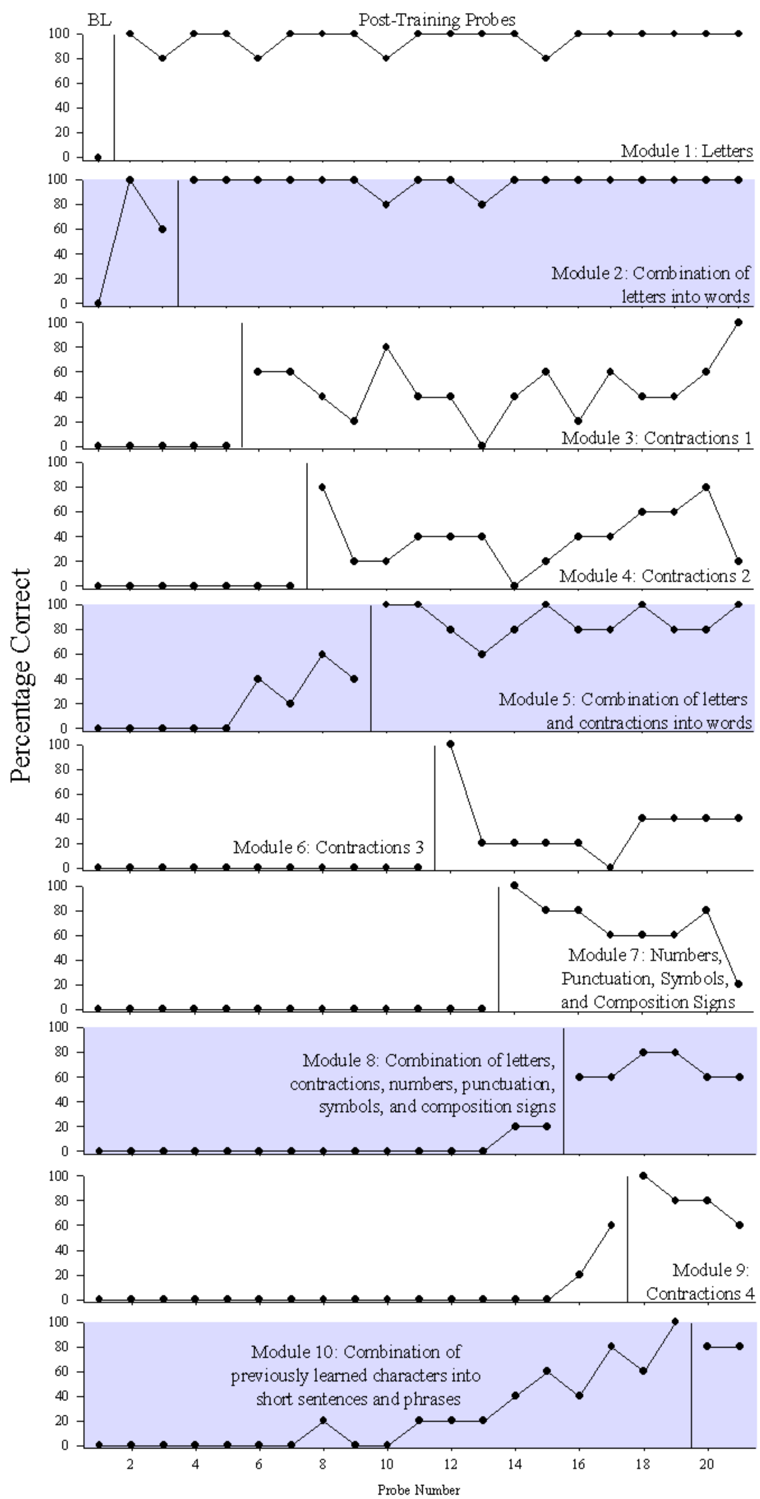

Figure 1. This figure shows results for pre- and post-training responding for Julie on braille-to-print construction probes for each module. Data from pre-training probes can be found to the left of the solid vertical line on each panel and data from the post-training probes can be found to the right of the solid vertical line. Shaded panels indicate modules for which elevated baselines would be expected due to overlap with stimuli from other modules.

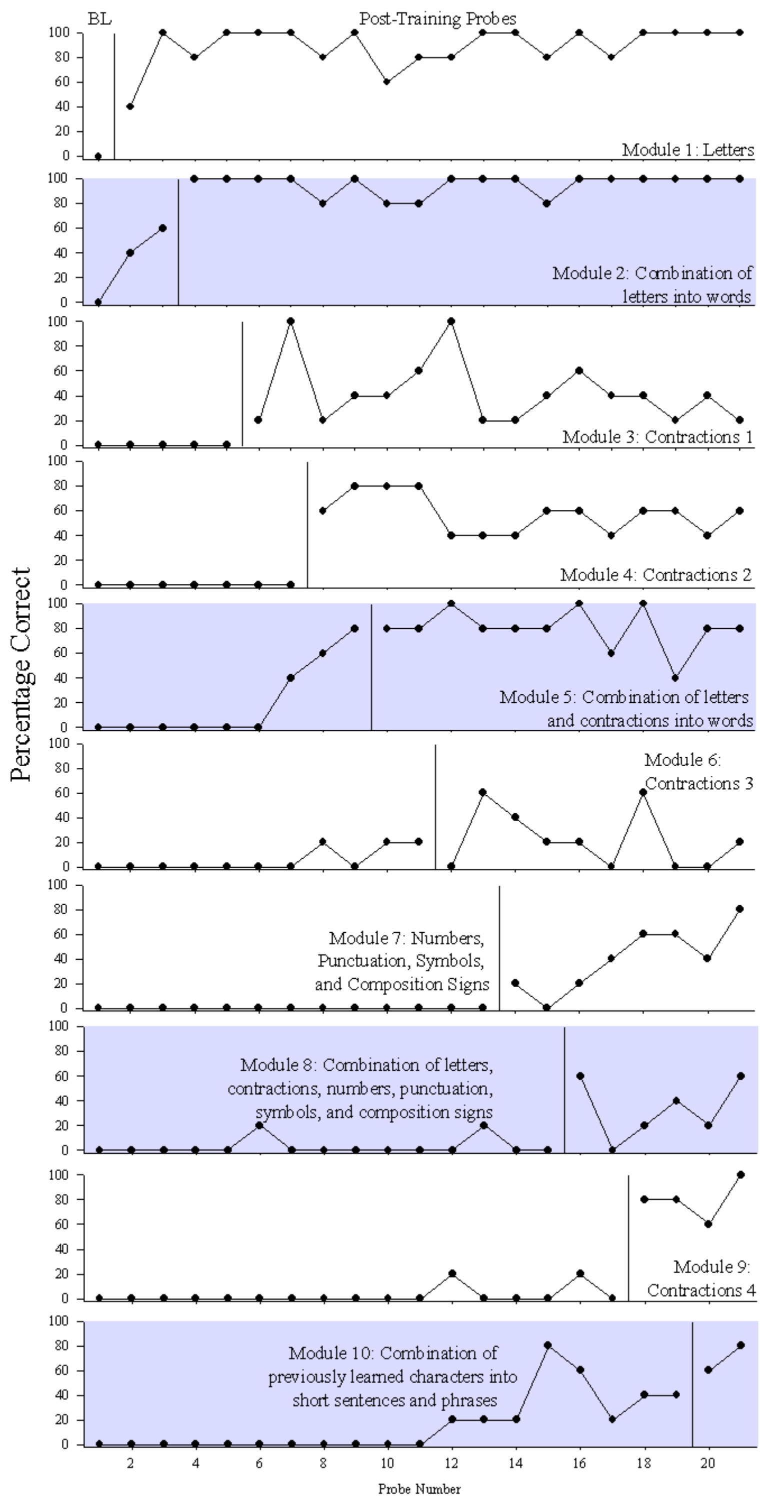

Figure 2. This figure shows results for pre- and post-training responding for Sophie on braille-to-print construction probes for each module. Data from pre-training probes can be found to the left of the solid vertical line on each panel and data from the post-training probes can be found to the right of the solid vertical line. Shaded panels indicate modules for which elevated baselines would be expected due to overlap with stimuli from other modules.

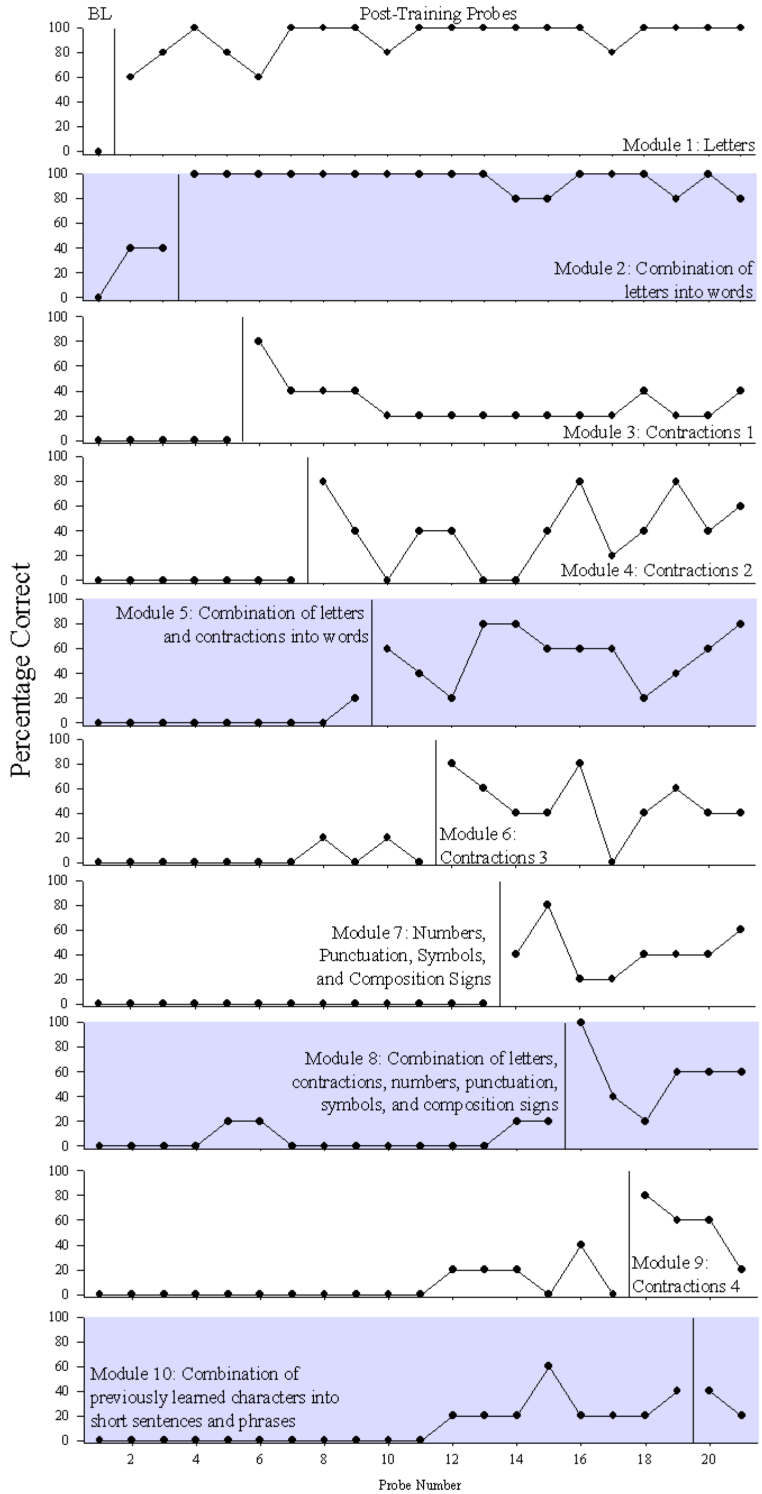

Figure 3. This figure shows results for pre- and post-training responding for Andy on braille-to-print construction probes for each module. Data from pre-training probes can be found to the left of the solid vertical line on each panel and data from the post-training probes can be found to the right of the solid vertical line. Shaded panels indicate modules for which elevated baselines would be expected due to overlap with stimuli from other modules.

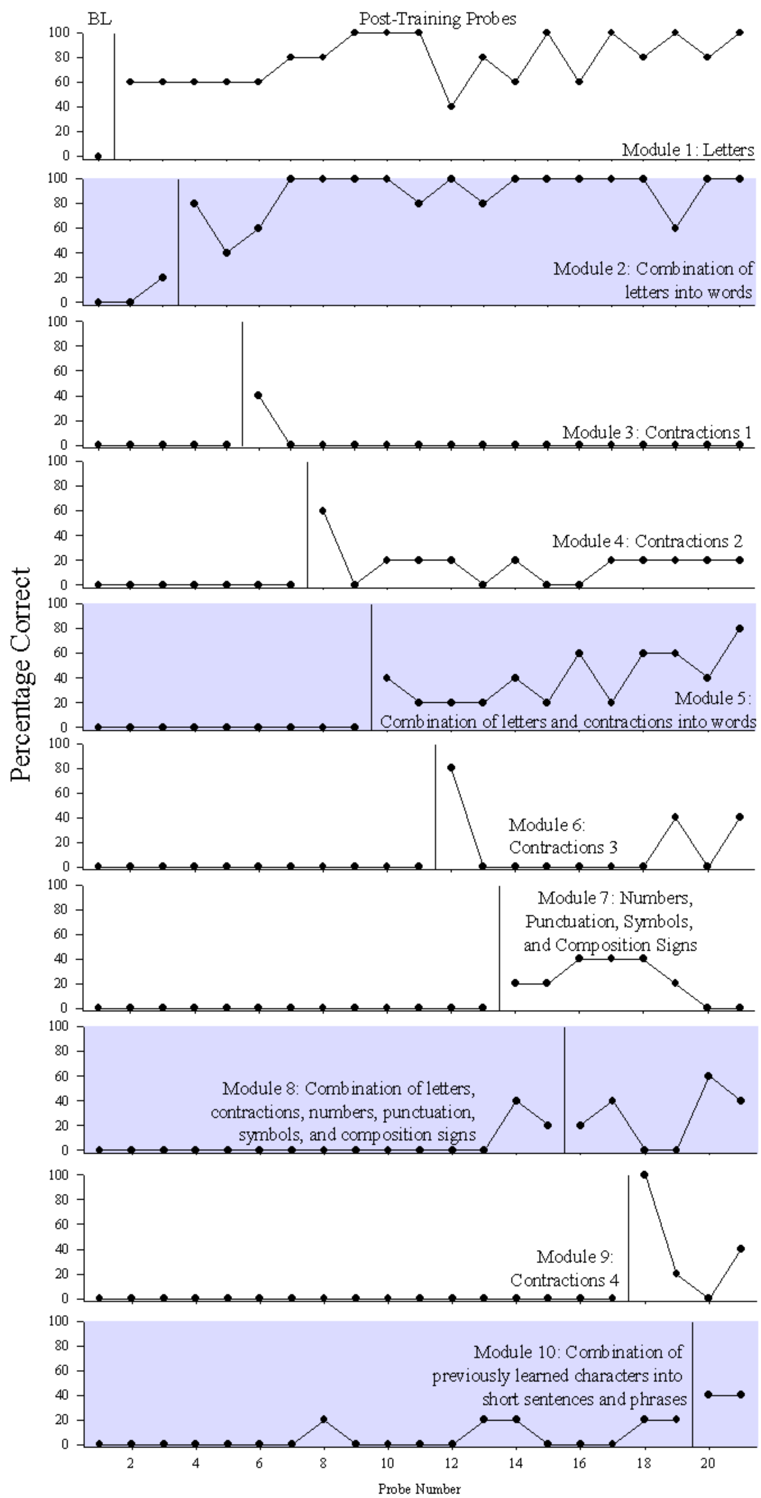

Figure 4. This figure shows results for pre- and post-training responding for Callie on braille-to-print construction probes for each module. Data from pre-training probes can be found to the left of the solid vertical line on each panel and data from the post-training probes can be found to the right of the solid vertical line. Shaded panels indicate modules for which elevated baselines would be expected due to overlap with stimuli from other modules.

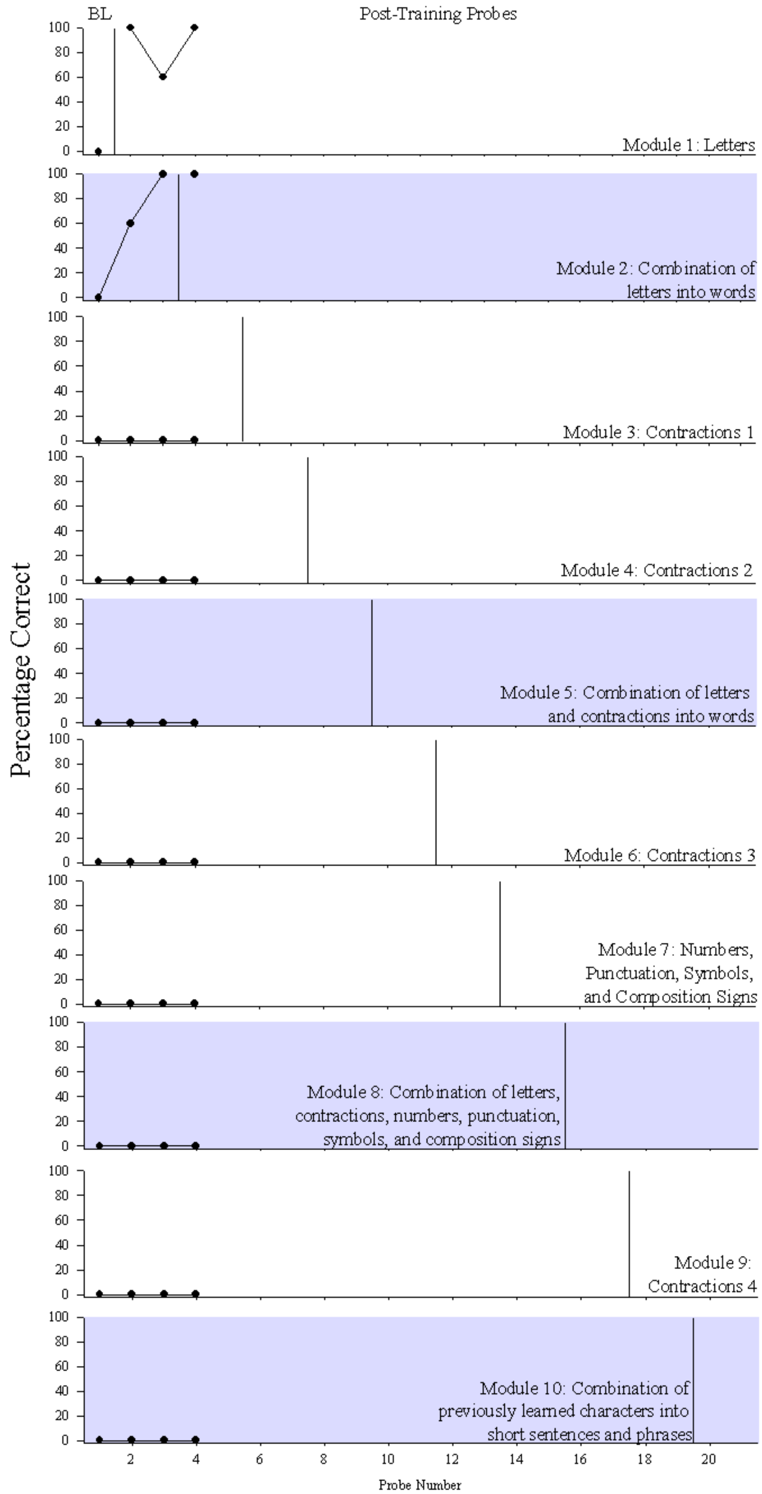

Figure 5. This figure shows results for pre- and post-training responding for Lexie on braille-to-print construction probes for each module. Data from pre-training probes can be found to the left of the solid vertical line on each panel and data from the post-training probes can be found to the right of the solid vertical line. Shaded panels indicate modules for which elevated baselines would be expected due to overlap with stimuli from other modules. Lexie only completed four construction probes before withdrawing from the study.

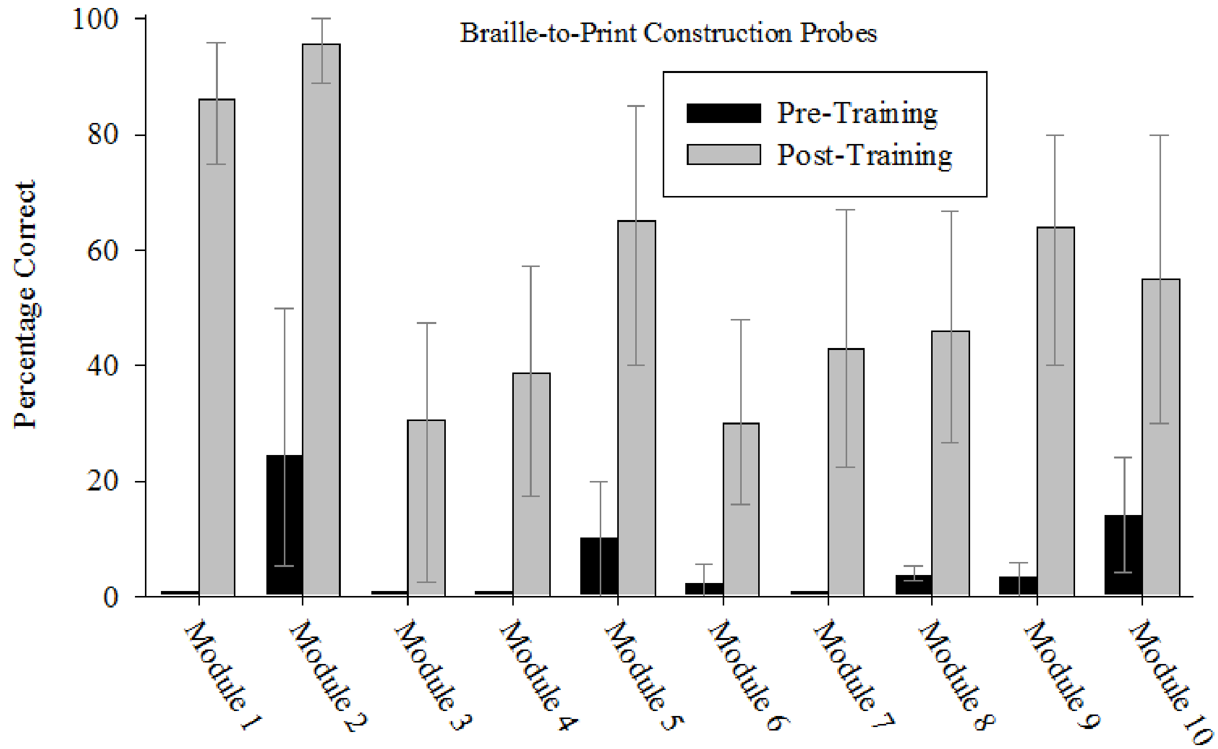

Figure 6. This figure presents summary data for responding to stimuli from each module on the pre-and post-training braille-to-print probes, averaged across participants. Black bars represent pre-training data, gray bars represent post-training data, and error bars present the range in percentage correct responding across participants.

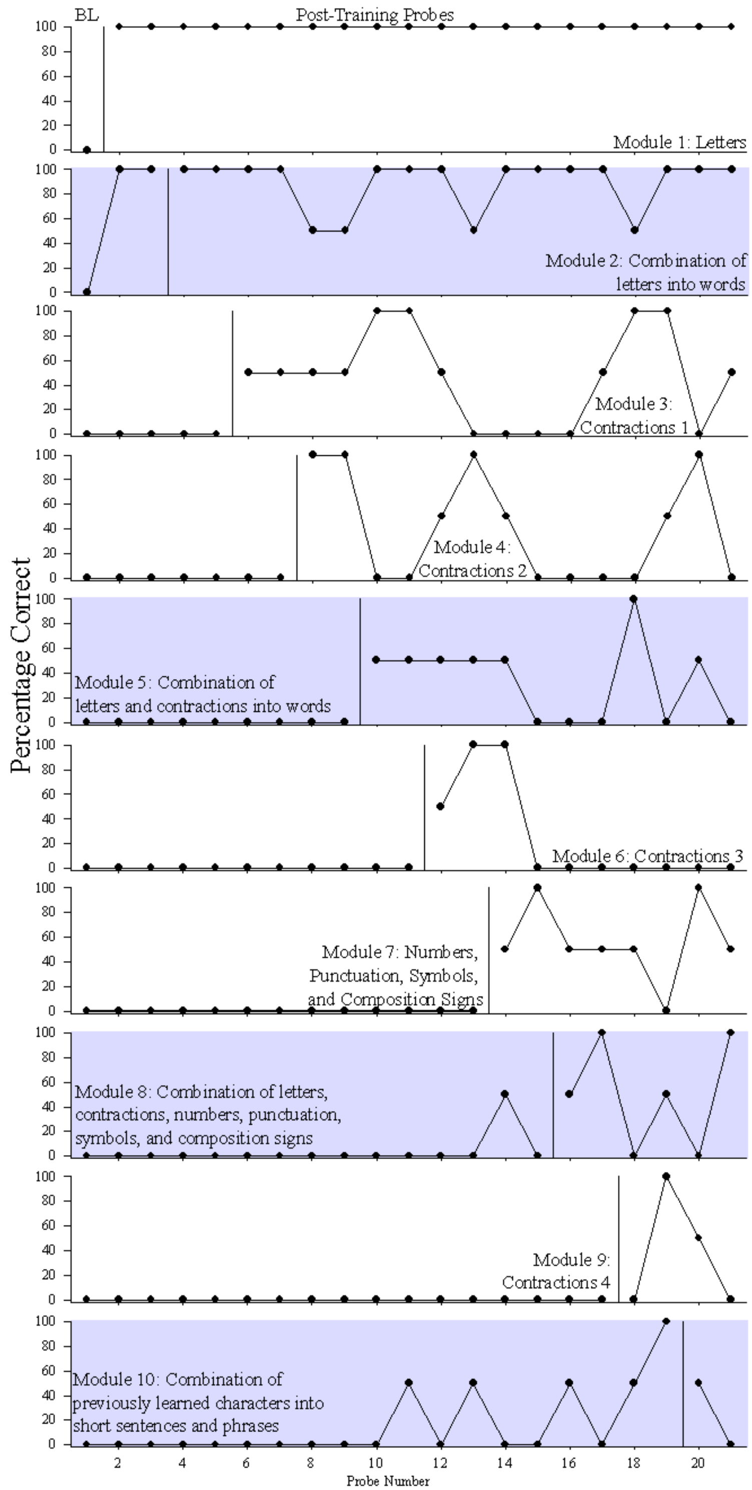

Figure 7. This figure shows results for pre- and post-training responding for Julie on print-to-braille construction probes for each module. Data from pre-training probes can be found to the left of the solid vertical line on each panel and data from the post-training probes can be found to the right of the solid vertical line. Shaded panels indicate modules for which elevated baselines would be expected due to overlap with stimuli from other modules.

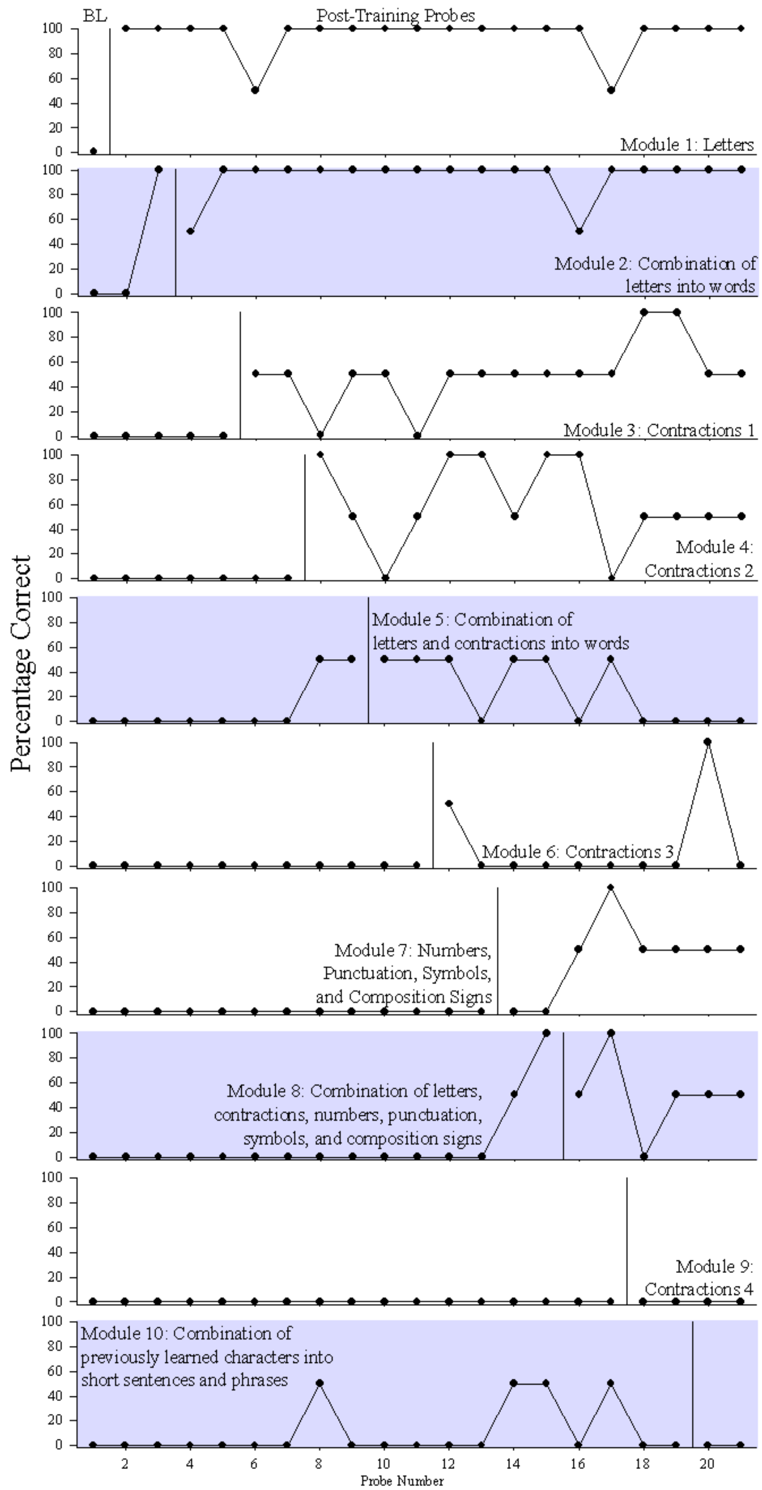

Figure 8. This figure shows results for pre- and post-training responding for Sophie on print-to-braille construction probes for each module. Data from pre-training probes can be found to the left of the solid vertical line on each panel and data from the post-training probes can be found to the right of the solid vertical line. Shaded panels indicate modules for which elevated baselines would be expected due to overlap with stimuli from other modules.

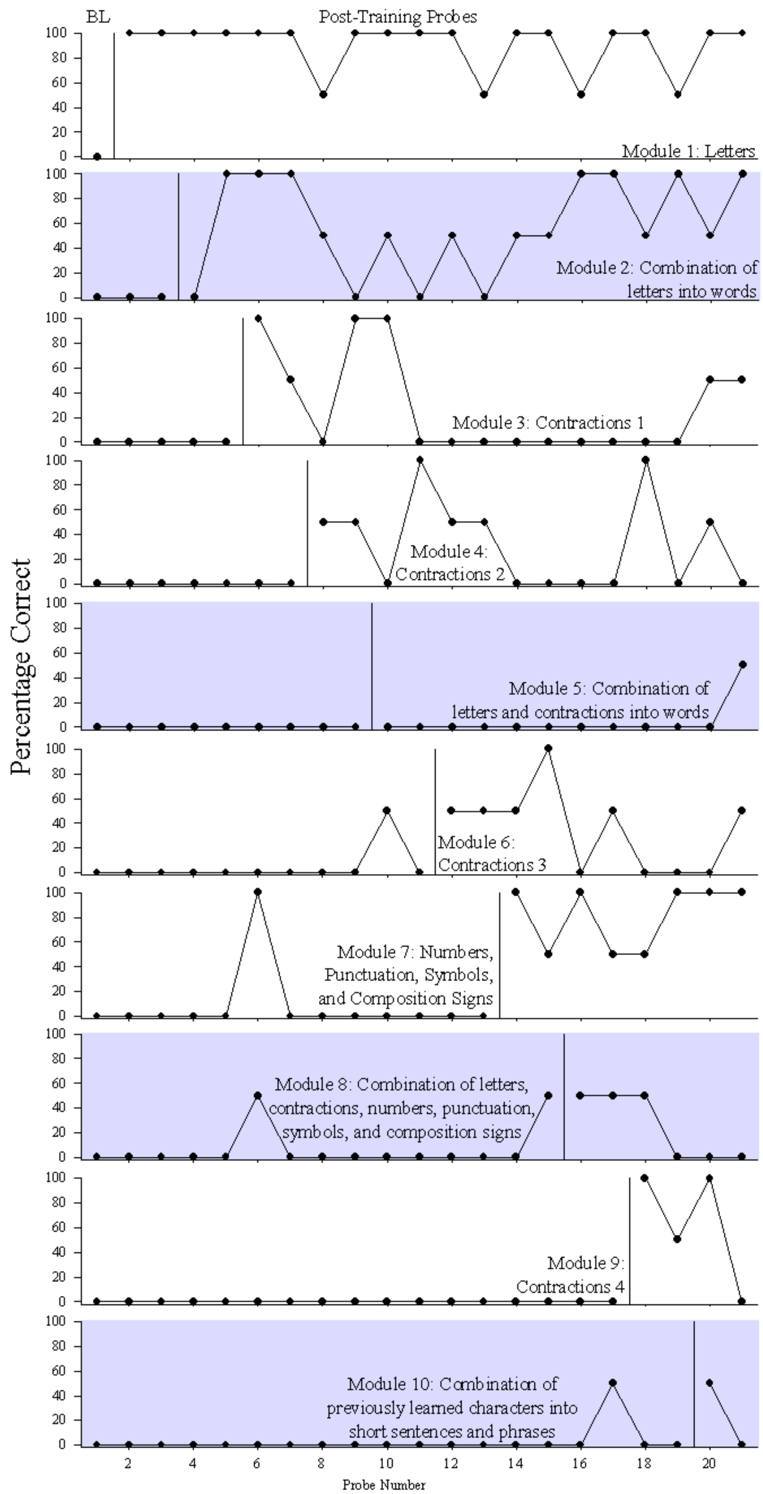

Figure 9. This figure shows results for pre- and post-training responding for Andy on print-to-braille construction probes for each module. Data from pre-training probes can be found to the left of the solid vertical line on each panel and data from the post-training probes can be found to the right of the solid vertical line. Shaded panels indicate modules for which elevated baselines would be expected due to overlap with stimuli from other modules.

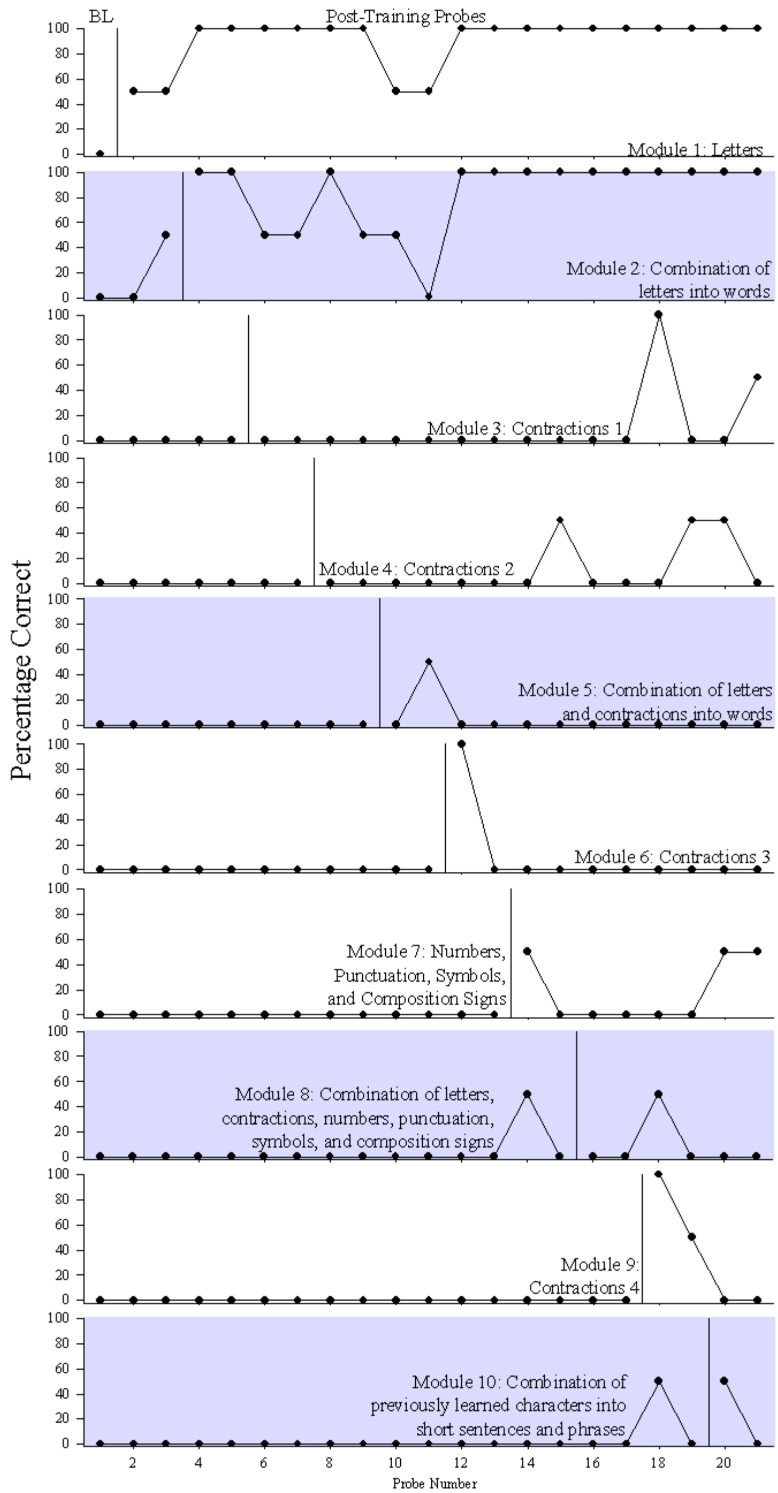

Figure 10. This figure shows results for pre- and post-training responding for Callie on print-to-braille construction probes for each module. Data from pre-training probes can be found to the left of the solid vertical line on each panel and data from the post-training probes can be found to the right of the solid vertical line. Shaded panels indicate modules for which elevated baselines would be expected due to overlap with stimuli from other modules.

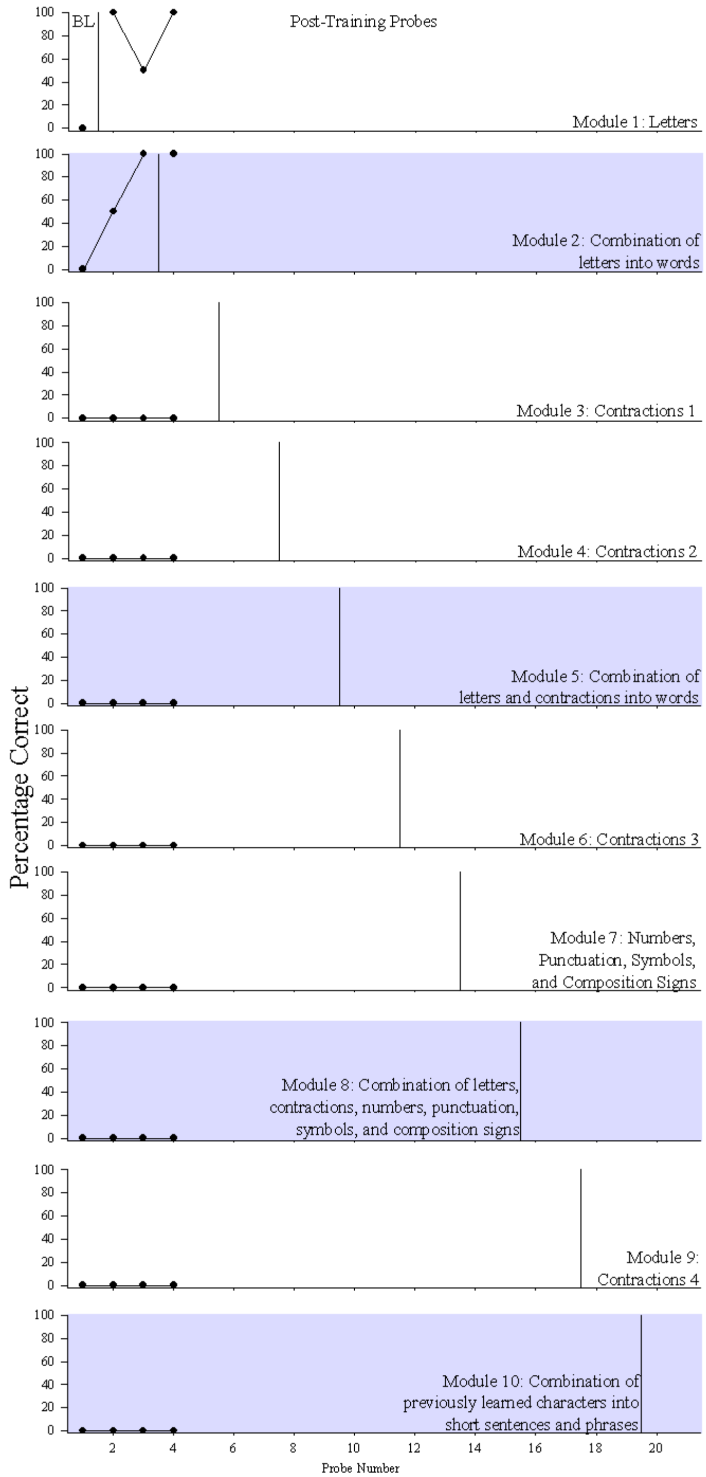

Figure 11. This figure shows results for pre- and post-training responding for Lexie on print-to-braille construction probes for each module. Data from pre-training probes can be found to the left of the solid vertical line on each panel and data from the post-training probes can be found to the right of the solid vertical line. Shaded panels indicate modules for which elevated baselines would be expected due to overlap with stimuli from other modules. Due to withdrawal from the study, Lexie only completed four print-to-braille construction probes.

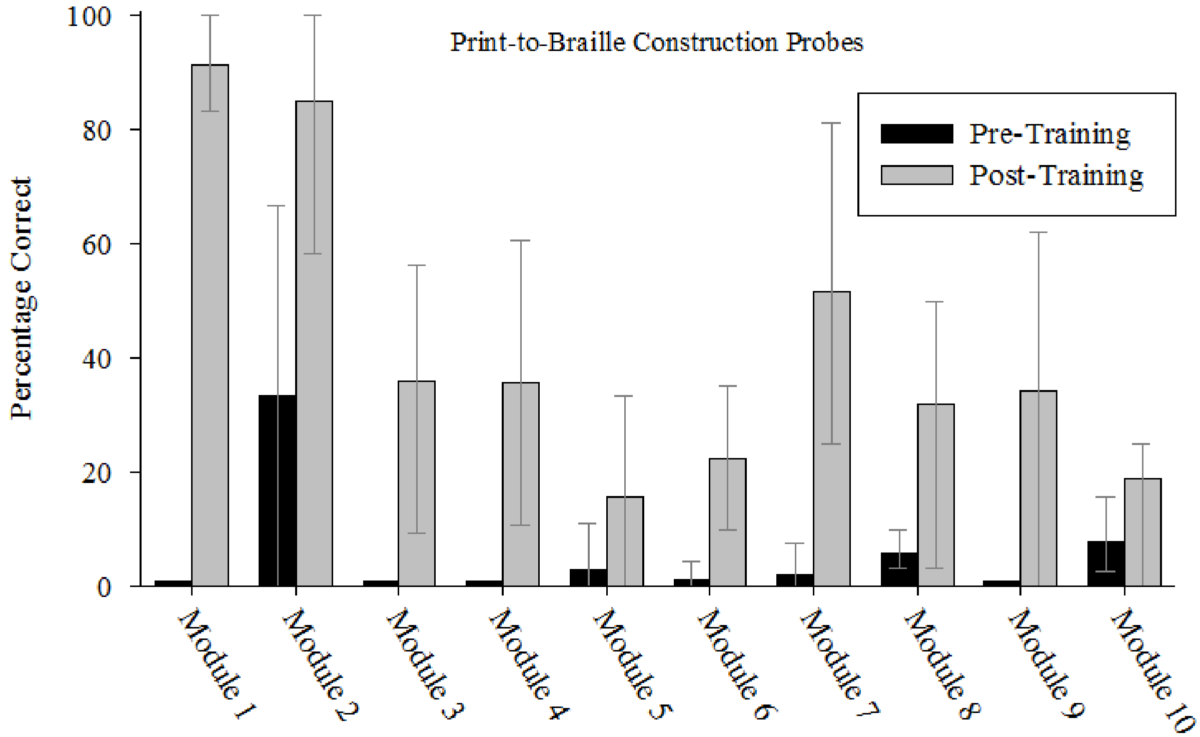

Figure 12. This figure presents summary data for responding to stimuli from each module on the pre-and post-training print-to-braille probes, averaged across participants. Black bars represent pre-training data, gray bars represent post-training data, and error bars present the range in percentage correct responding across participants.

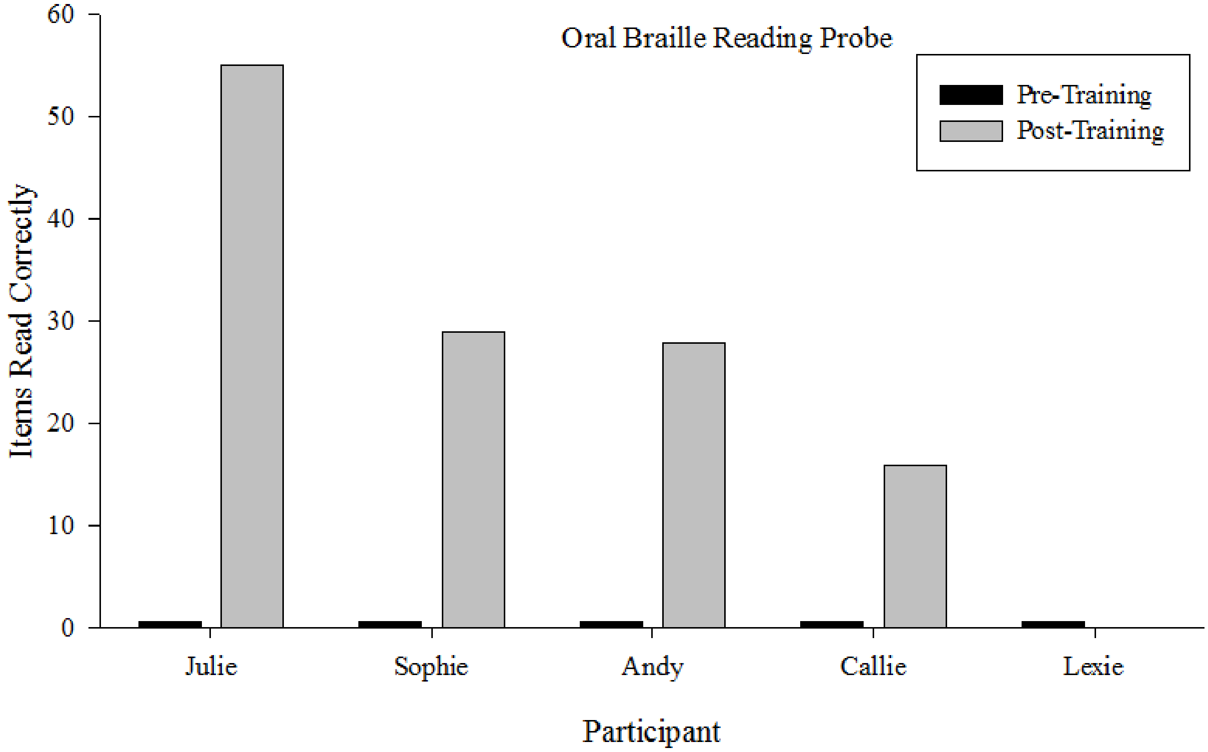

Figure 13. This graph presents results for the oral braille reading task. For each participant, number of items read correctly on pre-training probes is depicted by black bars and number of items read correctly on post-training probes is depicted by gray bars. Lexie did not complete the post-training probe.

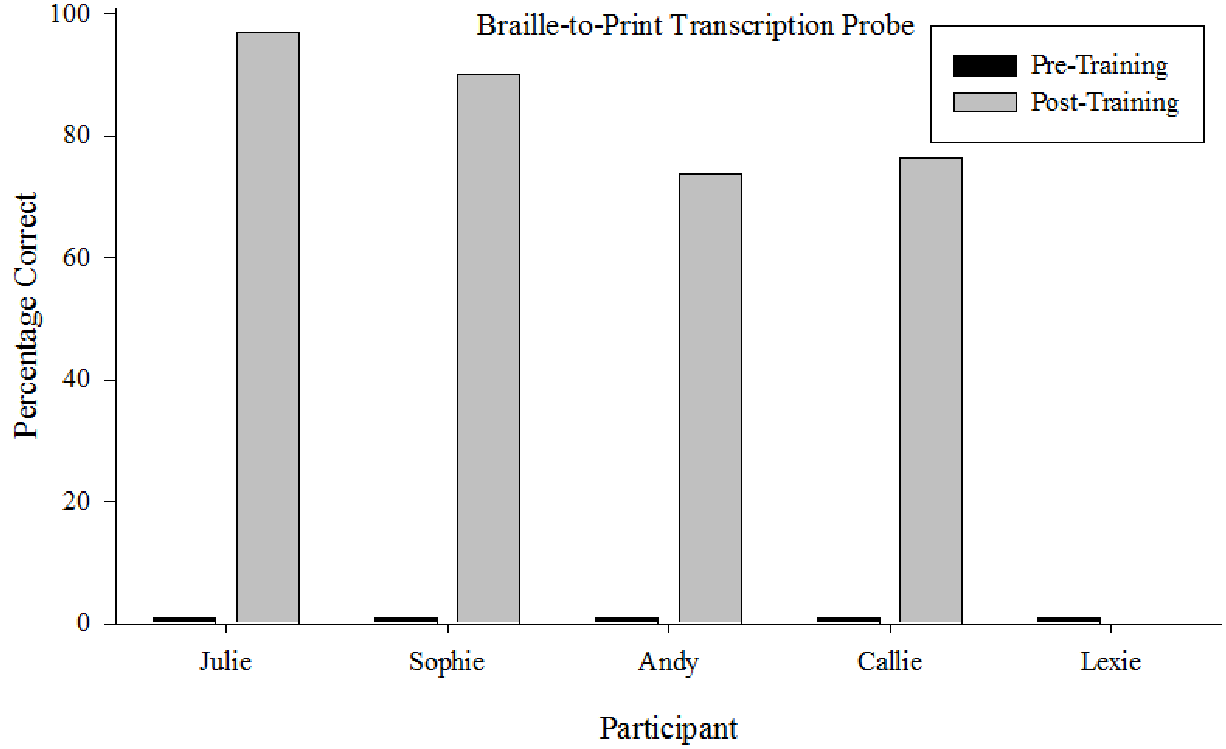

Figure 14. This graph presents results for the braille transcription task. For each participant, percentage correct on pre-training probes is depicted by black bars and percentage correct on post-training probes is depicted by gray bars. Lexie did not complete the post-training probe

Table 1

Assessments Each Participant Completed during Each Appointment

Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
WIAT ORF Subtest	X										
Braille-Reading Probe	X										X
Braille-Transcription Probe	X										X
Braille-to-Print Construction Probe (pre-training)	X	X	X	X	X	X	X	X	X	X	
Braille-to-Print Construction Probe (post-training)	X	X	X	X	X	X	X	X	X	X	X
Print-to-Braille Construction Probe (pre-training)	X	X	X	X	X	X	X	X	X	X	
Print-to-Braille Construction Probe (post-training)	X	X	X	X	X	X	X	X	X	X	X

Table 2

Training Time (min) to Mastery for All Participants on All Modules

Module	Julie	Sophie	Andy	Callie	Lexie	Mean
1	15.67	21.08	15.52	25.28	22.00	19.38
2	32.70	52.87	20.87	60.78	41.85	41.80
3	31.33	32.23	47.43	35.25	-	36.56
4	29.08	40.50	39.63	32.42	-	35.41
5	17.95	14.42	11.10	11.17	-	13.66
6	42.43	39.05	47.68	29.97	-	39.78
7	25.00	27.00	29.90	24.73	-	26.66
8	18.18	13.12	18.92	21.22	-	17.86
9	35.02	26.15	55.80	25.20	-	35.54
10	17.28	13.42	16.92	25.83	-	18.36
Total Time to Mastery	264.65	279.83	303.77	291.85	-	**285.01**

Note: Lexie completed only the first two training modules, thus no other data are available for that participant. Her data are not included in calculations of mean training time.

Table 3

Trials to Mastery for All Participants on All Modules

Module	Julie	Sophie	Andy	Callie	Lexie	Mean
1	350	300	317	415	356	346
2	487	644	351	919	564	600
3	494	452	689	607	-	561
4	-	584	765	564	-	638
5	272	247	242	241	-	251
6	609	642	814	552	-	654
7	409	447	545	483	-	471
8	260	217	306	413	-	299
9	563	422	884	489	-	590
10	285	248	322	461	-	329
Total Trials to Mastery	3728	4203	5235	5144	-	**4737**

Note. Lexie completed only the first two training modules, thus no other data are available for that participant. Trials to mastery for Julie's Module 4 training are unavailable due to a saving error on the computer program.

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Appendix A

Sample scoring guide for braille-reading probes

Participant Number: ____________
Appointment Number: ___________

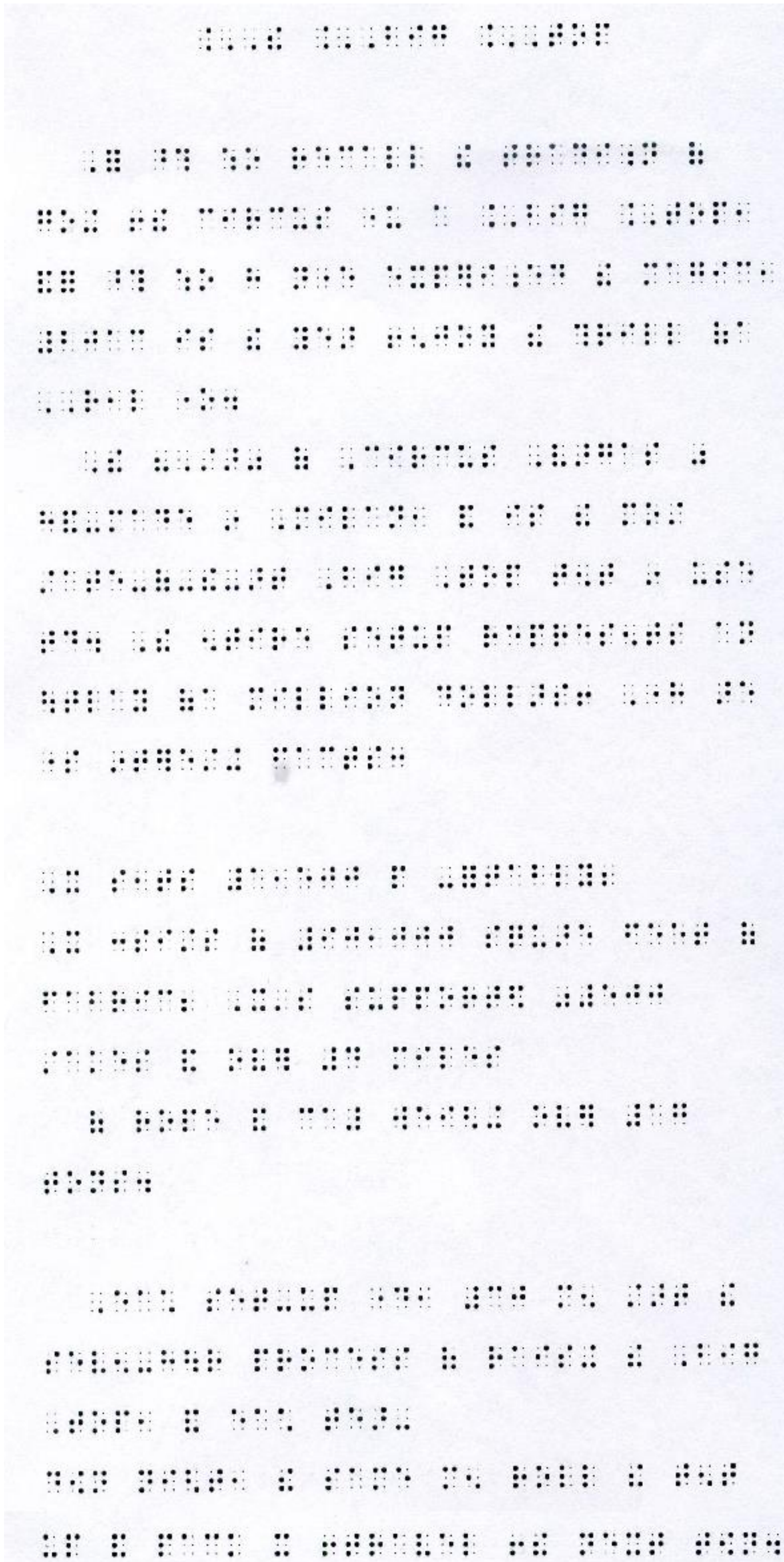
Braille Oral-Reading Probe Scoring Guide

Line	Character		Response
1	1	italics, single	
	2	capital, double	
	3	the	
	4	italics, single	
	5	capital, double	
	6	big	
	7	italics, single	
	8	capital, double	
	9	top	
2	1	capital, single	
	2	for	
	3	those	
	4	who	
	5	recall	
	6	the	
	7	tradition	
	8	of	
3	1	going	
	2	to	
	3	the	
	4	circus	
	5	under	
	6	a	
	7	italics, single	
	8	capital, single	
	9	big	
	10	italics, single	
	11	capital, single	
	12	top	
	13	comma	
4	1	and	
	2	for	
	3	those	
	4	who	
	5	have	
	6	never	
	7	experienced	
	8	the	
	9	magic	
	10	comma	

Line	Character		Response
5	1	number sign	
	2	2013	
	3	is	
	4	the	
	5	year	
	6	to	
	7	enjoy	
	8	the	
	9	thrill	
	10	of	
	11	a	
6	1	capital, double	
	2	real	
	3	one	
	4	period	
7	1	capital, single	
	2	the	
	3	open quote	
	4	capital, single	
	5	star	
	6	close quote	
	7	of	
	8	capital, single	
	9	circus	
	10	capital, single	
	11	Vargas	
	12	was	
8	1	hand	
	2	- (hyphen)	
	3	made	
	4	in	
	5	capital, single	
	6	Milan	
	7	comma	
	8	and	
	9	is	
	10	the	
	11	most	

Appendix B

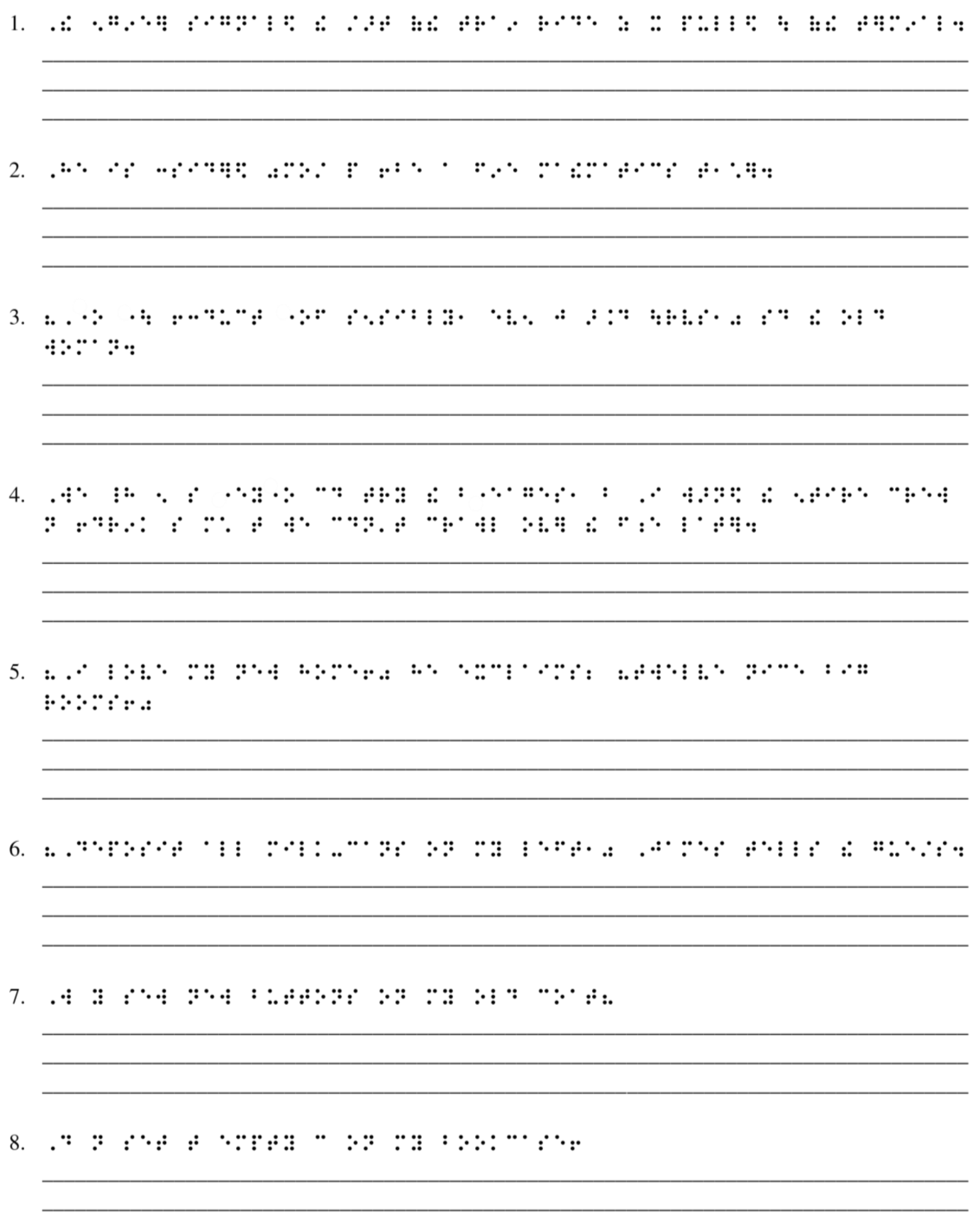
Braille-reading probe



Appendix C

Braille-transcription probe

Braille-Transcription Probe



9. [illegible]

____

____

____

10. [illegible]

____

____

____

11. [illegible]

____

____

____

12. [illegible]

____

____

____

13. [illegible]

____

____

____

14. [illegible]

____

____

____

15. [illegible]

____

____

____

Appendix D

Sample braille to print probe

Participant Number: __________
Appointment Number: __________

Number Correct: _______
Percentage Correct: _____

Braille-to-Print Probe 1

Stimulus Number	Braille Stimulus	Print Response	Stimulus Number	Braille Stimulus	Print Response
1			26		
2			27		
3			28		
4			29		(word)
5			30		
6			31		
7			32		
8			33		
9			34		
10			35		
11			36		
12			37		
13			38		
14			39		
15			40		
16			41		
17			42		
18			43		
19			44		
20			45		
21			46		
22			47		
23			48		
24			49		
25			50		

Module	Number Correct	Percentage Correct	Module	Number Correct	Percentage Correct
1			6		
2			7		
3			8		
4			9		
5			10		

Appendix E

Sample print to braille probe

Participant Number: ___________
Appointment Number: _________

Number Correct: _______
Percentage Correct: _____

Print to Braille Probe 1

Stimulus Number	Print Stimulus	Braille Response	Stimulus Number	Print Stimulus	Braille Response
1	z		11	Double Capital Sign	
2	magic		12	him	
3	conceiving		13	k	
4	that		14	out	
5	17 tons		15	ow	
6	and,		16	singer	
7	__ance		17	next	
8	the airport		18	cannot	
9	profile		19	He is in enough trouble	
10	3		20	paid	

Module	Number Correct	Percentage Correct	Module	Number Correct	Percentage Correct
1			6		
2			7		
3			8		
4			9		
5			10		

Appendix F

Module 1

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	⠛		

Appendix G

Module 2

Combination of Letters into Words					
Subset 1		Subset 2		Subset 3	
he	⠓⠑	box	⠃⠕⠭	cozy	⠉⠕⠵⠽
me	⠍⠑	eat	⠑⠁⠞	next	⠝⠑⠭⠞
my	⠍⠽	jam	⠚⠁⠍	pack	⠏⠁⠉⠅
no	⠝⠕	let	⠇⠑⠞	same	⠎⠁⠍⠑
we	⠺⠑	man	⠍⠁⠝	sure	⠎⠥⠗⠑
Subset 4		Subset 5		Subset 6	
likes	⠇⠊⠅⠑⠎	flocks	⠋⠇⠕⠉⠅⠎	college	⠉⠕⠇⠇⠑⠛⠑
magic	⠍⠁⠛⠊⠉	fruity	⠋⠗⠥⠊⠞⠽	patrons	⠏⠁⠞⠗⠕⠝⠎
movie	⠍⠕⠧⠊⠑	lesson	⠇⠑⠎⠎⠕⠝	prevail	⠏⠗⠑⠧⠁⠊⠇
quail	⠟⠥⠁⠊⠇	signal	⠎⠊⠛⠝⠁⠇	process	⠏⠗⠕⠉⠑⠎⠎
recall	⠗⠑⠉⠁⠇⠇	travel	⠞⠗⠁⠧⠑⠇	readmit	⠗⠑⠁⠙⠍⠊⠞

Appendix H

Module 3

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	__⠰⠇		

Appendix I

Module 4

Contractions 2									
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	⠦	the	⠮	can	⠉	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	⠿	lord	⠐⠇	between	⠆⠞		

Appendix J

Module 5

Combination of Letters and Contractions into Words					
Subset 1		Subset 2		Subset 3	
and for		bathe		demand	
cash		loud		effort	
high		singer		fetch	
of a		stoned		night	
stand		though		whole	
Subset 4		Subset 5		Subset 6	
android		butter		commenced	
awhile		nearly		mistake	
clothes		reduce		perilous	
lengthen		useless		profile	
school		withdraw		reaction	

Appendix K

Module 6

Contractions 3									
Subset 1		Subset 2		Subset 3		Subset 4		Subset 5	
again	⠁⠛	must	⠍⠌	word	⠘⠺	behind	⠆⠓	work	⠐⠺
after	⠁⠋	into	⠔⠞	children	⠡⠝	father	⠐⠋	name	⠐⠝
one	⠐⠕	much	⠍⠡	these	⠘⠮	day	⠐⠙	question	⠐⠟
mother	⠐⠍	such	⠎⠡	could	⠉⠙	before	⠆⠋	under	⠐⠥
some	⠐⠎	first	⠋⠌	either	⠑⠊	also	⠁⠇	through	⠐⠹
here	⠐⠓	cannot	⠸⠉	those	⠘⠹	below	⠆⠇	young	⠐⠽
Subset 6		Subset 7		Subset 8		Subset 9			
right	⠐⠗	tomorrow	⠞⠍	paid	⠏⠙	said	⠎⠙		
time	⠐⠞	would	⠺⠙	today	⠞⠙	your	⠽⠗		
part	⠐⠏	its	⠭⠎	letter	⠇⠗	quick	⠟⠅		
there	⠐⠮	itself	⠭⠋	friend	⠋⠗	tonight	⠞⠝		
where	⠐⠱	good	⠛⠙	their	⠸⠮	had	⠸⠓		
ought	⠐⠳	world	⠸⠺			should	⠩⠙		

Appendix L

Module 7

Numbers, Symbols, and Punctuation Identification							
Subset 1		Subset 2		Subset 3		Subset 4	
1		4		’		!	
2		6		*		(__)	
3		7		;		?	
5		8		:		. Period	
9		0		-		“ __ ”	
				,		‘ __ ’	
Subset 5		Subset 6		Subset 7		Subset 8	
]		¢		®		Number Sign	
[		@		™		Capital Sign	
°		$		©		Italic Sign	
&		/		Decimal Point		Double Capital Sign	
%		#		Letter Sign		Double Italic Sign	

Appendix M

Module 8

Combination of Letters, Contractions, Numbers, Punctuation, Symbols, and Composition Signs					
Subset 1		Subset 2		Subset 3	
$2	⠲⠼⠃	3°	⠼⠉⠰⠙⠛	2013	⠼⠃⠚⠁⠉
and,	⠯⠂	it's	⠭⠄⠎	5%	⠼⠑⠈⠒⠏
can't	⠉⠄⠞	one.	⠐⠕⠲	65¢	⠼⠋⠑⠈⠉
For	⠠⠿	*THE*	⠨⠠⠠⠮	"Star"	⠦⠠⠌⠜⠴
With	⠠⠾	town.	⠞⠪⠝⠲	*Top*	⠨⠠⠞⠕⠏
Subset 4		Subset 5		Subset 6	
30 men	⠼⠉⠚ ⠍⠢	17 tons	⠼⠁⠛ ⠞⠕⠝⠎	#5699	⠸⠹⠼⠑⠋⠊⠊
and/or	⠯⠸⠌⠕⠗	1920s	⠼⠁⠊⠃⠚⠎	©2006	⠘⠉⠼⠃⠚⠚⠋
dollar!	⠙⠕⠇⠇⠜⠖	4 miles	⠼⠙ ⠍⠊⠇⠑⠎	Dove®	⠠⠙⠕⠧⠑⠘⠗
fabric;	⠋⠁⠃⠗⠊⠉⠆	set-up	⠎⠑⠞⠤⠥⠏	facts:	⠋⠁⠉⠞⠎⠒
seven-hour	⠎⠑⠧⠢⠤⠓⠳⠗	@uwm.edu	⠈⠁⠥⠺⠍⠲⠑⠙⠥	M.D.	⠠⠍⠲⠠⠙⠲

Appendix N

Module 9

Contractions 4							
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					

Appendix O

Module 10

Combination of Previously Learned Characters into Short Sentences and Phrases			
Subset 1		Subset 2	
enough for me	[illegible]	after lunch	[illegible]
Here are some	[illegible]	enough people came	[illegible]
I do not have	[illegible]	For those who	[illegible]
under a	[illegible]	I might	[illegible]
You were	[illegible]	who have never	[illegible]
Subset 3		Subset 4	
Did she have	[illegible]	come at once	[illegible]
is the year	[illegible]	every other week	[illegible]
it consists of	[illegible]	go out this week	[illegible]
It was fine.	[illegible]	the airport	[illegible]
tomorrow morning	[illegible]	the tradition	[illegible]
Subset 5		Subset 6	
blowing bubbles	[illegible]	Did you watch	[illegible]
cat's tail	[illegible]	Enjoy the dinner!	[illegible]
have an afternoon nap	[illegible]	He is in enough trouble	[illegible]
I almost always have	[illegible]	He is outside.	[illegible]
supported by	[illegible]	I do believe	[illegible]

Curriculum Vitae
Brittany C. Putnam

EDUCATION

B.A. 2011 Fairfield University, Fairfield, CT. Psychology and French, Magna Cum Laude. Honors Thesis: Decreasing echolalia in a 9-year-old boy on the autism spectrum (Advisor: W. Ronald Salafia, Ph.D.)

M.S. 2013 University of Wisconsin-Milwaukee, Milwaukee, WI. Experimental Psychology with an emphasis in Behavior Analysis. Thesis: Teaching braille letters, numbers, punctuation, and contractions to sighted individuals (Advisor: Jeffrey H. Tiger, Ph.D.)

Ph.D. 2015 University of Wisconsin-Milwaukee, Milwaukee, WI. Experimental Psychology with an emphasis in Behavior Analysis. Dissertation: Teaching sighted students to read braille visually (Advisor: Jeffrey H. Tiger, Ph.D.)

PROFESSIONAL CERTIFICATION AND LICENSURE

Board Certified Behavior Analyst, BACB Certification Number 1-14-15278, February 2014

PROFESSIONAL ORGANIZATION MEMBERSHIP

2009 Student Member, Berkshire Association for Behavior Analysis and Therapy

2010- Student Member, Association for Behavior Analysis International

2012- Student Member, Wisconsin Association for Behavior Analysis

2012-2013 Student Member, Mid-American Association for Behavior Analysis

PROFESSIONAL POSITIONS

2010-2011 **Student Intern at Achieve Fluency**, Stamford, CT
Performed one-on-one teaching sessions with children with autism and other developmental disabilities both under direct supervision of program directors Christine Cukar-Capizzi and Danusia Pawska and independently. Additional responsibilities included collecting data, graphing student progress, assisting in program development by creating academic materials, researching and applying for insurance coverage of ABA services.

2011- **Graduate Project Assistant**, UW-Milwaukee, Milwaukee, WI.

2015 Providing behavior-analytic services for children with autism spectrum disorders under the supervision of Dr. Jeffrey Tiger, Ph.D. Responsibilities include conducting and interpreting functional analyses of problem behavior, developing treatment plans, implementing behavior-change procedures, conducting parent and teacher training, and assisting in the discharge process. Additional responsibilities include participating in the development of research projects within the lab and assisting in development of computer software to teach sighted individuals to read braille visually.

2012- **Behavior Therapist**, Tiger Center for ABA, Milwaukee, WI
2015 Providing behavior analytic services for children with autism spectrum disorders under the supervision of Dr. Jeffrey Tiger, Ph.D. Responsibilities include conducting and interpreting functional analyses of problem behavior, developing treatment plans, implementing behavior-change procedures, conducting parent and teacher training, and assisting in the discharge process.

2014- **LEND-Milwaukee Link Psychology Student Trainee,** Milwaukee, WI
2015 Leadership Education in Neurodevelopmental and Related Disorders (LEND) is an interdisciplinary training program funded by the Maternal and Child Health (MCH) Bureau. The focus of this program is to improve the services provided to individuals with disabilities and their families by educating future practitioners about specific disabilities and promoting an interdisciplinary approach to treatment. LEND consists of leadership trainings, weekly seminars related to specific disabilities, interdisciplinary research teams, experience with policy and advocacy for issues related to disability, and a weekly interdisciplinary clinic focusing on the diagnosis of autism spectrum disorders.

AWARDS AND HONORS

2011 UWM John and Lynn Schiek Research Fellowship

2012 UWM John and Lynn Schiek Research Fellowship
2013 UWM John and Lynn Schiek Research Fellowship

GRANTS

2012 UWM John and Lynn Schiek Research Grant

2013 UWM John and Lynn Schiek Research Grant

2014 UWM John and Lynn Schiek Research Grant

EDITORIAL SERVICE

Guest Reviewer
Journal of Applied Behavior Analysis

PUBLICATIONS

Tiger, J. H., Putnam, B. C., & Peplinski, C. S. (2014). Operant conditioning in developmental disabilities. In F. K. McSweeney and E. S. Murphy (Eds). *The Wiley Blackwell Handbook of Operant and Classical Conditioning* (pp. 559-580). Hoboken, NJ: Wiley-Blackwell.

Putnam, B. C. & Tiger, J. H. (in press). Teaching braille letters, numbers, punctuations, and contractions to sighted individuals. *Journal of Applied Behavior Analysis.*

Putnam, B. C. & Tiger, J. H. (In Preparation). Immediate and distal effects of supplemental food and fluid delivery on rumination.

Putnam, B. C. & Tiger, J. H. (In Preparation). Developing stimulus control over stereotypic behavior.

Putnam, B. C. & Tiger, J. H. (In Preparation). Teaching Sighted Students to Read Braille Visually.

PRESENTATIONS

Putnam, B. C., & Tiger, J. H. (2013, August). *Immediate and distal effects of food and fluid delivery on rumination.* Poster presented at the meeting of the Wisconsin Association for Behavior Analysis, Madison, WI. Also presented at the meeting of the Mid-American Association for Behavior Analysis, Milwaukee, WI, 2013, October.

Putnam, B. C., Geiger, H. M., & Tiger, J. H. (2014, March). *Immediate and distal effects of supplemental food and fluid delivery on rumination.* Poster presented at the Association of Professional Behavior Analysts Conference, New Orleans, Louisiana. Also presented at the meeting of the Association for Behavior Analysis International Conference, Chicago, Illinois, 2014, May.

Putnam, B. C. & Tiger, J. H. (2014, March). *Developing stimulus control over stereotypic behavior within a multiple schedule*. Symposium presented at the Association of Professional Behavior Analysts Conference, New Orleans, Louisiana. Also presented at the meeting of the Association for Behavior Analysis International Conference, Chicago, Illinois, 2014, May and at the Wisconsin Association for Behavior Analysis Conference, Madison, Wisconsin, 2014, August.

Putnam, B. C. & Tiger, J. H. (2014, August). *Teaching braille letters, numbers, punctuation, and contractions to sighted individuals*. Poster presented at the Wisconsin Association for Behavior Analysis Conference, Madison, Wisconsin, 2014, August. To be presented at the Association for Behavior Analysis International Conference, San Antonio, TX, 2015, May.