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Examining a Novel Response Modality: Teaching Sighted Individuals to Read Braille Visually

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EXAMINING A NOVEL RESPONSE MODALITY: TEACHING SIGHTED INDIVIDUALS TO READ BRAILLE VISUALLY

by

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ABSTRACT

EXAMINING A NOVEL RESPONSE MODALITY: TEACHING SIGHTED INDIVIDUALS TO READ BRAILLE VISUALLY

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Under the Supervision of Professor Jeffrey Tiger

In order to prepare teachers to instruct children with visual impairments in braille, previous research has taught sighted adults to match braille sample stimuli to print comparisons in a matching-to-sample (MTS) format and has assessed the emergence of other braille repertoires such as transcribing and reading following this training. Although participants have learned to match-to-sample with braille, they displayed limited emergence of other braille repertoires. This lack of generative responding may have resulted from participants' over-selective attending to components of compound braille characters during instruction. The current study taught three undergraduate learners to construct braille characters given a print sample—which required attending to each individual braille symbol—and again assessed generative braille responding. All participants met mastery of 378 braille construction responses and demonstrated superior generative responding across tests of transcribing braille than shown in previous research.

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Braille education provides the opportunity for individuals with severe visual impairment to develop literacy through their tactile senses. Visually impaired individuals who are fluent braille readers are typically more independent and more professionally successful than those who lack braille literacy (National Federation of the Blind, 2009). Due in part to these outcomes, access to braille education is mandated for all public-school students with a visual impairment per the Individuals with Disabilities Education Act (1997).

Despite this mandate, many schools fail to provide adequate braille education to their students. This is likely due at least in part to the cost associated with printed braille materials, but there is also a significant lack of individuals qualified to provide braille instruction (National Federation of the Blind, 2009). As a result, many school districts rely on itinerant braille instructors to service multiple schools and place daily braille education responsibility on general or special education teachers who are typically unfamiliar with the braille code. Many of these teachers elect alternative teaching methodologies including large print books or auditory presentation of material alone, and thus omit regular braille instruction from students' curriculum (National Center for Education Statistics, 2013).

Although there are numerous practical challenges associated with providing braille instruction, the omission of braille in these circumstances violates students' rights under IDEA and ensures a life of illiteracy for the students. The long-term solution to this complicated problem is to increase the number of braille-certified teachers in each district; however, this is unlikely in the near future. A more tenable short-term solution may be to develop improved braille proficiency for those general or special education teachers with daily contact with visually impaired students. With at least a rudimentary understanding of braille, these teachers could incorporate additional braille instruction while teaching their students. Recent research has begun evaluating programmed instruction to teach early level braille relations to sighted adults.

Scheithauer and Tiger (2012) taught four sighted college students the 26 braille counterparts to the English alphabet through a computer-based matching-to-sample (MTS) program. On each trial, the program presented a braille stimulus and participants selected the print equivalent from a multiple-choice array of five to six letters. The program provided immediate feedback for all responses and required error correction trials for incorrect responses. This training was introduced across five letter sets and the training program sequentially taught each set to mastery. Students were able to complete the program in a mean time of just over 30 min. These results were replicated with a larger sample of 81 participants in Scheithauer, Tiger, and Miller (2013). Putnam and Tiger (2015) extended this research to include teaching procedures for training the braille correspondents of not only the English alphabet, but also numerals, punctuation, grammatical symbols, and contractions separated into six modules using a similar computer-based matching-to-sample format. This study was conducted with four sighted college students who mastered all modules in a mean time of 2 hr 5 min.

Braille character recognition as targeted in these previous studies is an important skill, but bears little resemblance to the skills ultimately required of a braille teacher. In particular, teaching children with visual impairments will require teachers to transcribe print materials into braille for their students use and to read braille materials generated by their students. The practical value of the MTS training described previously will be determined by the extent to which it results in the development of these more important braille repertoires.

Putnam and Tiger (2016) assessed the emergence of these repertoires following MTS training. Specifically, their research assessed the untrained emergence of braille-to-print character transcription, braille-to-print sentence transcription, print-to-braille character transcription, and emergent braille reading following completion of braille-to-print MTS training. Although participants demonstrated mastery of the trained braille-to-print MTS relations, there was a limited emergence of these other important repertoires. In particular, participants tended to show strong generative emergence of relations involving one or a few braille characters (e.g., letters) but far less generative emergence of relations involving multiple braille characters (e.g., contractions, words, and sentences). This pattern indicated that a deficit of generative emergence may have resulted from poorly developed stimulus control caused by the MTS training. More plainly, the MTS procedure involved presenting braille stimuli and allowing participants to select from a comparison array of print options. When presented with a compound braille stimuli (i.e., those composed of two or more individual braille characters), it was possible for participants to make discriminations based upon individual characters rather than attending to the corpus of characters that composed the braille unit. For instance, when presented participants with ⠍⠁⠛⠊⠉ as a sample, and “likes,” “magic,” “movie,” “quail,” and “recall” as response options, participants could have consistently and accurately selected “magic” by attending only to the braille equivalents for “m” and “a.” If this were the case, it is not surprising that when presented with “magic” as a sample during a generative responding assessment, participants would have demonstrated difficulty producing the braille stimuli to which they had not been required to attend.

This over-attention to individual components of compound stimuli is commonly referred to as stimulus overselectivity (Dickson, Deutsch, Wang, & Dube, 2006; Dickson, Wang, Lombard, & Dube, 2006; Dube, Balsamo, Fowler, Dickson, Lombard, & Tomanari, 2006) and has been seen when teaching sight words to novice readers. In such cases, it is necessary to design an intervention to ensure that participants attend to each element of the compound sample stimulus. Walpole, Roscoe, and Dube (2007) accomplished this by requiring a differential observing response (DOR) while teaching sight words. Specifically, the researchers required participants to point to each component letter in a sample sight word. In the case of braille, a DOR in which participants are required to point to each dot in a braille sample prior to presenting the comparison stimulus array may ensure they are attending.

One could also program DORs for braille stimuli by changing the response modality of training from an MTS selection response to a braille construction response. That is, rather than conducting training of the braille stimulus as a sample, one could present the print stimulus as a sample and require participants to create the braille equivalents (i.e., by shading in a braille grid). In order to be scored as correct during training, respondents would need to accurately shade each braille dot, therefore ensuring attention to each. If the limited generative responding observed in Putnam and Tiger (2016) was a result of selective attending to braille stimuli, then ensuring an observing response to each braille character should promote robust generative responding. We designed the current study to evaluate the emergence of braille relations that would be important to teachers following a training of the print-to-braille relation. Similar to Putnam and Tiger (2016), we included 378 print-to-braille relations of letters, words, contractions, numerals, grammatical symbols and phrases. Unlike Putnam and Tiger, we conducted our training using paper-and-pencil worksheets rather than a computer-based training program to identify the utility of this approach with low-tech means prior to investing resources in software writing.

Method

Participants, Setting, and Materials

We recruited five undergraduate students through the University's online research participation pool. Of those initial five participants, one terminated their participation after the first appointment, and her results are not reported. One participant, Sam, dropped out part way through training with the 8^{th} module (roughly 75% of the study completed), and we report data for all modules that she completed. The remaining three participants, Taylor, Marie, and Shannon, completed all aspects of the study. The participants were all female between 21 and 22 years of age. All participants demonstrated print reading fluency greater than 12.9 grade level, which we assessed as inclusionary criterion described below. Individual Standard Scores for Oral Reading Rate were 104, 107, 107, and 107; Oral Reading Accuracy Standard Scores were 119, 97, 92, and 92; and Oral Reading Fluency Standard Scores were 106, 107, 107, and 107 for Sam, Taylor, Marie, and Shannon respectively. We selected undergraduates because they were demographically similar to the teachers for whom this training is ultimately intended.

Participants attended one to three appointments per week with a total of 11 appointments. Participants signed up for the first appointment on an online portal and then subsequently scheduled the other 10 appointments with the Student PI at the end of the first appointment. In the event a participant had to leave an appointment prematurely (e.g., attending class) and did not wish to withdraw from the study, we provided the option to schedule an additional appointment to finish an incomplete module. This occurred once for Marie and twice for Sam, the participant who withdrew during Module 8. We compensated participants $10 for each appointment attended (participants were paid again if they had to return to complete a module) as well as a $25 bonus at the end of the study when they completed all the appointments.

We conducted all appointments in an office with minimal distractions. Braille stimuli were presented on a series of worksheets that we presented to participants through a slider. The slider was made from laminated paper and contained an empty space large enough to show relevant stimuli one trial at a time. It was secured to the desk by two sides with an opening at the top and left side, through which each worksheet slid. Participants made responses on these worksheets using a pencil. For assessments requiring a vocal response, the experimenter audio recorded participants' responses using a laptop computer. A member of the research team was present to administer all training and assessment procedures.

Assessments: Dependent Variables, Measurement, and Interobserver Agreement (IOA).

At the beginning of the first appointment, the researcher briefed the participant on the purpose of the study and received written consent for participation and audio recording. During each of the first 10 appointments, participants completed a single training module. During select appointments (noted below) the participant also completed a number of assessments including oral reading fluency with print, oral reading fluency with braille, transcription of braille into print characters, transcription of print into braille characters, and translation of braille sentences into print. The purpose, methods, frequency, and IOA measures of each assessment are discussed below.

Oral reading fluency (ORF) – print (Prerequisite assessment). To assess oral reading fluency of printed English, the experimenter administered ORF subtest of the Wechsler Individual Achievement Test III (WIAT III; Psychological Corporation, 2009). The participant was given two 9-12th grade equivalent reading tests to determine if they were reading at the equivalent of a high school level. Participants were required to score above a Standard Score of 95; failure to meet this requirement resulted in exclusion from the study. This cut-off was selected as equivalent in difficulty to the braille passages we used to assess emergent braille reading.

Participants were asked to read the print passages aloud while the researcher scored according to the WIAT III administration materials. Each word was scored as correct, an error of commission (i.e., adding a word or phrase) or an error of omission (i.e., words that were provided to the participant, or substitutions, omissions, or transpositions of words in the passage). This assessment was administered once during the first appointment to assess the English reading ability of the participants.

A second observer scored audio recordings from 75% of WIAT III administrations to assess IOA. We compared both observers scoring records on a word-by word basis and divided the number of words in agreement by the total number of words in the passage and converted it to a percentage. IOA for the WIAT III ORF pre-assessment was 99.92% (Range 99.5%-100%).

Transcription of print to braille (Trained relations assessment). We administered a paper and pencil examination in which participants were asked to transcribe 20 print stimuli, made up of 2 stimuli randomly selected from each module, into their braille counterparts by filling in a braille grid (see Appendix A). We created 5 unique versions of this probe to ensure an adequate sampling of stimuli. We administered this assessment prior to training in appointment 1, after training during appointments 2, 5, and 8, and after the final training on appointment 10, allowing us to assess the direct effects of training in a multiple probe design across participants.

Each item was scored by a coder as either correct or incorrect, with skipped items counting as incorrect responses. A second coder independently scored 89% of assessments and compared results with the initial coder on an item-by-item basis. Coders agreed on 100% items.

Transcription of braille characters to print (generative responding assessment). Participants completed a worksheet that contained 50 braille stimuli, five items randomly selected from each of 10 modules, by transcribing the stimuli into printed English (see Appendix B). We created five unique versions of this probe to provide a broad sample of braille stimuli. Experimenters administered this probe prior to training in appointment 1, after training in appointments 2, 5, and 8, and after the final training on appointment 10. This conformed to a multiple-probe design across training modules and assessed the generative development of this skill.

Each item was scored by a coder as either correct or incorrect, with skipped items counting as incorrect responses. A second coder independently scored 89% of assessments and we compared results on an item by item basis. We divided the total number of items in agreement by the total number of items within the assessment and converted the quotient into a percentage; coders agreed on 100% of items.

Transcription of braille sentences to print (generative responding assessment). We assessed the untrained emergence of braille-to-print transcription by presenting participants with worksheets containing 15 sentences written in braille and comprised of components taught in the individual training modules (see Appendix C). Participants transcribed these 15 sentences into print in space provided on their worksheet. We conducted this test during the first and eleventh sessions as a pre- and post-training assessment of generative braille responding. We scored each item comprising a sentence (i.e., capitalization, letters, contractions, punctuation, etc.) as correct or incorrect. A second coder rescored 62% of these assessments independently to assess IOA. We compared the coders' records on an item-by-item basis; they agreed on 100% of items.

Oral reading fluency - braille (generative responding assessment). We assessed oral reading fluency with braille by having participants read a braille passage aloud, similar to those included on the Braille Certification exam, for up to 5 min (see Appendix D). The experimenter scored the accuracy of individual components including words, numbers, punctuation, grammatical symbols, and composition signs (see Appendix E). Participants were required to read items as they appeared in the passage presented in braille (e.g. indicating capitalization of a letter before reading the word). This assessment was administered once during the first visit (prior to any braille training) and once during the eleventh appointment (following completion of all braille training) giving us a pre-test and post-test measure of this skill.

We audio recorded these assessments to collect IOA measures. Each individual item was scored as either correct or incorrect, with skipped items counting as incorrect responses. A second coder scored 62% of these assessments and we compared coders records on an item-by-item basis; these records agreed on 100% of items.

Training Procedures

During each of the first 10 appointments, participants completed one training module. Each module was divided into five to nine subsets, each containing four to six target stimuli (see Appendix F). We assigned stimuli to these subsets based on the number of braille characters present in each word or contraction and overall visual similarity between items in order to promote discrimination among stimuli; these stimulus groupings are identical to those used in Putnam and Tiger (2016). Within a session, each stimulus from the targeted subset was presented three times in a random order. We considered a subset mastered when participants accurately transcribed greater than 90% of those target stimuli during a single session. Following mastery of the first subset, subsequent sessions also contained one presentation of each previously mastered stimulus within that module to provide incremental rehearsal; however, these rehearsal items were not factored into the mastery criteria for that subset. The number of trials within a session varied based upon the number of items within the subset and grew incrementally within modules as each new subset was introduced.

Module 1 (*Letters*) taught the 26 English letters and their corresponding braille stimuli. The module was divided into five subsets with five to six stimuli in each. Module 2 (*Combination of Letters in to Words without Contractions*) taught 30 words comprised of previously learned letters. This module was divided into six subsets with five stimuli in each.

Module 3 (*Contractions 1*) taught 37 contractions for common letter combinations. This module was split into seven subsets with four to six target stimuli in each. Module 4 (*Contractions 2*) taught 54 common braille contractions used for words. This module was split into nine subsets with six stimuli in each. Module 5 (*Combination of Letters and Contractions into Words*) taught 30 words that included the common braille contractions taught to this point. This module was split into six subsets with five stimuli in each.

Module 6 (*Contractions 3*) taught 53 additional braille contractions for words. This module was divided into 9 subsets with five to six stimuli in each. Module 7 (*Numerals, Punctuation, Symbols, and Composition Signs*) taught 42 numerals, punctuation marks, symbols, and composition signs. This module was split into eight subsets with five to six stimuli each. Module 8 (*Combination of Letters, Contractions, Numerals, Punctuation, Symbols, and Composition Signs*) taught 30 combinations of previously mastered stimuli. This module was divided into six subsets with five stimuli in each.

Module 9 (*Contractions 4*) taught a final group of 46 common braille contractions for words. This module was split into 8 subsets with five to six stimuli in each. The final module,

Module 10 (*Combination of Previously Learned Characters into Sentences and Phrases*) taught 30 common sentences and phrases that combined all previously learned concepts. This module was divided into six subsets with five stimuli in each.

Direct Training. In each training session, the experimenter presented participants with a worksheet, a pencil, and a slider used to present only one stimulus at a time. The worksheet contained multiple rows of print stimuli and blank braille grids (e.g., a row of 3-by-2 matrices). The slider was modeled after Skinner's GLIDER (Skinner, 1968) to present one stimulus at a time during teaching trials. On each trial, the participant created braille characters within the provided grid and then slid the worksheet through the slider to reveal the correct response. If the participant's response was correct, they moved on the next stimulus by sliding the worksheet again. If they were incorrect, they re-wrote the correct stimulus in another braille grid provided adjacent to the depicted correct answer (see Appendix G). The experimenter observed participants throughout this process to ensure their fidelity with this procedure (i.e., the experimenter prompted participants to correct errors if necessary and ensured they did not advance the slider to reveal the correct answer prior to responding). Once the participant completed a worksheet, the researcher either provided the next worksheet within that subset, or corrected the completed subset to determine mastery. If the participant reached mastery levels (90% or greater correct among target stimuli), they advanced to the next subset. If they had not met mastery criterion, the experimenter then presented either a different variation of the same subset (i.e., we re-randomized stimulus-presentation order to prevent faulty stimulus control) until the participant responded with correct braille transcriptions in 90% or more trials within a session.

Results

Completion of the training modules

Participants met mastery criteria for each training module attempted, except Sam who withdrew prior to completing Module 8. Thus, this version of braille training was successful in teaching 378 print-to-braille relations to mastery levels. The total assessment was completed in a mean of 35.7 calendar days per participant (range, 24 to 43 days) with the mean total training time of 14:57:37 (range 10:39:48 sec 18:15:16 sec). The training duration for individual modules is presented in Table 1; note that these data indicate the time spent completing training modules; not participating in pre- and post-training assessments.

Trained relations and generative responding assessments

Transcription of print to braille (trained relation). This assessment involved the presentation of 20 print stimuli, two from each module, from which participants transcribed braille equivalents by filling in a grid without feedback. Participant responding in these probes is depicted in Figure 1 with participants arranged in columns and modules arranged in rows. Taylor, Marie, and Shannon were the three participants who completed all training and their performances are presented in the first three columns; Sam's performance, who withdrew during Module 8 training, is depicted in the fourth column. We also summarized these data into Figure 2, which presents the mean pre- and post-training results for each module across participants. Pre-training probes occasioned zero correct responding across all modules and participants (except for 1 correct response by Taylor in Module 10) indicating no participant was capable of producing accurate braille characters prior to training. Following Module 1 training, performance immediately increased to and maintained at nearly 100% correct responding (*M* =

96.4%; range, 87.5% to 100%). There were similar patterns following training of the first combination module, Module 2, with 100% correct responding.

Module 3 training produced more variable results (*M* = 40%; range, 0% to 83.3%). Taylor and Shannon responded at 83.3% and 50% correct, respectively; whereas Marie and Sam did not engage in any correct responding. Module 4 training produced 70% correct responding across participants (range, 33% to 100%). Participants responded at elevated levels to Module 5 stimuli following training (*M* = 85%; range, 83.3% to 100%).

Participants responded the lowest overall following training on Module 6 (*M* = 25%; range, 0% to 75%). Taylor responded at 75% correct across probes, but Marie and Shannon responded at 0% post-training. Module 7 training produced higher outcomes (*M* = 83.3%; range, 75% to 100%). Each participant responded 75% correct to Module 8 stimuli following training.

Taylor responded with 100% accuracy on Module 9, but Shannon and Marie responded at zero levels. Module 10, the final combination module that included samples from all previously learned modules, saw 100% correct responding following training with each participant. In Figure 3, we reproduced the post-training results from Putnam and Tiger (2016) with the results from our current study for comparison. Participants in our study equaled or exceeded the performance of those in Putnam and Tiger (2016) in each module.

Transcription of braille to print (generative assessment). This assessment included 5 stimuli drawn from each of the 10 training modules, totaling 50 stimuli, from which participants were given a braille stimulus and asked to produce the written English counterpart. Individual participants' results from this assessment are depicted in Figure 4 with a summary figure presented in Figure 5. Across all modules there was no correct responding during pre-training except for 1 trial of a Module 5 stimulus for Marie and one session with 100% correct to Module

10 stimuli for Taylor. Following training, correct responding increased in each module to 74.3% (range, 55% to 95%) in Module 1, 77.1% (range, 60% to 90%) in Module 2, 38% (range, 20% to 66.7%) in Module 3, 36% (range, 13.3% to 66.7%) in Module 4, 64% (range, 53.3% to 66.7%) in Module 5, 33.3% (range, 10% to 70%) in Module 6, 60% (range, 40% to 90%) in Module 7, 80% (range, 60% to 100%) in Module 8, 73.3% (range, 40% to 100%) in Module 9, and 86.7% (range, 80% to 100%) in Module 10. In Figure 6, we present our post-training data for this assessment in comparison to those of Putnam and Tiger (2016), with the note that braille-to-print served as the directly trained relation in this previous study, but as a generative relation in the current study. Participants in Putnam and Tiger scored higher following training in Modules 1, 2, 4, and 5 whereas participants in the current study scored higher in modules 3, 6, 7, 8, 9, and 10.

Transcription of braille sentences to print. This assessment involved 15 complete sentences in braille to which participants responded by producing the print equivalents. The pre- and post-training results of this assessment are depicted in Figure 7. No participant engaged in correct transcription during pre-training, but after completing the print-to-braille construction training, Taylor, Marie, and Shannon correctly transcribed 97.3%, 78.9%, and 50.9% respectively. For comparison, the four participants in Putnam and Tiger (2015) transcribed a mean of 84% of sentences correctly (range, 73.9% to 96.9%). This is depicted graphically in Figure 8.

Oral reading fluency – braille. This assessment asked participants to read as much of a passage written entirely in braille as they could with a time limit of 5 min. The results of this assessment are depicted in Figure 9. All participants read 0 of the 202 possible items correctly at the pre-training assessment. Following training, Taylor, Marie, and Shannon read 39, 30, and 15 items, respectively. For comparison, the four participants in Putnam and Tiger (2015) read a mean of 32 items correctly (range, 16 to 55). These results are depicted graphically in Figure 10.

Discussion

The current study evaluated the emergence of generative braille relations when participants were taught to construct braille characters given print samples. Three participants completed this training in its entirety and demonstrated mastery level performance of 378 print-to-braille relations. This training also resulted in the untrained (generative) emergence of braille-to-print selection, transcription of braille sentences, and oral reading of braille. These results were similar to that of Putnam and Tiger (2016) demonstrating the untrained emergence of braille repertoires following instruction in a single relation.

This study differed from Putnam and Tiger (2016) and all previous research in this area by training the print-to-braille relation, requiring a construction response, in lieu of targeting the braille-to-print relation, requiring a selection response (Scheithauer & Tiger, 2012; Scheithauer, Tiger, & Miller, 2013; Putnam & Tiger, 2015; 2016). Putnam and Tiger (2016), in particular, evaluated the emergence of generative repertoires following braille-to-print MTS training and found that although those other important braille repertoires emerged, the levels of generative responding were too low to be useful in practice. The authors hypothesized that this may have been due to a failure of learners to attend to individual components of complex braille stimuli. Our targeting a construction of the braille character was designed to address this limitation. Thus, it is worthwhile to compare the outcomes observed in the current study to those of Putnam and Tiger.

First, and not surprisingly, the current iteration of the study took longer for individual participants to complete. Individual training times for each participant across modules is depicted in Figure 11. The longest mean completion time for a single module for Putnam and Tiger (2016) was just under 42 min, whereas the shortest mean completion time for a single module in the current study was 40 min with some modules requiring more than 3 hours to complete. Comparison data across the two studies are depicted in Figure 12. These longer completion times were expected in that physically constructing multiple braille characters during a trial is considerably more effortful and time consuming than selecting a single stimulus from a computerized array. The current study was also slowed by the manual sliding of worksheets by the participant and transition of worksheets by the experimenter. It is likely that a similarly computerized version of the current procedures, in which a participant could fill in a braille grid using a mouse or touch screen, would add to this procedure's efficiency by eliminated the manual slider. However, we would still expect longer training times than the simple match-to-sample response required by Putnam and Tiger (2016). These longer training times would need to be considered in the cost-benefit ratio should the current procedures result in superior generative braille repertoires.

In terms of the development of a print-to-braille repertoire, an assay of teachers' ability to produce braille content for their students, the current procedures resulted in far superior development to those of Putnam and Tiger (2016). These differences were most notable in Modules 4 (Contractions), 5 (Combination of letters and contractions into words), 7 (Numerals, punctuation, symbols and composition signs), 8 (Combination of letters, contractions, numerals, punctuation, symbols, and composition signs), and 10 (Combination of characters into short sentences and phrases). Each of these modules included compound stimuli to which learners needed to attend during training to perform at high levels during post-training.

In terms of the development of a braille-to-print repertoire, an assay of teachers' abilities to grade their students' work, the current procedures resulted in comparable outcomes to those of Putnam and Tiger (2016) with somewhat higher performance levels in Modules 7, 8, 9, and 10. Again, these particular modules included the greatest proportion of compound stimuli.

In terms of the development of braille sentence transcription and oral braille reading, the results of our current study and Putnam and Tiger were equivocal (see figures 8 and 10). Thus, the current procedures took considerably longer to complete training, but the results of training were equal to or greater than Putnam and Tiger in all outcome measures.

Given the superior outcomes associated with the current procedure, it is reasonable to question if these skill gains are offset by the added time required to complete training. For instance, Sam withdrew from participation following more than 3 hrs of training on Module 8 in the current study, citing her extended training times. She consistently required about 2 hours to complete a training module and nearly 4 hours to complete Module 3. There are likely motivational differences to learn braille between teachers and undergraduate psychology majors that could promote greater persistence among the target population for this training program, but exceedingly high-effort programs are unlikely to be adopted. We offer a few recommendations that may enhance future efficiency. First, at the onset of each module, we provided participants with a training sheet with correct answers outside of the slider to review the target relations, but we did not require participants to respond to these stimuli. Future studies may require participants to respond to these worksheets accurately prior to advancing in training, similar to how many errorless training programs begin with an immediate prompt (Wolery & Gast, 1984). This modification may then reduce the number of errors early in training that prolong training times. Second, participant fatigue may have played a role during these extended training sessions, both psychological and physical (from bubbling in the worksheets). It may be appropriate to either (a) set a time limit for each training sitting and break individual modules into multiple sittings or (b) break up modules into smaller units. The latter solution may create more clustered practice of stimuli within subsets with fewer interspersed mastered stimuli (Knutson & Kodak, unpublished manuscript) and thus enhance acquisition. Finally, the computerization of this task should minimize training time by eliminating delays in sliding, replacing, and scoring worksheets.

Although participants' performances improved relative to prior research, we are still obtaining fairly low levels of correct responding to some modules, notably modules 3, 6, and 9, which each target braille contractions. All participants met mastery criteria during training with these stimuli, but their performance did not maintain during post-training assessments. It is not clear as to why these modules' accuracy was low, whereas Module 4 (which also targets contractions) and Modules 5, 8, and 10's (which target combinations of these contractions with other stimuli) accuracy were higher. It is possible that these results are due in part to sampling a small number of relevant stimuli from each module (i.e., sampling error). We feel more appropriately conservative interpretations are that the training procedures were not establishing sufficient stimulus control to promote maintenance, or that the stimuli presented in subsequent modules disrupted established stimulus control. That is, after mastering a module, participants no longer received training or exposure to those stimuli, except when they appeared combined with other stimuli in combination modules. As new modules were introduced that shared stimulus features, it is possible that participants responding generalized across shared stimulus features rather than remained discriminated across unique characteristics.

Given the data from this evaluation and from Putnam and Tiger (2016), it appears that continued rehearsal of mastered stimuli with feedback may be necessary to maintain stimulus control and to teach discrimination between stimuli with shared features presented across modules. These rehearsals may be incorporated into training sessions, similar to the incremental rehearsal within modules, but instead would program incremental rehearsal across modules (e.g., training in Module 5 would involve responding to a sampling of stimuli from Modules 1 through 4). Note, however, that this modification is incompatible with attempts to enhance the efficiency of this program. Perhaps the ideal strategy will be to develop a fully effective training program first, and then subsequently work to improve its efficiency.

Although the current procedure resulted in improved tests of braille and print construction relative to Putnam and Tiger (2016), we did not see any notable improvements in the tests of sentence transcription or oral reading. It is likely the case that improving these latter repertoires depends upon the translation of contractions that were not maintaining in the former assessments. Thus, the goal of our continued research efforts will be to develop those contraction repertoires, to assess further generalization, to maximize the efficiency of this instruction to prepare teachers to serve this critically underserved population, and to assess the social validity of this training and its outcomes with these consumers.

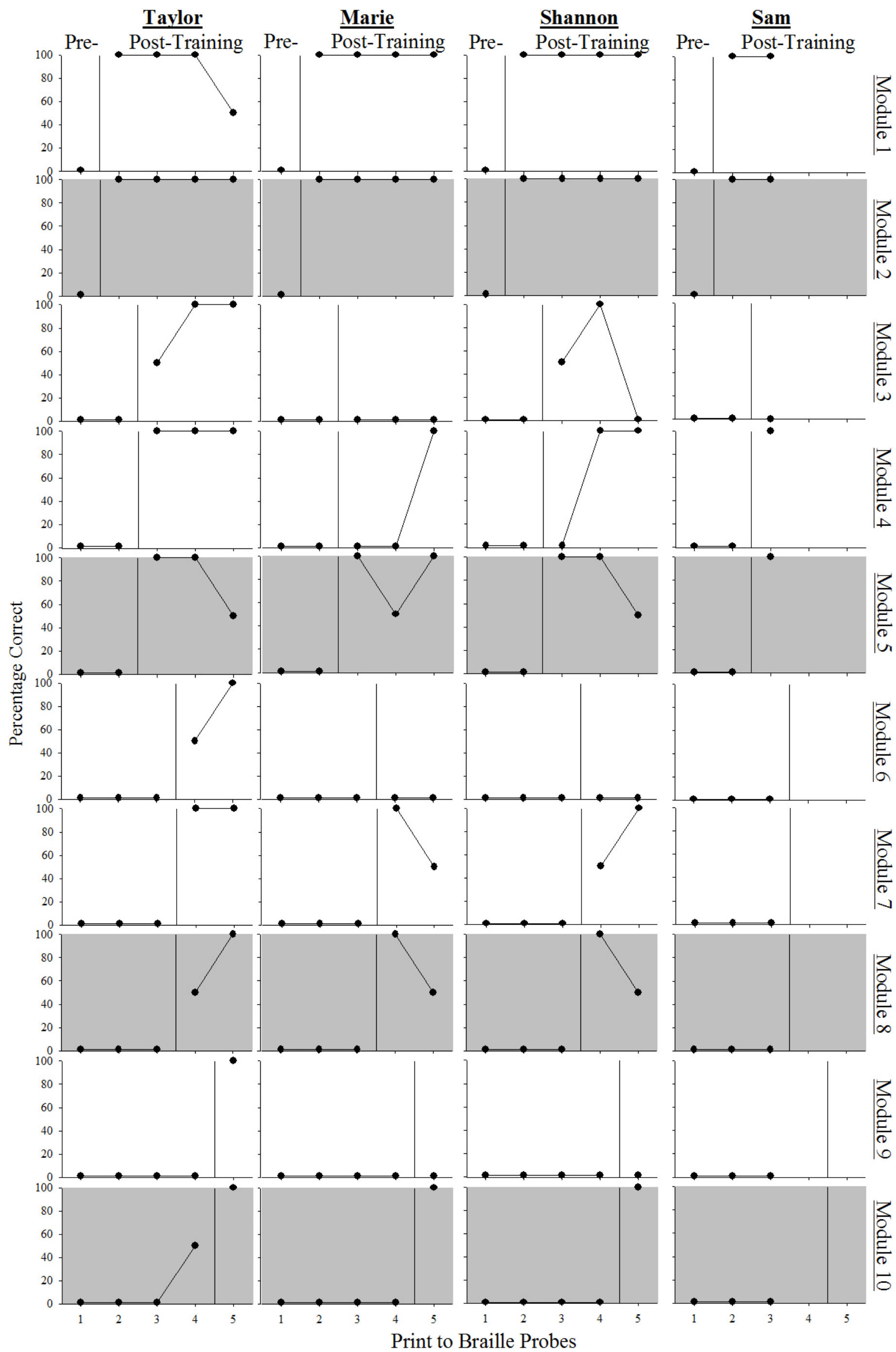

Figure 1. Results of participant scores of the transcription of print to braille trained relations assessment probe. These data depict the percentage correct of stimuli selected from each training module (represented across rows) across participants (shown in columns). Shaded panels represent modules that targeted combinations of previously mastered stimuli.

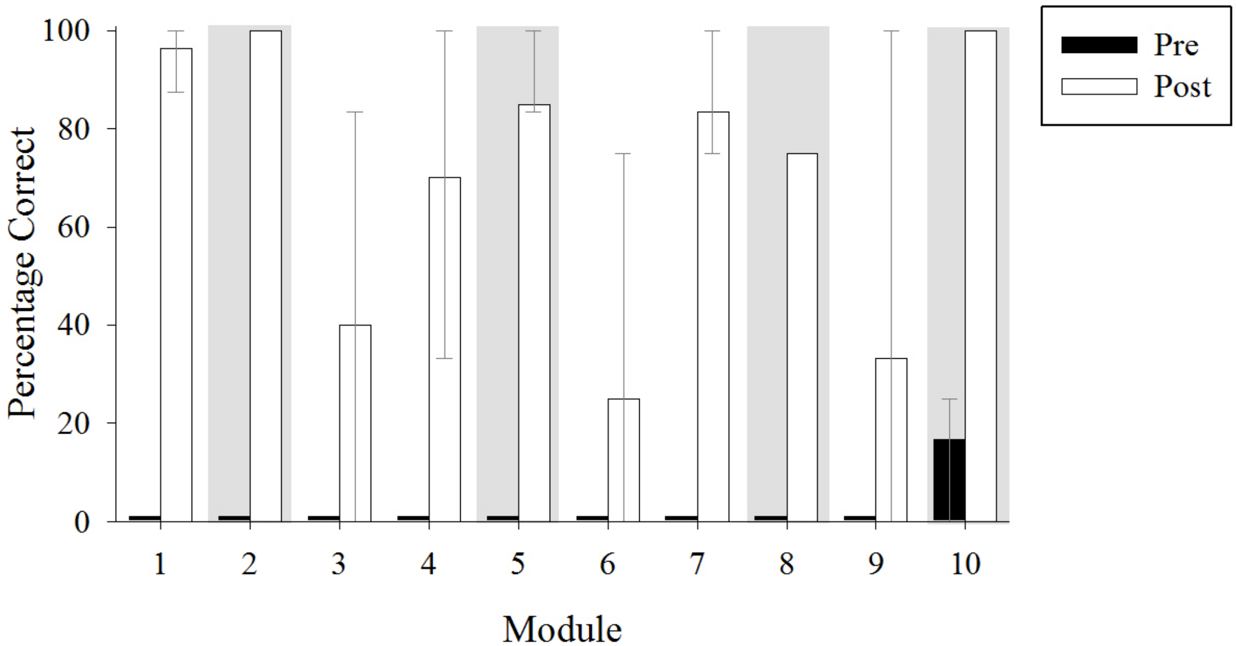

Figure 2. Summary of results from the transcription of print to braille trained relations assessment probe. These data depict the mean responding across pre-test and post-test conditions for each module.

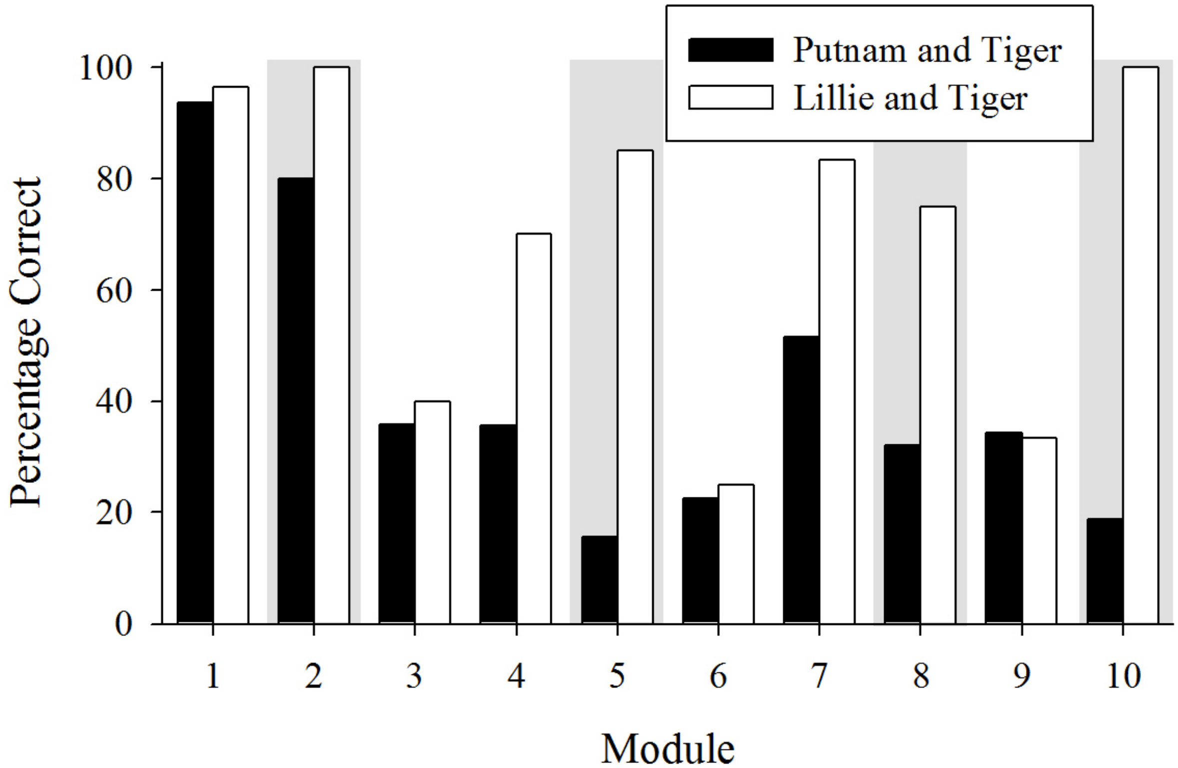

Figure 3. Summary results from the print to braille trained relation assessment compared to the same probes used following a MTS training format (Putnam & Tiger, 2016). These data depict mean post-test responding across modules for both the current study and Putnam & Tiger (2016). Shaded panels represent modules that targeted combinations of previously mastered stimuli.

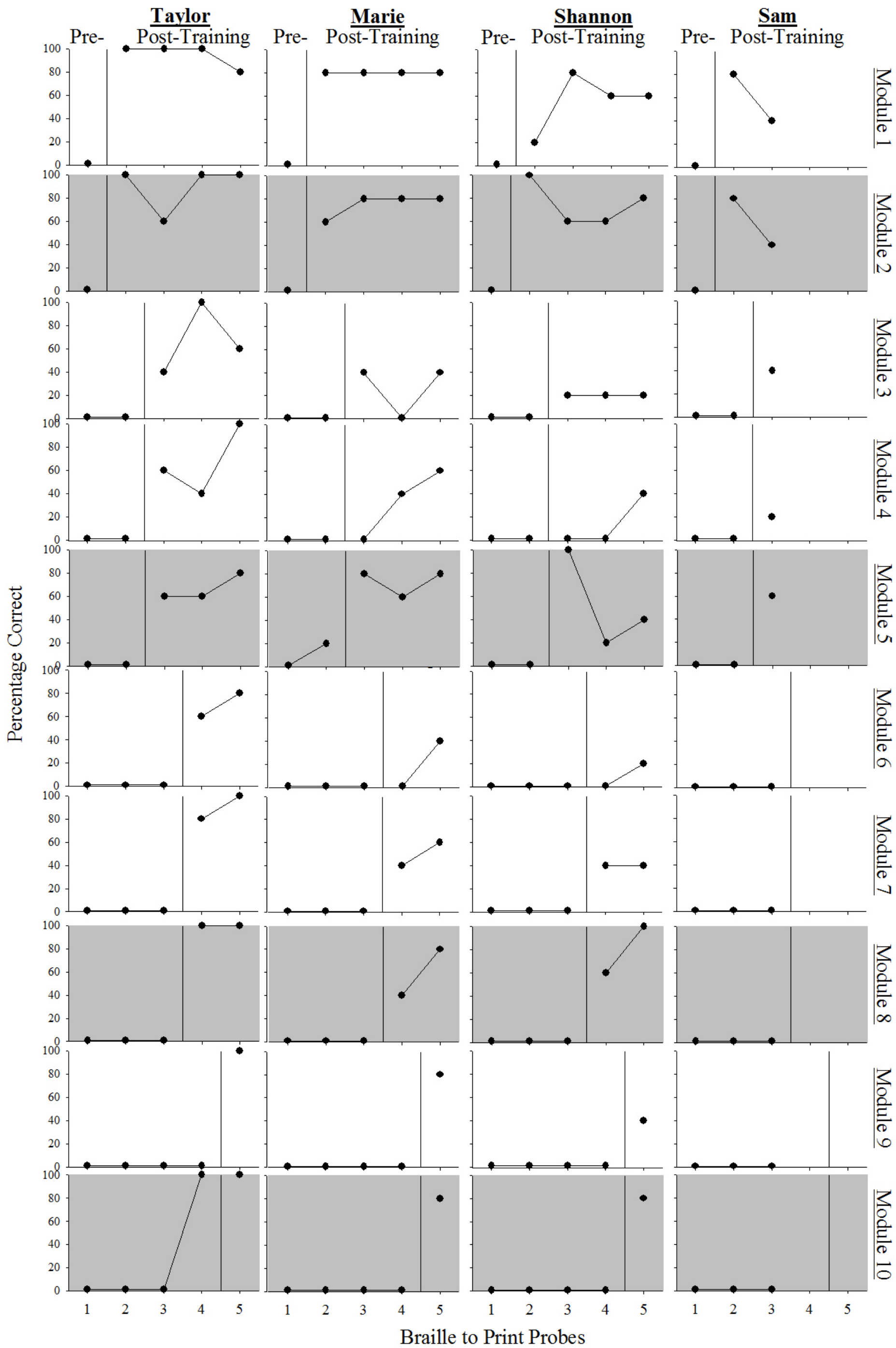

Figure 4. Results of participant scores of the transcription of braille to print generative-assessment probe. These data depict the percentage correct of stimuli selected from each training module (represented across rows) across participants (shown in columns). Shaded panels represent modules that targeted combinations of previously mastered stimuli.

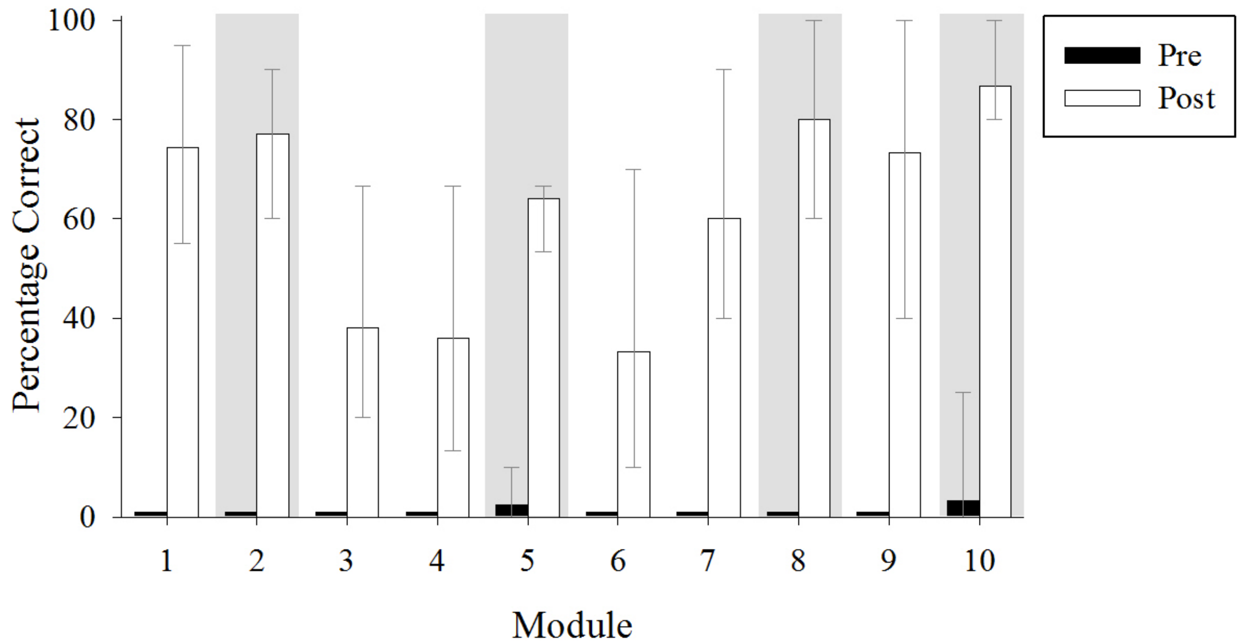

Figure 5. Summary of results from the transcription of braille to print generative-assessment probe. These data depict the mean responding across pre-test and post-test conditions for each module.

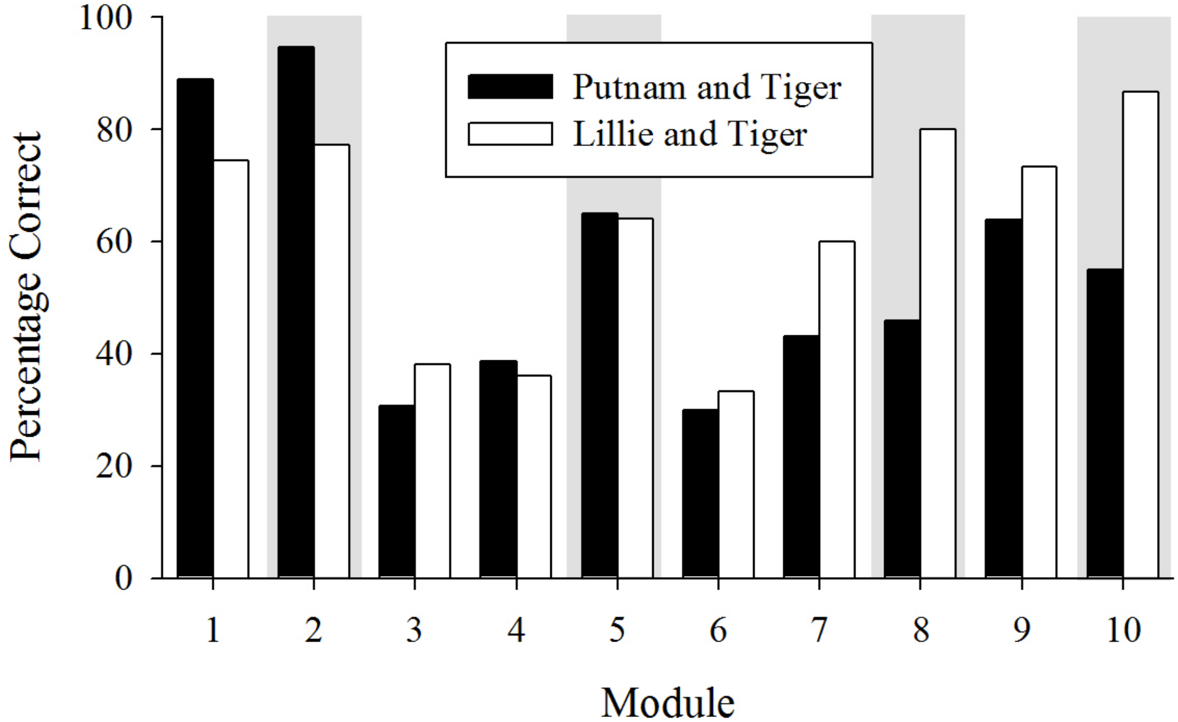

Figure 6. Summary results from the braille to print generative relation assessment compared to the same probes used following a MTS training format (Putnam & Tiger, 2016). These data depict mean post-test responding across modules for both the current study and Putnam & Tiger (2016). Shaded panels represent modules that targeted combinations of previously mastered stimuli.

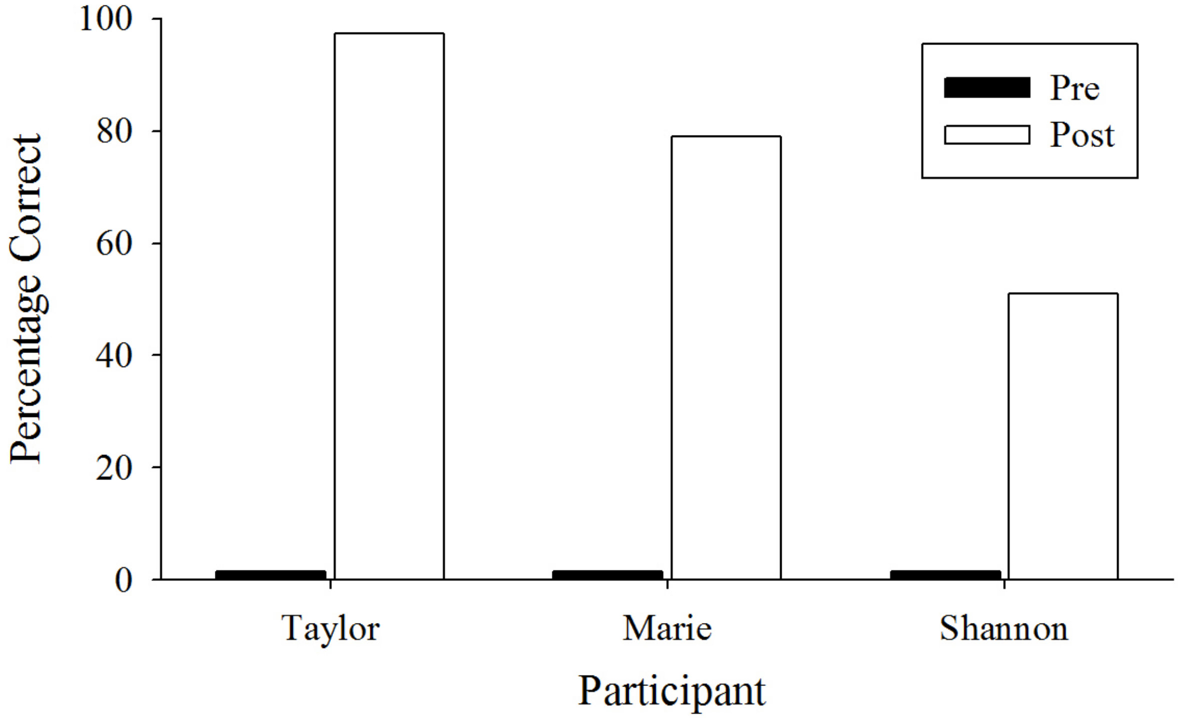

Figure 7. Results of the transcription of braille sentences to printed English generative-assessment probe across participants. Depicts the percentage of items transcribed correctly during pre-training and post-training assessments.

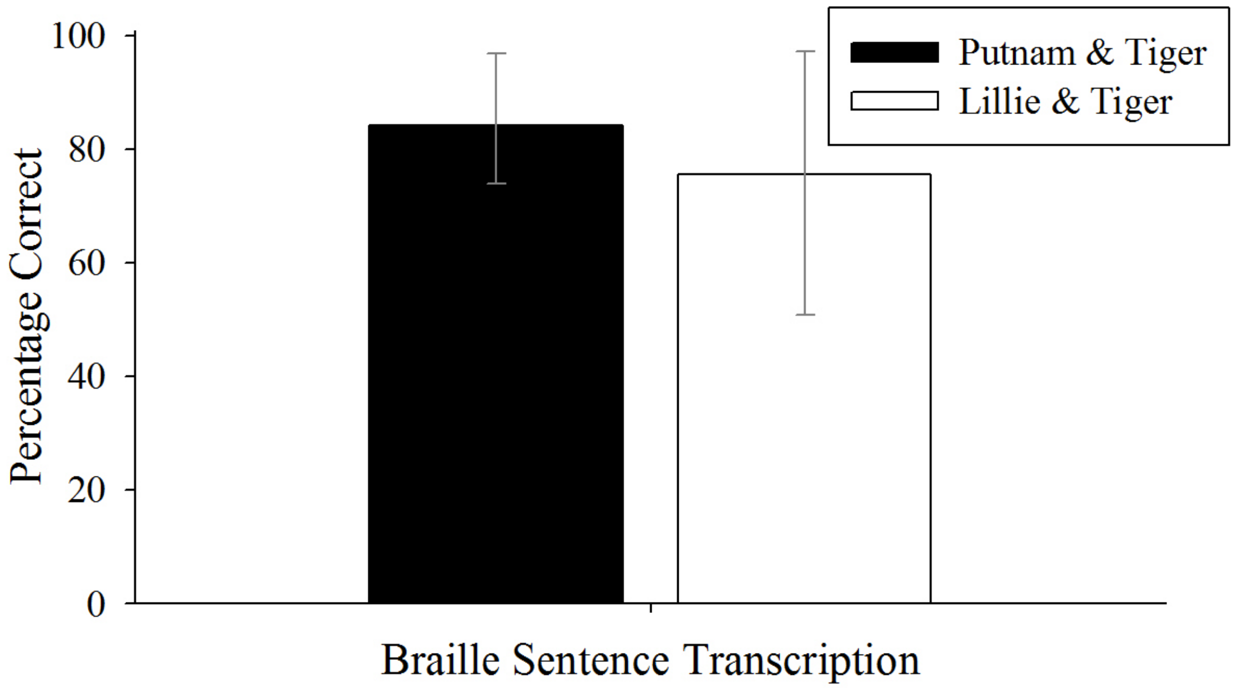

Figure 8. Summary results from the braille sentence transcription assessment compared to the same probe used following a MTS training format (Putnam & Tiger, 2016). These data depict mean post-test responding for both the current study and Putnam & Tiger (2016).

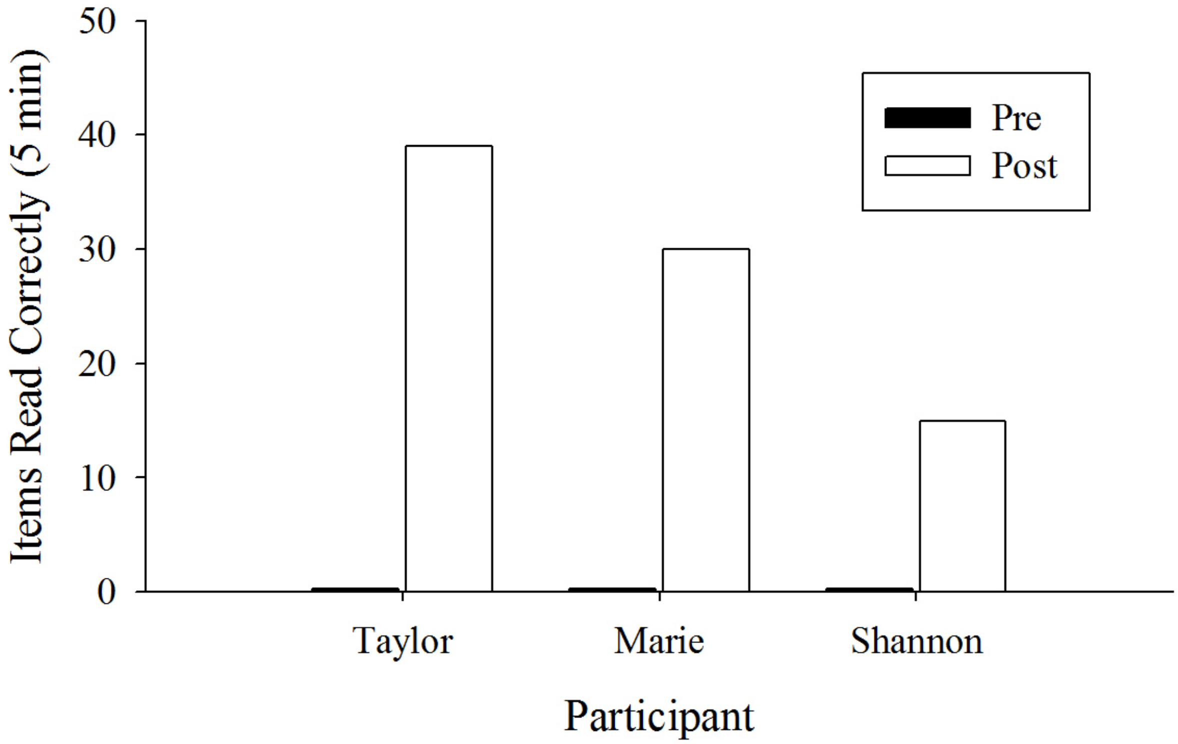

Figure 9. Results of the oral reading fluency - braille generative-assessment probe. Depicts the number of items read correctly during pre-training and post-training assessments across participants.

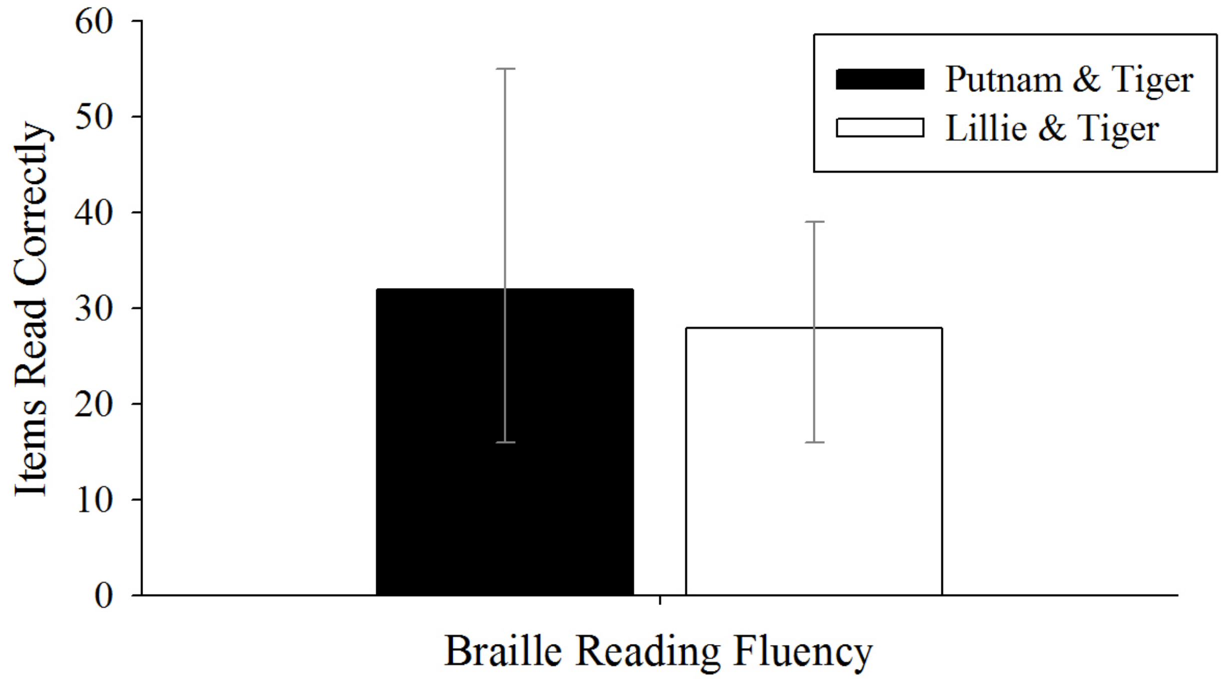

Figure 10. Summary results from the braille reading fluency assessment compared to the same probe used following a MTS training format (Putnam & Tiger, 2016). These data depict mean post-test responding for both the current study and Putnam & Tiger (2016).

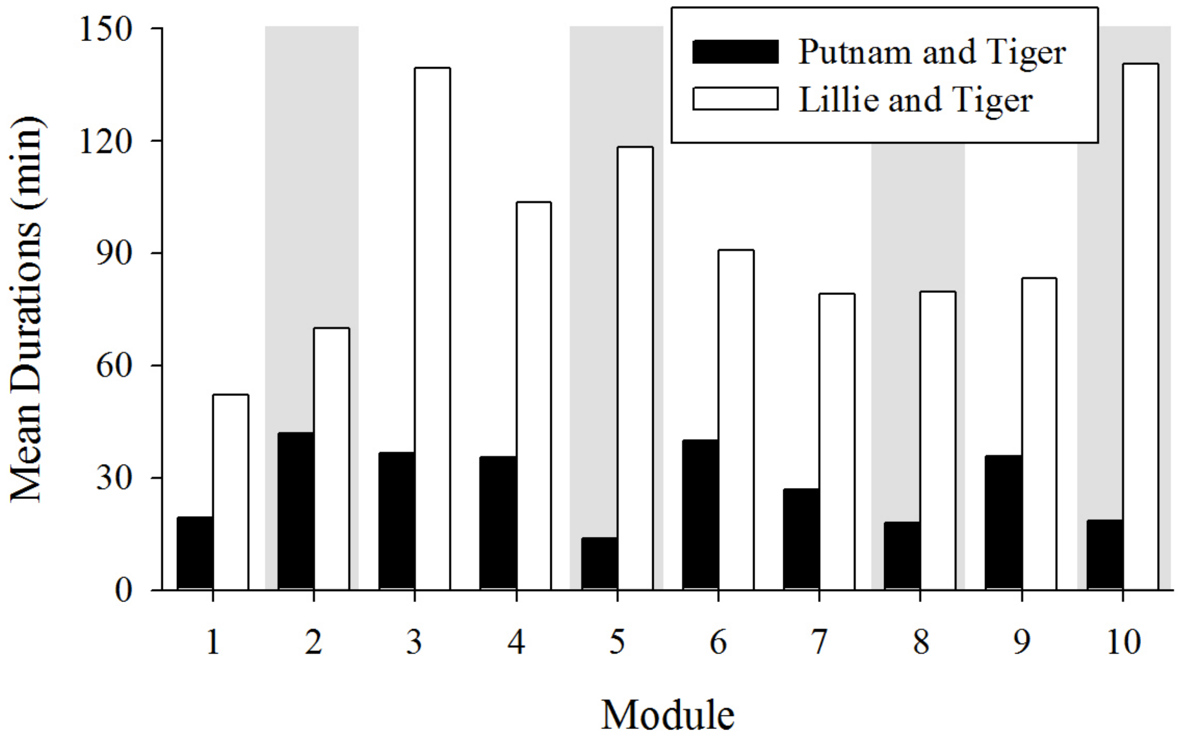

Figure 11. Mean training time across modules for both the current study and Putnam & Tiger (2016). Shaded panels represent modules that targeted combinations of previously mastered stimuli.

Table 1.
Training time to meet mastery (hr:min:sec)

Module	Taylor	Marie	Shannon	Sam	Mean
1	0:37:37	0:47:05	0:37:20	*1:26:12*	0:52:03
2	0:44:11	1:05:24	1:16:57	1:33:28	1:10:00
3	1:18:23	2:35:50	1:41:33	3:41:58	2:19:26
4	1:07:41	1:55:50	1:40:26	2:09:39	1:43:24
5	1:08:31	2:31:27	1:44:02	2:28:30	1:58:08
6	1:12:28	2:04:50	1:43:51	2:21:41	1:50:42
7	1:07:36	1:31:22	1:10:34	*1:26:15*	1:18:57
8	0:47:20	1:32:03	1:39:17	3:07:33*	1:46:33
9	1:10:27	1:54:01	1:05:21	-	1:23:16
10	1:25:34	2:46:22	2:49:28	-	2:20:28
Total	10:39:48	18:44:14	15:28:49	18:15:16*	15:47:02

*Incomplete

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Appendix A

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 B

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

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

Appendix C

Braille-transcription probe

Braille-Transcription Probe

1.

2.

3.

4.

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7.

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10.

11.

12.

13.

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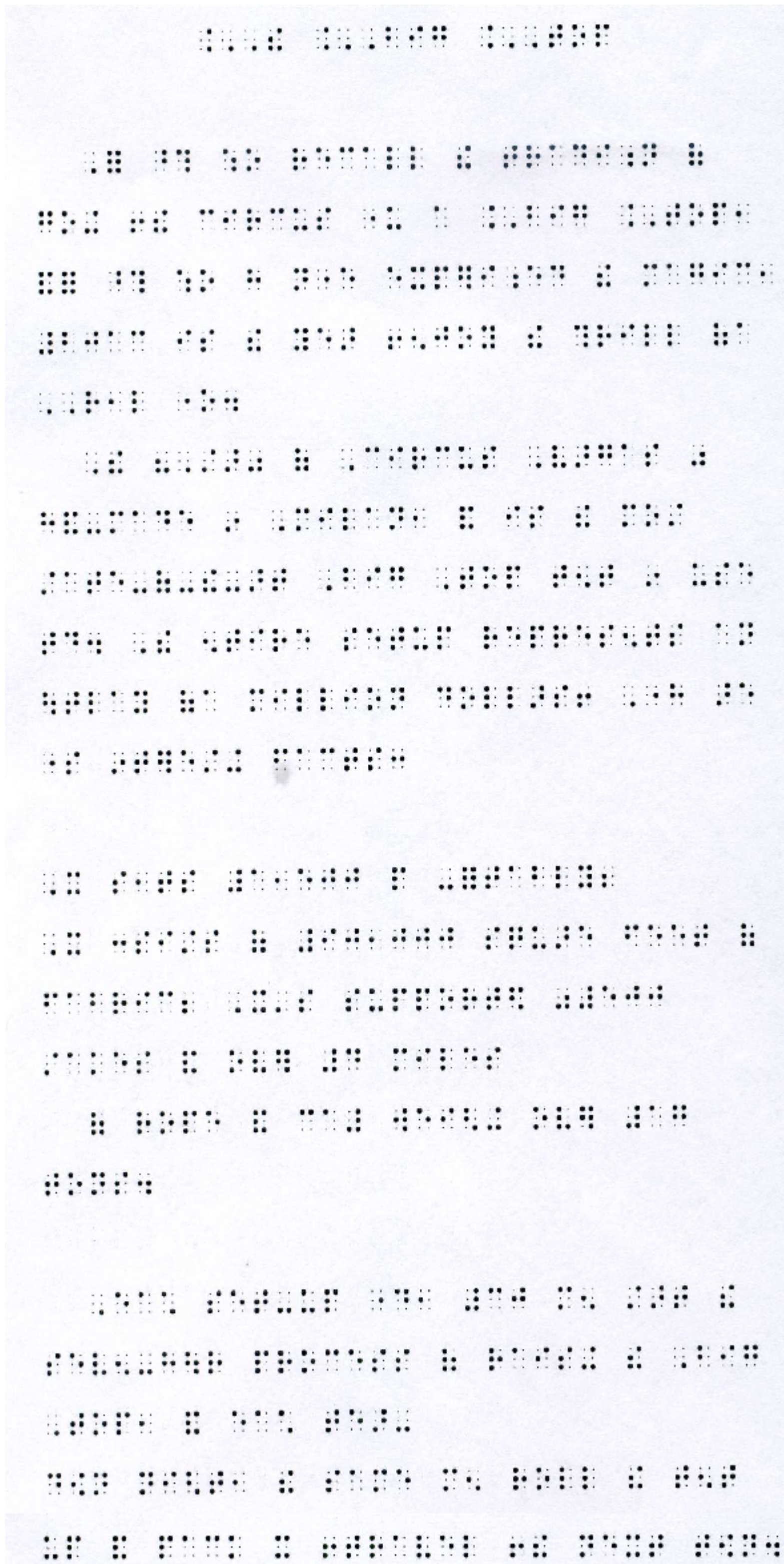
15.

Appendix D

Braille-reading probe



Appendix E

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 F

Modules 1-10 and Subsets

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	⠛		

Module 2

Braille Words without Contractions					
Subset 1		Subset 2		Subset 3	
he	⠓⠑	big	⠃⠊⠛	came	⠉⠁⠍⠑
hi	⠓⠊	box	⠃⠕⠭	next	⠝⠑⠭⠞
me	⠍⠑	eat	⠑⠁⠞	pack	⠏⠁⠉⠅
my	⠍⠽	let	⠇⠑⠞	same	⠎⠁⠍⠑
we	⠺⠑	man	⠍⠁⠝	sure	⠎⠥⠗⠑
Subset 4		Subset 5		Subset 6	
likes	⠇⠊⠅⠑⠎	flocks	⠋⠇⠕⠉⠅⠎	college	⠉⠕⠇⠇⠑⠛⠑
magic	⠍⠁⠛⠊⠉	fruity	⠋⠗⠥⠊⠞⠽	patrons	⠏⠁⠞⠗⠕⠝⠎
movie	⠍⠕⠧⠊⠑	lesson	⠇⠑⠎⠎⠕⠝	prevail	⠏⠗⠑⠧⠁⠊⠇
recall	⠗⠑⠉⠁⠇⠇	signal	⠎⠊⠛⠝⠁⠇	process	⠏⠗⠕⠉⠑⠎⠎
setup	⠎⠑⠞⠥⠏	travel	⠞⠗⠁⠧⠑⠇	readmit	⠗⠑⠁⠙⠍⠊⠞

Module 3

Contractions 1							
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	__⠰⠇		

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	⠆⠞		

Module 5

Braille Words with Contractions					
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	⠗⠑⠁⠉⠰⠝

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	⠩⠙		

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	

Module 8

Words, Numbers, Punctuation, Symbols, and Composition Signs Combined					
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.	

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	⠒⠉⠧				

Module 10

Short Sentences and Phrases			
Subset 1		Subset 2	
enough for me	⠢ ⠿ ⠍⠑	after lunch	⠁⠋ ⠇⠥⠝⠡
Here are some	⠠⠐⠓ ⠜ ⠐⠎	enough people came	⠢ ⠏ ⠉⠁⠍⠑
I do not have	⠠⠊ ⠙ ⠝ ⠓	For those who	⠠⠿ ⠘⠹ ⠘⠱
under a	⠐⠥ ⠁	I might	⠠⠊ ⠍⠊⠣⠞
You were	⠠⠽ ⠶	who have never	⠱⠕ ⠓ ⠝⠑⠧⠻
Subset 3		Subset 4	
Did she have	⠠⠙⠊⠙ ⠩⠑ ⠓	come at once	⠐⠉ ⠁⠞ ⠐⠕⠉⠑
is the year	⠊⠎ ⠮ ⠽⠑⠜	every other week	⠑ ⠕⠮ ⠺⠑⠑⠅
it consists of	⠭ ⠒⠎⠊⠌⠎ ⠷	go out this week	⠛ ⠳ ⠹ ⠺⠑⠑⠅
It was fine.	⠠⠭ ⠴ ⠋⠔⠑⠲	the airport	⠮ ⠁⠊⠗⠏⠕⠗⠞
tomorrow morning	⠞⠍ ⠍⠕⠗⠝⠬	the tradition	⠮ ⠞⠗⠁⠙⠊⠰⠝
Subset 5		Subset 6	
blowing bubbles	⠃⠇⠪⠬ ⠃⠥⠆⠇⠑⠎	Did you watch	⠠⠙⠊⠙ ⠽ ⠺⠁⠞⠡
cat's tail	⠉⠁⠞⠄⠎ ⠞⠁⠊⠇	Enjoy the dinner!	⠠⠢⠚⠕⠽ ⠮ ⠙⠔⠝⠻⠖
have an afternoon nap	⠓ ⠁⠝ ⠁⠋⠝ ⠝⠁⠏	He is in enough trouble	⠠⠓⠑ ⠊⠎ ⠔ ⠢ ⠞⠗⠳⠃⠇⠑
I almost always have	⠠⠊ ⠁⠇⠍ ⠁⠇⠺ ⠓	He is outside.	⠠⠓⠑ ⠊⠎ ⠳⠞⠎⠊⠙⠑⠲
supported by	⠎⠥⠏⠏⠕⠗⠞⠫ ⠴	I do believe	⠠⠊ ⠙ ⠃⠇⠧

Appendix G

Module training worksheet sample

Participant Number: _______________
Appointment Number: _____________

Session Number: _______________

Print to Braille Construction – Module 3 (Subset 1a)

Stimulus Number	Print Stimulus	Braille Response	Corrections
1	com_		
	Correct response:		
2	con_		
	Correct response:		
3	_bb_		
	Correct response:		
4	_cc_		
	Correct response:		
5	st		
	Correct response:		
6	ch		
	Correct response:		
7	_bb_		
	Correct response:		