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Vocabulary Word Instruction for Students Who Read Braille

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Abstract

The association made between the meaning, spelling, and pronunciation of a word has been shown to help children remember the meanings of words. The present study addressed whether the presence of a target word in braille during instruction facilitated vocabulary learning more efficiently than an auditory-only instructional condition. The authors used an adapted alternating treatments single-case experimental design with three students with visual impairments who read braille, collecting data on definition recall and spelling during each session. Data on definition recall were used to determine mastery. The results of this study are not consistent with previous findings with students who read print. Visual analyses of the data indicated that participants reached mastery in both conditions, but all three reached mastery on definition recall in fewer sessions in the auditory-only condition. Spellings of words were learned in the flashcard condition only, and possible implications of this are discussed. The difference in the unit of recognition and working memory load between reading braille and reading print is discussed as one possible explanation.

Comprehension is often seen as the ultimate goal of reading instruction. In fact, the National Reading Panel wrote that "comprehension is critically important to development of children's reading skills and therefore their ability to obtain an education" (National Institute of Child Health and Human Development [NICHD], 2000, p. 4-1). However, it is important to understand that multiple distinct cognitive processes interact to create the construct we commonly refer to as reading comprehension.

Perfetti, Landi, and Oakhill (2005) created a cognitive model of reading that recognizes the interactions between a written text, word identification, comprehension, and background knowledge. In a recent review, Savaiano, Compton, and Hatton (2014) used the Perfetti et al. (2005) model to frame existing braille reading research. They highlighted that the majority of researchers of braille reading have concentrated on word identification processes, specifically focusing on the perceptual features of the braille code itself and the rate at which students can decode braille.

Although decoding is an integral part of the reading process, it is only helpful for comprehension if the resulting word is part of the reader's vocabulary (NICHD, 2000). The age of onset of blindness, visual diagnosis, and presence of additional disabilities are only a subset of factors that could potentially affect the quality and quantity of early learning experiences of braille readers. There is a reciprocal relationship between vocabulary, comprehension, and amount

of reading (Nagy, 2005). Fewer experiences lead to less complete concept development and vocabulary to draw upon during word identification. Bigelow (1990) showed that young children who are blind experience differences in concept and language development than sighted peers. However, Savaiano et al. (2014) found no research explicitly addressing the importance and role of vocabulary and concept development in the braille reading process. This lack of information about vocabulary and concept development represents a substantial gap in our knowledge of braille reading, because we know little about the individual differences in the development of conceptual knowledge in students who are blind.

Vocabulary Instruction

Vocabulary may be taught directly and indirectly (NICHD, 2000). However, research has shown that direct instruction is more effective for teaching word meanings (Jitendra, Edwards, Sacks, & Jacobson, 2004; Marulis & Neuman, 2010). During direct instruction, vocabulary is taught through an explicit presentation of a target word and its definition. This strategy was found to be more effective than learning words in context (Pany & Jenkins, 1978; Pany, Jenkins, & Schreck, 1982) and was also helpful in making decoding more meaningful by adding to the oral language of the reader (NICHD, 2000).

To store words in memory for later use and retrieval, associations are formed between the spelling, pronunciation, and meaning of a word (Ehri & Rosenthal, 2007). This way, when a word is read aloud, the pronunciation of the word triggers the association with its meaning. Likewise, when a word is read silently, the spelling of the word triggers the association. This association, when used during instruction, has proven to help children remember the meanings of words. Rosenthal and Ehri (2008) taught unfamiliar words to groups of second- and fifth-grade children by defining words, depicting words, and using words in sentences—all elements of direct instruction. One set of words had the spellings visible, and the other set did not. The spellings helped students remember the meanings of words compared to the words without spellings. Although this association has the potential to facilitate the efficiency of word learning, written words are not often included in vocabulary instruction (Ehri & Rosenthal, 2007).

This lack of information about vocabulary and concept development represents a substantial gap in our knowledge of braille reading, because we know little about the individual differences in the development of conceptual knowledge in students who are blind.

Repeated exposures to targeted words is a component of vocabulary instruction highlighted by the National Reading Panel (NICHD, 2000); including the spellings of words during instruction is a simple method for incorporating this component. From the little we know about braille reading, it seems reasonable to presume that children who read braille would benefit from this type of instruction.

Braille, Vocabulary, and Spelling

Braille is an embossed code in which each unit (i.e., braille cell) is made from a combination of six dots. There are two forms of braille: uncontracted and contracted. Uncontracted braille assigns a unique dot configuration to each letter in the English alphabet. There is a one-to-one correspondence between letters and braille cells. Contracted braille represents common whole words and common letter combinations with one or more braille cells, removing the one-to-one correspondence between print letters and braille characters. Consisting of only six dots, there are limited configurations for braille characters. As a result, many braille contractions share the same shape but in a different location within the cell. Some braille contractions even share the exact same configuration, requiring syntax and context to discriminate the character.

As the individual characters become more difficult to discriminate, words become harder to read, because the unit of recognition in braille is the individ-

ual braille character (Nolan & Kederis, 1969). This sequential, one-cell-at-a-time perception may strain orthographic and phonological processing (Adams, 1990). Unfortunately, the body of research on teaching reading to children who read braille is limited (Savaiano et al., 2014).

The Alphabetic Braille and Contracted (ABC) Braille Study was a prospective nonrandomized, 5-year descriptive longitudinal study between 2002 and 2007. From these data, Wall-Emerson, Holbrook, and D'Andrea (2009) found vocabulary, measured by the Brigance Comprehensive Inventory of Basic Skills (Brigance, 1999), to be highly correlated with overall reading ability, as measured by the Johns Basic Reading Inventory (Johns, 2001). The majority of students enrolled in the study did not make expected gains in vocabulary, and vocabulary was emphasized as an area of "struggle" as students advanced in school. In the last year of the study, 47.2% of participants were performing below grade level in vocabulary, and across all years of the study, approximately 60% of participants were reading below grade level. The majority of participants were performing on or above grade level in spelling.

Recent research suggests that braille use does not affect spelling ability (Clark & Stoner, 2008; Clark-Bischke & Stoner, 2009; Wall-Emerson et al., 2009). Clark and Stoner (2008) administered the Test of Written Spelling (Larsen, Hammill, & Moats, 1999) to braille users and compared scores to the normative sample. Results showed that braille users had scores similar to the general population, as defined by the normative sample. However, Clark and Stoner's sample only included 23 participants. This sample size was not comparable to the size of the normative sample, and these 23 participants may not be representative of the general population of braille readers.

Clark-Bischke and Stoner (2009) did not include a comparison group in their examination of spelling. They calculated the number of words spelled correctly in participants' authentic writing samples to make comparisons between age levels of braille users. They found no consistent increase in number of words produced or in percentage of words spelled correctly as participant age increased. However, Clark-Bischke and Stoner eliminated braille errors from their spelling analysis. They reported a total of 32 braille errors but omitted them before calculating the number of words spelled correctly. These omissions were made on the theory that braille errors relate to the mechanics of written braille, rather than English spelling conventions. However, if words with braille errors were transcribed into print they would be misspelled. Failing to consider these errors as errors of spelling may have skewed the results.

Alternate Mode of Instruction

Research from the 1960s and 1970s on learning in blind children put forth the idea that listening could be a more efficient learning mode than reading for these students (e.g., Nolan, 1963; Tuttle, 1972). Tuttle (1972) compared comprehension of students reading braille to comprehension of students listening to normal or compressed speech. When participants were considered as a whole, there were no significant differences between the three conditions. However, Tuttle also created an index of learning efficiency and reported that braille was significantly less efficient for all participants, regardless of group.

The perception of braille as a less efficient medium for learning has endured, and instruction for students who are blind shifts to auditory media relatively early in their education. As such, we chose to use auditory-only instruction for the comparison.

The learning efficiency of braille described by Tuttle (1972) may relate to the unit of recognition and unique perceptual features of braille described by Nolan and Kederis (1969). The perception of braille as a less efficient medium for learning has endured, and instruction for students who are blind shifts to auditory media relatively early in their education. As such, we chose to use auditory-only instruction for our own comparison.

Present Study

In the present study, we examined whether the presence of a target word in braille facilitates vocabulary acquisition. To address this question, two instructional conditions were compared to determine whether a flashcard instructional condition was more effective than an auditory-only instructional condition. Both conditions included the following three components: (a) the target word was spoken aloud, (b) the target word was used aloud in a sentence, and (c) the target word definition was spoken aloud. The flashcard strategy included one additional component: The target word was presented in braille on a flashcard. Specifically, this study addressed the following research question: Do students who are blind learn (a) the meanings of words in fewer sessions and (b) to spell words more accurately via flashcard vocabulary instruction compared to auditory vocabulary instruction?

Method

Participants

The Institutional Review Board of Vanderbilt University approved this research, and informed consent and assent was obtained for all participants. To be included in the study, students had to (a) be diagnosed with a visual impairment, (b) read braille at a second-grade level, (c) be enrolled in Grades 3–6, (d) speak English as their primary language, and (e) have hearing within normal limits. Students were excluded if they had a motor impairment that affected their ability to read or write braille with two hands. Seven students from a specialized school for students who are blind and their caregivers consented to participate in this study; four were excluded because they did not meet the grade-level reading criterion. Of the three participants enrolled (see Table 1), Peter and Helen were primarily day students, although Helen stayed two nights and Peter stayed three nights a week on campus in the residences. Vincent was a residential student, meaning he was on campus from Sunday evening until noon on Friday. All three students included in the study were blind since birth and had additional disabilities.

Setting

We conducted the study in students' regular classrooms. The investigator sat next to students at a designated table in the classroom separate from the students' desks. The procedural fidelity (PF) observer, when present, was seated behind the student and the investigator or, when space was available, was seated next to the student and the investigator. The table was an appropriate height for all students and had enough surface area to accommodate study materials (i.e., rubber mat, braillewriter, and audio recorder). Other students, an educational assistant, and the classroom teacher were present in the room during sessions.

Materials

There were three word sets for each participant (flashcard, auditory, control), with six words in each set. To increase the likelihood that word sets were of equal difficulty, we ensured word sets were similar in terms of lexical characteristics. Words for the flashcard condition were brailled onto 2"× 3" cards. These flashcards were identical to cards used during classroom word study instruction. The top right corner of each index card was cut at an angle to facilitate correct orientation of the cards. In addition, a rubber mat was used to stabilize flashcards, and an Olympus digital voice recorder was used to record audio.

Word Sets

A database of words was created from random pages of *The Living World Vocabulary* (Dale & O'Rourke, 1981). Words with multiple definitions were omitted. Lists were then entered into The English Lexicon Project (Balota et al., 2007) and the Medical Research Council Psycholinguistic Database (Coltheart, 1981) to generate the desired lexical characteristics: (a) number of letters, (b) orthographic Levenshtein distance, (c) phonological Levenshtein distance, (d) number of

Table 1. Description of Participants

	Peter	Helen	Vincent
Age (in years)	12.7	11.1	9.5
Eligibility categories	Multiple disabilities: 1. Blind 2. Learning disability	Blind (recertified from multiple disabilities)	Multiple disabilities: 1. Blind 2. Learning disability 3. Other health impairment 4. Autism
Visual diagnosis	Bilateral anophthalmia	Optic nerve hypoplasia	Retinopathy of prematurity
Visual acuity	No light perception (O.U.)	No light perception (O.S.) Light perception–possibly (O.D.)	Light perception (O.U.)
Developmental spelling level	Syllable juncture	Syllable juncture	Syllable juncture
Braille contractions	131/189 (69%)	168/189 (89%)	169/189 (89%)
WJ-III Braille adaptation	Letter-word ID = 2.5 GE Passage comp. = 1.9 GE Word attack = 2.5 GE	Letter-word ID = 4.9 GE Passage comp. = 2.1 GE Word attack = 14.8 GE	Letter-word ID = 3.2 GE Passage comp. = 2.1 GE Word attack = 2.8 GE
WISC-IV	Verbal comp. = 68 Working memory = 80 Verbal deviation = 68	Verbal comp. = 81 Working memory = 68 Verbal deviation = 73	Verbal comp. = 93 Working memory = 88 Verbal deviation = 90

O.U. = both eyes; O.S. = left eye; O.D. = right eye; WJ-III = Woodcock–Johnson III Tests of Achievement (Woodcock, McGrew, & Mather, 2001); GE = grade equivalent; WISC-IV = Wechsler Intelligence Scale for Children IV (Wechsler, 2003).

phonemes, (e) number of syllables, (f) number of morphemes, (g) part of speech, (h) concreteness, and (i) imageability. The scales for imageablity and concreteness were integers from 100 to 700, and words must have had a score recorded for at least one of the scales to be included in the word sets. The 131 words that had a score for imageability or concreteness formed the master list.

The master word list was sorted by grade level and teachers were asked to select words that were unknown to the students and that they felt were appropriate for the student to learn. Teacher-selected words were given preference when creating word sets. Teachers approved any researcher-selected words. Teacher-selected words were not used if (a) the definition could not be reduced to five words and retain clarity (e.g., *aspect*), (b) the definition included the word or part of the word (e.g., *millstone*), (c) the word was a homophone for a more common word (e.g., *rein*), (d) the word was self explanatory (e.g., *lowland*), or (e) the student knew the meaning of the word. Definitions were culled from *The Living World Vocabulary* (Dale & O'Rourke, 1981), *Merriam-Webster's Word Central* (2014), and the *Merriam-Webster Learner's Dictionary* (Mairs, 2014).

The initial 18 words for each participant (six words in each word set) were chosen randomly from the pool of words remaining after teacher selection and definition selection. The lexical characteristics for each word were entered into SPSS 21.0 and words in each set were compared using ANOVA with a Bonferroni correction to control for multiple comparisons. These initial word sets were adjusted so there were no significant differences between groups on any of the lexical characteristics. For Helen and Vincent, the initial word sets were also the final word sets, because they did not know the meanings of any words during initial probe (see Procedures for Initial Probe for more detail). Peter correctly identified the full or partial meaning of three words from the initial word sets (*carnation, imagination*, and *squirm*). These words were replaced, statistical analyses were rerun, and word sets were adjusted to maintain comparability. Peter's third set of words became his final word set.

Table 2. Final Word Sets for Peter, Helen, and Vincent

Word set	Peter	Helen	Vincent
Flashcard	madame	centennial	brawl
	ashamed	punctual	frantic
	rejoice	bramble	frail
	chloride	defiance	centennial
	shilling	ashen	diversity
	interruption	mackerel	ashen
Auditory only	tweed	indolence	caravan
	century	conjugation	bramble
	frantic	rancid	immense
	kerchief	chloride	defiance
	sufferer	mosque	deface
	unnatural	shilling	wrath
Control/best alone	peso	persuasive	reliable
	bravery	wrath	shilling
	brawl	fraternal	dual
	caravan	fissure	persuasive
	industrious	immensity	sprint
	turpentine	tweed	rancid

Once word sets were finalized, sentences were created for each word. All sentences (a) used the exact form of the word, (b) provided additional context for the word, (c) did not restate the definition, and (d) had 10 or fewer words. Table 2 shows the final word sets for Peter, Helen, and Vincent.

Response Definitions and Measurement Procedures

Data on two dependent variables were collected during each session: definition recall and spelling. Definition recall was the primary dependent variable and was used to guide experimental design decisions.

Definition recall. Definition recall refers to the ability to produce the meaning of a target word when prompted with the question, "What does [word] mean?" Guidelines from the vocabulary subtest of the Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV; Wechsler, 2003) were used to measure definition recall of target words. A score of 0, 1, or 2 was recorded for each target word. A score of 2 was recorded for correct responses. A score of 1 was recorded for marginal or generalized responses, such as responding with an example of the word rather than a definition (e.g., responding "abcd" when asked, "What does the word *alphabet* mean?"). A score of 0 was recorded for incorrect responses, no response, gestural responses with no verbal elaboration, or a response of "I don't know." If an acceptable response was accompanied by an incorrect response, a score of 0 was recorded. If responses of different quality were provided at one time, and none were incorrect, the best response was scored. If the participant responded with the definition of a word anytime during probe, the response was scored. A total score for definition recall was calculated for each word set by adding the individual scores for the six words within each set, and this score was graphed.

Spelling. Spelling refers to the ability to write a word in braille using the correct letters and contractions. A score of 0, 1, or 2 was recorded for each target word. A score of 2 was recorded for correct

spellings using all appropriate letters and contractions. A score of 1 was recorded for spellings that were correct but did not include appropriate contractions. For instance, if the word *sing* was spelled *s-in- g* instead of *s-ing*, which uses the contraction for *ing*, it would be scored as a 1. A score of 0 was recorded for words that were spelled incorrectly or not spelled. A total score for spelling was calculated for each word set by adding the individual scores for the six words within each set, and this score was graphed.

Experimental Design

An adapted alternating treatments design (AATD; Sindelar, Rosenberg, & Wilson, 1985; Wolery, Gast, & Ledford, 2014) was used to compare the effects of two instructional strategies (flashcard and auditory-only) on correct vocabulary word definitions. Though we collected data on both definition recall and spelling, the definition recall was the primary dependent measure on which design decisions were based. In this study, strategies were alternated within each session. To facilitate detection of multitreatment interference or sequence effects in the comparison phase, we included a control word set and counterbalanced the order of treatment conditions across sessions. In addition, because the AATD involves the application of two or more instructional strategies to different behavior sets, it is critical that behavior sets be (a) nonreversible, (b) not already in the participant's repertoire, (c) independent, (d) functionally equivalent, and (e) of equal difficulty (Wolery et al., 2014). First, academic skills such as learning vocabulary word definitions are considered nonreversible behaviors; once words are learned, they typically are not unlearned after instruction stops. Second, we ensured participants did not know the selected word sets prior to initiating instruction (see previous description of word set selection). Third, the word sets are likely to be independent; learning one set of words would not likely influence performance on other sets of words. Fourth, the word sets are likely to meet the functional equivalence criterion; each set of words should be equally influenced by the same variables (i.e., each instructional strategy). Finally, our process for selecting word sets (described previously) addressed the most challenging criterion of ensuring equal difficulty.

Pretests

Pretests were administered to participants individually during the week prior to the start of the study. Pretests provided information on students' current level of proficiency with braille, word reading, decoding, and spelling (see Table 1).

Procedures

In each condition, participants responded to a question from the investigator. Participants had 5 s to respond. If they did not respond after 5 s, the investigator repeated the question and waited an additional 5 s. If they still did not respond, the item was scored as incorrect. Participants were given general praise statements (e.g., "good job" or "okay") after each response.

Initial probe (baseline). During the initial probe, data were collected on students' definition recall and spelling of target words until a stable baseline for definition recall was established. Because it was critical that participants' did not know the meanings of target words, when a score of 1 or 2 was recorded during initial probes, the word was replaced by a comparable word from the master list. Data were collected using initial probe procedures until three consecutive data points were collected with scores of 0 recorded for all 18 words.

Using a list randomizer from www.random. org, words were probed in a randomly determined sequence. Each probe followed the same procedure. The investigator asked the student, "What does [word] mean?" If the student responded, "I don't know", the investigator said, "That's okay, just do your best. How do you spell [word]?" If the student provided a response, the investigator provided a general praise statement and then continued, "How do you spell [word]?" If the student began to spell aloud, the investigator prompted him or her to write the word us-

ing the braillewriter. This procedure continued until all 18 words were assessed. Procedures for creating word sets ensured that participants did not respond correctly to any target words in the final word sets.

Comparison. The comparison condition consisted of instruction using two strategies: flashcard vocabulary instruction and auditoryonly vocabulary instruction. A control set of words was also probed during this phase, but no instruction took place with this word set. Each session included a probe of all word sets for definition recall and spelling at the beginning of the session. All sessions included instruction on two word sets: one using the flashcard strategy and one using the auditoryonly strategy. The order of instruction was randomly determined prior to each session. To begin instruction, the investigator explained, "We are going to learn some words today, and I will ask you about these words tomorrow. Let's start. The first word is [word]. What is the word?" After the student repeated the target word the investigator provided praise and continued, "[Word] means [definition]. [Uses word in a sentence]. What does [word] mean?" After the student repeated the definition, the investigator provided praise and continued to the next word. This procedure continued until both word sets were covered.

The procedure for the flashcard strategy differed slightly. Before the investigator said, "The first word is [word]," she placed a flashcard on the rubber mat in front of the student and said, "Here is the first word." The flashcard was then present during the instruction outlined above. If students did not independently move their hands across the braille, the investigator prompted them to touch the braille. When instruction on the word ended, the investigator removed the first card and placed the next flashcard on the mat. All target words were probed at the beginning of every session.

Mastery was defined as a total score of 12 for three consecutive sessions. Once mastery was reached in one strategy, the comparison condition continued until (a) the participant reached mastery in the less efficient strategy or (b) the slower strategy continued for twice the number of sessions it took to reach mastery with the more efficient strategy (Wolery et al., 2014). The faster strategy was defined as taking fewer sessions to reach mastery. The faster strategy from the comparison condition was used with the control set of words in a best alone condition.

Best alone and maintenance. The best alone condition was defined as the comparison condition in which the student reached mastery in fewer sessions. Using the control word set, the best alone condition used the procedures for whichever treatment condition met mastery in fewer sessions and continued until the participant reached mastery criterion. Instruction on the other two word sets ceased, but data collection continued to provide maintenance data for words taught during the comparison phase. After the best alone condition ended, the investigator continued to probe all three word sets once a week for at least 2 weeks.

Generalization probes of definition recall. After the best alone condition ended, there were three planned generalization sessions. Generalization sessions took place once per week on days when no maintenance probe occurred. Words from all three sets were used in short passages of no more than five sentences. Each passage included two words from each word set, for a total of six target words. Each passage was administered in its own session. Sentences were different from those used during instruction, and passages were administered by a research assistant (RA). Participants were instructed to read the passage aloud. At the end of the passage, the RA asked, "In the passage, what did the word [word] mean?" After all six target words were probed, the RA said, "We are all done. You did a really good job. Thank you for reading to me."

Interobserver Agreement (IOA)

Independent coders were trained to collect IOA data for both dependent variables (definition recall and spelling) from audio recordings and artifacts created

by the first author. Training continued until coders reached 90% agreement with the first author on both dependent variables.

A point-by-point method was used to calculate IOA for definition recall and spelling. Agreement or disagreement was determined for each target word. The percentage of agreement was calculated by dividing the number of agreements by the total number of agreements and disagreements and multiplying by 100. Discrepancy discussions took place when there was a disagreement between coders (Yoder & Symons, 2010). When disagreements occurred, the consensus code was recorded and graphed, but IOA data were calculated from the initial coding of the independent observers. Agreement checks were balanced across participants and conditions and conducted throughout the study. Independent coders were blind to which word set was assigned to which instructional approach.

IOA data were collected on 37% of sessions for Peter, 39% of sessions for Helen, and 38% of sessions for Vincent. Average IOA for Peter was 99 (97-100) for definition recall and 98.4 (97.2-100) for spelling. Average IOA for Helen was 100 for definition recall and 99.4 (98.1-100) for spelling. Average IOA for Vincent was 100 for definition recall and 98.1 (97.2-100) for spelling.

PF

Data on PF were collected through event recording (Ayres & Gast, 2010). The independent observer recorded occurrence or nonoccurrence of each step of the procedure. Some steps were meant to occur once per session: materials accessible and ready, student greeted, session recorded, read scripted directions, and student thanked and dismissed. Some steps occurred/ nonoccurred multiple times per session: definition recall probe, wait for response 5 s, provide general praise statement, spelling probe, flashcard provided, target word spoken aloud, definition spoken aloud, and used in a sentence aloud. The average percent fidelity for each step was calculated as the number of observed occurrences divided by the number of expected occurrences, multiplied by 100.

PF data were collected for 33% of all sessions for Peter, 37% of all sessions for Helen, and 33% of all sessions for Vincent. Average PF for Peter was 100 during initial probe, 98.4 (75-100) during comparison, and 99.9 (98.1- 100) during best alone. Average PF for Helen was 99.7 (94.4-100) during initial probe, 99.8 (98.8-100) during comparison, and 99.9 (98.2-100) during best alone. Average PF for Vincent was 98.1 (86.1-100) during initial probe, 99.7 (95.8-100) during comparison, and 99.7 (94.4-100) during best alone. One procedural step, materials accessible and ready, fell below levels of acceptance for Peter during comparison. During Session 6, which was the first session of instruction for Peter, one of the flashcards needed to be re-brailled. This mistake was identified and corrected before the investigator started working with Peter.

Social Validity

Questionnaires were used to assess teachers' perceptions of the vocabulary instruction at the end of the study. Questions addressed the importance of vocabulary instruction, procedures used during the study, and effects of the study.

Results

Using the vocabulary instruction procedures previously outlined, three participants who read braille learned the definitions of 18 randomly selected words. In addition, all three participants learned definitions in fewer sessions to mastery during the auditory-only condition. Table 3 presents the number of sessions required to meet mastery criterion for all participants. The mastery criterion was based on participants' correct identification of word meanings; however, data were also collected on participants' correct spelling of words. Spelling data from all three participants show that exposure to braille flashcards during vocabulary instruction increased students' correct spelling of words.

Although procedures were uniform across participants, session durations varied across participants. Ses-

Table 3. Number of Sessions to Mastery

	Peter	Helen	Vincent
Flashcard	6	23	9
Auditory	4	17	7
Best alone (auditory)	8	16	6

Table 4. Average Time per Session

	Time in Minutes (Range)		
Participant	Initial probe	Comparison	Best alone
Peter	10.5 (9.0–12.3) *n* = 5	12.8 (7.2–16.4) *n* = 6	10.8 (8.9–11.9) *n* = 8
Helen	7.3 (6.5–8.6) *n* = 3	10.5 (6.3–13.2) *n* = 23	10.9 (7.6–13.3) *n* = 16
Vincent	10.4 (9.4–12.2) *n* = 3	21.2 (15.3–25.6) *n* = 9	25.4 (22.5–27.7) *n* = 6

sions with Vincent, for example, ranged from 1.5 to 3 times as long as sessions with Helen and Peter during comparison and best alone conditions. Table 4 presents the average session duration for all participants.

Results for Definition Recall

Peter. Peter learned the definitions of 18 words over 16 sessions and maintained learning at mastery level. The top graph in Figure 1 provides Peter's total scores for definition recall. The first instructional session occurred the day before the probe in Session 7, which shows an immediate increase in correct responses for the flashcard condition and the auditory condition.

Data for Peter show low, stable performance for all three word sets in baseline, followed by an immediate increase in level and trend for the two instructional conditions relative to the control condition during the comparison phase. Peter reached mastery criterion in Session 10 for the auditory condition and in Session 12 for the flashcard condition. When the auditory strategy was used to teach the control set of words during a best alone condition, there was an immediate increase in correct responses, and Peter reached mastery criterion in Session 21. Although there is only a slight difference in number of sessions to mastery criterion, there is a pattern showing a clear differentiation between the control set and both instructional conditions.

Peter maintained his definition recall regardless of the strategy used as evidenced by continued correct responding for flashcard and auditory sets during the best alone condition and for all three words sets during maintenance. In addition, Peter generalized his definition recall to an unfamiliar person during circumstances different than intervention.

Helen. Helen learned the definitions of 18 words over 41 sessions and maintained learning at mastery level. The graph in the middle panel of Figure 1 provides Helen's total scores for definition recall. Session 4 was the first instructional session, and the probe in Session 5 shows an immediate increase in correct responses for the auditory condition. Helen reached mastery criterion during Session 21 for the auditory condition and during Session 27 for the flashcard condition.

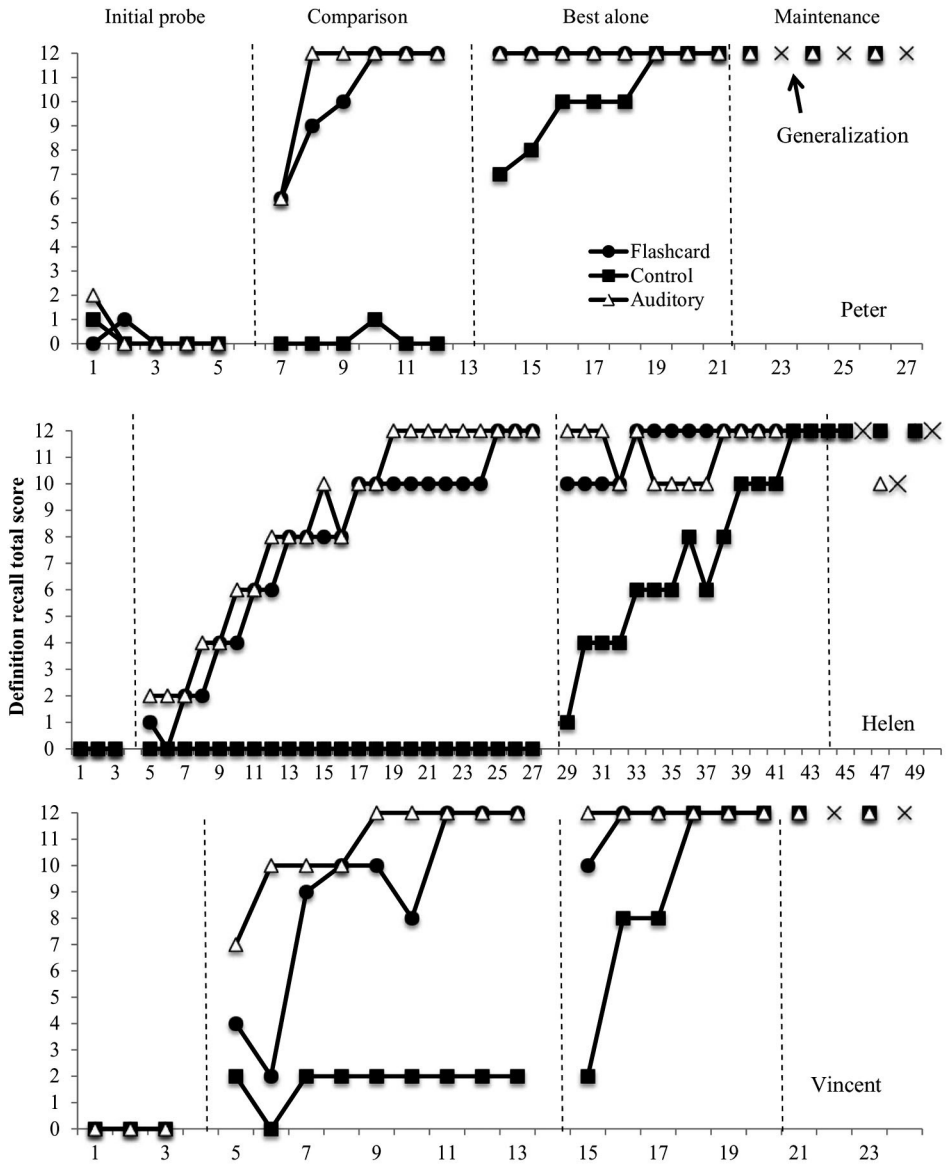

Figure 1. Total score for all target word definitions recalled for all participants.

When the auditory strategy was used to teach the control set of words during a best alone condition, there was not an immediate increase in correct responses, but she did show an increase in correct responses during the second probe, and she reached mastery criterion during Session 44. Visual analysis shows low, stable performance for both strategies in baseline with an immediate change in level and acceleration toward criterion for the auditory condition. However, there is no consistent differentiation between the two instructional strategies. However, visual analysis also shows that both strategies are effective when compared to a control set of words.

Helen was able to maintain her definition recall regardless of the strategy used, although she had several sessions that fell below a total score of 12 for flashcard and auditory sets during the best alone condition. Additionally, Helen was able to generalize her definition

recall to an unfamiliar person during circumstances different than intervention.

Vincent. Vincent learned the definitions of 18 words over 17 sessions and maintained learning at mastery level. The bottom graph in Figure 1 provides Vincent's total scores for definition recall. Session 4 was the first instructional session, and the probe in Session 5 showed an immediate increase in correct responses for all three word set conditions. Vincent reached mastery criterion during Session 11 for the auditory condition and during Session 13 for the flashcard condition. When the auditory strategy was used to teach the control set of words during a best alone condition, there was not an immediate increase in correct responses, but he did show an increase in correct responses during the second probe, and he reached mastery criterion during Session 20.

Vincent was able to maintain his definition recall regardless of the strategy used as evidenced by continued correct responding for flashcard and auditory sets during the best alone condition and for all three word sets during maintenance. In addition, Vincent was able to generalize his definition recall to an unfamiliar person during circumstances different than intervention.

Results for Spelling

Because the best alone condition for all participants was the auditory-only strategy, it is important to keep in mind that flashcards were not used during instruction of the control set.

Peter. The top graph in Figure 2 provides Peter's total scores for spelling. Following undifferentiated correct spelling across conditions in the initial probe phase, the level and slope of correct spelling in the flashcard condition increased relative to the auditory-only and control conditions in the comparison phase. At the start of the first instructional session, Peter correctly spelled two words from each word set. After repeated exposure to braille for the six words in the flashcard condition, Peter increased and maintained correct spellings for those words. He did not learn the correct spellings for words in the auditory set or the control set.

During generalization, Peter was exposed to the correct spellings of words from the auditory and control sets. During Sessions 24 and 26, Peter increased correct spellings of words in the control set. Overall, Peter correctly identified certain features of the words, which he incorporated into his responses (e.g., spelling *kerchief* with a *k* instead of a *c*), even if he still did not spell the word correctly.

Helen. The graph in the middle panel of Figure 2 provides Helen's total scores for spelling. Following undifferentiated correct spelling across conditions in the initial probe phase, the level and slope of correct spelling in the flashcard condition increased relative to the auditory-only and control conditions in the comparison phase. At the start of the first instructional session, Helen correctly spelled one word from each word set. After repeated exposure to braille for the six words in the flashcard condition, Helen increased and maintained correct spellings for those words. She did not learn the correct spellings for words in the auditory set or the control set.

Vincent. The bottom graph in Figure 2 provides Vincent's total scores for spelling. Following undifferentiated correct spelling across conditions in the initial probe phase, the level and slope of correct spelling in the flashcard condition increased relative to the auditoryonly and control conditions in the comparison phase. At the start of the first instructional session, Vincent inconsistently spelled words correctly. After repeated exposure to the six words in the flashcard condition, Vincent increased correct spellings for those words but did not maintain correct spellings. He did not learn the correct spellings for words in the auditory set or the control set.

Social Validity

Participants' teachers were asked to complete a six-question survey about vocabulary instruction and the procedures used in this study. Two participants had the same teacher. Teachers viewed vocabulary instruction as very important for their students this year and in the future. One teacher wrote, "Students need an understanding of vocabulary to comprehend what they are

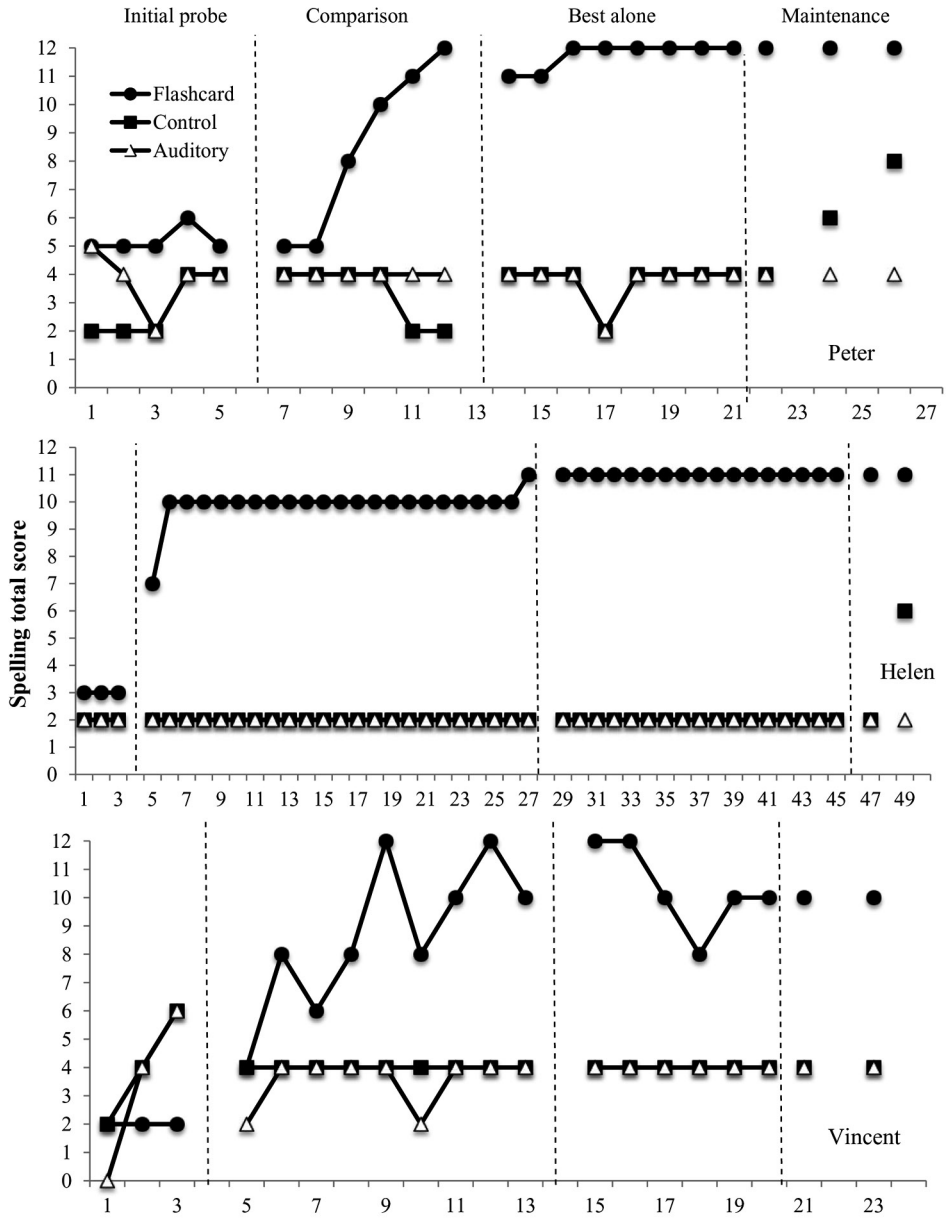

Figure 2. Total score for all target words spelled correctly for all participants.

reading/learning." Teachers saw visible positive effects of the intervention. One teacher wrote that the intervention "benefited students comprehension of subject matter." The other teacher responded, "Students get excited and use the vocab[ulary] they have learned, when it comes up during the day." Neither teacher noticed negative effects of the intervention.

In response to whether they would use the intervention strategy to teach vocabulary, there were mixed responses. One teacher responded she would be likely to use the strategy or have a paraprofessional use the strategy but provided no further explanation. The other teacher responded neither he nor a paraprofessional would be likely to use the strategy,

stating "my school has a specific word learning strategy we must use."

Discussion

This study was designed to evaluate whether vocabulary instruction with braille flashcards was more effective or efficient at teaching the meaning and spelling of vocabulary words than auditory-only instruction. Our theory was based on research with print readers showing that associations formed between the spelling, pronunciation, and meaning of a word can facilitate vocabulary instruction. However, the results of this study with braille readers were not consistent with previous findings with students who read print (i.e., Rosenthal & Ehri, 2008).

This study was designed to evaluate whether vocabulary instruction with braille flashcards was more effective or efficient at teaching the meaning and spelling of vocabulary words than auditory-only instruction.

All participants met mastery criteria for all 18 words, regardless of the instructional strategy used. However, participants learned the definitions of words two to six sessions faster in the auditory-only condition relative to the flashcard condition. Therefore, the data indicate that both instructional strategies are effective for teaching the meanings of vocabulary words to students who read braille, and patterns consistent across participants suggest fewer sessions to mastery when instruction is auditory-only, rather than having a flashcard present during instruction.

Definition Recall

All three participants learned definitions in fewer sessions to mastery in the auditory-only condition. It is possible that the sequential, one-cell-at-a-time perception of braille may strain orthographic and phonological processing (Adams, 1990), making listening and reading braille simultaneously more taxing to working memory than listening and reading print simultaneously. In effect, it is possible that the flashcard condition required students to split their attention between auditory information provided by the investigator and tactile information on the flashcard. In contrast, the auditory-only condition may have allowed students to focus all of their attention on the auditory information presented.

Although Helen was able to reach mastery in both conditions, doing so required 2.5 times as long as Peter or Vincent to learn the meanings of all 18 words. One possible explanation was Helen's working memory deficit, as measured by the WISC-IV (Wechsler, 2003). Based on WISC-IV scores, both Peter and Vincent had low average working memory, whereas Helen had extremely low working memory. Peter and Vincent were able to recall several definitions after the first instructional sessions, whereas Helen was usually able to recall one new definition per session. Helen began saying "[word] means…" out loud and waited several seconds to see if the phrase triggered her memory of the definition.

Correct definition recall maintained at 100% across participants, with some variability for Helen. During the best alone condition, her maintenance of the first two word sets decreased to 83% for several sessions (see Figure 1). The words learned last were *centennial* and *conjugation*. There was a period of time between Session 29 and Session 37 in which she recalled one or the other. The similarity of these words in length and beginning letter may have contributed to her confusion. However, she was able to correctly recall both words beginning in Session 38. This improved recall may have been due, in part, to the strategy Helen began using during Session 33. In addition, Peter and Helen were reported to use words spontaneously in conversations with other people.

Spelling

One reason for collecting spelling data was to address whether students would learn the correct spellings of words when the flashcard was present (correct spelling defined as using correct braille contractions as necessary). Although the auditory-only condition re-

quired fewer sessions to mastery for learning definitions, the flashcard condition was more effective for learning correct spellings. In fact, none of the participants learned to spell any new words in the auditory-only condition. The value of learning the meaning and spelling of a word was evident in the generalization probes, when students spent more time reading words from the auditory and control word sets than words from the flashcard set.

Even though more decoding was necessary to read those words, participants were able to read the words correctly. Peter was able to remember some spelling features from a single exposure during generalization and apply them to his spellings during maintenance probes. For instance, he corrected his spelling of *brawl* and *caravan*. He also corrected the first letter of the word *kerchief* (from *c* to *k*) as well as the first and final letters in *century* (from *sentree* to *centrey*). He eliminated the *w* he had been using to spell *sufferer* (*sufferwer*) and changed the *ai* he had been using to an *e* in the word *peso*. These slight corrections show that even a single exposure to the correct spelling of a word can impact an ingrained pattern of spelling.

Although all three students were able to learn the correct spelling of some words in the flashcard condition, they did not necessarily learn braille contractions through repeated exposure. As an example, Helen could read the *ble* and *ance* contractions found in the words *bramble* and *defiance*, but she was unable to use the contractions in her writing. This inability to write contractions was evident by her consistent scores of 1 for both words throughout the comparison phase. At one point, Helen's teacher explicitly taught her the *ble* contraction, and she incorporated it into her spelling of the word *bramble* in Session 27. Prior to that, even with daily exposure to the correct spelling in Sessions 5-27, she had been unable to spontaneously use the *ble* contraction.

Limitations

Although the pattern of sessions to mastery was evident across participants, there are limitations to the generalizability of findings from singlecase experimental design. All three participants were middle-grade students in a specialized school for students who are blind, in modified academic programs, with a maximum visual acuity of light perception. The results may not reflect the performance of students in inclusive settings or students who read braille and have residual vision. These participants were also proficient braille readers, and it is not assured that procedures would be as effective with beginning braille readers.

Vincent returned to his home district after the winter break, and we were unable to complete the last generalization session and maintenance probe. However, Vincent's maintenance of 100% in the previous two probes and the best alone condition provide evidence that his learning maintained.

We did not control teacher instruction and, as mentioned, one teacher did provide instruction in braille that led Helen to increase her total score for spelling. Although this increase in Session 27 cannot be contributed to the flashcard intervention, it occurred at the end of the comparison phase and her previous performance provides evidence that the flashcard condition had a significant effect on her increase in total spelling score.

One practical limitation of this study is the equation of definition recall with vocabulary learning. Although definitions are a key part of vocabulary instruction, there was no measure of whether students understood the meanings of the words by the end of the study. It is possible that students memorized the definitions without understanding them. There was anecdotal evidence that Peter and Vincent understood some words from their sets. Helen did not display similar hints to whether she understood the meanings. As such, it is possible that Helen did not increase her understanding of the words.

Implications for Research

To our knowledge, this study represents the first intervention research of vocabulary instruction for students who read braille. Additional studies are needed to confirm the findings reported here. Although study procedures may require more sessions to mastery for stu-

dents with below average working memory, it is clear that these procedures are effective for teaching definitions to mastery and, with slight modification, teaching correct spellings. Even though the auditory-only condition took fewer sessions to mastery, the difference of two sessions (Peter and Vincent) to mastery may not be instructionally relevant, especially considering what they gained in spelling.

Implications for Practice

Procedures used in this study provided four exposures to each target word during instruction and were constrained to a specific block of time during the school day. In practice, teachers have more freedom to integrate vocabulary words in activities throughout the day, providing multiple contexts as well as more exposure. Classroom teachers could include target words in writing activities and provide hands-on experience with more concrete words. It is possible that, in practice, teachers could provide enough exposures to words throughout a school day to supplement the explicit vocabulary instruction and make the strategy more efficient. Similarly, this procedure could be more effective if auditory instruction is separated from the presentation of the flashcard. Teachers would be able to direct all of their students' attention to the auditory information and then all of their attention to the flashcard.

Word choice will also play a role in affecting the efficiency of this vocabulary instruction procedure and holding students' attention. The words in this study were controlled on a variety of factors that classroom teachers will not need to consider. If the words are more relevant to the students, either intrinsically or academically, it is likely that teachers will see even more benefits from the use of this procedure.

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