Effects of a Word-Learning Training on Children With Cochlear Implants

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Preschool children with hearing loss who use cochlear implants demonstrate vocabulary delays when compared to their peers without hearing loss. These delays may be a result of deficient word-learning abilities; children with cochlear implants perform more poorly on rapid word-learning tasks than children with normal hearing. This study explored the malleability of rapid word learning of preschoolers with cochlear implants by evaluating the effects of a word-learning training on rapid word learning. A single-subject, multiple probe design across participants measured the impact of the training on children's rapid word-learning performance. Participants included 5 preschool children with cochlear implants who had an expressive lexicon of less than 150 words. An investigator guided children to identify, repeat, and learn about unknown sets of words in 2-weekly sessions across 10 weeks. The probe measure, a rapid word-learning task with a different set of words than those taught during training, was collected in the baseline, training, and maintenance conditions. All participants improved their receptive rapid word-learning performance in the training condition. The functional relation indicates that the receptive rapid word-learning performance of children with cochlear implants is malleable.

Over the last three decades, cochlear implants have improved the speech-perception abilities, and consequently, oral language outcomes of individuals with severe to profound hearing loss (Waltzman, Cohen, Green, & Rowland, 2002). Vocabulary knowledge, however, remains a particular area of linguistic weakness for preschool children with cochlear implants compared with age-matched peers with normal hearing (Connor,

Craig, Raudenbush, Heavner, & Zwolan, 2006; El-Hakim et al., 2001; Ganek, McConkey-Robbins, & Niparko, 2012; Hayes, Geers, Treiman, & Moog, 2009; Nicholas & Geers, 2006). In addition to having fewer total words in their lexicons, preschoolers with cochlear implants develop word knowledge at a slower rate than their peers (Nott, Cowan, Brown, & Wigglesworth, 2009). If children with cochlear implants are to enter school with comparable vocabulary to their hearing peers, then as preschoolers they will have to catch up to their peers with normal hearing. For this achievement to be possible, preschoolers with hearing loss must display a rate of vocabulary growth that is steeper than that of their hearing peers. The purpose of this study was to explore the malleability of rapid word learning of preschoolers with cochlear implants by evaluating the effects of a word-learning training on rapid word-learning performance.

Malleability of Word Learning of Children With Normal Hearing

Early word-learning research in children with normal hearing can inform and guide investigations of lexical growth in children with hearing loss. Researchers have focused on two aspects of the initial steps of word learning—fast mapping and rapid word learning. Fast mapping studies demonstrate the inclination of typically developing children to quickly link a word with a referent (Carey & Bartlett, 1978; Heibeck & Markman, 1987).[1] These studies, though informative, provide a very narrow picture of initial word learning.

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In contrast, studies of rapid word learning capture the process of storing a word-referent pairing in short-term memory for immediate retrieval, given some concentrated exposure to a word (Woodward, Markman, & Fitzsimmons, 1994). Rapid word-learning skills are evident in children with normal hearing as young as 13 months and children become much more proficient rapid word learners between 12 and 36 months of age (Houston-Price, Plunkett, & Harris, 2005; Woodward et al., 1994). Investigations of rapid word learning are hypothesized to be informative about the process of lexical learning, as rapid word learning allows children to quickly acquire new vocabulary from their environment.

When children participate in rapid word-learning tasks, they complete three steps: (a) connect the word and its referent, (b) encode phonological properties of the word, and (c) note semantic properties associated with the referent (Capone & McGregor, 2005; Collins & Loftus, 1975). Thus, children develop both a phonological representation and a semantic representation of a word. During initial exposure to a new word, children may build only partial representations. Repeated exposures to phonological and semantic properties of words likely improve a child's ability to later retrieve that word.

There is some initial evidence that the rapid word-learning abilities of children with normal hearing are malleable (i.e., the number of words learned rapidly can increase with practice). Gershkoff-Stowe and Hahn (2007) demonstrated that typically developing children improve their performance on rapid word-learning tasks after participation in structured activities that prime them to learn unknown words. Priming, in the context of this study, involved teaching children to name unknown objects. The word-learning skills of 16 typical children (16–18 months at study outset) with expressive vocabularies of 35–40 words were studied over the course of 10 weeks. An experimental group ($n = 8$) participated in training in which children heard and named unknown real words, whereas a control group ($n = 8$) participated in training in which children heard and named known words. Prior to and after the 10 weeks of training, children's performance on a rapid word-learning task was evaluated. Children who practiced naming unknown words

(i.e., experimental condition) demonstrated improved rapid word-learning skills; they retained more new, unfamiliar words presented in a structured receptive context as compared to children in the control condition. Additionally, the impact of the word practice training was observed on a parent report expressive vocabulary inventory. Although groups had a comparable expressive lexicon size at pretest, at post-test the experimental group had an average of 30 more expressive vocabulary words than the control group (reported Cohen's $d = 0.52$; this count excluded any words practiced by the experimental group in the training).

Word Learning of Children With Cochlear Implants

Children with severe to profound hearing loss come to the task of word learning at a disadvantage. First, they have less total listening experience or time with access to the full range of speech sounds than their same-age peers with normal hearing (Tomblin, Barker, Spencer, Zhang, & Gantz, 2005). The onset of word learning minimally coincides with when a child first has access to sound (i.e., receiving amplification such as hearing aids or cochlear implants). Current Food and Drug Administration-labeled indications do not support cochlear implantation under 12 months. Second, even with amplification and technological advances, access to acoustic information for children with hearing loss is degraded compared with normal hearing peers (Eisenberg, Shannon, Martinez, Wygonski, & Boothroyd, 2000). Third, most word-learning opportunities likely take place in acoustic environments that are not optimal. Even long-term cochlear implant users with more than 10 years of implant use struggle with speech perception in certain acoustic environments, such as listening in background noise (Davidson, Geers, Blamey, Tobey, & Brenner, 2011). Lack of access to acoustic information may impede preschoolers' building of phonological representations and semantic representations (Lederberg, Prezbindowski, & Spencer, 2000). These factors, individually and collectively, likely influence the words a child with hearing loss learns (or does not learn) throughout the day. Unfortunately, professionals cannot yet sufficiently alter implantation age, spectral resolution, or the full-time acoustic environment for

children with cochlear implants to eliminate the adverse impact of these factors.

As a result of learning challenges, children with cochlear implants demonstrate word-learning outcomes, as measured by experimental tasks that are poorer than their peers with normal hearing. To understand vocabulary development in children with cochlear implants, it is critical to explore performance on word-learning tasks. Recently, researchers have reported that children with cochlear implants have performed less proficiently than children of the same age with normal hearing on rapid word-learning tasks (Houston, Carter, Pisoni, Kirk, & Ying, 2005; Houston, Stewart, Moberly, Hollich, & Miyamoto, 2012; Tomblin, Barker, & Hubbs, 2007). If children with cochlear implants cannot learn comparable numbers of words from rapid word-learning opportunities (e.g., in their environment), they cannot be expected to develop a lexicon comparable to peers without hearing loss.

Based on evidence that the rapid word-learning performance of children with normal hearing is malleable, researchers must determine whether the rapid word-learning performance of children with cochlear implants is also malleable. If so, the malleability of rapid word learning of children with cochlear implants can be exploited to alter lexical outcomes for this population. To date, the effects of training on the rapid word-learning performance of children with cochlear implants have not been evaluated. Certainly, children with hearing loss can learn new vocabulary through direct instruction; however, learning vocabulary items through direct instruction does not replicate the efficiency of lexical learning in children with normal hearing (Luckner & Cooke, 2010). It is crucial for professionals to find ways to improve general word-learning performance to interrupt the adverse consequences of limited vocabulary knowledge on the academic achievement of children with hearing loss. If rapid word-learning performance can be improved, children with cochlear implants may be able to implement word-learning strategies to improve their lexical outcomes.

This study employed a single-subject design to evaluate the effects of a word-learning training on the rapid word-learning performance of children with hearing loss who use cochlear implants. The training in this study targeted the word-learning process as opposed

to teaching and testing the same words. That is, different words were used in the training than in the probe assessments. Thus, unique word sets were used in the training. The investigators posed two research questions about the malleability of the word-learning performance of children with cochlear implants: (a) Is there a functional relation between a word-learning training and the number of unknown words *comprehended* or *labeled* in a subsequent rapid word-learning probe? and (b) Is there a functional relation between word-learning training and the number of words comprehended in the presence of phonologically similar "distractor" words?

The training developed for this study explicitly highlighted steps of word learning as they occur for children with normal hearing. Recall that to store a new word for retrieval, a child must (a) connect the word and its referent, (b) encode phonological properties of the word, and (c) note semantic properties associated with the referent (Capone & McGregor, 2005; Collins & Loftus, 1975). Thus, the word-learning training included an identification component, label repetition, and a semantic teaching component. Based on the malleability of rapid word learning documented for children with normal hearing, the investigators hypothesized that the training would improve the rapid word-learning performance of children with cochlear implants, as measured by the number of words learned in each weekly probe assessment. Children with cochlear implants may have particular difficulty encoding and storing the phonological properties of a word; children with hearing loss may have poorer phonological representations of words as a result of their impaired speech perception. In contrast to children with normal hearing, children with hearing loss find it more difficult to learn words from lexically dense neighborhoods than lexically sparse neighborhoods (Kirk, Pisoni, & Osberger, 1995). Consequently, investigators hypothesized that children would learn fewer words in the presence of phonological "distractor" words in the word-learning probes.

Method

Experimental Design

A single-subject, multiple probe design across participants was employed to measure the impact of a word-learning training on children's rapid word-learning

performance (Horner & Baer, 1978). Single-subject methods are intended to measure a functional relation between an independent variable—the training—and one or more dependent variables—number of words comprehended and number of words labeled. The multiple probe design was preferred over other single-subject designs because rapid word learning is a learned rather than reversible behavior. Removal of the independent variable—training—should not cause a child to immediately revert back to his or her baseline level of rapid word learning. The dependent variables—number of words comprehended and number of words labeled—were tracked across participants rather than across behaviors because the word-learning training likely would not transfer to language learning behaviors other than vocabulary. To implement this study design, the investigators assumed that the dependent variables would respond in the same way to the independent variable (training) and that change in one participant's performance would not affect the performance of other participants. This design is appropriate to answer the research questions posed and to control for anticipated threats to internal validity by altering the length of the baseline across participants (Gast & Ledford, 2010).

The probe assessment was a rapid word-learning task. Probe assessments were collected from October to May on the following schedule: intermittently in the baseline condition, weekly in the training condition, and intermittently in the maintenance condition.

The order in which individual participants entered the training condition was determined a priori through random assignment. The training condition was 10 weeks in length. Single-subject design procedures require participants to serve as their own controls to demonstrate a functional relation between an intervention and a behavior (Kratochwill et al., 2010). Thus, participants entered training only after a stable baseline was observed. Participant 1 entered the training condition after a stable baseline on the receptive and expressive probe tasks was achieved as confirmed by two observers naive to the aims of the project (Gast & Ledford, 2010). Participant 2 entered the training condition after a stable baseline was achieved and after Participant 1 showed improvement on the receptive dependent variable beyond chance levels. The remaining participants entered the training under the

same conditions as Participant 2 (i.e., when improvement of the previous participant was beyond what was predicted by chance) rather than set intervals to control for threats to internal validity of the design (for a review, see Gast & Ledford, 2010). Participants 2 and 4 began the training during the same week due to time constraints within the school year (i.e., two participants needed to begin during the same week to complete the training period prior to the end of the school year).

Participants

Five preschool children (1 boy and 4 girls) with cochlear implants participated in this study. Children were eligible to participate if they had an expressive vocabulary of fewer than 150 words as measured on the MacArthur Bates Communicative Development Inventory-Words and Sentences (MCDI; Fenson et al., 2006). This vocabulary size eligibility criterion was established to ensure that children were in the initial period of lexical development (similar to participants in Gershkoff-Stowe and Hahn, 2007). Because vocabulary was deemed the most important eligibility criterion, participants ranged in chronological age from 3 years, 1 month to 5 years, 9 months and age of implantation ranged from 1 year, 11 months to 4 years, 4 months. The vocabulary criterion was selected rather than chronological or hearing age because recent word-learning research with children with hearing loss indicates that lexicon size largely drives rapid word-learning performance (Lederberg & Spencer, 2009). Inclusion of children with a variety of chronological ages reflects the variable nature of the vocabulary deficits of the broader population of children with hearing loss (see Ganek, McConkey-Robbins, & Niparko, 2012 for a review of outcomes). Participants had a diagnosis of congenital severe to profound, bilateral hearing loss as measured by automated brainstem response audiometry and had at least one cochlear implant device. No participant had a history of progressive hearing loss. All participants had (a) functional aided measurements that demonstrated hearing within the normal range (between 25 and 30 dB HL across 500, 1,000, and 2,000 kHz; most recent audiogram), (b) nonverbal intelligence quotients within the normal range, and (c) substantially depressed vocabulary development as compared to

chronological-age hearing peers (to ensure children were in the earliest period of lexical development). See Table 1 for individual child profiles.

Participants were recruited from a full-time, auditory-oral preschool for children with hearing loss. Children in this preschool learn to listen and to speak English using auditory amplification (e.g., hearing aids or cochlear implants) and receive 60 min of weekly individual speech-language intervention. Because the school adheres to an auditory-oral philosophy, neither teachers nor therapists use any form of formal manual communication, such as American Sign Language or Signing Exact English.

Of the 10 consent forms sent to parents, 6 were returned and 5 children (1 boy and 4 girls) were selected to participate. One child was unable to complete the probe assessment tasks and therefore, was excluded as a participant. Students in the school were not invited to participate if they (a) had an additional diagnosis known to affect cognitive and/or language development (e.g., Down syndrome, Noonan syndrome, autism spectrum disorder), (b) were unable to select an object from a field of four as indicated by the child's school speech-language pathologist, or (c) had documented visual impairment.

Four of the five participants (heretofore referred to as primary participants [Participant 1, 2, 3, and 4]) spoke only English in their home and school environments. The fifth participant was exposed to Spanish in the home by her mother and was included in this study as a case example. This participant (heretofore referred to as Participant 5) was included due to the paucity of literature on bilingual language development in children with cochlear implants. Her performance, in relation to other participants, provides information about the effects of this training on a child from a bilingual home, information that potentially provides a basis for future investigations.

At the outset of the study, a language assessment battery was administered to verify low linguistic knowledge across participants. Because comparisons are made across participants within a single-subject design, it is necessary to ensure participants have relatively equal levels of knowledge. The measures included the following: the *Expressive One Word Picture Vocabulary Test* (Brownell, 2000a), the *Receptive One Word Picture Vocabulary Test* (Brownell, 2000b), and the *Reynell Developmental Language Scales* (Reynell & Gruber, 1990). In addition, the *Primary Test of Nonverbal Intelligence* (Ehrler & McGhee, 2008) was administered to confirm normal nonverbal intellectual ability. A certified and licensed speech-language pathologist (E. Lund) administered these measures. See Table 2 for individual participant assessment profiles.

Development of Study Nouns: Unknown, Nonsense, and Known

To develop the probe assessment and training study word sets, 280 nouns unlikely to be part of the first 1,000 words that children with hearing loss learn were selected from Ling and Phillips' (1977) vocabulary guide. Preschool teachers in the auditory-oral school confirmed that participants knew none of these 280 words. Phonotactic probability and word length are factors that

Table 1 Participant characteristics

Participant	Age	Age at identification	Age at implant	Hearing loss	Devices	Intervention	Years of maternal education
1	3 years, 7 months	2 years, 2 months	2 years, 9 months	Bilateral profound	Cochlear implant, hearing aid	Auditory oral speech-language therapy	13
2	3 years, 1 month	2 years, 1 month	2 years, 7 months	Bilateral profound	Cochlear implant, hearing aid	Auditory oral speech-language therapy	17
3	3 years, 2 months	1 year, 2 months	1 year, 11 months	Bilateral profound	Bilateral cochlear implants	Auditory oral speech-language therapy, occupational therapy	16
4	4 years, 7 months	2 years, 7 months	4 years, 4 months	Bilateral profound	Bilateral cochlear implants	Auditory oral speech-language therapy	14
5	5 years, 9 months	3 years, 3 months	3 years, 9 months	Bilateral profound	Bilateral cochlear implants	Auditory oral speech-language therapy	8

Note. Participant 5 is a Spanish–English bilingual participant.

Table 2   Results of language and nonverbal assessment administered to all participants

Participant	ROWPVT SS	EOWPVT SS	RDLS E/R SS	PTONI SS	MCDI Total score
1	<55	<55	<63/<63	93	41
2	<55	<55	<63/<63	88	73
3	89	<55	<63/<63	91	120
4	<55	<55	<63/<63	86	121
5	<55	<55	<63/<63	116	149

Note. SS = standard score; ROWPVT = Receptive One Word Picture Vocabulary Test (Brownell, 2000b); EOWPVT = Expressive One Word Picture Vocabulary Test (Brownell, 2000a); RDLS E/R = Reynell Developmental Language Scales Receptive/Expressive scores (Reynell & Gruber, 1990); PTONI = Primary Test of Nonverbal Intelligence (Ehrler & McGhee, 2008); MCDI = MacArthur Bates Communicative Development Inventory (Fenson et al., 2006). All participants were monolingual English speakers with the exception of Participant 5 who was learning English and Spanish. Her MCDI score combined English and Spanish expressive vocabulary.

likely influence whether an individual word is learned by children with cochlear implants (Han, Storkel & Yoshinaga-Itano, 2011). In addition, high-frequency sounds in words influence word learning because they can be difficult to perceive for children with hearing loss (Stelmachowicz, Pittman, Hoover, Lewis, & Moeller, 2004). Thus, only words with one or two syllables and one or fewer high-frequency sounds (/s/, /f/, /ʃ/, or /θ/) were included in the 280-word corpus. Phonotactic probability (using Storkel & Hoover, 2010), word length in syllables, and number of high-frequency sounds were calculated for each of the 280 words in order to balance word sets for these features.

A total of 220 of the 280 unknown words were divided equally across 22 assessment word sets of 10 words per set (each set having words of comparable length, phonotactic probability, number of high-frequency sounds) and the remaining 60 were divided into 10 training word sets of 6 words per set. Note that words in the training set were not the same words tested in assessment sets (i.e., the words trained were not the same words assessed each week). Rhyming words or words differing by only one phoneme (e.g., *lace* and *vase*, *plug* and *plum*) were distributed to different study word sets. An additional 110 nonsense words were generated and assigned to the 22 assessment word sets (5 words per set). On each assessment word set, each nonsense word differed from one of the 10 real words by only one phoneme (e.g., *salo* was paired with *silo*). Words varied by consonant or vowel sounds. Nonsense words were included to simulate ecologically valid word-learning conditions, as the investigators judged that including words with only low neighborhood density did not represent realistic word-learning circumstances. For example, children with normal hearing learn words such as "bad" and "bed" and must distinguish between those words in everyday contexts. A photograph-quality picture card with a white background was constructed for each real word and each nonsense word (pictured with objects children were unlikely to have encountered, such as a spark plug).

Based on the MCDI, 20 known nouns were selected individually for each participant from the expressive words reported to be produced by the child. Picture cards for each word were constructed in the same manner as above. Thus, study materials included 390 unknown pictures (for 280 real words and 110 nonsense words) as well as 20 individualized known pictures per child.

The words targeted in the training and assessed during probes were not revealed to either teachers or parents of participants. These target words tend to occur infrequently in conversation (Ling & Phillips, 1977). Given that children with hearing loss demonstrate poor word-learning outcomes, the authors of this study made no effort to control participants' exposure to words outside of the study.

Procedures

Probe assessments.   The probe assessment, a rapid word-learning task, had 22 versions; each version utilized a unique unknown word set (i.e., word sets changed each week and were not the same word sets taught in the training). The versions were presented

to the participants in the same order (i.e., assessment word set 1 [10 unknown real words and 5 unknown nonsense words], assessment set 2, and so forth). The probe assessment had three phases: (a) introduction phrase, (b) expressive phase, and (c) receptive phase. In the introduction phase, the investigator (E. Lund) introduced pictures and labels of unknown words (one assessment word set). In the receptive and expressive phases, the investigator assessed the child's production and comprehension of the unknown words. Each phase had three rounds, and within each round, five words from the assessment word set were introduced, the five words were assessed expressively and then the five words were assessed receptively, before moving to the next round (see Figure 1). The sets of five words assessed were determined a priori to include up to two nonsense words (to answer research question two) and at least three real words. Rounds of five words were consistent across all participants. Order of presentation within rounds, however, was randomized. In sum, a probe assessment included 15 introduction, 15 expressive, and 15 receptive trials. In the sections below, the procedure for one round within each phase is explained.

Introduction phase. The investigator displayed on the table three pictures of known words (see above) and one picture of an unknown word. The investigator asked the child to identify the unknown pictured object (e.g., "Show me the _____.") If the child selected the unknown picture, the investigator praised the child and repeated the target six times. For example, if the pictures of log (unknown target), cat (known target), airplane (known target), and bus (known target) were displayed, the investigator said, "Yes! Log! Very good! This is the log. I see the log. You've got the log. Log. Can you say log?" If the child did not select the unknown

target picture, in this case log, the investigator removed the known target pictures, picked up the unknown target picture from the table, handed it to the child, and labeled it six times as in the above script (i.e., beginning with "This is the log.") This process was repeated for the five words in the round; order of word presentation was pre-determined.

Expressive phase. In the expressive phase, the investigator placed the five unknown pictures face-down away from the participant. One by one in a pre-determined, random order, the investigator turned a card over, asked "What is this?" and transcribed the participant's response according to the procedures outlined in *response definitions.* Following each expressive trial, the investigator offered praise (e.g., "good thinking, nice choice") regardless of the accuracy of the participant's response.

Receptive phase. In the receptive phase, the investigator selected four unknown pictures from the five unknown pictures targeted in that round and placed them on the table, face-up, in front of the child (preset selection and placement). The investigator asked the child to select a picture (e.g., "Where's silo?") in a pre-determined order albeit different from the expressive phase. The investigator recorded the child's receptive response (see Response Definitions and Measurement System for details). After the child's selection, the investigator removed the pictures from the completed trial, then positioned another four of the five unknown pictures in front of the child and asked for the next target. This procedure was repeated to provide an opportunity for identification of each of the five pictures targeted within the round. Although comprehension of each unknown word was tested only once, each of the pictures appeared in multiple receptive trials (once as a
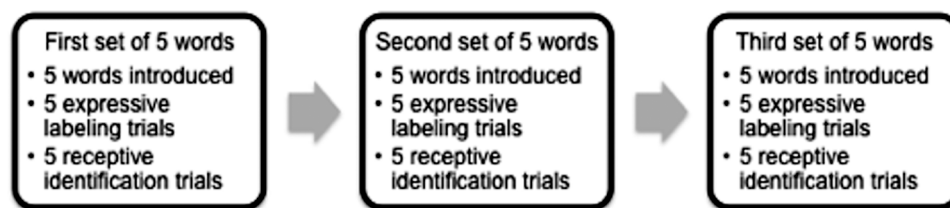

Figure 1 Probe assessment session order.

target and multiple times as a foil). In 10 of the 15 trials, a nonsense word picture and picture representing a real unknown word were presented as options within a trial (i.e., "salo" and "silo"). These distractor trials simulated real word-learning contexts encountered by children with normal hearing (e.g., children with normal hearing will learn similar words such as "Sam" and "sat"). In the other five trials, nonsense unknown word pictures were not included as "distractor" items (see Appendix for example order of one receptive trial). Following each trial, the investigator praised the child (e.g., "good thinking, nice choice"). At the end of the receptive phase, the investigator offered the participant a sticker, regardless of the accuracy of the participant's responses.

Word-learning training. The training condition involved 2-weekly word-learning training sessions (20 min) for 10 weeks. One training word set (6 words, 10 word sets, total 60 words) was used each week with the order of word sets consistent across participants. While participants were in the training phase, training was conducted on either Monday and Wednesday or Tuesday and Thursday according to the participants' classroom schedule. Probe assessments were completed on Friday (or the final day of the school week). Recall that words taught in the training were not the same words probed at the end of the week.

The training included three steps for each of the six unknown words: (a) identification, (b) label repetition, and (c) semantic teaching, each intended to guide the child through the process of rapidly learning a word. The first step, identification, was designed to increase the child's awareness of unknown words. The investigator set out pictures of three known words and one unknown word. The sequence of presentation was determined a priori and held constant across all children. One by one, the investigator picked up a card and said, "Do you know what this is?" If the child answered affirmatively, the investigator prompted the child to name the picture. Children named the known pictures on all opportunities. If the child did not respond, responded negatively, or incorrectly named the picture of the unknown word, the investigator said, "Uh oh, we need a name for this picture" and

named the picture. By drawing a child's attention to unknown targets, the investigator was explicitly teaching the child to recognize that he or she did not know a label for the picture.

The second step, label repetition, was intended to explicitly introduce the child to a phonological rehearsal strategy for learning new word labels. The investigator handed a plastic microphone to the child and signaled the child to repeat the word (e.g., "Say silo"). Regardless of imitative accuracy, the investigator and participant took turns talking into the microphone and producing each word four times (i.e., the child produced the word once after each adult model). If a child produced the wrong word or refused to produce a word, the investigator prompted the child a second and third time.

The third step, semantic teaching, was designed to allow children to connect the referent with other familiar information. The investigator provided a detail about each picture. For each unknown word picture, the detail script was established a priori. For example, for the unknown word "cricket," the investigator said, "A cricket is a kind of bug. Cricket!" Thus, the investigator produced each unknown word at least nine times within a single word-learning training session.

Maintenance condition. The 6 weeks of the maintenance condition followed the 10 weeks of the training condition. The probe assessment was administered at Week 3 and Week 6 to monitor retention of rapid word-learning performance. No word-learning training sessions were conducted in the maintenance condition.

Response Definitions and Measurement System

Assessment. The dependent variables in this study included (a) the number of words comprehended in the receptive phase of the probe assessment and (b) the number of words labeled in the expressive phase of the probe assessment. Because each probe assessment involved a unique word set and did not include any words learned in the training, these dependent variables were representative of general rapid word-learning performance. Change in the dependent variables was determined by visual analysis and confirmed by

observers trained in single-subject methods and naive to the study purpose (Gast & Ledford, 2010).

In the receptive phase of the probe assessment, a response was accepted as correct if the child selected the correct picture from a field of four by physically making contact with the card. If more than one card was touched, the investigator accepted the last card touched as the child's response. If no response was given, a single repetition of the question was provided after approximately 10–15 s. Nonresponses and error responses were counted as incorrect. Number of words comprehended was determined by summing correct responses, for a maximum of 15 correct responses.

In the expressive phase of the probe assessment, a response was accepted as correct if the child produced the vowel in the target word and consonants conforming to his or her speech patterns during imitations of target words in the introduction phase. If no vocal response was given, the investigator moved to the next trial after approximately 15 s. Nonresponses and error responses were counted as incorrect. Number of words labeled was determined by summing correct responses, for a maximum of 15 correct responses.

Interobserver agreement and procedural fidelity. All assessment and training sessions were video recorded. An independent observer (undergraduate student research intern, psychology major) collected agreement data for approximately 35% of probe assessments for the baseline condition and for the training condition using video recordings. The observer used a random number generator to select probe assessments randomly across conditions. The first author (E. Lund) trained the observer; the observer read the study protocol and participated in one probe assessment and one training session. First author (E. Lund) and observer response data were compared and the total number of point–by–point agreements was divided by the overall number of trials and multiplied by 100 to determine a percentage of agreement (Ayers & Gast, 2010). Results are displayed in Table 3.

An independent observer collected agreement data for approximately 33% of sessions within baseline and training conditions across all participants. The observer again used a random number generator to select sessions to be coded for fidelity. The first author (E. Lund) did not know a priori which sessions would be observed. The procedures for assessing the dependent variables were checked via video recording by the observer who collected interobserver agreement data. The number of steps completed was divided by the number of steps that should be completed according to the steps outlined in *Procedures* and multiplied by 100 (Billingsley, White, & Munson, 1980). Results are displayed in Table 3.

Results

This study investigated the existence of a functional relation between a word-learning training and receptive and expressive rapid word learning in children with cochlear implants. Participants engaged in three sequential conditions: baseline, training, and maintenance. In the baseline condition, children completed only the probe assessment task; in the training condition, the child participated in 2-weekly word-learning training sessions and completed the probe task; and in

Table 3 Reliability and procedural fidelity

Condition	Participant	Probe reliability, %	Probe fidelity, %	Training fidelity, %
Baseline	1	100.0	94.9	n/a
	2	99.3	95.2	n/a
	3	100.0	95.5	n/a
	4	99.3	91.7	n/a
	5	99.3	92.3	n/a
Training	1	100.0	94.3	99.3
	2	100.0	99.5	98.2
	3	99.3	100.0	98.5
	4	100.0	96.8	100.0
	5	99.3	99.8	99.3

Note. n/a = not assessed during this condition.

the maintenance condition, children completed only the probe assessment task at the end of each week.

Receptive Rapid Word Learning

In the receptive assessment, children were asked to select an unknown pictured object from a set of four unknown pictures. In the receptive trials of the probe assessment, participants responded to nearly all prompts (less than 1% nonresponses for each participant). Figure 2 displays results from the receptive trials for Participants 1–4. All participants displayed behavior consistent with chance levels (as represented by the dotted line) in the baseline condition; thus, baselines were considered stable. Although Participant 4 had two data points above chance levels, her average baseline as compared to her training condition performance remained stable. In the training condition, all participants demonstrated

marked increases in the correct answers. Change in performance during the training condition was not immediate, and no participant selected more than nine correct words within a single probe session. Overall, the performances across Participants 1–4 demonstrate and replicate a functional relation between word-learning training and number of words comprehended.

In the maintenance condition, assessment evaluated whether the influence of the word-learning training on rapid word-learning performance was evident when training was withdrawn. Recall that the probe task was a planned for administration at Week 3 and Week 6 of the maintenance phrase. Due to school year time constraints, only Participant 1 was assessed at two maintenance time points, Participants 2 and 4 at one point, and Participant 3 was not assessed.

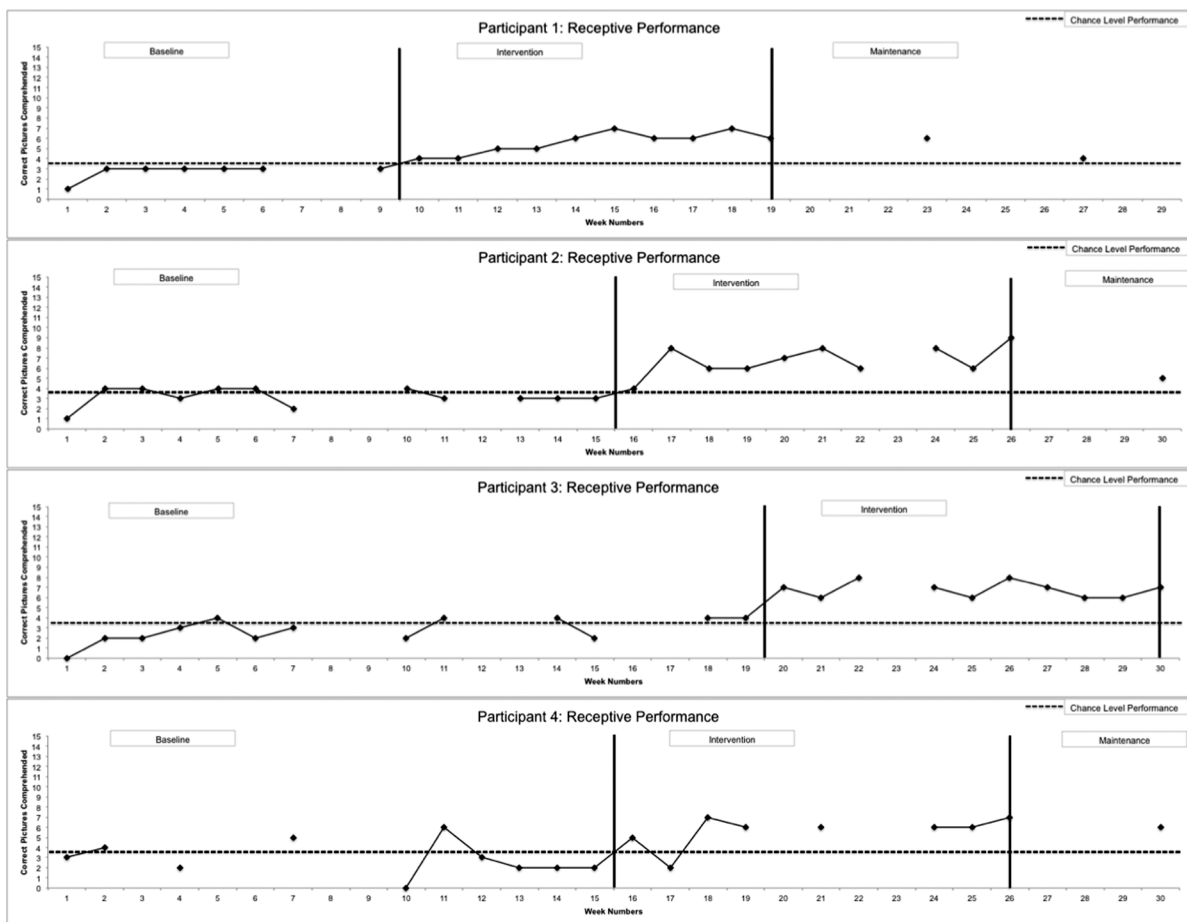Participant 1 demonstrated continued above-chance performance at 3 weeks. But, at 6 weeks, her performance

Figure 2 Participants' receptive rapid word-learning performance.

declined substantially relative to her performance in the training condition and approximated chance performance. Participants 2 and 4 displayed maintenance performance that remained slightly above chance level. However, both data points were lower than the average performance displayed in the training condition.

Expressive Rapid Word Learning

In the expressive assessment, children were asked to label unknown pictures. Within the expressive assessment, nonresponse rates (i.e., times when the child provided no response) were higher than in the receptive phase, but still relatively low (Participant 1: 2% baseline, 8% training; Participant 3: 13% baseline, 5% training; Participants 2, 4, and 5: 0% baseline, 0% training). Results are displayed in Figure 3 for Participants 1–4.

All participants achieved a stable baseline for the expressive trials of the probe task; virtually, no labels

were provided for unknown pictures. In the training condition, Participant 1 did not improve her performance. Participants 2–4 showed improved performance overall; however, each participant only increased labeling performance by one word and this increase was observed in less than 50% of probe assessments. Similarly, there was no change in expressive rapid word learning from the baseline condition to the maintenance condition (i.e., performance returned to baseline levels). The observed pattern of performance in the expressive phase does not indicate that a functional relation exists between word-learning training and labeling performance.

Receptive Rapid Word Learning With Phonological "Distractors"

Within 10 of the 15 trials in each receptive probe assessment, a phonological distractor word was present in the array of pictures (see Appendix). Recall that
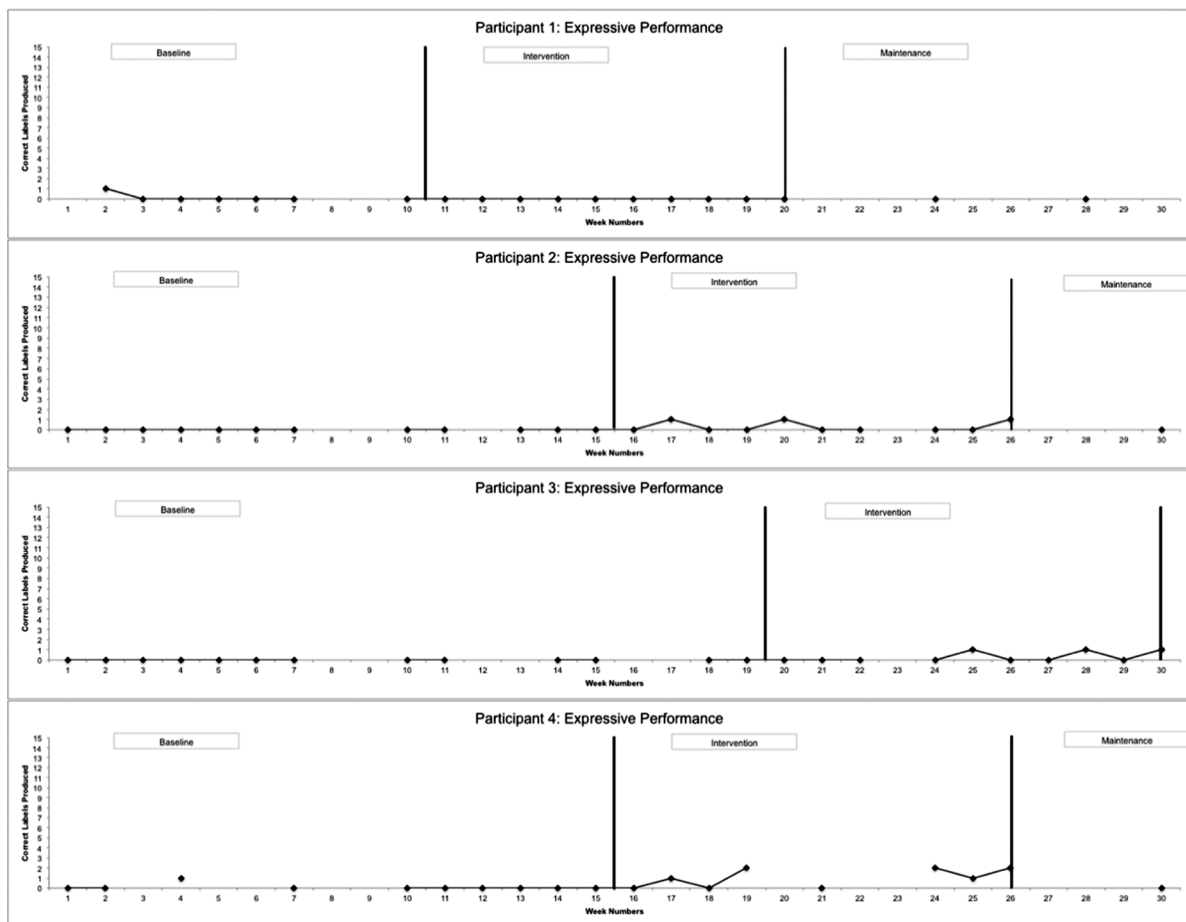

Figure 3   Participants' expressive rapid word-learning performance.

distractors were nonsense words paired with unnamed objects in the introduction phase of the assessment probe. Nonsense words varied from one other target by only one phoneme (e.g., "salo" and "silo"). Figure 4 displays error-analysis results from these trials. Points in this figure represent the number of correct pictures selected and the number of distractor pictures selected. All participants were more likely to receptively identify the correct picture in the presence of a distractor in the training condition than in the baseline condition. Thus, a functional relation existed between the training and decreasing effects of phonological distractor words.

Participant 5 Performance: A Case Example

Participant 5 was described separately from the other participants because she was exposed to a second language (Spanish) at home. Her performance represents a case example of the effects of the word-learning training on the rapid word-learning outcomes of a child with a cochlear implant from a bilingual environment. Participant 5's performance across the receptive and expressive probe tasks is displayed in Figure 5. Participant 5's performance was remarkably similar to the primary participants. Performance on the receptive probe was consistently above chance in the training condition, but her rate of improvement occurred faster than those of the first four participants. In addition, her performance on the maintenance probe task was higher than the performance of the other four monolingual participants. On the expressive probe task, Participant 5's performance did not improve. Similar to the other participants, Participant 5 also showed improvement in the selection of targets over time in the presence of phonological distractors. Thus, despite differences in language environment, the bilingual participant's results
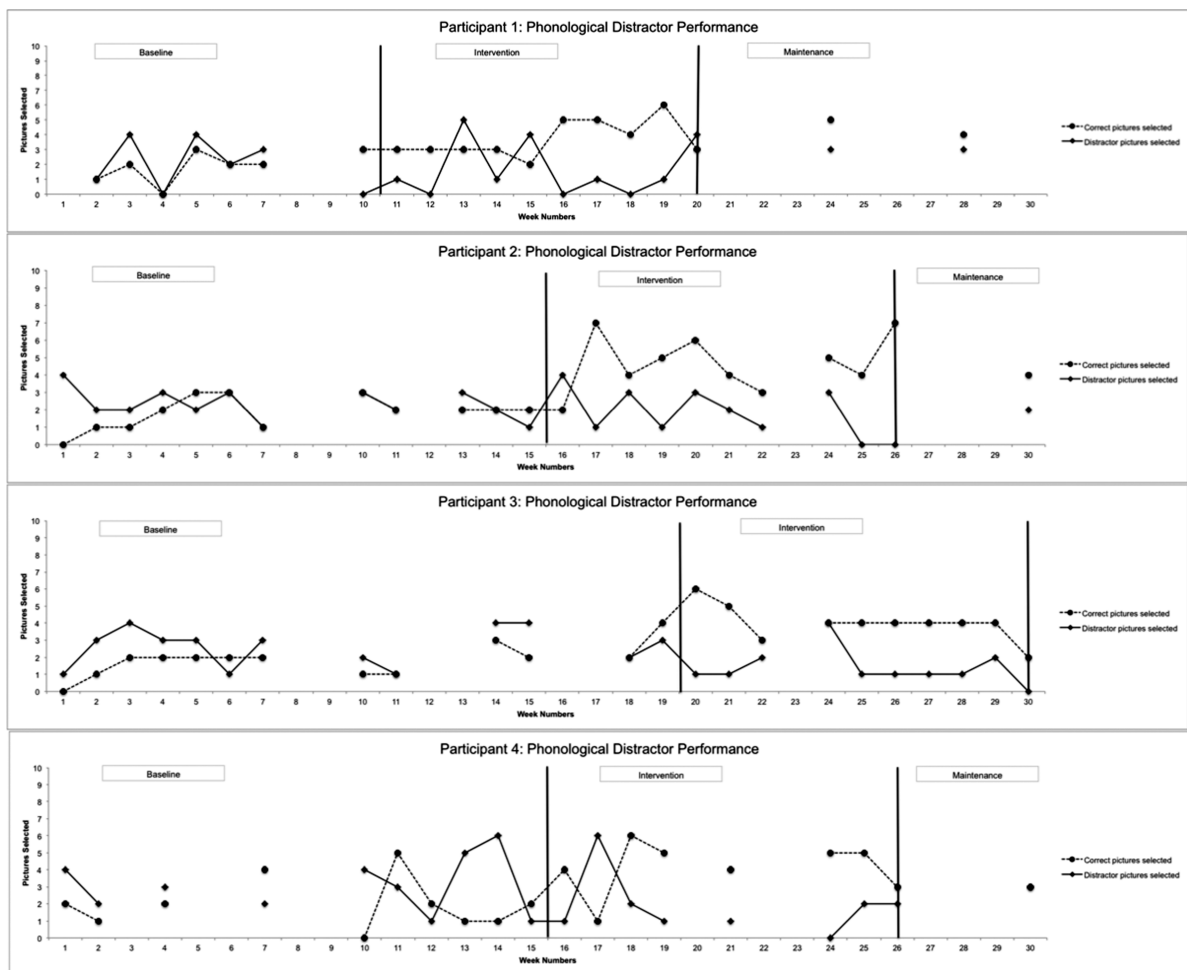

Figure 4 Participants' phonological distractor performance.
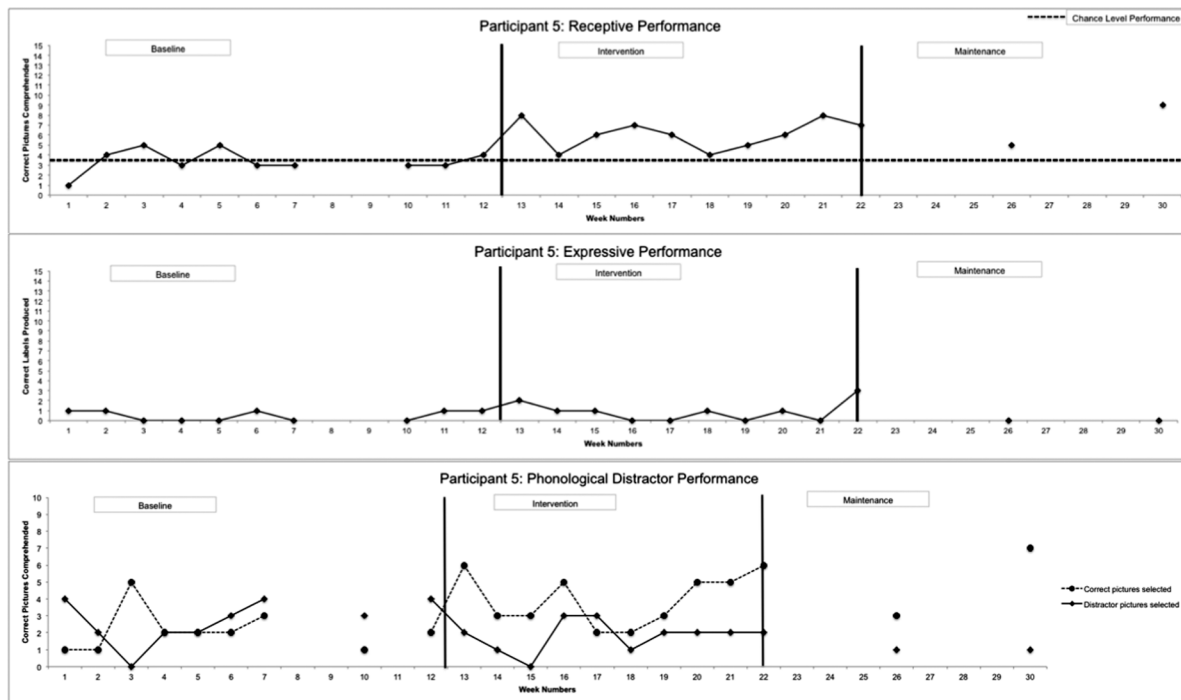
Figure 5   Receptive and expressive rapid word-learning performance of Participant 5.

are consistent with the results displayed by the mono-lingual (primary) participants.

Discussion

This study evaluated the effects of a word-learning training on the rapid word-learning performance of children with cochlear implants. Although other studies have evaluated word-learning performance and rates of vocabulary growth in children with coch-lear implants, this study is the first to evaluate the impact of a training on general rapid word learning for these children. The purpose of this study was to determine whether the rapid word-learning perfor-mance of preschool children with cochlear implants was malleable. Investigators found a functional rela-tion between word-learning training and receptive rapid word learning; however, no consistent func-tional relation was indicated for expressive rapid word learning. Thus, receptive rapid word learning is malleable for children with cochlear implants in the earliest stage of lexical development.

Receptive Rapid Word learning

A functional relation was demonstrated between the word-learning training and receptive rapid word learning. All four primary participants and the case example participant improved their comprehension performance from the baseline condition to the train-ing condition. A comparison of the average baseline condition performance and average training condition performance reveals that Participants 1, 4, and 5 (case example) improved their average receptive rapid word-learning performance by 18%. Participants 2 and 3 improved their average receptive rapid word-learning performance by 24% and 27%, respectively.

Because the performance of each participant increased from chance level to above chance level, change in receptive rapid word learning was con-strued as meaningful. To "catch up" with the vocabu-lary knowledge of normal hearing peers, children with cochlear implants must improve their word-learning performance at a rate greater than that of normal hear-ing peers. Data from this study indicate receptive rapid word learning of children with cochlear implants can increase as a result of practice learning unknown words. In other words, the receptive word-learning perfor-mance of children with cochlear implants was malle-able. Thus, interventions targeting the word-learning process may allow children with cochlear implants to improve their receptive rapid word-learning rate. Professionals can begin to explore the possibility that

systematic training can improve the overall lexical learning process.

Expressive Rapid Word Learning

No functional relation was demonstrated between word-learning training and expressive rapid word learning. Although three of the four primary participants displayed some improvement in expressive labeling from the baseline condition to the training condition, it is difficult to justify the very limited change as clinically meaningful. Participants improved their performances by only 1 of 15 possible words from baseline to training. It is not logical to think a training that influences performance in such a limited way would warrant continued implementation in the current form with the goal of improving expressive performance. Expressive rapid word-learning performance was not malleable under the current training. Given that receptive learning generally is thought to occur alongside or even before expressive learning, it is possible that participants did not have the prerequisite word-learning foundation or sufficient time to rapidly learn expressive labels for new objects. Children with normal hearing also display this pattern of behavior: children who have not yet entered a "productive naming explosion" learn more words in receptive tasks than expressive tasks (Woodward et al., 1994). Replication of this study with more intensive focus on expressive learning or with children who have larger vocabularies may demonstrate that children with cochlear implants can improve their expressive rapid word learning over a short period of time.

Receptive and expressive performance across individual participants did not appear to be influenced by either length of time of cochlear implant use (i.e., "hearing age") or vocabulary size at the onset of study participation. Inclusionary criteria for this study limited both the participants' range of vocabulary knowledge and time with exposure to the full range of speech sounds. Future work using a fully powered group study design may determine the extent to which a broader range of cochlear implant use and vocabulary knowledge moderate the effects of word-learning training on rapid word-learning performance.

Receptive Rapid Word Learning With Phonological "Distractors"

Phonologically similar "distractor" words were included in 10 of the 15-weekly probe assessment trials to evaluate the impact of phonological similarity on rapid word learning. The presence of these distractor words may have reduced the overall rate of expressive and receptive rapid word learning reported in this study. However, children did not learn words without phonological distractor counterparts at a consistently higher rate than words with distractors. Further, children were as likely to recall an expressive label for a word with a phonological distractor as for a word without a distractor. All participants were more likely to receptively identify the correct picture in the presence of a distractor in the training condition than in the baseline condition. The more consistent performance in the intervention condition is encouraging, perhaps indicating further that children with cochlear implants can improve their rapid encoding of phonological representations. This finding could represent preliminary evidence to motivate a study in which children attempt to learn equal numbers of words with and without "distractors" present.

Future Directions

A single-subject design was chosen to determine whether the word-learning training described could be beneficial for individual children with cochlear implants. Specifically, investigators used this method to determine whether the rapid word-learning performance of children with cochlear implants was malleable. The results of this study indicate that the training can improve the receptive rapid word-learning performance of at least some children with cochlear implants, thus establishing the malleability of receptive rapid word learning. The next step in this line of inquiry is to generalize these findings to the larger group of children with cochlear implants. Single-subject design is intended only to identify functional relations between two variables in a subset of a population (Horner et al., 2005). Single-subject design does not include a control group of children with normal hearing. Future investigations may consider use of a group design to evaluate the effects of this training on the broader population of children who use cochlear implants versus children

with normal hearing. For example, the case example of Participant 5 demonstrates that a child from a bilingual home can also benefit from training targeting the word-learning process; however, more research is needed to generalize this finding to the population of bilingual children with cochlear implants.

Limitations of this study relate to the ecological validity of the design. The probe measure was designed to capture weekly change in performance across receptive and expressive variables. However, change on this measure does not necessarily translate to general changes in children's lexical knowledge at home and in the classroom. Further investigations may evaluate broader changes in lexical knowledge outside of an experimental context using parent and teacher report. Findings that training can influence receptive word learning in a tightly controlled context should lead to future studies that measure more ecologically valid outcomes. In addition, a research speech–language pathologist (E. Lund) implemented the training outside of a classroom or typical therapy context. Future studies should evaluate the effects of the training when the child's classroom teacher or clinical speech–language pathologist is the interventionist to ensure the training can be implemented in an ecologically valid setting. Overall, this study demonstrates promise that the rate of word learning in children with cochlear implants may be malleable and it establishes reasons for professionals to explore systematic training that takes advantage of this malleability.

Note

1. Within the developmental psychology literature, fast mapping refers to a child's initial connection or link between a word and its referent, using cues from the linguistic and nonlinguistic environment, given limited (e.g., one verbal presentation) and very brief exposure to the word (sometimes referred to as a disambiguation task; Mervis & Bertrand, 1994). Some communication disorders researchers have labeled rapid word-learning tasks as fast mapping; the variation in the use of these terms is a potential source of confusion in the extant literature (for further explanation, see Rice, Buhr, & Oetting, 1992).

Conflicts of Interest

No conflicts of interest were reported.

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Appendix

Sample presentation of receptive trial items for a set of five pictures

Unknown "real" objects: silo, loom, funnel.
Unknown "nonsense" objects: salo, loof.

Appendix Table A1 Order pictures presented in one receptive probe trial

First pictures presented	Second pictures presented	Third pictures presented	Fourth pictures presented	Fifth pictures presented
Silo	**Loof**	**Funnel**	**Loom**	**Salo**
Loom	Salo	Loom	Loof	Funnel
Salo	Loom	Salo	Silo	Loof
Funnel	Funnel	Silo	Funnel	Silo

Note. Bolded items represent pictures requested by investigator.