Word-Learning Abilities in Deaf and Hard-of-Hearing Preschoolers: Effect of Lexicon Size and Language Modality

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Deaf and hard-of-hearing (DHH) children’s ability to rapidly learn novel words through direct reference and through novel mapping (i.e., inferring that a novel word refers to a novel object) was examined. Ninety-eight DHH children, ranging from 27 to 82 months old, drawn from 12 schools in five states participated. In two tasks that differed in how reference was established, word-learning abilities were measured by children’s ability to learn novel words after only three exposures. Three levels of word-learning abilities were identified. Twelve children did not rapidly learn novel words. Thirty-six children learned novel words rapidly but only in the direct reference task. Forty-nine children learned novel words rapidly in both direct reference and novel mapping tasks. These levels of word-learning abilities were evident in children who were in oral-only and in signing environments, in children with cochlear implants, and in deaf children of deaf parents. Children’s word-learning abilities were more strongly correlated to lexicon size than age, and this relation was similar for children in these different language-learning environments. Acquisition of these word-learning abilities seems based on linguistic mechanisms that are available to children in a wide range of linguistic environments. In addition, the word-learning tasks offer a promising dynamic assessment tool.

Researchers estimate that hearing 2-year-olds typically learn between two and nine new words per day (Golinkoff et al., 2000). The ability to rapidly learn new words in a variety of contexts is fundamental to the development of a large vocabulary as well as later literacy skills. Interest in children’s word-learning abilities was first motivated by an observation by Carey (1978) that hearing 3-year-olds were able to infer the meaning of a new word, “chromium,” when told simply “Bring me the chromium tray, not the blue one, the chromium one.” Emphasizing the speed with which these children learned new words, Carey referred to this type of word learning as “fast mapping.” This informal observation inspired investigators to systematically examine children’s ability to learn new words using novel word-learning tasks. In these tasks, an adult uses a nonce (nonsense) word to refer to a novel object. The child is then asked to select a referent for the word (e.g., “Give me a dax”). The more stringent studies include a test of the child’s ability to generalize the word to a different but similar referent (another example of a dax). By varying the frequency of input as well as the cues present when the nonce words are initially presented, researchers have documented developmental changes in children’s word-learning abilities (Hollich, Hirsh-Pasek, & Golinkoff, 2000).

Researchers have proposed a variety of cognitive and linguistic mechanisms that enable the development of children’s remarkable word-learning abilities. For instance, Mervis and Bertrand (1994) proposed that children gain new word-learning abilities based on changes in their nonlinguistic cognitive skills, especially categorization abilities. Others suggest that children
have innate cognitive-linguistic constraints or biases that guide word learning (Woodward & Markman, 1998). In contrast, associative learning theorists who espouse connectivist theories propose that word-learning abilities or biases are based on attentional processes that develop due to statistical regularities in linguistic input (Smith, 2000). Social-pragmatic theorists propose these abilities are a reflection of children’s culturally acquired knowledge about adults' intentions and social cues to how words are used (Akhtar & Tomasello, 2000). Recently, rather than one mechanism, researchers have convincingly argued that word-learning abilities can be best characterized as changes that occur along multiple dimensions (Akhtar & Tomasello; Golinkoff et al., 2000; Waxman & Lidz, 2006). The following is a description of some of the developmental changes suggested by research on hearing children’s ability to learn names of objects (i.e., nouns)—the focus of the current study.

**Slow Word Learning**

Diary data and experimental research with hearing infants indicate that 1-year-olds retain a new word only after hearing it many times (Dromi, 1999; Hollich et al., 2000). In addition, young toddlers learn words for referents that are perceptually salient. Even with very explicit social-pragmatic cues (e.g., partner’s eye gaze at or pointing to referent), young toddlers typically do not learn the label of an object unless they find it intrinsically interesting. The word-referent link is most likely made through associative processes (Hollich et al.).

**Direct Rapid Word Learning**

Sometime between 16 and 24 months, changes typically occur that facilitate acceleration of word learning. First, children are able to “fast map” or rapidly form an initial representation of the phonological form and meaning of a word after only a few exposures (Dromi, 1999; Hollich et al., 2000). Second, they become adept at learning the meaning of words based on the social-pragmatic cues given by adults (e.g., eye gaze toward, pointing to referent). This change may be based on the development of the general ability to infer the referential intention of others (Akhtar & Tomasello, 2000; Golinkoff et al., 2000; Hollich et al.).

In addition to socially based word-learning abilities, toddlers and even infants may have internal constraints or biases that help them determine the meaning of words (Woodward & Markman, 1998). An example of these biases is the assumption that a word refers to a whole object instead of its parts or attributes. Another is the principle of mutual exclusivity, that is, the idea that every object has a name and only one name. It is unclear to what extent these biases are cognitively determined and to what extent they are based on regularities in input (Waxman & Lidz, 2006). However, several studies suggest that these biases may result in genuine word learning only when they are supported by social-pragmatic cues from adults during early word learning (Evey & Merriman, 1998; Graham, Poulin-Dubois, & Baker, 1998).

**Indirect Word Learning**

Between 24 and 30 months, typically developing hearing children develop the ability to learn the meaning of new words in contexts when speakers give no direct cues for reference. This learning process can be considered inductive in contrast to earlier deductive learning when reference was directly established by an adult. For example, 2.5-year-olds reliably infer that a novel word refers to a novel object rather than a familiar one (Evey & Merriman, 1998; Graham et al., 1998). To illustrate, if a child is looking at a lion, elephant, and gazelle, and an adult says, “Oh look, a gazelle,” the child who already knows “elephant” and “lion” will assume “gazelle” refers to the novel animal. This word-learning ability has been called novel mapping (Lederberg, Prezbindowski, & Spencer, 2000; Masur, 1997), Novel Name-Nameless Category Principle (Mervis & Bertrand, 1994), disambiguation effect (Graham et al.), and even just fast mapping (Brackenbury, Ryan, & Messenheimer, 2006). Surprisingly, 3-year-old hearing children’s acquisition of words learned through such indirect processes is as robust as those that are acquired through direct reference (Jaswal & Markman, 2003).

The goal of the current study is to explore whether deaf and hard-of-hearing (DHH) children’s development of word-learning abilities is similar to that of hearing children. Deaf children with deaf parents,
who experience a rich visual language environment, typically develop age-appropriate vocabulary knowledge (Anderson & Reilly, 2002). A case study of a hearing child with deaf parents provides some evidence that children acquiring American Sign Language (ASL) also develop age-appropriate word-learning abilities (Brackenbury et al., 2006). In contrast, past research has shown that the lexicons of DHH children with hearing parents tend to be smaller, to develop more slowly, and to be more variable than those of hearing children (Anderson, 2006; Blamey, 2003; Lederberg, 2003), although reports of children with early intervention are more promising (e.g., Yoshinaga-Itano, 2003). Many DHH children with hearing parents are not exposed to a complete language system because their parents lack fluency in sign, signing only one or two words per utterance (Lederberg; Meadow-Orlans, Spencer, & Koester, 2004). The ability of DHH children to access spoken language is also variable and depends on a number of factors including level of hearing loss, age of identification, and quality of early intervention, as well as age of effective use of amplification and/or cochlear implants (Spencer & Marschark, 2006). Those children who lack a fluent and complete language model have fewer opportunities to learn new words and thus have smaller lexicons. Impoverished and variable input might also interfere with the development of word-learning abilities. Thus, research with young DHH children provides an opportunity to investigate the development of word-learning abilities in children who are acquiring language in environments that vary greatly in the nature of linguistic input. In addition, given that many DHH children typically develop lexicons at a slower rate than hearing children who have similar nonverbal cognitive abilities, the study of the word-learning abilities of DHH children may provide information about the relative import of nonverbal versus linguistic-related cognitive processes on word learning.

Research on DHH children’s word-learning abilities have primarily focused on what cognitive and language characteristics relate to elementary school-age children’s ability to rapidly learn novel words. Gilbertson and Kamhi (1995) studied hard-of-hearing children’s ability to learn spoken novel words whose meaning was directly established by the researcher. These children had no problems learning word meanings. However, ability to accurately produce the words was more variable and highly correlated with scores on the Peabody Picture Vocabulary Test. Using the same task, Wilstedt-Svensson, Lofqvist, Almqvist, and Sahlén (2004) studied spoken word learning by Swedish school-age children with cochlear implants who were exposed to both spoken and signed languages. Novel word learning related to children’s performance on tasks of complex auditory working memory and auditory phonological short-term memory. Using a more indirect reference task, Pittman, Lewis, Hoover, and Stelmachowicz (2005) and Stelmachowicz, Pittman, Hoover, & Lewis (2004) found that school-age DHH children learned fewer spoken novel words (measured with a comprehension task) than age-matched hearing children. The number of new words learned correlated with receptive vocabulary.

The above studies of school-age DHH children demonstrate that they are able to learn new words in both direct and indirect contexts and that their word learning is related to vocabulary knowledge and cognitive skills in theoretically meaningful ways. However, the studies have used different measures and have all examined acquisition of spoken words only. Thus, auditory perception and processing abilities were prerequisite to successful performance on the word-learning tasks, and variations in those abilities may have complicated interpretation of the results. In addition, unlike the research with hearing children summarized above, the focus of this research was on the efficiency of word learning (i.e., the number of words learned) rather than on the acquisition or development of word-learning abilities.

Lederberg et al. (2000) focused on the development of word-learning abilities by assessing two types of novel word learning in 19 3- to 5-year-old DHH children who were in one school that used signs in combination with spoken language. Both tasks were adapted from ones used by Mervis and her colleagues with hearing children (Mervis & Bertrand, 1994, 1995; Romski, Sevcik, Robinson, Mervis, & Bertrand, 1996). One task assessed children’s ability to learn novel words after only three exposures when referents were directly marked through social-pragmatic cues; the other required rapid word learning through novel
mapping. Similar to Mervis and colleagues, children were categorized as “having” a word-learning ability if they learned two to four novel words in a task. Results suggested that these word-learning abilities were still developing during preschool for some DHH children who were language delayed. Two children were not able to learn new words rapidly in either task. Five children learned new words rapidly but only with direct reference. Eleven children were able to learn new words using both direct reference and novel mapping. These three levels of word-learning abilities were related to an index of the size of the children’s expressive vocabulary but not their chronological age. When reassessed over the next year and half, the two children who started without the ability to learn words in either task first acquired rapid word learning with direct reference and then, eventually, novel mapping. The five children who initially required direct reference eventually developed the ability to learn new words through novel mapping. Word-learning abilities were sometimes acquired as long as 3 years after the age typical for hearing children.

Because all children had nonverbal cognitive skills of at least a typically developing 2.5-year-old hearing child (a chronological age at which most hearing children have acquired novel mapping abilities), the results suggested that attainment of these word-learning abilities was related to the development of linguistically-based abilities rather than nonverbal cognitive development. Furthermore, although these skills were significantly delayed, there did not appear to be a critical age-based period for their acquisition because all children eventually acquired novel mapping. Finally, the study underscored that DHH children who are in the same preschool classroom may need very different types of input to learn new words. However, conclusions from this study were considered tentative because of the relatively small sample size and consequent small numbers of children performing at each word-learning level. In addition, all the participating children were in the same school and were using the same language system (speech combined with sign). Thus, it was not clear whether the results could be generalized to other groups of DHH children.

The primary goal of the current study was to replicate the study by Lederberg et al. (2000) in order to increase the confidence with which these earlier findings can be generalized and to explore the potential impact of DHH children’s language-learning environment on word-learning abilities. The current study included 98 children from 12 different schools. These schools included oral-only as well as oral plus sign and sign-only environments. Deaf children with deaf parents as well as children with cochlear implants participated. The large and diverse sample allowed us to examine word-learning abilities of children who were developing these skills in very different types of language-learning environments. In addition, given the typical lack of congruence between cognitive and linguistic skill levels in some (though not all) DHH children, results may provide some insight into the underlying bases for acquisition of these word-learning abilities.

We expected the earlier results (Lederberg et al., 2000) to be replicated. Specifically, we hypothesized that DHH children would exhibit three levels of word-learning abilities: (a) Some DHH preschoolers would not be able to learn new words rapidly either through direct reference or novel mapping, (b) some DHH preschoolers would learn new words rapidly but only when reference was established directly, and (c) some DHH preschoolers would learn new words rapidly through both direct reference and novel mapping. We expected that these levels of word-learning abilities would be more strongly related to children’s vocabulary knowledge (as measured by an index of lexicon size) than to their chronological age.

Method

Participants

Ninety-eight DHH children, ranging in age from 27 to 82 months old (mean age 55 months; SD = 12.2), participated in the study. There were 49 girls and 49 boys. Ethnic background of the children and their families was diverse: 59 Caucasians, 16 African-Americans, 5 Hispanic/Latino, 1 Asian-American, 4 biracial, and 13 unknown. Seven of the children were twins. Nine came from homes in which the primary language was a spoken language other than English. Results of vocabulary assessment (to be described below) indicated that most of the children were language
delayed. An effort to recruit participants from varied geographic areas and program types resulted in inclusion of children from five states who attended 12 different schools (including public, private, and state schools) in rural, urban, and suburban settings. Participants represented all children at the participating preschools serving children with hearing loss (a) whose parents gave consent, (b) whose teachers believed they understood at least 10 object names and could identify appropriate referents, and (c) could pass a pretest showing that they could follow directions and participate in the tasks. The rate of parental consent for participation in the study was high. Therefore, almost all children served by these preschools from September 1997 through February 2000 were included, except for those few who had developmental disabilities that prevented them from acquiring 10 object names. Because most of the participating schools served neither 2- nor 6-year-olds, there were fewer participants at these ages than at 3–5 years of age. In addition, because 6-year-olds are typically not in preschool, it is likely these children were retained in preschool because of cognitive and/or language delays.

Ninety of the 98 children had a congenital hearing loss: 3 had mild loss, 14 had moderate loss, 9 had moderately severe hearing loss, 20 had severe hearing loss, and 46 had profound hearing loss. The average age of identification of congenital hearing loss was 18 months (SD = 12 months). Of the eight children who were not born with hearing loss, average age of acquired hearing loss was 17 months (range 9–42 months). Etiologies of hearing loss were identified as genetic (24), meningitis or other illness (10), prematurity or maternal illness during pregnancy (13), other causes (3), and unknown (48).

Thirty-seven of the children were enrolled in oral (speech only) schools, 58 were in schools where teachers used simultaneous communication consisting of speech and an English-based sign system or conceptually based signs, and 3 children were in bilingual (ASL/written English) programs. Except where specifically noted, children’s language-learning environments were divided into two categories for all analyses in this article: (a) oral programs (using spoken language only) and (b) schools using signs (with or without accompanying speech).

Eighty-six children had only hearing parents, six had a hard-of-hearing parent, and six additional children had one or two deaf parents. Deaf parents reported using ASL with their children. To obtain an indication of parents’ signing skills for children in signing programs, teachers were asked to rate parents’ sign skills on a five-point scale that ranged from none (1) to expert (5). For the children who were enrolled in signing programs and had hearing parents, the modal teacher rating of mothers’ signing skill was poor (2): “knows very few signs, rarely signs to child.” The modal rating of fathers’ signing skill was none (1). Based on these ratings, it appears that hearing parents whose children were in educational programs using signs were generally not skilled signers.

Twenty-three of the children had cochlear implants. The average age of implantation was 31 months (SD = 9.6, range = 22–55 months) and the average time since implantation was 22 months (SD = 11.6, range 2–44). Seventeen of these children were in oral schools and six were in schools that used signs plus speech.

Materials and Procedures

Vocabulary assessment: measures and procedures. Three measures of children’s vocabulary were obtained.

Grammatical Analysis of Elicited Language-Pre-sentence Level. Using the single word vocabulary section of the Grammatical Analysis of Elicited Language-Pre-sentence Level (GAEL-P) (Moog, Kozak, & Geers, 1983), we asked children to label 30 replica objects. Although this test was standardized using only spoken English, it was administered in the language system used in each child’s school. Thus, it was administered to some children in signs only, to some in combined speech and sign, and to some in spoken language only. For the current study, the score for this test was the number of objects labeled correctly.

Carolina Picture Vocabulary Test. Receptive vocabulary was assessed using the Carolina Picture Vocabulary Test (CPVT), a directly administered test developed to assess the signed vocabulary of deaf children (Layton & Holmes, 1985). Children are required to point to the correct picture (out of four on each
The test was administered in the language system used in each child’s school.

MacArthur communication development inventory—words and sentences. Teachers of children in oral or sign-plus-spoken English programs were asked to identify all words that the children produced (signed or spoken) from the 680-word checklist included in the communication development inventory (CDI) for American English (Fenson et al., 1993). This measure has been used with deaf children, in signing as well as in oral programs (Lederberg et al., 2000; Mayne, Yoshinaga-Itano, Sedey, & Carey, 2000; Meadow-Orlans et al., 2004; Thal, DesJardin, & Eisenberg, 2007). The teachers of the three children in bilingual programs, in which the primary focus during early years is on acquisition of ASL, completed the ASL version of the CDI (Anderson & Reilly, 2002). Although the CDI checklists are designed to be completed by parents, we asked teachers to complete the form. Given small class sizes and program’s focus on language, we hypothesized that teachers would be valid informants. In addition, parents were not the primary source of linguistic input for many children in signing programs, and it was expected that teachers would have a more complete knowledge of signs the children knew and used.

Research suggests that the CDI is a more accurate measure of young children’s early vocabulary knowledge than directly administered tests (GAEL-P and CPVT) were used in the current study to confirm that the teacher-completed CDIs related to other measures of vocabulary knowledge.

Word-learning tasks and procedures. Children were administered two novel word-learning tasks that were identical in structure but differed in the way reference was established. Table 1 displays the overall structure of both word-learning tasks but with the objects and words used in the novel mapping task. Although similar in basic structure, the two word-learning tasks utilized different procedures and objects. In the direct reference task, the researcher established the meaning of the novel words through social-pragmatic cues, including pointing. In the novel mapping task, meaning had to be inferred by the child. We first describe the structure of both tasks, then the procedures of the individual tasks.

Table 1  Structure and categories of objects used in word-learning tasks

<table>
<thead>
<tr>
<th>Novel word</th>
<th>Type of trial</th>
<th>Type of object</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td></td>
</tr>
<tr>
<td>DAX</td>
<td>Exposure 1</td>
<td>Pastry blender</td>
</tr>
<tr>
<td></td>
<td>Generalization 1</td>
<td>Pastry blender</td>
</tr>
<tr>
<td>TIV</td>
<td>Exposure 2</td>
<td>Corkscrew</td>
</tr>
<tr>
<td></td>
<td>Generalization 2</td>
<td>Corkscrew</td>
</tr>
<tr>
<td>FAPI</td>
<td>Exposure 3</td>
<td>Rope clip</td>
</tr>
<tr>
<td></td>
<td>Generalization 3</td>
<td>Rope clip</td>
</tr>
<tr>
<td>NUPA</td>
<td>Exposure 4</td>
<td>Tea strainer</td>
</tr>
<tr>
<td></td>
<td>Generalization 4</td>
<td>Tea strainer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Target</td>
<td>Distracter</td>
</tr>
<tr>
<td></td>
<td>Mommy</td>
<td>Shoe</td>
</tr>
<tr>
<td></td>
<td>Baby</td>
<td>Hat</td>
</tr>
<tr>
<td></td>
<td>Baby</td>
<td>Hat</td>
</tr>
<tr>
<td></td>
<td>Dog</td>
<td>Car</td>
</tr>
<tr>
<td></td>
<td>Dog</td>
<td>Car</td>
</tr>
<tr>
<td></td>
<td>Banana</td>
<td>Chair</td>
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<tr>
<td></td>
<td>Banana</td>
<td>Chair</td>
</tr>
<tr>
<td></td>
<td>Bird</td>
<td>Airplane</td>
</tr>
<tr>
<td></td>
<td>Bird</td>
<td>Airplane</td>
</tr>
</tbody>
</table>

Structure of the word-learning task. Each task had nine sets of objects (see Table 1). One set was for a pretest trial, and four paired sets were for exposure and generalization trials of each of four novel words. Stimuli for both tasks included familiar and novel objects. Familiar objects were those that the child could already label correctly. We selected familiar objects based on published lists of early lexicons of hearing (Fenson et al., 1993) and deaf children (see Anderson, 2006, for a review). In addition, to assure that children actually knew labels for the familiar objects, teachers indicated individual children’s lexical knowledge on a short checklist of object names. When the teacher indicated that a child did not know an
object name, it was replaced with a different, known object. For children with very small lexicons, familiar categories of objects were used for more than one word-learning trial during a task. For example, small shoes might be used on several trials in the word-learning tasks. Although a category of object might be repeated across a task, particular exemplars were only used once. For each paired set of trials (i.e., exposure and generalization), different exemplars of the same three familiar categories of objects were used. In order to facilitate speech discrimination when spoken language was used, the names of the objects in a trial differed in their initial spoken phoneme.

Novel objects were unusual objects typically not found in preschool children’s environments (e.g., cherry pitter). Each paired set of trials contained different exemplars of the same category of novel objects (the “target”). For two pairs of novel objects in a word-learning task, the novel exemplars differed only in color. The other two pairs of novel exemplars differed in two or more dimensions (e.g., color, size, texture, and/or shape). We replaced any novel object that a child recognized with another novel object before the end of the exposure trial. Recognition was operationalized by the child labeling the novel object (correctly or incorrectly) or indicating by an action that he or she understood its function. This occurred with the same frequency in both tasks—13 times out of 392 trials (4 novel objects \( \times \) 98 children) in each task.

Language used in word-learning tasks. Consistent with previous research with both hearing and deaf children, nonsense (or nonce) words were used to refer to the novel objects when spoken language was used in a task. For each word-learning task, half the spoken nonce words were one syllable and half were two syllable words. A set of nonce signs was created for use with children in signing environments by a linguist who specializes in ASL and three deaf ASL specialists. The nonce signs were consistent with phonological rules for ASL (Valli & Lucas, 1995). Parameters represented in ASL phonology that distinguish one ASL sign from another include specific handshapes, types of movement, location, and orientation of hands during production. The nonce signs used in this study were created from unique combinations of exemplars from each of these parameters and were judged by the ASL team of specialists to be distinct from existing ASL signs but exhibiting characteristics of linguistically “acceptable” signs. For example, one nonce sign consists of \( Y \) handshapes made by both hands and is produced with elbows bent so that forearms are upright in front of the signer’s body, with palms facing each other. The \( Y \)s are then tapped together twice. This nonce sign was paired with the nonce spoken word \( dax \) to refer to a novel object. Because reduplication of movement often marks nouns in ASL (Valli & Lucas, 1995), it was used in production of nonce signs created for this study. Because we did not want children’s word learning to be facilitated by iconicity, we were careful not to use iconic, or “classifier-like” nonce signs, as might be used in ASL to represent some of the tool-like novel objects. A specialist in Signed English systems reviewed all the nonce signs to determine that they would also be acceptable in those systems. These nonce signs are available upon request from the authors.

The examiners conducted the tasks in the language or language system used in each child’s school (i.e., speech only, both sign and speech, or sign only). Conceptual signing was used for simultaneous communication, and articles and copulas were not signed. For example, when the researcher said, “Where is the dax?” “Where dax?” was signed.

Pretest. Both tasks started with a pretest trial that served the purpose of familiarizing the children with the task and ensured that children could comply with the basic task demands. The researcher showed the child four familiar objects and asked for two of them (e.g., “Where is the dog? Give me a shoe.”). If a child selected the wrong object for a word, the missed object was replaced with another familiar object and the children were asked for a different familiar object. All 98 participants identified two familiar objects correctly on the pretest. Three additional children were dropped from the study because they did not correctly select two familiar objects on the pretest and thus indicated they could not do the task.

Novel mapping task. This task assessed whether children inferred that a novel word referred to a novel
object when the referent was not directly marked by social or linguistic cues. The four novel words listed in Table 1 were introduced during this task. For each word, there was an exposure trial followed by a generalization trial. During the exposure trial, the children played briefly with each of the three familiar and one novel target objects. The researcher demonstrated a function of each object as she handed it to the child (e.g., rolled the car on the table) but never labeled the objects. Then, after lining up the toys, the child was asked for a familiar object (e.g., “cup, cup, where is a cup?”) and a novel object (e.g., “dax, dax, give me a dax”). After the first question, the object selected was placed back with the other objects so the number of objects was the same for all questions. The researcher looked directly at the child and was careful not to give any clues as to the referent of the words. The order of the requests for familiar and novel objects was counterbalanced across trials, and nonspecific feedback was identical for correct and incorrect answers.

For the generalization trial, the researcher showed the children different exemplars of the four types of objects used during exposure (i.e., three familiar and one novel). In addition, the generalization trial included a new type of novel object (i.e., a distracter) to ensure the children were not solely using a novelty bias to select a referent (see Table 1). After the children played with the objects, the researcher lined them up and asked the child to indicate the referent of the nonce word and a familiar word (e.g., “dax, dax, where is the dax?” and “shoe, shoe, where is the shoe?”) in counterbalanced order across the task.

Direct reference task. The structure and procedure was identical to the novel mapping task described above and shown in Table 1 except that the researcher labeled the objects three times as they were presented to the child during the pretest and exposure trials (e.g., “apple, apple, look an apple; lep, lep, look a lep”). The researcher used eye gaze, pointing, and manipulation to make reference clear while labeling the objects, and care was taken to ensure the child attended to the object and to the linguistic stimulus either simultaneously or in quick succession. The order the toys were labeled was varied across trials, although strict counterbalancing was not followed.

Children’s language environment and developmental disabilities—measures and procedures.

Background questionnaire. Teachers completed a questionnaire designed by the researchers to gather descriptive information about the participants including age, cause of deafness, and previous educational experiences. Teachers also described the children’s language environment in the home (e.g., language spoken, rating of signing abilities of mother and father), and they indicated suspected or diagnosed developmental delays in cognitive, socioemotional, attention, and motor development.

Developmental Profile II. Teachers completed the Physical and Self-Help subscales of the Developmental Profile II, a standardized checklist of developmental milestones from birth to 9 years old that is designed to screen for developmental disabilities (Alpern, Boll, & Shearer, 1980). These two scales have been used successfully to identify developmental levels as appropriate or delayed in a series of previous studies of young DHH children (Meadow-Orlans et al., 2004).

General administration procedures. Children were assessed individually at their school by a researcher fluent in his or her language system. The tasks were given on separate days in the following standard order: novel mapping, direct reference and language measures. The novel mapping task was always given first because the explicit linking of novel labels to novel objects in the direct reference task (if it were presented first) could potentially “teach” the children a pattern of responding that would skew results for the more difficult novel mapping task. All language measures and teacher-completed questionnaires were collected after the word-learning tasks were completed.
Table 2 Mean (SD) of number of words produced or comprehended on CDI, CPVT, and GAEL-P for 2- through 6-year-olds

<table>
<thead>
<tr>
<th>Age in years</th>
<th>Number of children</th>
<th>CDI</th>
<th>CPVT</th>
<th>GAEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>7</td>
<td>66 (28)</td>
<td>18 (18)</td>
<td>18 (6)</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>167 (117)</td>
<td>38 (26)</td>
<td>19 (7)</td>
</tr>
<tr>
<td>4</td>
<td>37</td>
<td>228 (161)</td>
<td>55 (31)</td>
<td>22 (9)</td>
</tr>
<tr>
<td>5</td>
<td>26</td>
<td>257 (168)</td>
<td>70 (33)</td>
<td>23 (7)</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>312 (214)</td>
<td>69 (37)</td>
<td>25 (7)</td>
</tr>
</tbody>
</table>

Correlation with age 0.37** 0.49*** 0.28**

Note. Mean number of words produced on the CDI and GAEL; number of words comprehended on the CPVT. Bivariate correlations between age in months and raw scores on vocabulary measures.

**p < .01. ***p < .0001.

Results

Vocabulary Assessment

Table 2 displays the participants’ age and results of vocabulary assessments. Number of words checked on the CDI correlated highly with the number of words children produced on the GAEL-P, r(92) = .74, p < .001, and number of words they comprehended on the CPVT (raw score, r(91) = .84, p = .000; percentile score, r(91) = .81, p < .0001). These strong correlations were maintained when age was controlled: CDI with GAEL-P, r(92) = .71, p < .001, CDI with CPVT raw score, r(91) = .81, p < .001, and percentile score, r(91) = .79, p < .001. (Six children were not included in these analyses because they were missing scores on the tests due to researcher error.) The strong correlations among CDI, GAEL-P, and CPVT scores supported use of teacher-rated CDIs as valid indices of relative lexical size. It is important to note that teacher-rated CDI may underestimate absolute lexical size. An analysis of a subsample of the DHH children from this study who were in oral-only language programming found that while teacher-completed CDIs were strongly correlated with mother-completed CDIs, lexicon size was estimated to be 30% larger by mothers (Farran, Lederberg, & Jackson, in press). Therefore, caution should be used when comparing teacher-completed CDIs with norms for parent-completed CDIs.

Chronological age (measured in months) and vocabulary were only moderately correlated in this sample (see Table 2) It is possible that the higher correlation of age and the CPVT was due to an increased ability of older children to guess the meaning of iconic signs included in the CPVT (Tolar, Lederberg, Gokhale, & Tomasello, 2008; White & Tischler, 1999).

Word-Learning Performance on Two Word-Learning Tasks

To describe the development of word-learning abilities, we first categorized children according to whether children reliably learned words in a particular task. “Learning a word” was operationalized as the child selecting the target novel object on both the exposure and generalization trials for that word. Children were judged to be able to reliably learn words in a word-learning task if they learned at least two of the four words in that task. This was the criteria first developed by Mervis and Bertrand (1994) with hearing toddlers and later used in studies of children with intellectual disabilities (Mervis & Bertrand, 1995; Romski et al., 1996) and deaf preschoolers (Lederberg et al., 2000). The results of these studies suggest that this procedure resulted in meaningful distinctions in children’s word-learning abilities. In addition, the probability of obtaining this criterion by chance is equal to .01. The first series of analyses were conducted to address the following questions: Did DHH preschoolers exhibit three levels of word-learning abilities? Did the language modality of the children’s environment interact systematically with these levels? Was there evidence that these levels represent a developmental progression in word-learning abilities from slow word learning to rapid word learning based on direct reference to novel mapping? Finally, did children who could learn novel words through both direct and indirect reference learn better in one context than the other?
As predicted, performance across the two tasks showed that DHH preschoolers exhibited all three levels of word-learning abilities. Twelve children were categorized as Slow Word Learners because they learned zero or one word in each of the two tasks. Thirty-six children were categorized as Rapid Word Learners because they learned two, three, or four words in the direct reference task but zero or one word in the novel mapping task. Forty-nine children were categorized as Novel Mappers because they learned at least two of the four words in each of the two tasks. As is shown in Table 3, language modality did not appear to affect the proportion of children at the three levels of word learning, $\chi^2(2, N = 97) = 1.74, p = .42$.

Only one child’s performance did not conform to the developmental progression through the word-learning levels that was proposed. This child learned two words in the novel mapping task but none in the direct reference task. All other children who passed the novel mapping task also passed the direct reference task. A large number of children passed the direct reference task but did not reach criterion on the novel mapping task. Although indirect evidence, this pattern suggests a developmental progression from direct to indirect learning. The child who could not be categorized into one of the three levels of word learning was dropped from other analyses, resulting in an $n$ of 97 for subsequent analyses.

Further evidence that this categorization scheme represents a developmental progression in word-learning abilities is found by more closely examining the number of words learned on those tasks “passed” by Rapid Word Learners and Novel Mappers. Novel Mappers were significantly better word learners than Rapid Word Learners even on the direct reference task (Novel Mappers $M = 3.6$ words learned, $SD = 0.6$; Rapid Word Learners $M = 3.0$ words, $SD = 0.9$), $t(83) = 6.168, p < .001$. In addition, Novel Mappers learned significantly more words in the direct reference task ($M = 3.6, SD = 0.64$) than in the novel mapping task ($M = 2.8, SD = 0.78$), $t(48) = 6.28, p < .0001$, thus indicating that learning novel words was easier with direct reference than through indirect reference even for children at the highest level of word learning.

**Error patterns on the two tasks.** Children’s errors on these tasks were analyzed for further insights into what might be causing children not to learn a word. For the direct reference task, errors on the exposure trial may be caused by children not making the original link between referent and novel word even though it was directly demonstrated. This could be because the child did not understand the social-pragmatic cues of referential intention or because they did not form a representation of the label itself or its link to the referent after only three exposures. On the other hand, errors on the generalization trial might be caused by inability to remember a word-referent link over a slightly longer period of time or a failure to understand that a label can represent a category of similar objects. Slow Word Learners had problems with both the exposure and generalization aspects of the direct reference task. Fifty-eight percent ($n = 7$) of Slow Word Learners

### Table 3  Number and percentage of children in oral and signing language environments at three levels of word-learning abilities

<table>
<thead>
<tr>
<th>Word-learning level</th>
<th>Language used by school program</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spoken English</td>
<td></td>
</tr>
<tr>
<td>Slow word learners</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>%</td>
<td>16%</td>
<td>12%</td>
</tr>
<tr>
<td>Rapid word learners</td>
<td>11</td>
<td>36</td>
</tr>
<tr>
<td>%</td>
<td>30%</td>
<td>37%</td>
</tr>
<tr>
<td>Novel mappers</td>
<td>20</td>
<td>49</td>
</tr>
<tr>
<td>%</td>
<td>54%</td>
<td>51%</td>
</tr>
<tr>
<td>Total number</td>
<td>37</td>
<td>97</td>
</tr>
</tbody>
</table>
chose a familiar instead of the novel object on at least one exposure trial; 100% made errors on at least one generalization trial. For the Rapid Word Learners, only 30% (n = 11) made errors on an exposure trial, whereas 56% (n = 20) made errors on a generalization trial. Only 4% (n = 2) of Novel Mappers made errors on exposure, whereas 28% (n = 14) made errors on generalization.

Analysis of the errors made on the novel mapping task reinforces the conclusion that Novel Mappers had a novelty bias, whereas the others did not. The three word-learning groups differed significantly on the proportion of generalization trials for words they did not learn in which they chose the distracter (the most “novel” object available on the generalization). This occurred for 58% of the words not learned by Novel Mappers, 26% for the Rapid Word Learners, and 14% for Slow Word Learners, F(2, 84) = 9.15, p < .000. Post hoc comparisons indicated Novel Mappers differed significantly from the other two, who did not differ from each other.

Relations Between Word-Learning Abilities and Vocabulary

The next series of analyses explored the relations between the three levels of word learning and vocabulary and age to address the following questions: Were the three levels of word-learning ability more strongly related to children’s vocabulary knowledge than their chronological age? Were relations between word-learning abilities and vocabulary the same for children raised in different language-learning environments?

All children. As is evident in Figure 1, word-learning levels differed in lexicon size. A 3 (word-learning level) × 2 (language environment) analysis of variance (ANOVA), with age as a covariate, revealed that word-learning level accounted for 34% of the variance in lexicon size, F(2, 93) = 24.08, p < .001. The covariate of age was only marginally significant, F(1, 93) = 3.45, p < .07, η² = .04. Table 4 displays the ages of children at the three levels of word-learning abilities. Given the marginal degree of association between chronological age and lexical size, follow-up planned comparisons included age as a covariate. These analyses showed that children categorized as Slow Word Learners had significantly smaller CDI vocabularies than Rapid Word Learners, F(1, 45) = 3.78, p = .019, and Rapid Word Learners had significantly smaller vocabularies than Novel Mappers, F(1, 85) = 23.60, p < .001.

The association between word-learning levels and lexicon size was remarkably similar for children across the two language environments. Consistent with earlier analyses, there was no significant main effect for

<table>
<thead>
<tr>
<th>Word-learning level</th>
<th>Chronological age</th>
<th>Physical developmental age</th>
<th>Self-help developmental age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Slow word learners</td>
<td>55</td>
<td>12</td>
<td>48</td>
</tr>
<tr>
<td>Rapid word learners</td>
<td>50</td>
<td>12</td>
<td>42</td>
</tr>
<tr>
<td>Novel mappers</td>
<td>60</td>
<td>10</td>
<td>58</td>
</tr>
</tbody>
</table>

Note. For chronological age, Slow Word Learners = 12; Rapid Word Learners = 36; Novel Mappers = 49. For physical and self-help developmental age, Slow Word Learners = 11; Rapid Word Learners = 32; Novel Mappers = 47.
language modality, $F(2, 90) = 0.07, p = .80, \eta^2 = .001$, and no interaction between word-learning level and language modality, $F(2, 90) = .16, p = .85, \eta^2 = .004$. In fact, mean lexicon size for the three word-learning levels was very similar for the children in oral and signing environments; Slow Word Learners, oral $M = 57$ words, signing $M = 57$; Rapid Word Learners, oral $M = 127$, signing $M = 115$; Novel Mappers, oral $M = 326$, signing $M = 311$.

Children with cochlear implants. The 23 children with cochlear implants were distributed across all three word-learning levels. Performance on the word-learning tasks was especially strongly associated with CDI scores for this subgroup. A one-way ANOVA, with age as a covariate, revealed that word-learning level accounted for 48% of the variance in CDI lexicon size, $F(2, 19) = 8.74, p = .002$; lexicon size was as follows: 6 Slow Word Learners, $M = 56$ words; 8 Rapid Word Learners, $M = 118$ words; 11 Novel Mappers, $M = 288$ words. Age accounted for only 1% of the variance, $F(1, 19) = .204, p = .66$. The small number of participants with cochlear implants precluded analyses of other potentially significant variables such as duration of implant use and age of first use.

Deaf children with deaf parents. The performance of the six children with deaf parents was distributed across the three word-learning categories. One child was a Slow Word learner (age = 30 months; CDI = 43 words). There were three Rapid Word Learners (age = 34, 39, and 39 months; CDI = 49, 124, 228 words). Two were Novel Mappers (age = 56 and 64 months; CDI = 365, 429 words). Because of the small sample, it was not appropriate to statistically relate lexicon size with word-learning level. However, the total number of words learned in the two tasks (range 1–7) correlated significantly with CDI scores, Spearman’s rho = .81, $p < .03$ (one tailed). Unlike the sample as a whole, chronological age accounted for a large share of variance for both lexicon size, Spearman’s rho = .98, $p < .001$, and number of words learned in tasks, Spearman’s rho = .82, $p < .03$ (one tailed). Information was not obtained about the age at which the deaf parents learned sign language nor their degree of “native” fluency; however, the children’s strong age-lexicon-word learning association probably reflects age-appropriate language-learning experiences.

Word-Learning Abilities and Developmental Disabilities

Next, we addressed two questions: Did DHH children have nonverbal cognitive abilities at least equivalent to hearing 2.5-year-olds? Does having nonlanguage developmental delays interfere with DHH children developing the word-learning abilities assessed in this study? Table 4 displays the developmental ages of the three word-learning groups on the Physical and Self-Help subscales of the Developmental Profile II. Seven children were missing scores. The average age on the two subscales exceeded 3.5 years for all three word-learning levels. In addition, all but five children had physical and self-help developmental ages above 2.5 years of age, the age that the word-learning processes assessed in this study are typically developing in hearing children.

Using normative tables, children’s scores on the subscales were classified as falling below the typical range for their chronological age (i.e., scores labeled “borderline” or “delayed” by the test’s authors). Twenty children had scores in this range on the physical development subscale, and five additional children scored below expected levels on both subscales. Children whose scores were within the typical range for their age were found in all three word-learning groups, with 55% of Slow Word Learners, 69% of Rapid Word Learners, and 79% of Novel Mappers scoring within age-level expectations on the two developmental subscales. Despite a trend for more children with below-expected scores to be in the lower word-learning levels, differences did not reach statistical significance, $\chi^2(2, N = 91) = 3.08, p < .20$.

On the other hand, there was a significant difference in the proportion of children at the three levels identified by their teachers as having or not having suspected or diagnosed disabilities, $\chi^2(2, N = 97) = 7.18, p < .03$. Slow Word Learners were more likely to have a reported disability (66%) than either the Rapid Word Learners (31%) or Novel Mappers (26%). As is shown in Table 5, the most common disabilities reported for Slow Word Learners were attention and motor problems.
Discussion

This study examined word-learning abilities of DHH children, many of whom had delays in language development in general and vocabulary development specifically. We replicated the previous finding of Lederberg et al. (2000) that DHH preschoolers can be classified into one of three levels of word-learning ability and that performance on the word-learning tasks were more strongly related to the number of words the children had in their lexicon than to their chronological age or measured nonverbal developmental levels. These findings were not affected by the primary modality of the children’s language-learning environment. Both theoretical and applied implications of the results are discussed below.

Development of Word-Learning Abilities

Children of similar ages demonstrated three very different levels of word-learning ability. Slow Word Learners did not learn words quickly, even when conditions were as advantageous as they were in the direct reference task. In that condition, examiner made the link between word and object explicit by using multiple cues (e.g., eye gaze, holding, or pointing to object), and the word was presented three times in rapid succession. Examiners made every effort to ensure the children were attending to the link between word and referent. For example, objects were only labeled when children were visually attending to the word (either by looking at the sign or lips) and the object simultaneously (by signing on the object or holding object up near face) or sequentially (e.g., signing in visual field and then pointing to object). Labeling occurred while children were engaged and interested in the labeled novel objects, and no other distractions were present.

Comprehension (not production) was assessed immediately after labeling. Thus, it was particularly surprising that these children frequently did not choose the correct object seconds after they were told the referent. Even more errors were made on the immediate generalization. Children classified as Slow Word Learners knew how to apply words to categories of objects. They all selected the correct objects for familiar words, even though the specific objects were not familiar to them. It was only in learning new words quickly that their performance deteriorated. These Slow Word Learners, whose chronological age ranged from 2 to 6 years old, had average CDI lexicons of fewer than 60 words. Because all but two of the DHH children had been in programming emphasizing language experiences for over 2 years, these children had been very slow to learn new words in their naturalistic environments. Other researchers have also observed very slow lexical growth among some deaf children (Anderson, 2006; Blamey, 2003; Lederberg, 2003). Children in our study who functioned as Slow Word Learners on the tasks were more likely than other participants to be identified by their teachers as having disabilities, especially those with an attentional or motor component. Many researchers have noted the importance of attentional control for learning language by deaf children (Spencer & Harris, 2006). In addition, some Slow Word Learners had clear histories of inconsistent or limited access to language models. For example, two Slow Word Learners had been unsuccessful in their previous oral-only environment, probably indicating difficulties processing oral-only language, and had only recently been placed in a signing environment. Another Slow Word Learner was in a school using oral-only language and used a cochlear implant; however, the cochlear implant was not received until the child was more than 55 months of age. Thus, slow acquisition of vocabulary may occur for a variety of reasons, including lack of consistent

<table>
<thead>
<tr>
<th>Table 5 Number of children in each word-learning level whose teachers reported a suspected or diagnosed disability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disability</strong></td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td>Cognitive</td>
</tr>
<tr>
<td>Attention</td>
</tr>
<tr>
<td>Motor</td>
</tr>
<tr>
<td>Emotional</td>
</tr>
<tr>
<td>Visual</td>
</tr>
<tr>
<td>More than one disability</td>
</tr>
</tbody>
</table>

Note. Slow Word Learners = 12; Rapid Word Learners = 36; Novel Mappers = 49. Table details number and percentage of children at each word level. Twelve children had two or more disabilities. Therefore, the numbers exceed 97 and percentages add to more than 100.

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exposure to accessible language models and the presence of other disabilities.

Over a third of the preschoolers were Rapid Word Learners, learning new words quickly—but only when the referent of the new word was explicitly demonstrated. These children were able to quickly store a representation and referent of a word and generalize it to a novel instance of the referent. While similar in age to the Slow Word Learners, their larger lexicons (on average, 140 words) suggest that they were able to learn new words more rapidly in their natural environment when their conversation partners were sensitive to the need to clarify referents. However, children in this word-learning group were unable to infer the meaning of a new word in a context in which reference was not clearly established. Anecdotally, these children appeared uncertain and searched for pragmatic cues to guide their response in the novel mapping task. Because the examiners were careful not to offer pragmatic-based guidance to them, these children often acted as though they had no basis for choosing a referent; they did not consistently choose one type of object (either novel or familiar) on the exposure and generalization trials of novel words. Thus, these preschoolers had not acquired the ability to match a new word and its referent on the basis of indirect cues, a process firmly established by 2.5 years of age by typically developing hearing children. The Rapid Word Learners were, then, unlikely to learn new word meanings when adults were not directly teaching them new words.

Half of the participants in the current study were categorized as Novel Mappers; they rapidly learned new words in both direct and indirect word-learning contexts. Their facility with learning new words in these two contexts was consistent with their larger lexicons; their vocabulary was, on average, twice as large as that of Rapid Word Learners. It was noted, however, that although Novel Mappers were able to acquire words in both direct reference and novel mapping contexts, they still learned words that were explicitly taught better than those acquired in the indirect word-learning task. This contrasts with a report by Jaswal and Markman (2003) that typically developing hearing 3-year-olds acquired words equally well in direct and indirect word-learning tasks.

The lexical size of the DHH children in this study was generally low for age, lower according to CDI norms (Fenson et al., 1993) than typical lexical size of 3-year-old hearing children. The equivalence of the effectiveness of direct and indirect word-learning contexts for the DHH children in this study may, therefore, simply indicate that they have not yet reached a lexical size that makes indirect word learning relatively easy. However, educators have long remarked that DHH children learn fewer words incidentally than hearing children (Easterbrooks & Baker, 2002), and other researchers have noted that deaf mothers make great efforts to directly indicate the referents of signs by using repeated signs plus pointing with language-learning children (Spencer & Harris, 2006). This raises the possibility that direct instruction linking referent and its representation may continue to be advantageous for DHH children beyond the developmental stage at which it loses its advantage for hearing children.

There are several reasons why indirect word learning may be relatively difficult for DHH children, even if they are capable of inferring meaning through novel mapping. First, DHH children’s home and school environments are likely to focus on language “teaching.” Many, therefore, will have more experience in direct word-learning contexts than hearing children and may become more dependent on this assistance. However, contrary to this hypothesis, an analysis of a subsample of mothers of children (in oral programming) from the current study suggests that mothers of slow and rapid word learners did not use direct reference more often than would be expected for hearing children of equivalent language levels (Farran et al., in press). Alternatively, it may be that continuing advantages for directly established reference stem from DHH children’s extradependence on visual attention for processing language and potential additional cognitive demands from sharing visual attention to language and environmental objects and events (Spencer & Harris, 2006). In addition, some of the processes that underlie the rapid and effortless incidental word learning typical of hearing children may depend on early exposure to language, something that did not happen with many of the children included in this study, for which data were collected from 1997.
through 2000. More recent research suggests changes in medical and educational interventions (e.g., Universal Newborn Hearing Screening; early exposure to sign language; early amplification and cochlear implantation) have resulted in the current generation of deaf children developing vocabulary at a faster rate than the study sample (Connor, Craig, Raudenbush, Heavner, & Zwolan, 2006; Yoshinaga-Itano, 2003). Future research should explore whether DHH children whose vocabulary learning is accelerated compared to those in the current study show improved ability to learn words in indirect contexts.

In the current study, word-learning abilities of children from different language-learning environments were equally related to the size of their lexicon: whether they were acquiring language through speech, sign, or both; in children who had cochlear implants and children who had deaf parents. The consistency of the results across these diverse linguistic environments strongly supports that slow word learning, rapid word learning with direct reference, and novel mapping are steps in the development of language. The robustness of these processes is also supported by demonstrations of rapid word learning in other children who experience atypical language development, including children with specific language impairment (Dollaghan, 1987; Ellis Weismer & Evans, 2002), Down syndrome (Chapman, Kay-Raining Bird, & Schwartz, 1990; Mervis & Bertrand, 1995), and severe mental retardation (Romski et al., 1996). Novel mapping has also been demonstrated by children with Williams syndrome (Stevens & Karmiloff-Smith, 1997).

What is the basis for the acquisition of these abilities? Based on research with typically developing children, some have suggested that these skills develop because of general cognitive changes (e.g., infants’ increasing memory and symbolic abilities or toddlers’ categorization skills) (Mervis & Bertrand, 1994). However, the current study indicates that nonverbal cognition is not sufficient to develop these word-learning abilities. Teachers’ assessments on the Developmental Profile II suggested that the nonverbal developmental skills of almost all DHH children in this study were more advanced than a typical hearing 2.5-year-old and included such skills as sorting objects by categories. Previous research has shown that deaf and hearing preschoolers perform similarly on nonverbal cognitive assessments such as the McCarthy Scales of Children’s Abilities, as well as spatial ordering, classification, and numerical invariance tasks (Bond, 1987). This suggests that these word-learning skills do not develop as a consequence of nonverbal cognitive achievements in the absence of accompanying language development. Likewise, these results are not consistent with a hypothesis that novel mapping is the inevitable result of an innate linguistic constraint such as mutual exclusivity. If these word-learning abilities were solely based on innate constraints, it is not clear why DHH children would have to develop a large lexicon, regardless of their level of cognitive development, to use such constraints to learn new words.

The finding that these skills seemed to emerge in conjunction with lexicon size, regardless of degree of language delay or the modalities used in a child’s language-learning environment, suggest that they have a strong basis in linguistic knowledge. Our research is insufficient to determine which linguistic process causes the emergence of rapid word-learning and novel mapping skills. However, connectivist theories have the advantage of offering a single learning mechanism for the acquisition of both word-learning abilities, namely that these abilities result from changes in memory and attention that occur as lexicon knowledge increases. For example, research with hearing toddlers (Werker, Fennell, Cocoran, & Stager, 2002) suggests that rapid word learning depends on a lexicon of 20–50 words because word learners need to have stored a sufficient number of phonological representations of familiar words to be able to attend and remember the phonological detail in novel words quickly. Research by Storkel (2001) also supports the hypothesis that phonological knowledge derived from lexical knowledge affects the rapid acquisition of a semantic representation of novel words. If this is true, then the current study suggests that it does not matter whether these representations are based on a spoken or signed linguistic system. In addition, although signs are visually accessible/perceptible to all deaf children, while spoken language is not, rapidly storing the representation of a word seems to occur only after the child has developed a sufficiently large lexical base. This is similar to the discontinuity of hearing infants’ perceptual
abilities and their ability to store phonemic representations. It is not just the accessibility to perceptual input that is crucial here. Rather it is the storing of the phonological system that is required to quickly learn new instances in the system.

Connectivist theories can also explain the emergence of novel mapping. Samuelson and Smith (2000) posit that children’s ability to infer reference for new words are based on changes in their attentional and memory processes derived from regularities in input. Similarly, Evey and Merriman (1998) suggest that children will develop novel mapping when they have built up enough strong associations between familiar words and their referents that their attention is directed to the novel object in the presence of a novel word.

Our results have implications for social-pragmatic theories that posit that these word-learning processes are derived from increased knowledge of referential intentions based on repeated experiences of how novel words are used by adults in their environments (Akhtar & Tomasello, 2000). If children develop these abilities from regularities in input, our findings suggest that these regularities are robust and present across diverse language-learning environments. The environments of subgroups in our study differed in primary modality, perceptual accessibility, attention requirements, and the manner and fluency with which language was presented to them. Yet all these children must have been experiencing patterns of regularity in their language input sufficient to support developing more advanced word-learning abilities. One such regularity may be that children are more likely to experience more contexts in which adults use a novel word to refer to the only object present for which the child does not already have a label as their lexicons grow.

Word-Learning Tasks as Assessment Procedures

The two novel word-learning tasks administered in this study seem to have promise as quick and dynamic ways to assess the ability of a DHH child to acquire new words from experience—and to provide a guide as to the degree of contextual support required by that child at a certain point in their development. Researchers focused on atypical vocabulary development have long recognized the assessment potential of novel word-learning tasks, suggesting that this type of “task provides an experimental analog of the natural vocabulary learning process” (Ellis Weismer & Evans, 2002, p. 20). However, realizing this potential has been blocked by contradictory findings. On the one hand, consistent with our findings, researchers have found learning in novel word-learning tasks related to lexical knowledge among 2- to 3-year old children with Down syndrome and with Williams syndrome (Mervis & Bertrand, 1995), late talking toddlers (Ellis Weismer & Evans, 2002), and youth with severe mental retardation (Romski et al., 1996). On the other hand, contrary to their expectations, investigators found no relation between task performance on a variety of different types of novel word-learning tasks and scores on vocabulary tests among 4- to 8-year old children with specific language impairments (Dollaghan, 1987; Gray, 2003; Rice & Watkins, 1996) and children and adolescents with Down syndrome (Chapman et al., 1990). In fact, in a review of the literature, Rice and Watkins (1996) concluded that there is “little association between children’s past lexical accomplishments (i.e., their accumulated lexicons) and their aptitude for gaining new words in comprehension during fast-mapping tasks.” (p. 198).

A developmental framework may be useful in interpreting the results. Performance on a particular word-learning task may only assess important individual differences in vocabulary development during the period when the relevant word-learning ability is being acquired. Before or after a particular word-learning ability emerges in children, differences in lexicons would not be attributable to, nor related to, that particular ability. Developmental studies could isolate which tasks are appropriate for which developmental level. For example, Werker et al. (2002) found the ability to learn phonetically similar novel words related to lexicon size for 14-month-olds but not for 20-month-olds. She concluded that the ability to represent fine phonetic detail of words is only available to 14-month-olds with larger vocabularies but available to all 20-month-olds. In a similar way, comprehension in the type of word-learning tasks used in this study may not be useful for assessing word-learning abilities...
for DHH children later in language development; Gilbertson and Kamhi (1995) found that ability to learn words, when measured by comprehension, on a rapid word-learning task did not relate to lexical knowledge for hard-of-hearing elementary school children, while production did.

Assessments of word-learning abilities may be particularly important for children whose language skills are not consistent with their cognitive skills or chronological age. DHH children’s age and cognitive skills may lead teachers and parents to assume too early that these children will acquire vocabulary through “natural” interaction. Adults naturally increase object-referent cues (e.g., slower speech, word repetition, pointing to an object while talking about it) when communicating with infants and young toddlers. However, older, language-delayed, DHH toddlers and preschoolers also need these contextual supports if they are still in the earlier stages of word learning. Categorization of children’s performance into levels of word-learning abilities can provide therapists and teachers with information about the kinds of contexts and teaching strategies that will be most effective with an individual child at a specific time in his or her development. Thus, children performing at the Slow Word Learner level may need repeated exposure to words with referents that are of interest to them. Rapid Word Learners can learn words quickly but only with direct reference. Finally, Novel Mappers are capable of learning words incidentally in naturally occurring conversations but can still benefit from having the referent for a new word explicitly indicated. By tailoring the language-learning environment to the children’s word-learning abilities, the children’s vocabulary development may be accelerated. Samuelson and Smith (2000) found that intensive vocabulary training tailored to typically developing hearing toddlers’ word-learning abilities resulted in general vocabulary acceleration. Because of its potential, future intervention research is called for to explore this possibility in DHH children who are experiencing atypical language development.

**Funding**

U.S. Department of Education (H023C0183); March of Dimes Foundation (12-FY97-0404, 12-FY98-0029).

**Note**

1. Probability of choosing the target novel object for a given word is .25 on exposure $\times .20$ on generalization $= .05$. Probability of getting at least two words correct on the task is the sum of probabilities for each possible combination of two, three, and four words correct over four trials. The formula is $1 - P$ (none or only 1 right) $= 1 - [(.95)^4 + 4(.95 \times .05)] = 1 - .985981 = .014019$.

**References**


Received December 27, 2007; revisions received April 12, 2008; accepted April 21, 2008.