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Evaluating the Structure of Early English Literacy Skills in Deaf and Hard-of-Hearing Children

Mi-Young Webb*[,1], Amy R. Lederberg[1], Lee Branum-Martin[1], and Carol McDonald Connor[2]

[1]Georgia State University and [2]Arizona State University

*Correspondence should be sent to Mi-Young L. Webb, Educational Psychology, Special Education, and Communication Disorders, Georgia State University, PO Box 3979, Atlanta, GA 30302–3979 (e-mail: epemyw@gsu.edu).

Abstract

Better understanding the mechanisms underlying developing literacy has promoted the development of more effective reading interventions for typically developing children. Such knowledge may facilitate effective instruction of deaf and hard-of-hearing (DHH) children. Hence, the current study examined the multivariate associations among phonological awareness, alphabetic knowledge, word reading, and vocabulary skills in DHH children who have auditory access to speech. One hundred and sixty-seven DHH children (M_{age} = 60.43 months) were assessed with a battery of early literacy measures. Forty-six percent used at least 1 cochlear implant; 54% were fitted with hearing aids. About a fourth of the sample was acquiring both spoken English and sign. Scores on standardized tests of phonological awareness and vocabulary averaged at least 1 standard deviation (*SD*) below the mean of the hearing norming sample. Confirmatory factor analyses showed that DHH children's early literacy skills were best characterized by a complex 3-factor model in which phonological awareness, alphabetic knowledge, and vocabulary formed 3 separate, but highly correlated constructs, with letter-sound knowledge and word reading skills relating to both phonological awareness and alphabetic knowledge. This supports the hypothesis that early reading of DHH children with functional hearing is qualitatively similar to that of hearing children.

Hearing children learn to read an alphabetic language by acquiring the alphabetic principle—by learning to translate letters and printed words into *spoken* phonemes and words. Empirical and theoretical research indicates that early reading depends on children's phonological awareness (PA), alphabetic knowledge, and language abilities (Storch & Whitehurst, 2002; Wagner et al., 1997; Whitehurst & Lonigan, 1998), and this knowledge has supported the development of more effective literacy instruction (Juel & Minden-Cupp, 2000; National Early Literacy Panel, 2009). According to Ehri (2014), children's knowledge of the phonological structure of words and grapheme–phoneme correspondences provides them with the foundation that connects written words to vocabulary stored in memory.

Learning to read has long been an area of difficulty for many deaf and hard-of-hearing (DHH) children; their average literacy outcomes have remained significantly below those of hearing children for decades (Cupples, Ching, Crowe, Day, & Seeto, 2014; Spencer & Marschark, 2010), and it is not clear why. Ineffective instruction may be a key reason. However, without a clear understanding of the underlying mechanisms and malleable sources of influence by which DHH children develop reading (which may not be the same as hearing children), developing effective instructional regimes is difficult. For example, the importance of spoken phonology for reading has been well documented (Bus & van IJzendoorn, 1999; Lonigan et al., 2009; National Early Literacy Panel, 2009). It is not surprising that DHH children, who have decreased and different access to spoken phonology, typically struggle to learn to read (Lederberg, Schick, & Spencer, 2013). However, the relative importance of spoken phonology and language in early reading for DHH children is hotly debated, with implications for how instruction is designed and implemented. There are three general theoretical perspectives about the reading processes of DHH children.

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First, some argue that DHH children read through the same processes as hearing children and thus must learn to represent and be aware of spoken phonology of words (Musselman, 2000; Paul, Wang, & Williams, 2013; Perfetti & Sandak, 2000). Paul et al. (2013) refer to this as the qualitative similarity hypothesis. Second, others assert that DHH children can read through visually based processes and bypass spoken phonology. This includes the use of fingerspelling or *directly* mapping of written words to spoken or signed words (i.e., visual recognition of the word, typically referred to as sight word recognition (see Allen et al., 2009; Goldin-Meadow & Mayberry, 2001 for reviews). These alternative processes may decrease or even eliminate the role of spoken phonology in reading and increase the role of language. Third, still others have hypothesized that the role of spoken phonology depends on DHH children's auditory access to spoken language (Easterbrooks et al., 2015; Lederberg et al., 2013; Easterbrooks & Beal-Alvarez, 2013; Koo, Crain, LaSasso, & Eden, 2008). Some DHH children do not hear and thus do not have the ability to represent spoken phonology based on auditory information. These children may use alternative, visually based processes to read as proposed by theorists adhering to the second perspective. In contrast, many DHH children, especially in the current generation, are fitted with cochlear implants or hearing aids that enable them to have sufficient speech perception skills that they can hear, at least to some extent, spoken language. In this paper, we refer to these children as DHH children with *functional* hearing. We define DHH children with functional hearing as DHH children who can select a referent of spoken words through audition alone. The third perspective asserts that the early literacy skills of DHH children with functional hearing resemble that found for hearing children, as proposed by adherents of the first perspective.

Research relevant to distinguishing these three perspectives includes comparisons across groups of children as well as examinations of reading processes within a particular subgroup of DHH children. The current study took the latter approach. The goal of this study was to examine how PA, alphabetic knowledge, and vocabulary function among young DHH children with functional hearing, an important subgroup of DHH children. Relations among scores on multiple measures of these constructs were tested using confirmatory factor analysis (CFA), applying theoretical models found among hearing children's literacy skills. These models will indicate if relations among early literacy skills of DHH children with functional hearing appear qualitatively similar to those found for hearing children.

Defining Key Constructs of Early Literacy Skills

In the sections that follow, each of the three constructs, PA, alphabetic knowledge, and vocabulary, is defined and the nature of the construct for hearing children is described. We then review research about the development of the construct in DHH children with functional hearing.

Phonological awareness

PA, a metalinguistic skill, refers to the sensitivity and ability to manipulate sound units apart from their meanings. Phonological awareness typically proceeds from awareness of large units (e.g., rhyme recognition or production) to small units (e.g., segmentation of phonemes, blending phonemes into words). Children's awareness of large sound units develops during preschool, while phonemic awareness (awareness of individual phonemes) primarily develops during the early elementary school years (Stanovich, Cunningham, & Cramer, 1984). Although developmentally sequenced, most studies suggest that different PA abilities relate to a single, unitary phonological ability (Anthony & Lonigan, 2004; Stahl & Murray, 1994; Stanovich et al., 1984). Phonological awareness facilitates children's understanding of relations between speech and alphabetic orthography and helps children perceive the abstract categories of sounds (i.e., phonemes) that are represented by letters in words (Torgesen & Mathes, 2000).

Phonological awareness among DHH children

Even with the best audiological technology, DHH children still have less access to sound and, hence, decreased access to spoken language compared to hearing children (Connor & Zwolan, 2004; Nittrouer, Caldwell, Lowenstein, Tarr, & Holloman, 2012). Neither cochlear implants nor hearing aids provide these children with access to full speech signals because the acoustic signal received from these devices makes phonemic information less accessible (Nittrouer et al., 2012). Hence, DHH children with functional hearing are developing PA in the context of weak, different, and more variable spoken phonological information than their hearing peers.

DHH children with functional hearing in preschool and kindergarten, on average, perform at least 1 *SD* below the mean on standardized tests of PA, with large individual differences (Ambrose, Fey, & Eisenberg, 2012; Cupples et al., 2014; Easterbrooks, Lederberg, Miller, Bergeron, & Connor, 2008). Some research shows that the characteristics of DHH children's PA resemble to those of hearing children and are related to reading (Ambrose et al., 2012; Easterbrooks et al., 2008; Webb & Lederberg, 2014). Other research suggests that there are differences in the nature of PA of hearing children and DHH children with functional hearing. For example, Spencer and Tomblin (2009) found that, unlike hearing children, DHH children with cochlear implants performed much better on an elision task than on a blending task. Cupples et al. (2014) found that DHH kindergarteners' scores on blending, elision, and phoneme identification tasks were only weakly correlated with each other, therefore suggesting there may not be one construct underlying these different types of PA. James and her colleagues suggest that DHH children with cochlear implants do not acquire phoneme-level PA prior to learning to read (James, Rajput, Brinton, & Goswami, 2009). Kyle and Harris (2011) found that PA was not a predictor of DHH children's early reading abilities, after accounting for speech reading abilities. Thus, DHH children's decreased access to sound may result in PA playing a decreased or different role in early reading.

Alphabetic knowledge

Alphabetic knowledge refers to three types of alphabetic skills that build on each other: letter-name knowledge, letter-sound knowledge, and word reading. All three relate to acquisition of the alphabetic principle. Learning to read begins with learning to associate letters with their names and with their phonemes or sounds (Shmidman & Ehri, 2010). Hulme and Snowling (2013) posit that both letter-name and letter-sound knowledge are reflective of children's visual-phonological associative learning abilities. Treiman and colleagues, however, suggest that letter-name and letter-sound knowledge may differ in important ways (Treiman, Kessler, & Pollo, 2006; Treiman, Tincoff, Rodriguez, Mouzaki, & Francis, 1998). Many children, especially in the United States and Canada, learn letter-names initially and then use the phonetic cue in letter-names to learn letter-sounds. Therefore, phonological processing skills may play a more important role in letter-sound learning than letter-name learning.

Children use their alphabetic knowledge in their early word reading, by sounding out letters with their associated name or sound (Ehri, 2014). According to Ehri's phase theory of word reading, preschoolers may initially read a few words through visual recognition of a symbol in context (e.g., reading the McDonald's sign). However, as they acquire alphabetic knowledge, young children apply that knowledge to read words by using their letter-sound knowledge to sound out words (Ehri, 2014). Recognition of "sight words" typically only occurs after children have applied their alphabetic knowledge in decoding the words multiple times. Thus, during early reading, word identification or word reading and alphabetic knowledge build on each other and may represent one underlying construct: the acquisition of the alphabetic principle. However, others (e.g., Frith, 1985) suggest that readers may use nonphonological (visual) routes to directly map a printed word to a spoken word stored in their lexicon.

Alphabetic knowledge among DHH children

It is not clear whether DHH children's letter-name and letter-sound knowledge and word reading skill reflect one underlying ability. There are only a few studies that describe alphabetic knowledge and word reading in young DHH preschoolers and kindergarteners with functional hearing (Ambrose et al., 2012; Easterbrooks et al., 2008). These studies suggest that DHH children's letter-name knowledge is not delayed compared to hearing children. In contrast, DHH children appear delayed in their acquisition of letter-sound knowledge (Kyle & Harris, 2011; Easterbrooks et al., 2008). This suggests that the learning processes for these two types of alphabetic knowledge may differ for DHH children. The role of the alphabetic principle based on spoken phonology in DHH children's word reading is controversial. Some researchers suggest that DHH children resemble hearing children in how they read words: that is, they apply their alphabetic knowledge to decode words (Lederberg et al., 2013; Wang, Trezek, Luckner, & Paul, 2008). On the other hand, others (Allen et al., 2009; Goldin-Meadow & Mayberry, 2001) suggest that decreased access to speech leads DHH children to rely less on spoken phonology and more on nonphonological, visual reading strategies, including direct mapping between printed words and their signed or spoken words (e.g., using primarily whole word or visual word recognition). Thus, whether DHH children's alphabetic knowledge and word reading form a cohesive construct (i.e., a single factor) is unknown.

Vocabulary

Hearing children's vocabulary knowledge refers to the phonological and semantic representations of spoken words. Such knowledge includes the ability to produce the correct word for a referent (expressive vocabulary) and to recognize the meaning of spoken words (receptive vocabulary). Researchers have long recognized that individual differences in vocabulary knowledge play an important role in reading (Joshi, 2005; Lonigan et al., 2009; Lonigan, Burgess, & Anthony, 2000; Storch & Whitehurst, 2002). Research suggests that vocabulary plays a direct role in reading by making a critical link between children's ability to decode words and to understand what they have read (Joshi, 2005; Whitehurst & Lonigan, 1998). Vocabulary also has an indirect role in reading through facilitating the development of PA. As children learn more words, they need to distinguish among the similar-sounding words. To quickly and accurately differentiate between similar-sounding words, children must represent the sequence of sounds that constitute each known word in their memory (Goswami, 2001; Metsala, 1999).

Vocabulary knowledge among DHH children

Many DHH children born to signing deaf parents learn vocabulary at typical rates in natural interactive environments (Musselman, 2000). Some DHH children with functional hearing receive sufficient access to their hearing parents' spoken language through cochlear implants or hearing aids to develop age-appropriate vocabulary (Hayes, Geers, Treiman, & Moog, 2009). But the vast majority of DHH children experience delays in language development due to the periods of language deprivation before they are given access to language either through audiological interventions or exposure to sign language. Even after intervention, DHH children differ widely in the ease with which they acquire vocabulary (Davidson, Geers, & Nicholas, 2014). As a result, many DHH children enter school with smaller lexicons and greater individual differences compared to hearing children (Lederberg et al., 2013). In addition to a delay, vocabulary representations differ in some fundamental ways from hearing children. For those who sign, the "phonology" or features of sign language (e.g., handshape, location, movement) do not map onto the spoken phonology represented in alphabetic writing systems. Even for those who are acquiring spoken language, differences in children's speech perception result in different access to and representations of the spoken phonological representations of words (Lederberg et al., 2013). Hence, some argue that DHH children's language delays may play a large role in their struggles to acquire reading skills—much larger than PA (Dillon, de Jong, & Pisoni, 2012; Mayberry, del Giudice, & Lieberman, 2011).

Present Study

The present study focuses on describing these constructs and relations among them for DHH children with functional hearing in order to begin to test the key theories and the mechanisms each proposes in supporting DHH's children's developing literacy. Several studies have found that PA, alphabetic knowledge, word reading, and vocabulary are correlated for young DHH children with functional hearing (Cupples et al., 2014; Dillon et al., 2012; Easterbrooks et al., 2008; James, et al., 2009). However, to the best of our knowledge, the structure or dimensionality of early literacy skills of DHH children has not been studied with a sample large enough to permit falsifiable models. Previous studies were limited by small sample sizes and thus employed regression methods to examine associations among these skills. Given that literacy skills are highly related to one another, are measured with error, and potentially reflect one or more underlying constructs, methods such as CFA are better suited because they allow investigation of multivariate relations among early literacy skills (Mehta, Foorman, Branum-Martin, & Taylor, 2005; Mehta & Neale, 2005).

We used CFA to address two related questions. First, to what extent do PA, alphabetic skills, and vocabulary form integrated constructs for DHH children with functional hearing? CFA enables us to determine how well different measures (e.g., expressive and receptive vocabulary) indicate the hypothesized construct, as well as the nature of the construct (e.g., whether vocabulary is one or several abilities). Second, what are the relations among these three constructs? We tested three hypothesized models that assess relations among PA, alphabetic knowledge, word reading, and vocabulary. All models assessed whether spoken PA was important for early literacy of DHH children with functional hearing; none of the models would show good model fit if spoken phonology was not important for these DHH children's early literacy skills. The three models differ on the degree to which PA is integrated with alphabetic skills and word reading. CFA also indicates the strength of the relation between the constructs. Each of these models is described in the following sections and depicted in Figure 1.

Hypothesized Models of Early Literacy Skills in DHH Children

Two-factor model

Theoretical and empirical studies have found a basis for a 2-factor model of early literacy skills in hearing children, in which PA, alphabetic knowledge, and word reading skills form a single construct that is separate but related to language abilities or vocabulary (Mehta et al., 2005; Mungas et al., 2013; Storch & Whitehurst, 2002). Most researchers agree that children's reading skills rely on children's facility with spoken phonology and that many struggling readers have a phonological core deficit—that is, an inability to access and be aware of the phonemic representations of words that are stored in long-term memory (Metsala, Stanovich, & Brown, 1998; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Such a deficit may result in PA and alphabetic knowledge functioning as one construct. PA and alphabetic knowledge may merge into one construct also because they have strong reciprocal relations, especially during early reading instruction (McGuinness, McGuinness, & Donohue, 1995; Perfetti, Beck, Bell, & Hughes, 1988). Studies using CFA have found that this 2-factor structure best describes early literacy skills (i.e., code-related and language abilities) in first through fourth grade hearing children (e.g., Mehta et al., 2005; Mungas et al., 2013; Storch & Whitehurst, 2002).

This theoretically based 2-factor model is presented in Figure 1A. The first six measures (rectangles) in Figure 1A involve code-based skills of PA and alphabetic knowledge. The additional three measures are of vocabulary. The two circles represent the theoretically specified latent factors and are allowed to be correlated.

Three-factor model

We also hypothesized that literacy skills might be represented by three separate constructs—PA, alphabetic knowledge, and vocabulary (see Figure 1B). Theoretically, PA, alphabetic knowledge, and vocabulary are developed through different cognitive

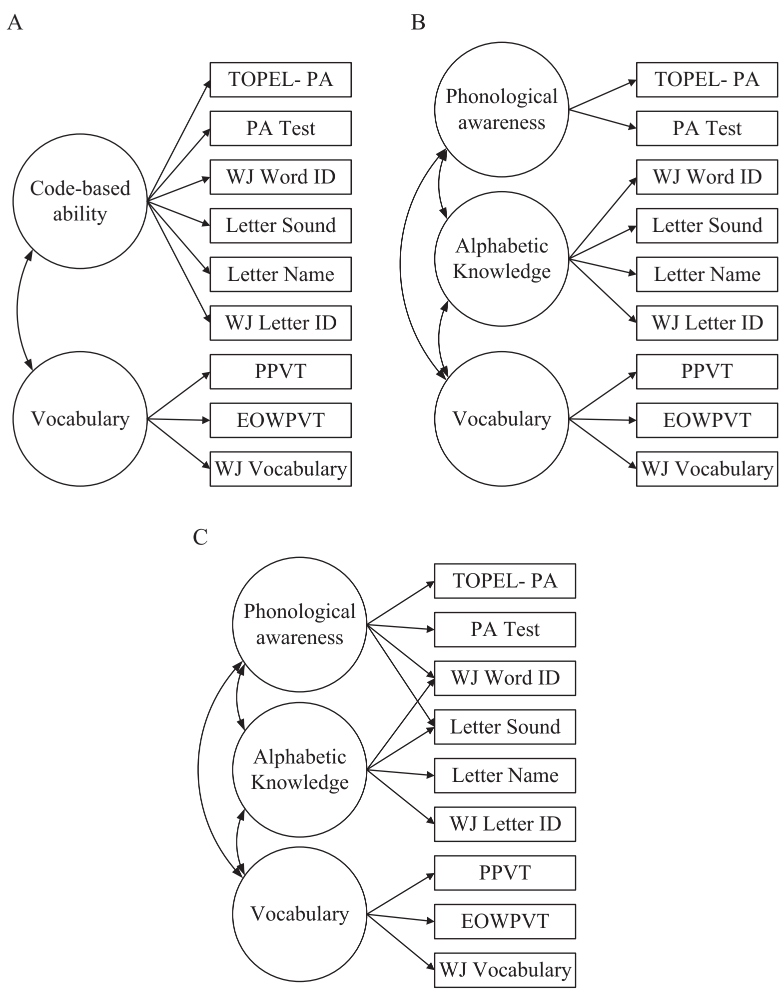

Figure 1. Three confirmatory factor models (A: 2-factor model; B: 3-factor model; C: complex 3-factor model) evaluating factor structure of early literacy in DHH children based on the models of young hearing children.

Note. TOPEL-PA = Test of Preschool Emergent Literacy-Phonological Awareness; PA Test = Phonological Awareness Test; WJ Word ID = Woodcock-Johnson Word Identification; Letter Sound = letter-sound knowledge test; Letter Name = letter-name knowledge test; WJ Letter ID = Woodcock-Johnson Letter Identification; PPVT = Peabody Picture Vocabulary Test-IV; EOWPVT = Expressive One Word Picture Vocabulary Test; WJ Vocabulary = Woodcock-Johnson Expressive Vocabulary subtest.

processes and experiences (Whitehurst & Lonigan, 1998), and PA and alphabetic knowledge may not merge into one construct until children have gone beyond the emergent literacy stage when the alphabetic principle plays a crucial role in reading. Some empirical research with hearing children reports that PA and alphabetic knowledge are distinct constructs (Lonigan et al., 2000; Sénéchal, LeFevre, Smith-Chant, & Colton, 2001). Some studies suggest that hearing loss affects the development of PA more than alphabetic knowledge because letters provide visual support for DHH children's perception and acquisition of spoken phonemes (Lederberg et al., 2013). Such a distinction between alphabetic versus phonological ability could suggest that their early literacy skills would be better explained by a 3-factor model than by a 2-factor model (compare Figure 1B to 1A).

Complex 3-factor model

While, traditionally, the tasks used in assessments of letter-names, letter-sounds, and word reading skills have been assumed to measure one construct related to the alphabetic principle, PA may play a crucial role in identifying the sounds of letters as well as in word decoding. We therefore hypothesized an alternative, complex 3-factor model (see Figure 1C). Model 1C specifies that letter naming is unique to alphabetic knowledge, but success on letter-sounds and word reading tasks are the result of two related but separable abilities: alphabetic knowledge and PA.

Research suggests that DHH children generally develop age-appropriate letter-name knowledge but are delayed in letter-sound knowledge, PA, and word reading (Ambrose et al., 2012; Easterbrooks et al., 2008; Kyle & Harris, 2011). As Treiman et al. (1998) noted, letter-name knowledge may be acquired through paired-associate learning, similar to learning vocabulary. The finding that DHH children develop age-appropriate letter-name knowledge suggests that this skill may not be strongly dependent on PA. In contrast, spoken phonology may play a more crucial role in learning letter-sound associations and word reading abilities. If access to phonology of spoken language is disrupted, as it is for DHH children, PA may be a limiting factor in letter-sound learning and word reading. Thus, we hypothesized that letter-sound knowledge and word reading skills may reflect both DHH children's PA and alphabetic knowledge.

In order to test these models, we used multiple measures for each of the constructs that have been developed to assess these skills in hearing children. This also allowed us to assess the adequacy of measures developed for hearing children when used with DHH children with functional hearing.

We posed the following research questions:

1. To what extent do these three hypothesized models adequately describe the early literacy skills of DHH children with functional hearing?
2. What is the relative strength of the relations among PA, alphabetic knowledge, and vocabulary in the best fitting of these models?
3. What do the results of the best of these models suggest about the quality of the assessments for measuring skills of DHH children with functional hearing, given they were developed to be used with hearing children?

Method

Participants

One hundred and sixty-seven participants who attended school programs for children with hearing loss in a variety of school settings, including a private oral school, classes in public schools, and state schools for the deaf, were included in the study. To obtain a large enough sample, we recruited participants over seven consecutive school years from classes or schools that served DHH children in a large metropolitan area and one state school for the deaf in another state. We used a school-based strategy for recruitment—enrolling children who were attending self-contained class for DHH children. During the first year, we recruited participants (*n* = 66) between the ages of 42 and 95 months; thereafter, participant recruitment targeted children who were between 42 and 69 months. No child provided data in more than one school year.

To be included in this study, children had to have sufficient functional hearing to have at least some speech perception abilities, as evidenced by their performance on the Early Speech Perception Test (ESP; Moog & Geers, 1990). We administrated the ESP to a total of 234 children. The performance on the ESP was classified into four speech perception categories: 1 = no pattern perception (e.g., not able to distinguish between one and two syllable spoken words; *n* = 55; 23.4%), 2 = pattern perception (*n* = 9; 3.8%), 3 = some word identification (*n* = 15; 6.4%), and 4 = consistent word identification (*n* = 155; 66.0%). Only children who scored at 3 or 4 were included in this study. We also excluded three children who used fingerspelling on the letter-name knowledge test, because the role of letter-name for these children in early literacy skills is likely to have differed from children who used the spoken letter-names. Thus, a total of 167 DHH children were included in the current study (73 girls and 94 boys).

Table 1 provides the demographic and descriptive characteristics of this economically and ethnically/racially diverse sample. Forty-six percent had cochlear implants (*n* = 77); 90 were hard of hearing and used hearing aids. Among the 90 hard-of-hearing children, 13 (14.4%) had mild hearing loss (better ear-pure tone average, BE-PTA between 20 and 40 dB), 27 (30.0%) had moderate hearing loss (between 41 and 55 dB), 26 (28.9%) had moderately severe hearing loss (between 56 and 70 dB), 9 (10.2%) had severe hearing loss (between 71 and 90 dB), and 2 (2.3%) had profound hearing loss (91 dB or greater). Thirty-seven children (22.2%) were in preschool (*M* age = 47.2 months, range 38–59 months), 64 (38.3%) were in prekindergarten (*M* age = 55.0 months, range 45–61 months), 38 (22.8%) were in kindergarten (*M* age = 66.5 months, range 60–74 months), and 28 (16.8%) were in first or second grade (*M* age = 82.0 months, range = 73–95 months). About a quarter of the children were in environments (classes or homes) where both speech and sign were used to communicate (either together or separately); 75% were exposed to only spoken language. Fifty-six (33.6%) were from families whose home language was other than spoken English.

Assessment Procedures and Measures

Examiners administered a battery of language and literacy assessments in the fall of the school year. All examiners were certified teachers of DHH children and had extensive experience in the language of the child's school. Each of the assessments was administered individually in a quiet, familiar room in the school building. For all assessments, examiners used the communication mode of the school for the instructions—either spoken language, simultaneous communication (sign and speech), or sign only. However, the ESP and the PA test items were delivered solely in spoken English with no accompanying sign or fingerspelling, although directions were signed when appropriate. The participating children completed two standardized measures

Table 1. Demographic characteristics of participating children

Characteristics		Mean or % (*n*)	*SD*	Range
Chronological age at the fall assessment (months)		60.43	12.45	38–95
Age at identification (months)		13.72	14.86	Birth-68
Age of implantation (months) (*n* = 76)		28.42	11.73	12–66
BE-PTA for children with hearing aid (*n* = 88)		63.91	24.09	22–110
Ethnicity	White	40.7% (68)		
	Black	23.4% (39)		
	Hispanic	16.2% (27)		
	Multiracial	12.0% (20)		
	Other	5.7% (10)		
Maternal education level	Less than 12 years	7.8% (13)		
	High school graduate	19.8% (33)		
	Some college or technical	14.4% (24)		
	College graduate	31.1% (52)		
	Graduate school	13.8% (23)		
Parental deafness or hard of hearing	Mother	6.0% (10)		
	Father	4.2% (7)		
Communication mode at home	Spoken language	71.3% (119)		
	Simultaneous communication	22.8% (38)		
	American Sign Language	2.4% (4)		
Communication in the classroom	Spoken English	74.3% (124)		
	Simultaneous communication	18.6% (31)		
	Communication in sign	6.6% (11)		

Note. The total number of children and % may not correspond to the samples size due to missing information. BE-PTA = better ear-pure tone average.

of PA, three standardized measures of vocabulary, a standardized measure of letter-word identification, and researcher developed letter-name and letter-sound knowledge measures (see Figure 1). Details about each of the measures are provided in the following sections.

Early Speech Perception Test

The ESP requires children to discriminate through audition alone among single words and/or multi-syllable words with different stress patterns (Moog & Geers, 1990). Children must select correct referents of spoken words from closed sets of pictures/objects. The results are used to place children in four speech perception categories ranging from no pattern perception to consistent word identification. This measure was used to identify children who had functional hearing, defined as those children who were able to identify the referents of some or most spoken words tested (i.e., score of 3 or 4)

Phonological awareness measures

The Test of Preschool Early Literacy-Phonological Awareness subtest (TOPEL-PA; Lonigan, Wagner, Torgesen, & Rashotte, 2007) was designed to assess the elision and blending abilities of preschoolers, using multiple-choice and free-response formats for the two PA skills (a total of four subtests). The TOPEL-PA required children to manipulate both word- and phoneme-level sounds. A subtest was not administered to a child if the child responded to both of the two practice items incorrectly, and the administration of the subtest was discontinued if a child responded incorrectly to three consecutive items. All items on the TOPEL-PA were scored either correct or incorrect. Standard scores based on hearing children are available for 3- to 5-year-olds. Internal consistency reliability (Cronbach's α) for the sample was .92.

The PA Test (Robertson & Salter, 2007) measures large and small unit PA on separate tests. We administered four PA Test subtests: rhyming discrimination, syllable segmentation, initial phoneme isolation, and phoneme blending. The PA Test was normed on 5- to 9-year-old hearing children. Because our sample included younger children, we used the modifications that are developed and validated by Webb, Schwanenflugel, & Kim (2004) for hearing 4-year-olds. All items on the PA Test were dichotomously scored (i.e., correct or incorrect), and internal consistency reliability for the sample was .93.

Webb & Lederberg (2014) examined the validity of the TOPEL-PA and PA Test for young DHH children with functional hearing. Based on classical item analyses that included item difficulty, item discrimination, and internal consistency (Cronbach's α), they concluded that the items on the two tests had good psychometric properties.

Letter-name and letter-sound measures

An experimenter-developed letter-name knowledge (Letter Name) test required children to name lowercase letters (a total of 23 letters) that were presented individually in random order on index cards. An examiner pointed to each letter and asked, "What is this letter?" Children provided either the spoken or fingerspelled name. A letter-sound knowledge test (Letter Sound) assessed children's ability to identify the sounds associated with the alphabet letters (or graphemes) that were presented individually in random order on index cards. The Letter Sound test included 18 consonants, 3 diagraphs, and 5 vowels (both short and long sounds). An examiner asked, "What sound does this letter make?" All items on the Letter Name and Letter Sound tests were scored either as correct or incorrect. Internal consistency reliability for the sample was .97 for Letter Name and .96 for Letter Sound.

Letter-name and word reading measures

The Letter-Word Identification subtest of the Woodcock-Johnson Tests of Achievement-III (WJ-LWID; Woodcock & Mather, 2001) provided two measures: another measure of letter-name knowledge and a measure of word reading skills. Children were asked to identify large type letters (letter identification) and to read simple words (word identification). While these two skills are combined on one test, the two skills may not measure a single underlying construct (see Cupples et al., 2014 for similar decision). We therefore created two separate variables, WJ Letter ID (the total number of correct letter naming items—maximum score is 13) and WJ Word ID (the total number of correct word reading items), Items on the WJ-LWID test are ordered by difficulty, and the starting point (or basal rule) was determined by a combination of a child's age and responses to the initial items. Each item was scored as either correct or incorrect. A correct spoken or signed response was scored as correct. Internal consistency reliability of the WJ-LWID for the sample was .94. Internal consistency reliability for the sample was .90 and .93 for WJ Letter ID and WJ Word ID, respectively.

Vocabulary measures

The Peabody Picture Vocabulary Test, Fourth Edition (PPVT; Dunn & Dunn, 2007) was used to assess children's receptive vocabulary. PPVT requires a child to select one of four pictures that best depicts a word spoken and/or signed by the assessors (depending on the language environment of the child.) The Picture Vocabulary subtest of the Woodcock-Johnson Tests of Achievement-III (WJ Vocabulary; Woodcock & Mather, 2001) and the Expressive One Word Picture Vocabulary Test-III (EOWPVT; Brownell, 2000) assessed children's expressive vocabulary and require a child to name (using either speech or sign or both) pictures of increasingly unfamiliar items. Administrators used standard basal and ceiling rules for all three tests. For children acquiring only spoken language, vocabulary tests were administered according to the standard protocol for hearing children. These tests had to be adapted for children who were acquiring sign in order to accurately assess their vocabulary knowledge. A team of proficient signers created a list of standard signs that assessors used when administering the PPVT. The team also created a standard list of acceptable signs for all items on the expressive vocabulary tests. A child needed to produce either the correct spoken or signed word on the expressive measures to be scored correct. Thus, these tests were designed to measure the children's vocabulary knowledge irrespective of modality or language. Each item on the vocabulary measures was scored as either correct or incorrect. Internal consistency reliability for the sample was .96 for PPVT, .83 for WJ Vocabulary, and .95 for EOWPVT.

Results

Data Screening and Descriptive Statistics

Preliminary analyses of univariate and multivariate normality and outlier screening were conducted using SPSS (Version, 17.0, 2008) syntax developed by DeCarlo (1997). Outliers were identified if a squared Mahalanobis distance was greater than 27.88 (at the α level of .001); the analyses identified two multivariate outliers. A careful evaluation of the data did not detect any data entry errors, and the outlier cases were determined to represent valid cases. Confirmatory factor analyses when the outlier cases were deleted from the data yielded similar results as when the cases were included in the analyses in terms of model fit, parameter estimates, and standard errors. Hence, we included the outlier cases in the final analyses. Additionally, a relative multivariate kurtosis of 1.33 indicated that the assumption of multivariate normality was reasonable (less than $|2|$).

Descriptive statistics for total scores on all variables, including the means, *SD*s, and intercorrelations are shown in Table 2. Additionally, average standard scores for the tests that were available for calculation are reported. These children were delayed in both language and PA skills, averaging, at least 1 *SD* below the mean for the tests' norming samples of hearing children (see Table 2). On average, the DHH children read 3.12 words ($SD = 5.35$) on the WJ-LWID. Eighty-four percent read less than seven words on the WJ-LWID. Thus, the vast majority of these children would be considered emergent or early readers. Moreover, it is worth noting that the WJ Letter ID and WJ Word ID identification scores were only moderately correlated ($r = .51$) with each other (Table 2), suggesting a possible distinction to be tested in the subsequent models. Intercorrelations among the variables were moderate to strong, indicating cohesiveness among the scores on the early literacy measures.

Evaluation of the Hypothesized Measurement Models

We conducted a series of CFA to examine the degree to which the three hypothesized measurement models of early literacy skills in DHH children fit the data (see Figure 1). These

Table 2. Descriptive statistics and intercorrelations among the early literacy measures

	1	2	3	4	5	6	7	8	9
1. TOPEL-PA	—								
2. PA Test	.66	—							
3. WJ Word ID	.44	.57	—						
4. Letter Sound	.58	.68	.64	—					
5. Letter Name	.42	.58	.55	.77	—				
6. WJ Letter ID	.35	.53	.51	.70	.83	—			
7. PPVT	.45	.46	.39	.50	.50	.54	—		
8. EOWPVT	.47	.51	.45	.54	.57	.56	.77	—	
9. WJ Vocabulary	.31	.35	.33	.43	.56	.57	.70	.81	—
M raw scores	10.89	8.74	3.12	8.87	12.90	8.96	51.94	35.23	12.10
SD raw scores	6.98	9.10	5.35	9.19	8.50	3.79	18.14	13.00	3.86
M standard scores[a]	83.79	—	—	—	—	—	79.33	80.35	89.50

Note. $n = 167$ for means and standard deviations of the total scores or raw scores on each test. Mean standard scores for Woodcock-Johnson Letter Word Identification was 100.46. Standard scores for norming sample of all tests have $M = 100$ with $SD = 15$. TOPEL-PA = Test of Preschool Emergent Literacy-Phonological Awareness; PA Test = Phonological Awareness Test; WJ Word ID = Woodcock-Johnson Letter Word Identification, word identification; Letter Sound = letter-sound knowledge test; Letter Name = letter-name knowledge test; WJ Letter ID = Woodcock-Johnson Letter Word Identification, letter-name knowledge; PPVT = Peabody Picture Vocabulary Test-IV; EOWPVT = Expressive One Word Picture Vocabulary Test; WJ Vocabulary = Woodcock-Johnson Expressive Vocabulary subtest.
[a]Standard scores are shown only for descriptive interpretation, with dashes indicating tests for which standard scores were not available.

three a priori models are nested versions of each other, ranging from simple (only two factors) to complex (in the case of the third model). We conducted CFAs using Mplus 7.11 with full information maximum likelihood estimation method for missing data.

Table 3 shows model fit indices for each model, including the χ^2 test, comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square of error of approximation (RMSEA), and the standardized root mean square residual (SRMR; for discussion of issues in model fit, see Marsh, Hau, & Wen, 2004). These indices suggest that the 2-factor model in first row of Table 3 did not have good fit. The 3-factor model in row 2 had a reasonable model fit, except for RMSEA. The complex 3-factor model in row 3 had an excellent model fit. The rightmost column of Table 3 shows the test of model comparison as measured by the χ^2 difference test: 3- versus 2-factor model ($\Delta\chi^2$ (2) = 29.27, p < .001) and complex 3- versus 3-factor model ($\Delta\chi^2$ (2) = 36.95, p < .001). Both χ^2 difference tests and evaluation of the fit indices showed that the 3-factor model fit better than the 2-factor model, and that the complex 3-factor model fit better than the simple 3-factor model.

The fully standardized estimates from the complex 3-factor model (from Figure 1C) are presented in Figure 2, with three latent factors on the left and the nine observed variables on the right. The correlations between the factors are represented by curved double-headed arrows. The arrows from the latent factors represent factor loadings (i.e., standardized pattern coefficients or test-to-factor correlations, which, when squared, represent R^2). The curved, double-headed arrows on each observed test (rectangles) represent residual variances (1 – R^2 in this fully standardized solution).

The loadings for the three factors were high for the simple, single-factor indicators (e.g., TOPEL-PA and PA Test to PA), ranging from 0.74 to 0.94. The loadings for the complex indicators, WJ Word ID and Letter Sound, were split across the factors for PA and Alphabetic Knowledge. The error variances for the indicators were generally low, except for TOPEL-PA (0.45) and WJ Word ID (0.53). Finally, the factor correlations among the constructs indicate that the associations among the three factors were strong and relatively homogeneous (0.58 to 0.67).

As noted in the previous section, all participants could be considered as beginning readers. However, given a wide range of age, we conducted additional analyses with (a) age as a covariate in the three hypothesized models and (b) excluding 10 children who were older than 7 years (or 83 months) from the models. Results of these CFAs yielded essentially the same results. The complex 3-factor model resulted in best model fit. When children who were older than 7 years were excluded from the study, for instance, model fit remained excellent, χ^2 (22) = 43.50, p = .004, CFI = .98, TLI = .96, RMSEA = .08, and SRMR = .04. The parameter estimates and standard errors were similar to the model in Figure 2. The results of these models are available in Supplementary Figure 1 to this article.

Discussion

Better understanding early literacy constructs and how they are associated to support DHH children's developing reading skills promises to inform more effective reading instruction. However, the role of PA in DHH children's developing literacy is hotly debated, and efforts to date to develop effective early literacy instruction for DHH children have met with mixed results (Luckner & Handley, 2008; Qi & Mitchell, 2012). The present study is the first to our knowledge to use theoretically a priori models to examine the relations among early literacy skills in a relatively large sample of young DHH children with functional hearing. The confirmatory factor analytic approach also allowed us to examine the validity of the measures developed for hearing children as indicators of the underlying constructs for DHH children with functional hearing. Our sample was composed of deaf children with cochlear implants and children with mild to profound hearing losses who use hearing aids. All children were able to identify the referent for spoken words on the ESP. Thus, these audiological devices allowed the children some (though by no means complete) auditory access to spoken language. Children's scores on standardized tests for vocabulary and PA averaged more than 1 *SD* below the mean of the hearing norms.

Our results indicate that the structure of early literacy skills of DHH children with functional hearing are consistent with theories of early reading developed for hearing children. Specifically, like hearing children, DHH children appear to be acquiring the alphabetic principle—with spoken PA and

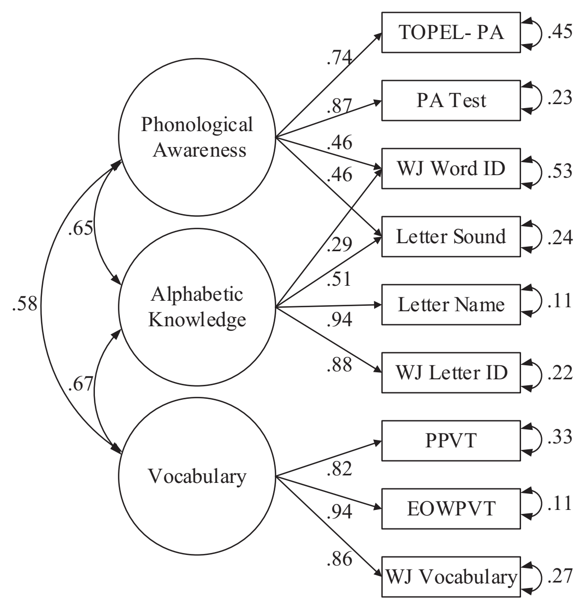

Figure 2. Fully standardized estimates for the complex 3-factor model for the structure of early literacy skills in DHH children.

Table 3. Fit indices for measurement models of early literacy in DHH children

Model	χ^2	*df*	CFI	TLI	RMSEA	SRMR	$\Delta\chi^2$
Two-factor model	108.56***	26	.92	.88	.14	.06	—
Three-factor model	79.29***	24	.94	.92	.12	.05	29.27***
Complex 3-factor model	42.34**	22	.98	.97	.07	.03	36.95***

Note. RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; CFI = comparative fit index; TLI = Tucker-Lewis index; $\Delta\chi^2$ = chi-square difference, 2 *df* each.
**p < .01, ***p < .001.

vocabulary both highly related to alphabetic skills. This supports previous research that spoken PA and vocabulary both relate strongly to DHH children's alphabetic skills and early word reading abilities (Cupples et al., 2014; Dillon et al., 2012; Easterbrooks et al., 2008; James, et al., 2009). Our results suggest that the structure of these abilities among DHH children with functional hearing is qualitatively similar to that among hearing children. Hence, literacy instruction that is effective for hearing children is likely, with some adaptation, to be effective for DHH children with functional hearing.

Confirmatory factor analyses enabled us to describe more clearly the nature of these constructs, the adequacy of our tests to measure the constructs, and relations among these abilities. We found that the 2-factor model did not capture adequately the nature of these children's skills, suggesting that PA and alphabetic knowledge are not fully integrated in these young DHH children. This lack of integration may reflect the fact that the DHH children are primarily prereaders or early readers and such integration may only happen after children have more advanced alphabetic skills. This is consistent with Scarborough's (2001) reading theory that posits where skills become more integrated as reading develops. Indeed, the 2-factor model primarily has been found among elementary school hearing children (Mehta et al., 2005; Mungas et al., 2013; Storch & Whitehurst, 2002).

The children's early literacy skills were adequately explained by a 3-factor model. In this model, PA, alphabetic knowledge, and vocabulary formed separate but highly correlated constructs, as others have found with young hearing preschoolers (Lonigan et al., 2000; Whitehurst & Lonigan, 1998). However, this simple 3-factor model, while adequate, did not fit the early literacy skills of DHH children as well as the complex 3-factor model. The following section discusses the complex 3-factor model in more detail. First, we discuss each construct separately, then relations among the constructs.

Phonological Awareness

We used two tests of PA, which encompassed skills that varied in nature (blending, elision, and rhyme), in grain sizes (words, syllables, and phonemes) as well as visual picture formats and spoken-language tasks. Despite these differences, the high factor loadings for the tests (.74 for the TOPEL-PA Test and .87 for the PA Test) indicate that they both measured one underlying PA construct. This is consistent with research with hearing children that suggests that, although different PA skills may develop at different times, these skills all relate to one underlying ability—that is, children's ability to access the sublexical structure of spoken words (Anthony & Lonigan, 2004; Lonigan et al., 2000). Despite the consistent finding that hearing loss interferes with access to spoken phonology and DHH children's PA is delayed compared to hearing children, these tests are strong indicators of PA in DHH children. This supports other research that has used standardized tests normed for hearing children to measure PA skills in DHH children with functional hearing (e.g., Ambrose et al., 2012; Easterbrooks et al., 2008; Webb & Lederberg, 2014).

Alphabetic Knowledge and Word Reading

The complex 3-factor model indicated that letter-name knowledge, letter-sound knowledge, and word reading skills did not form one simple construct (alphabetic knowledge). Instead, the two tests of letter-name knowledge formed one construct, while letter-sound knowledge and word reading skills were directly influenced by both alphabetic knowledge and PA. Thus, word reading and letter-sound knowledge may rely more on access to spoken phonology than learning letter-names.

Some researchers have proposed that children develop alphabetic knowledge through paired-associate learning in which a child associates letters' shapes with particular names and sounds (Hulme & Snowling, 2013; Shmidman & Ehri, 2010; Treiman et al., 2006). Our findings support Trieman's hypothesis that the nature of the paired-associate learning differs for letter-name and letter-sound knowledge (Ellefson, Treiman, & Kessler, 2009; Treiman et al., 1998). DHH children do not generally have trouble learning letter-name associations, and research suggests that they develop age-appropriate letter-name knowledge (Ambrose et al., 2012; Easterbrooks et al., 2008). In contrast, letter-sound tasks also involve isolating relevant phonemes, which are abstract units of spoken phonology that do not appear in the speech stream, are difficult to hear, and do not have the acoustic properties of words. Our results suggest that letter-sound knowledge reflects both children's PA and alphabetic knowledge. Trieman provides evidence that hearing children frequently learn letter-sound correspondences by isolating the phoneme in a letter's name (e.g., sound *b in the letter name bee*) and that children's PA abilities support this learning process (Foy & Mann, 2006; Kim, Petscher, Foorman, & Zhou, 2010; Share, 2004; Treiman et al., 1998). Research suggests that letter-sound learning occurs through a similar process for DHH children with functional hearing (Goldberg & Lederberg, 2015), with implications for developing effective instruction.

Word reading skills also related to both PA and alphabetic knowledge. This result suggests that, despite decreased access to spoken phonology, DHH children with functional hearing use phonological decoding and encoding processes to identify letter sounds and to read words. That is, they do not appear to compensate for their decreased access to phonology by using primarily whole word or visual word recognition, even during early reading (Goldin-Meadow & Mayberry, 2001). Instead, our results suggest that PA plays a key role for DHH children in reading words and is likely important to acquiring the alphabetic principle. Many current reading curriculums for DHH children rely on the whole-word method. However, emerging findings, including the findings of this study, suggest that explicit instruction in the alphabetic principle for DHH children is likely to be highly effective in supporting early literacy development.

Vocabulary

As has been found with models with hearing children, vocabulary skills formed a separate latent construct from other early literacy skills (Mehta et al., 2005; Storch & Whitehurst, 2002). Both receptive and expressive vocabulary scores loaded well on this construct (with factor loadings ranging from .82 to .94). While some researchers have speculated that hearing loss differentially affects receptive and expressive language (Spencer, Barker, & Tomblin, 2003), our results suggest that receptive and expressive tests clearly measured a single underlying construct: vocabulary knowledge. The DHH children averaged more than 1 *SD* below the mean of the tests' norming sample (see Table 2). Thus, they had smaller lexicons than are typical of hearing children of their age. A quarter of the sample was in a signing environment and had lexicons that contained both sign and spoken words. Despite these differences from the tests' hearing norming samples, the high factor loadings and low error terms suggest that the tests developed for hearing children are excellent indicators of DHH children's vocabulary abilities. The tests also may be an excellent indicator of overall language. A recent study with both monolingual (spoken English and American Sign Language users) and bilingual/bimodal DHH children showed that scores on the vocabulary measures were highly correlated with other aspects of language e (e.g., English and ASL syntax) (Lederberg et al., 2014). These results along with other research strongly indicate the need for ongoing and intensive focus on developing language for DHH children.

Relations Among the Constructs

We found moderately strong homogenous relations among the three constructs (r = .58 to .67). It is striking that the magnitudes of correlations among these constructs in our sample are highly similar to those found in hearing children (e.g., Mehta et al., 2005; Burgess & Lonigan, 1998; Storch & Whitehurst, 2002). Reading is a process of translating a sequence of visual symbols into meaningful language, which is a result of both decoding and language (Hoover & Gough, 1990; Scarborough, 2001). While learning to read, students need to develop all three components of early reading skills: PA, alphabetic knowledge, and vocabulary. These skills are simultaneous and highly related to each other (and perhaps even develop reciprocally over time). Our findings support the hypothesis that the structure of reading skills in DHH children with functional hearing is qualitatively similar to that in hearing children (Easterbrooks et al. 2015; Paul et al, 2013) and do not tend to support theories suggesting that DHH children with functional hearing can bypass learning the alphabetic principle (Goldin-Meadow & Mayberry, 2001; Allen et al., 2009). Our results show that knowing letter-name knowledge may not be sufficient for word reading and that early reading relies on learning letter-sound correspondences and developing PA.

Methodology: Why Confirmatory Factor Analysis Instead of Regressions?

Questions of concurrent relations among reading, phonological, and language constructs are common, both in DHH research as well as in reading research among hearing children. Frequently, such questions are modeled as separate regressions to develop proportions of variance explained in a particular outcome. Multivariate methods such as CFA used here overcome specific limitations of regression for reading skills, including multicollinearity, measurement error, and an arbitrary model definition.

As has been found in most reading research, our measures were moderately to highly correlated, which clearly exceed many recommendations regarding multicollinearity for regression. With such high correlations among variables, focus on unique variances ignores the large amount of shared variance. While various statistical corrections can be made to predictors in a regression model, a direct model of the intended multivariate structure can be more informative because of its focus on shared variance: the latent factors specified by theory.

Because essentially all observed test scores in education have measurement error, reliability is a key concern in reading research. Predictor scores in regression, however, are taken at face value, with no allowance for measurement error (Bollen, 1989; Cohen, Cohen, West, & Aiken, 2003). Therefore, reliance on particular regression coefficients over others (e.g., PA vs. vocabulary) without corrections for unreliability may lead to inaccurate conclusions. Indeed, we found certain tests (e.g., TOPEL-PA, with an R^2 of 1 − 0.45 = 0.55; see Figure 2) had sufficient error to be considered only moderate indicators of their construct (e.g., PA). Using multiple measures of each construct allowed us to more accurately measure the underlying construct (i.e., at the latent level, with measurement error controlled). This is the first study to use multiple measures of each construct in a confirmatory factor model for DHH children.

In the ideal world, a factor model and a series of regressions would yield the same answers; however, in a world of multicollinear variables with measurement error, single-outcome regression can often lead us astray, especially when our univariate models do not match our multivariate theories. In our study, relations were very high and some measures were doubly predicted by two constructs simultaneously. In such complex systems, questions of “unique” prediction can become problematic and unreliable, for both statistical and conceptual reasons. The high, homogeneous relations among these constructs suggest that asking which construct is more important than another is perhaps a misleading question—given how interrelated these abilities are.

Educational Implications

Consistent with past research, the present study found that DHH children may be delayed in their development of PA, alphabetic skills, and vocabulary, and these constructs are separate but strongly related. Again, these findings indicate that effective, early literacy instruction of DHH children will likely focus on facilitating all three constructs. The similarity of the structure of DHH children’s early literacy skills to those of studies with hearing children suggest that interventions developed for hearing children may serve as a basis for interventions for DHH children. However, such interventions may need to be adapted to DHH children’s abilities (e.g., decreased access to spoken phonology and slower word learning abilities). There is emerging evidence that such interventions can improve DHH children’s knowledge in all three areas (Lederberg, Miller, Easterbrooks, & Connor, 2014). However, more research is needed to explore what types of educational interventions can be effective in improving these important early literacy skills. The results of the current study also suggest that standardized tests developed for hearing children can be used to monitor and evaluate the effectiveness of instruction for DHH children.

Limitations

The current study included only DHH children with functional hearing to evaluate the empirical appropriateness of theories of early reading skills. The best model for early literacy skills in the DHH children was a hybrid of the 2-factor and 3-factor models found for hearing children. Without a hearing comparison group, we cannot conclude whether the complex 3-factor model of early literacy skills of DHH children is the same or different from the structure of early literacy skills of hearing children. Future research that allows for a multiple-group approach is needed to rigorously test differences in the structure of early literacy skills for DHH and hearing children.

While CFA has advantages over univariate approaches, it also has disadvantages, especially related to sample size requirements. This is particularly difficult when addressing research questions for a low incidence, heterogeneous population such as DHH children. In this paper, we treated our sample as one group—ignoring potentially important differences within the sample. We included a wide age range, 3.5 to 7 years, of DHH children. This age range for typically developing hearing children would include children past the learning to read phase. In contrast, almost all children in the current sample were prereaders or early readers. However, having a large age range may obscure developmental changes in the structure of early literacy skills. While we conducted sensitivity tests for older children in the current study (i.e., conducting CFAs without children older than 7 years), further research will be needed to determine the extent to which the structure of early literacy skills differs for DHH children at different ages.

Similarly, we were unable to fit dependable multiple-group CFAs for interesting subgroups of children with different levels of hearing loss, communication modes, and sign language abilities. We simply had insufficient numbers of children to assess if the final model was reflective of important subgroups of DHH children. For example, we have hypothesized that the role of spoken phonology depends on DHH children's functional hearing and the acquisition of sign language (Easterbrooks et al., 2015). Future research with larger samples should compare the structure of literacy skills for children who differ in their language (bilingual vs. monolingual) and hearing abilities (functional or not) in this heterogeneous population. This is crucial for testing different theoretical perspectives of how DHH children learn to read, and to be able to describe reading of all DHH children.

Because our PA measures required children to be able to hear the stimuli and respond with speech, we could not include children without functional hearing in the tests used in our current models. Past research has used nonverbal tasks (e.g., picture-based) to assess PA in DHH children without spoken-language abilities. Future research that assesses PA using these tests for DHH children with and without functional hearing in a model similar to ours would indicate if these two types of DHH children learn to read through qualitatively different processes and if such tasks are good indicators of PA for diverse DHH children.

The present analysis did not account for classroom clustering, which may be an important source of differences (Mehta et al., 2005; Mehta & Neale, 2005), including effects for instruction, peer effects, and group selection. The present study collected 167 students from 35 classrooms in 13 schools. Given the small sample size, clustering was not modeled, but could be a productive issue for future research.

Conclusions

This study extends our understanding about the nature of early literacy skills in DHH children. We found early literacy formed three constructs—PA, alphabetic knowledge, and vocabulary—that had strong homogeneous associations with one another. Word reading and letter-sound knowledge were related to both PA and alphabetic knowledge, thus indicating the importance of spoken phonology for early reading. Our findings support the hypothesis that the structure of reading skills in DHH children with functional hearing is qualitatively similar to that of hearing children (Easterbrooks et al. 2015; Paul et al., 2013). DHH children with functional hearing appear to learn and read through the acquisition of the alphabetic principle. Early intervention that facilitates development of PA, alphabetic knowledge and vocabulary may help to prevent reading delays in DHH children with functional hearing.

Supplementary Data

Supplementary material is available at http://jdsde.oxfordjournals.org/.

Conflicts of Interest

No conflicts of interest were reported.

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