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Schooling Effects on Early Literacy Skills of Young Deaf and Hard of Hearing Children

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Already well documented for hearing children, schooling's effects on early literacy skills for young students who are deaf or hard of hearing (DHH) were examined for the first time in the present study. Piecewise growth curve modeling was used to describe 3-, 4-, and 5-year-old students' growth in phonological awareness, letter-word identification, and vocabulary during 2 years of schooling and the intervening summer ($N = 56$). Amplification mode was cochlear implants for 45% of the sample and hearing aids for 54%. Classroom communication mode was spoken language only (for 61%) or sign language (39%). Across all skills, significant growth occurred during the 2 years of schooling but *not* during the summer. These findings underscore early education's importance in promoting DHH children's critical early skills. Universal preschool intervention, including during summer, may be important in ensuring that DHH children have an adequate foundation when schooling begins.

Keywords: early literacy, early intervention, language development, schooling effects, deaf, hard of hearing

Language and literacy skills developed during the preschool years are foundational for later school success. Many deaf and hard of hearing (DHH) children enter formal schooling, typically about 5 years of age, with inadequate language and literacy skills (Cupples, Ching, Crowe, Day, & Seeto, 2014; Kyle & Harris, 2011; Webb, Lederberg, Branum-Martin, & Connor, 2015). For hearing children, there is evidence that preschool intervention can lead to improvement in these early skills (Love et al., 2005; Skibbe, Grimm, Bowles, & Morrison, 2012). Less evidence exists for DHH children. A few studies show that researcher-designed interventions during preschool can improve targeted language and literacy skills of DHH children (see, e.g., Lund & Douglas, 2016; Richels, Schwartz, Bobzien, & Raver, 2016; Wang, Spychala, Harris, & Oetting, 2013). While this research indicates that these skills are responsive to intervention, it does not show whether early schooling specifically has an effect on their development. The goal of the present article is to present evidence that schooling during the preschool years, specifically when children are ages 3–5 years, leads to increased growth in DHH children's language and literacy skills relative to when such children are not in school.

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One way to demonstrate the effects of schooling is to compare rates of growth during the school year to rates during the summer, when children are not in school. In the present study, we examined the growth of three foundational skills—identification of letters and words, phonological awareness (PA), and vocabulary—over a 2-year period among DHH children who were enrolled in preschool through kindergarten classes taught by teachers of the deaf. We also examined whether children's chronological age in the fall of the first year of the study (i.e., whether they were 3 or 4 years old) and use of audiological technology (i.e., cochlear implants or hearing aids) influenced schooling effects.

Language and Literacy Skills

In the present study, we were specifically interested in schooling effects on letter-word identification, PA, and vocabulary because these skills are related to later reading skills for both DHH children (Easterbrooks, Lederberg, Miller, Bergeron, & Connor, 2008; Kyle & Harris, 2011) and hearing children (Storch & Whitehurst, 2002). For hearing children, Storch and Whitehurst (2002) used structural equation modeling to demonstrate that alphabetic knowledge, PA, and vocabulary in prekindergarten and kindergarten predicted later reading ability. Similarly, the findings of two longitudinal studies of young DHH children (ages 3–5 years in one study and 5–6 in another) suggest that PA, vocabulary, and alphabetic knowledge during preschool or kindergarten predict later reading abilities (Easterbrooks et al., 2008; Kyle & Harris, 2011), though the need for more research specifically regarding early literacy among DHH children has been noted (Williams, 2004). We explore the literature among DHH children for each of these skills below.

Identification of Letters and Words

Preschoolers and kindergarteners typically learn to recognize letters and to read simple words as part of their schooling experiences. Some research suggests that DHH preschoolers develop age-appropriate letter identification but start to show delays in word identification skills in kindergarten and first grade (Ambrose, Fey, & Eisenberg, 2012; Easterbrooks et al., 2008; Kyle & Harris, 2011). Others find somewhat delayed ability to recognize letters as early as preschool in this population (Werfel, 2017). In the present study, we acquired evidence on whether development of the ability to identify letters and basic words is a result of schooling experiences by testing whether children showed more gains in letter-word knowledge during the school year than during the summer months.

Phonological Awareness

PA is the ability to identify and manipulate the sounds of spoken language and is another important skill children frequently develop during the preschool years. For hearing children, preschool PA is predictive of later reading abilities (Lonigan, Burgess, & Anthony, 2000). Lederberg, Schick, and Spencer (2013) have proposed that the importance of PA to reading for DHH children depends on DHH children's access to spoken language. Research has shown that reading and PA are strongly related for DHH children who have sufficient functional hearing to acquire spoken language (with or without sign; Ambrose et al., 2012; Colin, Magnan, Ecalle, & Leybaert, 2007; Cupples et al., 2014; Easterbrooks et al., 2008; Webb & Lederberg, 2014). These same studies found that DHH preschoolers were delayed in PA, thus suggesting the importance of early intervention to acquisition of this skill. Intervention studies suggest that explicit instruction can lead to gains in PA for DHH children acquiring spoken language and thus would support the hypothesis that PA will be affected by a child's presence at school (Gilliver, Cupples, Ching, Leigh, & Gunnourie, 2016; Guardino, Syverud, Joyner, Nicols, & King, 2011; Lederberg, Miller, Easterbrooks, & Connor, 2014; Wang et al., 2013). In addition, Webb and colleagues (Webb & Lederberg, 2014; Webb, Patton-Terry, Bingham, Puranik, & Lederberg, 2018) found that PA assessments developed for hearing preschoolers were valid when used with young DHH children who were acquiring spoken language (with or without sign). These studies suggest that it is important to establish schooling effects on PA for the subsample of DHH children who have auditory access to spoken language.

On the other hand, because these PA assessments require the use of spoken language, they cannot be validly used with DHH children who do not have sufficient speech perception to hear the spoken stimuli. In addition, the role of spoken PA is more controversial for DHH readers without auditory access to spoken language. Some suggest that spoken PA is less important for this population (Hirshorn, Dye, Hauser, Supalla, & Bavelier, 2015; Lederberg et al., 2013), and thus may not be as important to examine. Others claim that all DHH children must develop English PA to become good readers (Mayer & Trezek, 2014; Paul & Lee, 2010). Researchers who take the latter position would argue that it is just as important to measure schooling effects on PA for these children as for DHH children who are acquiring spoken language. However, in the present study we did not do so because we could not use standard PA assessments with DHH preschool children who were not developing spoken-language skills.

Vocabulary

Vocabulary knowledge during preschool is an important predictor of later language and literacy abilities for both hearing and DHH children (Cooper, Nye, Charlton, Lindsay, & Greathouse, 1996; Quinn, Wagner, Petscher, & Lopez, 2015; Richels et al., 2016). On average, DHH preschoolers have delayed acquisition of English vocabulary and show wide individual differences in vocabulary acquisition (Harris, Terlektsi, & Kyle, 2017; Johnson & Goswami, 2010; Lederberg & Beal-Alvarez, 2010). One reason for these differences is that DHH children differ in the ease with which they acquire vocabulary, especially incidentally (Davidson, Geers, & Nicholas, 2014; Lederberg & Beal-Alvarez, 2010). Research suggests that DHH children benefit from explicit instruction in vocabulary whether they are acquiring sign or spoken language (Lederberg et al., 2014; Richels et al., 2016; Trussell & Easterbrooks, 2015). Such explicit vocabulary instruction is less likely to occur at home (Farran, Lederberg, & Jackson, 2009). Indeed, on the basis of longitudinal analyses, several researchers have concluded that young DHH students seem to experience accelerated vocabulary learning during their first year in preschool (Hayes, Geers, Treiman, & Moog, 2009; Nittrouer, 2010). While their findings are suggestive of a schooling effect, these researchers did not compare growth during the school year to growth outside school and thus could not definitively assert the presence of a schooling effect.

In summary, research suggests that these skills—letter-word identification, PA, and vocabulary—are important to develop during the preschool years, and serve as a foundation for later language and literacy success. Furthermore, there is some evidence that intervention can improve the development of these skills among DHH children. There has been no systematic research on the effects of schooling among DHH children in their earliest years of formal instruction. In an effort to address the absence of such research, the present study examined whether schooling facilitates children's learning of letter-word identification skills, PA, and vocabulary during the early school years.

Schooling Effects Among Hearing Children

Examining the effects of schooling on the development of hearing children's skills can address both developmental and pedagogical inquiries. In recent years, a growing body of research has employed methodologies that consider the extent to which observed changes in skill are attributable to such schooling effects, as opposed to age-related growth (e.g., McCoach, O'Connell, Reis, & Levitt, 2006; Skibbe et al., 2012). One such method compares growth rates when children are in school versus out of school. Steeper rates of growth during the school year relative to the summer would denote *schooling* effects rather than developmental or age effects on students' learning, suggesting a significant impact of schooling and instruction on the growth of the measured skill.

A number of studies have examined the effects of schooling on hearing students' literacy growth (Alexander, Entwisle, & Olson, 2001; McCoach et al., 2006; Skibbe et al., 2012). In the only study to address schooling effects that included preschoolers, Skibbe et al. (2012) explored whether schooling effects existed for 383 children over a 5-year period, beginning in the first year of preschool (approximately age 3) and ending in second grade (approximately age 8). They found that typically developing hearing children demonstrated stronger growth in both letter-word identification and PA during the academic year than during the summer. The schooling effect varied by age and skill; PA showed a significant schooling effect for 3-, 4-, and 5-year-olds, while letter-word identification only showed a schooling effect for 5- and 6-year-olds. Skibbe et al. found that there was only a weak schooling effect for vocabulary, and that it was only present for children of elementary school age. Rates of growth in vocabulary during the school year were similar to rates during the summer for 3- and 4-year-olds. Even for kindergarteners and first graders, schooling had a much weaker effect on vocabulary than on letter-word identification and spoken PA. Skibbe et al. concluded that growth in letter-word identification and PA may depend on explicit instruction for young hearing children, and that such instruction is more typical in school than at home. The researchers also found that home and school appear equally supportive of vocabulary learning among hearing preschool children.

Research on schooling effects among hearing elementary school children has produced similar conclusions. McCoach et al. (2006) found strong schooling effects for literacy skills among hearing kindergarteners and first graders. In a meta-analysis of studies of older elementary school–age hearing students, Cooper et al. (1996) found schooling effects for reading but not for vocabulary. Generally, research supports the argument that among hearing children, schooling effects exist for letter-word identification skills and PA in the preschool and elementary school years. In contrast, children's vocabulary learning has been found to be more linear, with equivalent rates of growth during the summer and the academic year.

Understanding whether and for which skills schooling effects exist for DHH children enrolled in preschool and kindergarten has important implications for both practice and policy. While home-based early intervention and formal school-age education seem to be universal for DHH children, preschool education generally appears to be less widespread. Though there are no data on rates of preschool attendance for DHH children in particular, the Organization for Economic Cooperation and Development reports that in a number of countries, children do not begin formal education until age 5 years. Also, the OECD recently found that in high school, hearing children who had been enrolled in 2 years of early education outperformed their peers who had not received early education (OECD, 2017). The presence of schooling effects would indicate the need for policy and instructional adjustments for those working with young DHH children regarding early learning opportunities. The presence of schooling effects among young children would (a) provide evidence that early education is an important intervention for DHH children, and (b) suggest that year-round schooling (i.e., providing school during the summer) may be an effective option for improving outcomes for DHH children.

Research Design and Questions

In the present article, we describe and compare growth in 3-, 4-, and 5-year-old DHH children's letter-word identification skills, PA, and vocabulary across 2 years of schooling and the intervening summer. Our study drew upon an archival database of a larger study that had examined the language and literacy development of DHH children during the early school years (N = 167; Webb et al., 2015). In the larger study, Webb et al. (2015) reported that the DHH children were delayed in PA and vocabulary in the fall of the school year and that these skills were related to the children's letter and word identification skills. About a third of the children in the study by Webb et al. (n = 56) had an additional year of data (i.e., a total of 2 years of data), which enabled us to study schooling effects for this subsample. Data collection occurred in a U.S. city where preschool education was the norm for DHH children and was available free of charge to parents of DHH children who were 3 years old when school started (August). In these schools, children attended self-contained DHH classes and were taught by a certified teacher of the deaf.

The sample varied along many dimensions, including chronological age, age of identification, parental education, audiological technology, and communication mode. Any of these characteristics may have influenced schooling effects. Given the small sample size, we were limited to studying just two characteristics. We selected *age* and *audiological technology* not only because of the small sample but because of these two characteristics' potential relevance to practice and policy. In the fall of the first year of the present study, half of the children were 3 years old; the other half were 4 years old. In addition, about half of the children had cochlear implants (CIs) and half used hearing aids.

Specifically, we addressed two research questions:

1. Do the rates of growth of letter-word identification skills, PA, and vocabulary during 2 years of schooling differ from the rate of growth during the intervening summer for a sample of DHH preschoolers?
2. To what extent do chronological age and use of audiological technology influence growth rate over the 2 years?

Method

Participants

The present study drew upon an archival database of a larger study that examined the language and literacy development of DHH children during the early school years (*N* = 167; Webb et al., 2015). Per institutional review board requirements, approval was obtained from all appropriate agencies and participants. The participants in the present study (*N* = 56) were *all* children from that larger study who had 2 full years of assessment data (i.e., both fall and spring of 2 consecutive years). In the fall of the first year of the present study, the mean age of the 56 children was 49.71 months. For the purposes of the study, we divided them into two age groups: either 3 years old (*n* = 28; mean age = 44.7 months) or 4 years old (*n* = 28; mean age = 54.5 months) in the fall of the first year. Therefore, by the fall of the second year these students were either 4 or 5 years old. In general, children who were 3 were in their first year of schooling, those who were 4 were in their second year of schooling, and those who were 5 were in the third year of schooling (typically kindergarten). All participants had a hearing loss of 41 dB or greater and were educated in self-contained classrooms for students who were DHH with trained teachers of the deaf. Table 1 shows demographic data for both the 56 children who were in the total sample who were assessed for letter-word identification and vocabulary and the subsample of children with functional hearing (*n* = 38) who were assessed for PA.

Twenty-three percent of the children (*n* = 13) had bilateral CIs, 21% (*n* = 12) had unilateral implants, 54% (*n* = 30) used hearing aids without CIs, and 2% (*n* = 1) were not amplified because of a lack of cochlear nerves. According to teacher report, 100% of the children who had implants almost always used them at school, and 96% almost always used them at home. The teachers also reported that 100% of the children with hearing aid(s) almost always used them at school, while 76% almost always used them at home. Degree of hearing loss (unaided) was only available for children without CIs. For the 25 children with CIs, age of implant was on average about 26 months, but the range was between 13 and 46 months. Average age of identification was 12 months, and ranged from birth to 38 months.

Home Context

The parents of the children in the sample were diverse, both educationally and ethnically (see Table 1). According to teacher reports, the language(s) used at home also varied widely. Of the 34 children who were learning only spoken English in school, 26 had parents who only spoke English at home, 4 had parents who were bilingual (English plus another language), and 4 had parents who only spoke a language other than English (e.g., Spanish). Of the 22 children who were in signing classes, 12 had parents who used American Sign Language (ASL). Ten of these 12 children were also exposed to spoken English in the home. Only 4 children enrolled in signing programs were exposed to only spoken language at home. Four children had one or two DHH parents; 3 of whom reported using ASL at home while the other used spoken English.

School Context

Students were enrolled in classes in 10 schools and had 1 of 17 teachers. These schools included a state school for deaf children that primarily used ASL (*n* = 10 children; 1 school), self-contained classes that used only spoken language (*n* = 30 children; 4 schools), and self-contained classes that used both sign and spoken lan-

Table 1. Demographic Characteristcis of Study Participants in Full Sample and for Subsample That Was Tested for Phonological Awareness

Category	Variable	Full (*N* = 56)	PA (*n* = 38)
Amplification	Used hearing aid only	30 (54%)	19 (50%)
	Bilateral CI	13 (23%)	11 (29%)
	Unilateral CI	12 (21%)	8 (21%)
	No amplification used	1 (2%)	0 (0%)
Better-ear pure tone average, unaided (dB)[a]	*M* (*SD*) Range	73.11 (22.19) 41–120	62.50 (13.20) 41–92
Hearing loss (dB)[a]	Moderate (41–70) Severe (71–90) Profound (91+) Not reported Used CI	15 (27%) 6 (11%) 6 (11%) 4 (7%) 25 (45%)	13 (34%) 3 (8%) 0 (0%) 3(8%) 19 (50%)
Age at implantation, months (*n* = 25)	*M* Range	25.58 13–46	27.00 13–46
Communication mode used in class	Speech only	34 (61%)	30 (79%)
	Sign with or without spoken language	22 (39%)	8 (21%)
Parent hearing status	Deaf (one or both)	4 (7%)	1 (3%)
	Hearing	52 (93%)	37 (97%)
Race/ethnicity	White	22 (39%)	19 (50%)
	Black	19 (33%)	11 (29%)
	Hispanic	9 (16%)	4 (11%)
	Mixed race	3 (5%)	2 (5%)
	Asian/Pacific Islander	2 (4%)	1 (3%)
	Other	1 (2%)	1 (3%)
Mother's education level	Less than high school	4 (7%)	1 (3%)
	High school graduate	13 (23%)	9 (24%)
	Some college or technical school	10 (18%)	5 (13%)
	College graduate	20 (36%)	16 (42%)
	Postcollege education	5 (9%)	5 (13%)
	No response	4 (7%)	2 (5%)

Notes. Because of rounding, not all sets of percentages equal 100. CI = cochlear implant.
[a]Better-ear pure tone average (average hearing threshold level at set frequencies) and hearing loss level were calculated only for children without CIs. Audiograms were unavailable for four children.

guage, largely simultaneously (n = 16 children; 5 schools). Teachers in the self-contained classes varied in their sign language use from more ASL-like to more English-like. Teachers did not use a standardized curriculum. The year before data collection began for the present project, Easterbrooks, Lederberg, and Connor (2010) conducted observations of the language and literacy instruction in the 10 schools that enrolled the students who made up the sample. Easterbrooks et al. found that teachers varied widely in their language and literacy instruction and classroom practices.

Measures

Early Speech Perception Test

The Early Speech Perception Test (ESP) is an assessment in which children are asked to identify differences between single words and/or multisyllabic words with varied stress patterns through the use of hearing (Moog & Geers, 1990). This assessment identifies children as belonging in one of four speech perception groups, which range from having no perception of speech patterns (score of 1) to being able to identify spoken monosyllabic words through audition alone (score of 3 or 4). Children with a score of 1 are judged not to have auditory access to spoken language (i.e., to lack functional hearing).

Phonological Awareness Test

The Phonological Awareness Test (2nd ed.), or PAT-2 (Robertson & Salter, 2007), is a standardized assessment of PA for children ages 5–9 years. Because the majority of children in the present study were less than 5 years old at the time of initial testing, we used the off-level modifications developed by Webb, Schwanenflugel, and Kim (2004). These modifications were (a) adding two practice items, drawing upon feedback generated by Webb et al. (2004); (b) not administering a subtest if all three practice items were incorrect; (c) discontinuing a subtest if the child missed three items in a row; and (d) readministering the first practice item if a child seemed to forget the purpose of a subtest. Psychometric analyses indicate that the PAT-2 with modifications is valid for young hearing children (Webb et al., 2004). In a study of 167 DHH preschoolers, Webb and Lederberg (2014) concluded that the PAT-2 with modifications had excellent psychometric properties for assessing PA of young DHH children. This conclusion was based on classical item analyses that included item difficulty, item discrimination, and internal consistency (Cronbach's a = .93). Webb and Lederberg also found that scores on the PAT-2 with modifications correlated highly with scores on the Test of Preschool Early Literacy—Phonological Awareness (TOPEL-PA; Lonigan, Wagner, Torgesen, & Rashotte, 2007).

We administered the four PAT-2 subtests (Rhyming Discrimination, Syllable Segmentation, Initial Phoneme Isolation, and Phoneme Blending) that have been validated in the studies by Webb and colleagues and that measure PA skills that are developing when children are 3 to 5 years of age. The Rhyming Discrimination subtest assesses children's ability to identify whether two presented words rhyme (e.g., "Do these words rhyme? *Book; Look*"). The Syllable Segmentation subtest assesses the ability to divide given words into syllables (e.g., "Touch the dot one time for each syllable in the word *can-dy*"). The Initial Phoneme Isolation subtest measures the ability to identify the first phoneme in a given word (e.g., "What is the beginning sound in the word *bite*?"). Finally, the Syllable Segmentation subtest assesses the ability to blend phonemes together to form a word when the phenomes are presented individually (e.g., "What word is this? / p–o–p [pop]?"). Each subtest consists of 10 items, with each item scored as correct (1) or incorrect (0); for the test as a whole, the maximum score is 40. We used raw scores for analyses because there were no standard or *W* scores available for the children who were younger than the norming sample. The items on the PAT-2 were administered in spoken English. Therefore, the 18 children who scored a 1 (no pattern perception) on the ESP in the fall of the first year of the study were not given the PAT-2 because they would not be able to hear the items. Table 1 shows the demographic characteristics of the children who were tested for PA. This sample included 19 children who were hard of hearing and wore hearing aids and 19 who had at least one CI.

We excluded DHH children without functional hearing from the PA assessment. In Table 1, the children included in the full sample but not in the PA subsample were those who were not able to discriminate spoken words through audition alone (as measured on the ESP in the fall of Year 1). DHH children without access to speech sounds cannot respond validly to standard PA tasks, such as those in the PAT-2, that require children to hear the auditory stimulus and respond with speech. Researchers have been able to measure spoken PA of DHH elementary school children using nonverbal picture-based tasks—for example, asking which two words sound the same (e.g., Kyle & Harris, 2011). Researchers in the field (e.g., Easterbrooks et al., 2008; Webb et al., 2015) have also attempted to do so with DHH preschoolers using picture-based subtests of the TOPEL-PA (Lonigan, Wagner, Torgesen, & Rashotte, 2007) and the Rhyming and Alliteration tests of the Individual Growth and Development Indicators (McConnell, 2003). However, in these studies, none of the DHH preschoolers without functional hearing could respond successfully to any of the practice items on these tasks. Therefore, in the present study we could only examine the effect of schooling on PA for DHH children who had functional hearing and were acquiring spoken language (with or without sign).

Letter-Word Identification Subtest

The Letter-Word Identification subtest of the Woodcock-Johnson III Tests of Achievement (WJ-III) assesses student knowledge of letters and print words (Woodcock, Mather, & McGrew, 2001). For the Letter-Word Identification subtest, students name individual letters and isolated words of increasing difficulty. For children who used spoken language, standard WJ-III administration procedures were followed in the present study. For children who signed, acceptable responses were generated by a panel of expert deaf and hearing adults. These included fingerspelled letters (for letter names) or signed words (for printed words). In a study that used these procedures with a large sample of DHH children (*N* = 566), Webb, Branum-Martin, and Lederberg (2016) concluded that the WJ-III Letter-Word Identification subtest has good psychometric properties for both DHH children who respond in speech and those who respond with sign. Their conclusion was based on evidence from item response theory (item difficulty and item discrimination), confirmatory factor analyses, and internal consistency (Chronbach's a = .94). The WJ-III achievement scoring program converts children's raw scores to standard scores and *W* scores based on hearing norms. We report standard scores to describe how the DHH children compared to hearing norms. We use *W* scores in our growth analyses because *W* scores place children on an equal interval metric, similar to a Rasch score. Researchers prefer *W* scores (when available) when examining growth over time because change is measured by means of a common unit (Kaufman & Lichtenberger, 2006). Unlike standard or raw scores, this common unit means that the amount of gains children of different ages make in *W* scores can be compared within the same test (but not across tests).

Expressive Picture Vocabulary Subtest

Children's expressive vocabulary was assessed with the Expressive Picture Vocabulary subtest of the Woodcock-Johnson III Tests of Achievement (WJ-III Vocabulary; Woodcock et al., 2001, referred to hereafter as Vocabulary). This assessment asks students to provide a spoken or signed word when presented with a picture. Examiners used a list of acceptable signs generated by deaf and hearing expert signers to score whether a signed response was correct. Each English word had specific signs that would be accepted as correct according to the expert panel, and some words had multiple acceptable signs. For instance, for the English word *bed*, the standard sign for BED was acceptable, but related signs such as SLEEP were not. For the English word *car*, acceptable signs included an S-handshape iconically related to a steering wheel, two C-handshapes where the heel of the C-shape of the nondominant hand taps the thumb and index finger of the C-shape on the dominant hand, and a fingerspelled response. Webb at al. (2015) found that the WJ-III Vocabulary had an internal consistency reliability of Chronbach's a = .83 with a sample of young DHH children and was highly correlated with scores on the Peabody Picture Vocabulary Test. Raw scores, standard scores based on hearing norms, and *W* scores were available. We report standard scores to describe our sample and used *W* scores in our growth analyses.

Procedure

All examiners were certified teachers of deaf students and were fluent in the language used by the school in which testing occurred. Students were tested individually in a quiet room. In schools that used both spoken language and sign language, the test administrator gave instructions in speech and sign simultaneously; in the ASL-using school, the test administrator gave instructions in ASL; in classrooms where only spoken English was used, the test administrator gave instructions in spoken English. Standard administration of instructions was developed in ASL and simultaneous sign and English, and examiners were trained in this administration. Although the instructions were delivered in this manner, children in any environment could respond in ASL, English-based sign, spoken language, or any combination. All assessments included here were expressive; therefore, the students determined the language of the response.

Examiners assessed the children on the PAT-2, WJ-III Letter-Word Identification, and WJ-III Vocabulary tests in the fall and spring of the school year for 2 consecutive years (four testing sessions total). They administered the ESP in the fall of the first year the children were in the present study. The WJ-III Letter-Word Identification and WJ-III Vocabulary, and the directions for the PAT-2 and ESP, were administered in the language of instruction typical in the child's educational placement—which meant that some children were tested in spoken English only, some in both spoken and signed English, and some in ASL only. While test administration instructions were administered in the language of the school, the WJ-III Letter-Word Identification, and WJ-III Vocabulary tests assessed children's expressive skills; thus, children could respond to the print or pictures stimuli using spoken and/or signed words regardless of the language of their educational placement. Items for the PAT-2 and ESP were administered only in spoken English. Teachers completed a demographic questionnaire on the students that included audiological, family, and school information.

Results

Descriptive Statistics

In the fall of the first year of the present study, children's standard scores were in the average range for letter-word identification skills and the low-average range for expressive vocabulary. Standard scores were higher in the spring than in the fall for both academic years. The 38 children participating in the PA assessments earned scores that were generally below average compared to hearing norms. Descriptive statistics are provided in Table 2.

The three early literacy skills were moderately to strongly correlated with each other across time points: PA with letter-word identification, $r(37) = .692$, $p < .001$; PA with vocabulary, $r(37) = .546$, $p < .001$; letter-word identification and vocabulary, $r(57) = .528$, $p < .001$. CI use had a weak but significant positive correlation with PA ($r = .17$) and letter-word identification skills ($r = .22$), but not vocabulary.

Growth in Literacy Skills

To examine growth in PA, letter-word identification skills, and vocabulary, we created models using hierarchical linear modeling (Raudenbush, Bryk, Cheong, & Congdon, 2004) that incorporated gains in scores from the fall of Year 1 to the spring of Year 2, assuming that rates of gains (per month) would vary during Year 1, over the summer between Years 1 and 2, and during Year 2. Following procedures used by McCoach et al. (2006), we created piecewise growth curve models using exposure variables, with children nested in repeated measures over time. We created three time-varying level 1 variables to control for the cumulative amount of instruction prior to each testing date: Exp1, the months (to closest half-month) of Year 1 instruction experienced prior to assessment administration; Exp2, the months of Year 2 instruction experienced prior to assessment administration; and SumExp, a dichotomous variable, which was coded "1" if summer had occurred prior to that specific assessment and "0" if it had not. For example, a child who was given the Year 2 pretest in August, when school begins in the state where testing occurred, would have a "1" for Year 1, having completed all of the first year of schooling; a "1" for summer, since summer had occurred; and a "0" for

Table 2 Assessment Scores for Child Participants (N = 56)

	Fall, Year 1	Spring, Year 1	Fall, Year 2	Spring, Year 2
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Phonological awareness raw score[a]	3.93 (5.70)	10.60 (9.38)	11.27 (10.6)	19.64 (10.19)
Letter-word identification standard score	96.66 (17.49)	103.97 (14.44)	102.63 (16.23)	105.92 (16.97)
Letter-word identification *W* score	317.21 (37.43)	345.11 (29.5)	352.39 (31.71)	380.42 (37.18)
Expressive vocabulary standard score	89.53 (20.37)	94.14 (12.79)	91.95 (15.70)	93.98 (13.36)
Expressive vocabulary *W* score	441.25 (26.4)	456.13 (14.9)	458.34 (16.9)	465.90 (12.8)

[a]*n* = 38. Score is out of 40 items. There is no standard score available for the Phonological Awareness Test (2nd ed.).

Year 2, having been tested at the very beginning of the school year and not exposed to any Year 2 instruction. This yielded four estimates: π_{0i}, which is child *i*'s score in the fall of Year 1; π_{1i}*(*EXPYEAR* 1_{ti}), which is the rate of growth (i.e., slope) for Year 1; π_{2i}*(*EXPSUM*$_{ti}$), which is the rate of growth during the summer; and π_{3i}*(*EXP2*$_{ti}$), which is the rate of growth for Year 2. Thus, the model for PA (PAT-2) would be

$$PAT_{ti} = \pi_{0i} + \pi_{1i}{*}(EXPYEAR\ 1_{ti}) +$$
$$\pi_{2i}{*}(EXPSUM_{ti}) + \pi_{3i}{*}(EXP2_{ti}) + e_{ti}$$

where PAT_{ti} is the predicted PA achievement score for child *i* at time *t* and e_{ti} is the time-specific error (or residual) of child *i* at time *t*. The level 2 equation was

$$\pi_{0i} = \beta_{00} + r_{0i}$$
$$\pi_{1i} = \beta_{10} + r_{1i}$$
$$\pi_{2i} = \beta_{20} + r_{2i}$$
$$\pi_{3i} = \beta_{30} + r_{3i}$$

where β_{00} is the fitted mean score for the fall of Year 1, β_{10} is the is the fitted mean rate of growth (in months) for Year 1, β_{20} is the fitted mean rate of growth during the summer, and β_{30} is the fitted mean rate of growth for Year 2. The *r* values represent the child level 2 random effects. The same models were created for letter-word identification skills and vocabulary.

The results produced by these models are provided in Tables 3, 4, and 5. They reveal that there was significant growth across all skills during Year 1 and Year 2, but not during the summer. Consider, for example, the results for PA (Table 3) for the fixed effects: The intercept represents the fitted mean of the sample when all other variables are held constant at 0. Year 1 slope is the mean rate of gain in PA score per month across the sample, which was significantly greater than 0 ($p < .001$). That is, children gained, on average, 1.18 points per month during the school year. Summer slope is interpreted the same way except

Table 3 Results of Piecewise Growth Models for Phonological Awareness, Including Fixed and Random Effects

Phonological awareness fixed effects

Fixed effect	Coefficient	*SE*	Approximate *df*
Intercept, β_{00}	2.07	1.01*	33
Year 1 slope, β_{10}	1.18	0.21***	33
Summer slope, β_{20}	-1.33	1.21	33
Year 2 slope, β_{30}	1.16	0.16***	33

Phonological awareness random effects

Random effect	*SD*	Variance component	*df*	χ^2	*p*
Intercept, r_0	1.93	3.75	33	41.86	.139
Year 1 slope, r_1	0.79	0.63	33	65.11	<.001
Summer slope, r_2	2.70	7.27	33	36.61	.304
Year 2 slope, r_3	0.62	0.39	33	52.066	.019
level 1, *e*	4.33	18.08			

Note. Deviance = 954.56.
* $p < .05$. *** $p < .001$.

Table 4 Results of Piecewise Growth Models for Letter-Word Identification Skills, Including Fixed and Random Effects

Early letter-word identification skills fixed effects

Fixed effect	Coefficient	*SE*	Approximate *df*
Intercept, β_{00}	309.275	5.696***	51
Year 1 slope, β_{10}	4.251	0.501***	51
Summer slope, β_{20}	-0.583	2.403	51
Year 2 slope, β_{30}	3.754	0.359***	51

Letter-word identification skills random effects

Random effect	*SD*	Variance component	*df*	χ^2	*p*
Intercept, r_0	39.65	1572.21	51	383.13	< .001
Year 1 slope, r_1	2.79	7.82	51	122.13	< .001
Summer slope, r_2	3.17	10.07	51	51.99	.435
Year 2 slope, r_3	1.55	2.41	51	75.57	.014
level 1, *e*	11.54	133.25106			

Note. Deviance = 1927.550469.
***$p < .001$

Table 5 Results of Piecewise Growth Models for Vocabulary, Including Fixed and Random Effects

Vocabulary fixed effects

Fixed effect	Coefficient	*SE*	Approximate *df*
Intercept, β_{00}	436.614	4.087***	51
Year 1 slope, β_{10}	2.289	0.360***	51
Summer slope, β_{20}	-0.503	1.772	51
Year 2 slope, β_{30}	0.964	0.184***	51

Vocabulary random effects

Random effect	*SD*	Variance component	*df*	χ^2	p
Intercept, r_0	29.67	880.45	51	1069.15	< .001
Year 1 slope, r_1	2.41	5.82	51	302.07	< .001
Summer slope, r_2	10.00	100.06	51	96.27	< .001
Year 2 slope, r_3	0.93	0.87	51	95.45	< .001
level 1, *e*	5.33	28.42			

Note. Deviance = 1675.803110.
***$p < .001$.

that the rate of gain was essentially 0 (p = .304). For the Year 2 slope, children again demonstrated significant gains in PA score per month: on average, 1.16 points/month. The random effects reveal that there was significant between-child variability for Year 1 and Year 2 slope, but not for the intercept or for summer slope.

Results in Tables 4 and 5 are interpreted in the same way. Results for letter-word identification skills in Table 4 indicate that children gained, on average, 4.25 points per month in Year 1 and 3.75 points per month in Year 2, but lost 0.58 points per month during the summer (see coefficient for slopes). Results for expressive vocabulary in Table 5 indicate that children gained, on average, 2.29 points per month during Year 1 and 0.96 points per month in Year 2, but lost 0.50 points per month during the summer.

We then added child characteristics to the models at level 2, including whether the children used at least one CI (= 1; hearing aids or nothing = 0) and whether they were age 3 years (= 0) or 4 years (= 1) at the time of initial testing. The models for those skills that showed significant child-level characteristics are provided in Tables 6 and 7, respectively. Figure 1 presents the fitted growth curves and significant effects of either CI or age where they existed.

There was a significant effect of having a CI for gains in children's PA skills. As Table 6 shows, for Year 1, having a CI was associated with a 0.85 point/month gain advantage (so a 1.327 gain/month, Year 1 slope by CI interaction effect, β_{11}); by comparison, children with no CI generally made gains of 0.471/month (β_{10}). Children with a CI generally made faster gains in PA during their first year than children with hearing aids. Children in both groups experienced schooling effects for PA, with no significant growth over the summer, and then parallel growth in the second year. There was no significant difference based on having a CI in rates of growth for letter-word identification or vocabulary ($p > .05$).

Looking at Table 7, we see that age was significant for letter-word identification skills. Children who were 4 years old in the fall of Year 1 and 5 years old in the fall of Year 2 made greater gains per month, by a margin of 1.613 points (in Table 7, see coefficient for β_{31}), in Year 2 compared to children who were 3 years old in the fall of Year 1 and 4 years old in the fall of Year 2. For all children, there were significant gains in letter-word identification, on average, in Year 1 and Year 2, but not over the summer. Older children made faster gains in their kindergarten year. There was no significant effect of age on rates of growth of PA or vocabulary ($p > .05$).

Discussion

The present study was a longitudinal study of young DHH children. Unlike typical longitudinal studies, in which children are assessed once per year, this study assessed children twice per year, in both the fall and the spring. This made it uniquely suited to examining schooling effects for this population. The findings reported here have significant implications for the early educational experiences of DHH children.

Schooling Effects on Language and Literacy Skills

Letter-Word Identification

Our analysis found significant effects of schooling on letter-word identification for young DHH children. It was when they were in school—*not* over the summer—that children progressed at a significant rate in their ability to name letters and read simple words. It is worth noting that, overall, the children in the present study had age-appropriate letter-word identification

Table 6 Cochlear Implant Effect on Phonological Awareness

Fixed effect	Coefficient	*SE*	*t* ratio	Approximate *df*	*p*
For intercept, π_0					
Fitted mean, β_{00}	3.310448	0.888034	3.728	47	< .001
Cochlear implant, β_{01}	-2.668304	1.473608	-1.811	47	.077
For Year 1 slope, π_1					
Fitted mean, β_{10}	0.471270	0.179657	2.623	47	.012
Cochlear implant, β_{11}	0.856664	0.302625	2.831	47	.007
For summer slope, π_2					
Fitted mean, β_{20}	-0.629967	1.394569	-0.452	47	.654
Cochlear implant, β_{21}	-0.600172	2.013669	-0.298	47	.767
For Year 2 slope, π_3					
Fitted mean, β_{30}	1.108765	0.223832	4.954	47	< .001
Cochlear Implant, β_{31}	0.070846	0.299418	0.237	47	0.814

Final estimation of variance components

Random effect	*SD*	Variance component	*df*	χ^2	*p*
Intercept, r_0	2.20591	4.86604	35	46.59662	.091
Year 1 slope, r_1	0.77599	0.60217	35	77.59097	< .001
Summer slope, r	2.68052	7.18516	35	43.54194	.152
Year 2 slope, r_3	0.68266	0.46602	35	66.83031	.001
level 1, e	4.00076	16.00607			

Note. Deviance = 1144.219828.

skills, a finding that is consistent with those of earlier research (Cupples et al., 2014; Easterbrooks et al., 2008). Explicit instruction in letter names and print words found in the classroom environment likely accounts for the significant growth in these skills observed during the school years. For example, many preschool teachers explicitly teach letter names and recognition of simple sight words in the context of reading simple books (Easterbrooks et al., 2010).

For letter-word identification, whether the child was 3 or 4 years old in the fall of the first year of the present study was a significant predictor of longitudinal growth, but only in the second year. A schooling effect was found across the full sample. However, children who were in kindergarten (i.e., age 5 years) made more rapid gains than children who were in prekindergarten (i.e., age 4 years) in the second year of the study. An acceleration in the acquisition of letter and word identification skills in kindergarten was also found by Skibbe et al. (2012) for hearing children. It may be that once children are 4 years of age, they are more developmentally prepared to acquire these skills; hence the accelerated

Table 7 Effect of Chronological Age in Year 1 on Letter-Word Identification Skills

Fixed effect	Coefficient	*SE*	*t* ratio	Approximate *df*	*p*
For intercept, π_0					
Fitted mean, β_{00}	300.762	8.486	35.439	53	< .001
Age 4 years, β_{01}	17.209	11.139	1.545	53	.128
For Year 1 slope, π_1					
Coefficient β_{10}	4.670	0.812	5.748	53	< .001
Age 4 years, β_{11}	-0.836	1.003	-0.834	53	.408
For Summer slope, π_2					
Coefficient β_{20}	0.870	4.086	0.213	50	.832
Age 4 years, β_{21}	-2.762	4.800	-0.575	50	.568
For Year 2 slope, π_3					
Coefficient β_{30}	2.974	0.459	6.467	53	< .001
Age 4 years, β_{31}	1.613	0.692	2.328	53	.024

Final estimation of variance components

Random effect	*SD*	Variance component	*df*	χ^2	*p*
Intercept, r_0	38.368	1472.108	53	386.40508	< .001
Year 1 slope, r_1	2.664	7.098	53	140.72921	< .001
Year 2 slope, r_3	1.422	2.022	53	79.63502	.010
level 1, *e*	11.614	134.906			

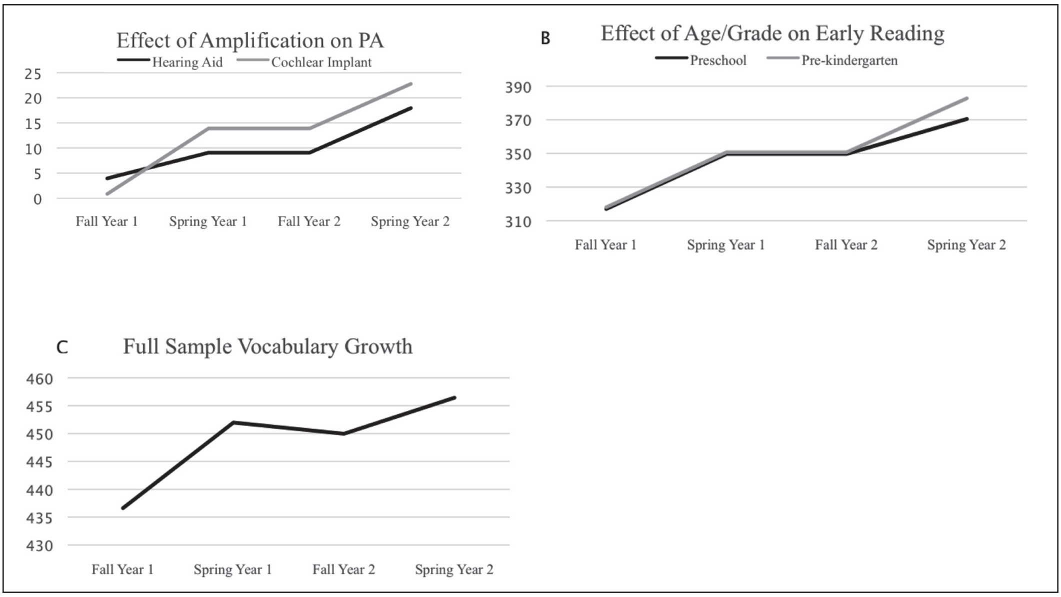
Notes. Deviance = 1908.590223. 3 (mean age = 44.00 months) = 0; 4 (mean age = 54.89 months) = 1.

growth observed during this year. On the other hand, it could be that teachers of older children are more likely to focus on identifying letters and words than teachers of preschool-age children. Although they demonstrated slightly different trajectories during the second year of study, both cohorts experienced schooling effects, a finding that underscores the importance of early schooling in promoting these letter-word identification skills. We found effects of schooling in preschool and prekindergarten where Skibbe et al. did not. Although this might be a difference between hearing and DHH children, it is also possible that letter-word identification skills are more commonly taught in schools now than when Skibbe et al. collected their data. Further research is necessary to fully understand the development of these skills among young DHH children.

Phonological Awareness

Our results also indicate that early schooling matters for the development of PA among young DHH children who are acquiring spoken language (with or without sign). We only examined growth in PA for a subsample of the DHH children who had auditory access to spoken language.

Figure 1. Fitted Growth Curves During the Academic Year and Summer Months for Phonological Awareness (A; for students with and without a cochlear implant), Early Reading Skills (B; for 3- and 4-year-olds), and Vocabulary (C)



Note. Phonological awareness (A) is raw scores (n = 38); early reading skills (B) and vocabulary (C) are *W* scores (N =56).

This group included hard of hearing children who wore hearing aids and children with more severe hearing losses who had CIs. During both school years, participating children made steady progress, but showed no significant growth over the summer. Explicit instruction has been shown to support the development of PA among DHH children (Gilliver et al., 2016; Lederberg et al., 2014; Miller, Lederberg, & Easterbrooks, 2013). There is evidence that parents of hearing children are unlikely to engage in explicit PA instruction without specific guidance on how to do so (Justice, Kaderavek, Bowles, & Grimm, 2005), and the same may be true for parents of DHH children. Explicit instruction with trained teachers appears to be necessary for the continued development of PA among DHH children who are developing spoken language.

Deaf children with CIs began the present study with lower PA scores and experienced significantly greater rates of growth during Year 1 compared to children who were hard of hearing and wore hearing aids. Because the average age of cochlear implantation was 25 months, it is possible that limited access to meaningful auditory information contributed to lower initial scores. As children gained experience with the CI during Year 1, they demonstrated greater rates of growth when compared to children with hearing aids—and maintained this rate through Year 2. However, neither group experienced significant PA growth during the summer, and mean rates of growth during Year 2 were essentially the same.

Vocabulary

Significant schooling effects were also observed for vocabulary, with children demonstrating significant rates of growth during the school year but not over the summer. Unlike hearing preschoolers, DHH children do not appear to gain vocabulary skills at the same rate during the summer months as they do during the academic year, perhaps because DHH children are less likely to develop vocabulary knowledge through incidental language exposure (Lund & Douglas, 2016). This finding is consistent with those of studies with DHH children showing acceleration in vocabulary growth when children are enrolled in preschool (Hayes et al., 2009; Nittrouer, 2010). In a similar finding to those of these studies, we found greater vocabulary gains in Year 1 than in Year 2, which suggests that vocabulary gains decelerate over time. There was no significant effect of amplification use or age on rates of vocabulary growth.

The children in the present study scored within the average range on the vocabulary measure. However, analysis conducted with the larger sample (Webb et al., 2015) suggests that the WJ-III Vocabulary subtest may overestimate vocabulary knowledge as compared with similar measures. In the larger sample, while the DHH children averaged a standard score of 89 on the WJ-III Vocabulary, they averaged only 79 on the Peabody Picture Vocabulary Test, fourth edition (L. M. Dunn & D. M. Dunn, 2007) and 80 on the Expressive One-Word Picture Vocabulary Test (Brownell, 2000). Although the standard scores on the assessment we used for this analysis may be inflated, Webb et al. (2015) found these three tests to be highly correlated. Therefore, we believe that the pattern of gains on this test is valid.

These results have important implications for the education of young DHH children. Given the less than ideal academic outcomes for many DHH students (Qi & Mitchell, 2012), and the fact that children in the present study made significant progress when they were engaged in schooling, locating year-round learning opportunities may be especially important for this population. However, just as research has identified a pervasive lack of summer learning opportunities for minority children and children from homes of low socioeconomic status, which may lead to poorer academic outcomes than for students with greater educational opportunities (Flores, 2007), it is likely that a summer learning opportunity gap exists for DHH students. Considering that deafness is a low-incidence disability, there are arguably fewer summer programs that are fully accessible to and designed for DHH children. It may be necessary for schools and other organizations that serve DHH students to consider how such opportunities may be added to the services they provide.

Methodological Implications

Most longitudinal research completed with DHH children measures skill areas once per year (e.g., Colin, Leybaert, Ecalle, & Magnan, 2013; Harris, et al., 2017; Kyle & Harris, 2011). Such an approach does not take into account potential schooling effects and the effects that proximity to an extended break may have on skill development. Studies using these methods may be insensitive to the effects of schooling on learning and development. This may cause underestimation of children's growth over the course of an academic year if during the summer they lose some of the gains they made during the academic year. The present findings suggest that the results of testing of student development may differ depending on the point in the school year when annual testing occurs. For DHH children, it is possible that annual testing would suggest little progress over the year when, in fact, progress made during the school year is lost or dampened as a result of an extended break.

Limitations

The findings of the present study indicate that learning occurs at a greater rate when students are in school. However, our study design does not indicate what *type* of schooling is necessary for learning to occur. All children who participated in the study attended preschool programs that were taught by trained teachers of the deaf in a region of the United States where such educational opportunities are universal. Previous observations of preschool classes for DHH children in this region suggest that literacy activities are common in these schools (Easterbrooks et al., 2010). We do not know if schooling will have similar effects for children attending alternative types of programs (e.g., mainstream preschool programs without a trained teacher of deaf students or a play-focused curriculum) or if schooling effects vary by characteristics of school and home. Research with hearing children suggests that the quality of the classroom affects children's learning (Marcon, 2002); this further suggests that schooling effects may not be generalizable to all preschools. Additionally, because we did not compare the development of children who were enrolled in school with that of children who were not enrolled, we cannot definitely conclude that preschool is necessary for children's learning to occur. However, by comparing the same students' rates of growth when they were both in school and out of school, we can say that at least for our participants, faster growth occurred while the children were in school than when they were not.

We did not assess the PA of children who could not perceive spoken words because the test required children to be able to perceive and manipulate spoken words. We are unable to say, as a result, whether there were schooling effects for PA for these children. Future researchers may test this through use of a nonverbal PA test with these children. However, we have found DHH preschoolers with limited speech perception unable to select pictures of words that start with the same sound or that rhyme (Easterbrooks et al., 2008). These tasks resemble those used with DHH elementary school children (Kyle & Harris, 2011). It may be that such assessment requires a level of metalinguistic skill not present in preschool children.

In addition, our sample was too small to enable us to examine more than two child characteristics for schooling effects. Our sample was diverse across a number of dimensions, however, including parental education, languages used at home and at school, and presence of additional disabilities. All of these characteristics have the potential to influence schooling effects, and future research should consider the potential impact of each. Similarly, although this was a longitudinal study encompassing 2 academic years and the intervening summers, it was relatively short. Future researchers may wish to examine these effects over a longer span of time.

Our variable regarding the use of hearing technologies (i.e., CIs and hearing aids) most likely oversimplified the way children use and benefit from amplification. Although it is straightforward to say whether or not a child has a hearing aid or CI, it is not indicative of the way in which it is used and how much benefit it confers (or what types of benefits). In addition, our outcome measures for letter-word identification and vocabulary did not require spoken language. Therefore, our analysis of audiological technology for these two measures is limited.

Finally, the present study only examined schooling effects among DHH children ages 3–5 years. Similar research with hearing children has examined schooling effects through early elementary school (e.g., see McCoach et al., 2006; Skibbe et al., 2012). We are unable to speculate about how schooling effects may continue to affect the development of foundational and even advanced language and literacy skills for DHH children beyond kindergarten. This is an important avenue for future research with this population.

Conclusion

The present study underscores that for young DHH children, even those as young as 3 years, schooling matters. The significant effect of schooling on children's early literacy skills may indicate a need to establish early educational opportunities during the summer, or perhaps provide support for parents as they incorporate language and literacy experiences into the child's home environment. Our findings indicated that 3-year-olds demonstrated significant rates of growth in all three areas while in school; therefore, beginning school at a younger age may play a critical role in supporting DHH children's development. Although increasingly common in the United States, preschool is not a universal opportunity in all countries. For locations where preschool education starting at age 3 is not currently in place, these findings underscore the importance of establishing ways for DHH children to receive early and systematic instruction in foundational literacy skills.

Note

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