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Emergence of Consonants in Young Children with Hearing Loss

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This study investigates consonant development in the spoken language of 269 children with hearing loss between 15 and 84 months of age. Children with mild, moderate, severe, and profound degrees of bilateral hearing loss, including those with cochlear implants, were evaluated. Speech samples from 885 different test sessions of 25-minute parent-child interactions were analyzed to determine phoneme development across a variety of age levels and degrees of hearing loss. This study reports the age at which 50% and 80% of the children produced each of the consonants in the English language. Overall, children in all of the hearing loss groups produced most English consonants by 84 months of age. The data suggest that children with hearing loss develop phonemes in a similar pattern to children with typical hearing, although the rate of development is delayed for later-developing consonants and the delay increases with the degree of hearing loss.

Introduction

The ultimate goal of early intervention is to provide children with hearing loss the opportunity to achieve developmental milestones at appropriate ages. In order to determine appropriate speech development of children with hearing loss, normative data from children with typical hearing must be used; however, families and interventionists also are interested in how an individual

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child's speech production compares to other children with a similar degree of hearing loss. General descriptions of phoneme development in young children using cochlear implants or digital hearing aids have typically involved a relatively small number of participants and, in some cases, children with a wide range in degree of hearing loss. Data from larger sample sizes within specific categories of hearing loss would increase external validity and provide benchmarks that could be used to compare a given child's speech development to other children with the same level of hearing loss.

Reported benchmarks for the specific age at which children with typical hearing develop various phonemes vary to some extent across studies (Sander, 1972). This appears to be primarily due to methodological differences between studies. For example, the manner in which a sample was obtained may vary in terms of whether spontaneous or imitated productions are considered and whether single words or connected discourse is analyzed. Dubois and Bernthal (1978) found that single word articulation measures overestimated conversational usage in children with speech disorders. This finding also was supported by Ertmer (2010) for children with hearing loss.

Another methodological difference between studies is the researchers' criteria and definition of mastery. Across studies, mastery is generally defined as the age at which between 75% and 100% of the children within a sample produce a given sound correctly, but the specific percentage varies depending on the study as does the criteria for correct production. Early work by Wellman, Case, Mengert, and Bradbury (1931) described the ages at which a sound was produced correctly by 75% or more of the children. A more stringent criterion was set by Poole (1934), who reported all of the children tested produced the sound correctly. Later work by Templin (1957) identified when each sound was produced correctly in the initial, medial, and final position of words by 75% of the children tested. A modified version of this criterion was used by Prather, Hendrick, and Kern (1975), who identified when 75% of the children tested demonstrated correct production of a given sound in at least two positions of a word.

Sander (1972) proposed a reworking of the data collected by Wellman et al. (1931) and Templin (1957) that would better represent variations in the age of phoneme acquisition across sample groups. Specifically, Sander suggested reporting both an average age of acquisition, which he defined as the point when 50% of children produce a particular consonant correctly, as well as an upper age limit, at which 90% of children have mastered the use of a particular consonant. This is reported in whole age increments to avoid implying a false sense of accuracy.

Although there are differences in the literature regarding descriptions of phoneme development, general trends can be found. For example, stops (/p,b,d,t,k,g,ʔ/), nasals (/m,n,ŋ/), and /w/are typically established prior to fricatives (/f,v,θ,ð,s,z,ʃ,ʒ/), affricates (/tʃ,dʒ/), liquids (/l,r/), and /j/ (Goldman & Fristoe, 2000; Prather et al., 1975; Sander, 1972; Smit, Hand, Freilinger, Bernthal, & Bird, 1990; Templin, 1957; Watson & Scukanec, 1997).

Speech Development in Children with Hearing Loss

Phoneme development in children with hearing loss is complex to characterize as variables such as degree of hearing loss, age of identification, and type of amplification may influence development (Yoshinaga-Itano & Sedey, 2000). Children diagnosed with hearing loss prior to universal newborn hearing screening, regardless of the degree of hearing loss, are likely to have significantly poorer speech production than children with typical hearing (Gordon, 1987; NIH Consensus Statement, 1995; Robbins, Renshaw, & Berry, 1991; Stoel-Gammon, 1988; Stoel-Gammon & Otomo, 1986; Yoshinaga-Itano, Stredler-Brown, & Jancosek, 1992). Even in early-identified children, phoneme production appears to be delayed with fricatives and affricates being the most difficult to produce (Moeller et al., 2007). Another variable that may influence early phoneme development is the educational approach chosen for a child (Bouchard, Le Normand, & Cohen, 2007). Much of the literature suggests that better speech production is achieved by children who participate in educational programs that emphasize the acquisition of spoken language (Bergeson & Pisoni, 2004; Bouchard et al., 2007; Moog & Geers, 2003; Tobey, Geers, Brenner, Altuna, & Gabbert, 2003).

By 5 to 18 years of age, children with mild to moderate degrees of hearing loss may have few articulation errors and may closely approximate the speech production of children with typical hearing (Elfenbein, Harden-Jones, & Davis, 1994). However, in younger children (10 months to 7 years of age), speech intelligibility and phonological skills are typically delayed (Moeller et al., 2007; 2010). This is apparent for children both identified early and late. However, Moeller and colleagues (2007) state that the delays for children identified early are less pronounced than suggested by previous research.

As the degree of hearing loss becomes more severe, children are more likely to have poorer speech production outcomes as their ability to discriminate phonemes appropriately is reduced due to limitations in auditory perception (NIH Consensus Statement, 1995; Robbins et al., 1991). Production errors in children with the most severe degrees of hearing loss typically include voicing errors, omissions or distortions, and nasalization of phonemes (Hudgins & Numbers, 1942). Individuals with profound hearing loss and little access to auditory input are likely to have delayed or disordered speech production, even when using amplification due to inadequate gain available in hearing aids and the distortion within the auditory system (Geers, Moog, & Schick, 1984; Levitt, McGarr, & Geffner, 1987). Children with profound hearing loss are more likely to make errors with affricate and fricative phonemes than children with less severe degrees of hearing loss (Gordon, 1987).

The advent of cochlear implants has allowed children with severe and profound hearing losses to increase access to auditory input over what was available to them with hearing aids, which can eventually lead to better speech production (Dawson et al., 1995; Geers & Moog, 1994; Kirk & Hill-Brown, 1985; Spencer, Tye-Murray, & Tomblin, 1998; Svirsky, Robbins, Kirk, Pisoni, & Miyamoto, 2000; Tobey & Hasenstab, 1991). Research has shown that in children with cochlear implants, the number of correct phonemes improves over time and they often develop a nearly complete phonemic repertoire (Blamey, Barry, & Jacq, 2001).

However, despite these significant improvements in speech production, studies that compare children with cochlear implants to children with typical hearing continue to document lower accuracy and persistent delays in those with cochlear implants (Ertmer & Goffman, 2011; Ertmer, Kloiber, Jung, Kirleis, & Bradford, 2012; Warner-Czyz & Davis, 2008; Warner-Czyz, Davis, & MacNeilage, 2010). Tye-Murray, Spencer, and Wooodworth (1995) reported on the speech production of 28 children with an average of 3 years of cochlear implant experience and found that children with lower ages of cochlear implant use demonstrated a faster acquisition of phonemes. Additionally, among children with cochlear implants, those whose educational programs had a stronger emphasis on listening and spoken language demonstrated better speech development (Tobey et al., 2003).

Purpose

Children with hearing loss are at an increased risk for not achieving appropriate speech production due to limited access to auditory information. Although previous research has provided information describing overall patterns of phoneme development and typical errors of children with hearing loss, less information is available illustrating the development of individual phonemes. The purpose of this paper is to describe the consonant development of children with various degrees of hearing loss. Specifically, this study documents what Sander (1972) describes as the first distinct stage of speech sound mastery or the age at which a sound first appears in a child's consonant repertoire. Development is described within each category of hearing loss in terms of the age at which 50% and 80% of the children are producing each phoneme in spontaneous language.

Method

Participants

This study included 269 children with bilateral hearing loss between 15 and 84 months of age ($M = 46.27$ months; $SD = 20.27$ months). Longitudinal data were available for the majority of these children (n=226) resulting in 885 total speech samples collected from 1996 to 2010. Hearing loss was present in 6.3% (n=17) of mothers and in 7.8% (n=21) of fathers. Table 1 provides demographic information for the participants at each test session.

Maternal Level of Education

Maternal level of education was used as an indicator of socioeconomic status. Data were available for all but 2 of the participants. The mean education level for the total group was 14.18 years (range: 4 to 21 years). More specifically, 9.0% (n=24) had less than a high school education, 32.6% (n=87) had a high school diploma, 12.7% (n=34) had at least some post high school education, 31.5% (n=84) had a college degree, and 14.2% (n=38) had an advanced educational degree. The percentage of high school graduates and higher is consistent with Colorado and national statistics (U.S. Census, 2007–2011). The percentage of mothers with a bachelor's degree and higher is 10% greater than reported for the state of Colorado.

Degree of Hearing Loss

The participants' degree of hearing loss was determined by the pure tone average (PTA; average of hearing thresholds at 500, 1000, and 2000 Hz) in the better hearing ear. The participants were divided into five groups. The children in the first four groups wore hearing aids and were divided as follows: mild (better ear PTA: 26–40 dB hearing loss), moderate (better ear PTA: 41–70 dB hearing loss), severe (better ear PTA: 71–90 dB hearing loss), and profound (better ear PTA: $>$ 90 dB hearing loss). The category of profound hearing loss included children who later received a cochlear implant as well as those whose families chose not to pursue cochlear implantation. The fifth group was comprised of children who used cochlear implants. Their pre-implant unaided hearing in the better ear ranged from severe to profound. Children with auditory neuropathy spectrum disorder (ANSD) were excluded from this study.

Sixty-eight participants were categorized as having a mild hearing loss, 93 as moderate, 40 as severe, 20 as profound, and 48 as cochlear implant. Twelve children were included in the total count of participants in both the cochlear implant category as well as the severe or profound categories because they had speech samples both prior to and after implantation. At each age, these 12 children were placed in the appropriate degree of hearing loss category depending on their amplification status at the time of the sample.

Age of Identification

Age of identification of hearing loss was available for all but 2 participants. The median was 2.0 months (range: birth to 48 months). Over half of the

Table 1. Demographic characteristics within each age range (number of participants at each test session)

	Age group +/− 2 months							
Characteristic	*15* (*n*=26)	*21* (*n*=81)	*27* (*n*=139)	*33* (*n*=169)	*48* (*n*=147)	*60* (*n*=137)	*72* (*n*=111)	*84* (*n*=72)
Gender								
Male	10	38	69	81	75	68	59	40
Female	16	43	70	88	72	69	52	32
Degree of loss								
Mild	12	34	48	45	34	28	20	11
Moderate	7*	33	51	64	48	42	37	24
Severe	4*	7*	17	22	21	21	11	6
Profound	1*	3*	5*	6*	8*	7*	3*	4*
Cochlear implant	2*	4*	18	32	36	40	41	28
Ethnicity								
Non-Caucasian	5	16	32	40	34	32	31	24
Caucasian	21	65	107	129	114	105	80	48
Age of identification								
By 6 months	24	69	100	102	74	70	59	35
After 6 months	2	11	38	65	71	66	51	36
Mother's education								
Below high school	0	4	7	10	9	7	10	7
High school	1	18	40	60	46	48	40	22
At least some college	3	6	15	18	22	18	18	12
College degree	12	33	50	51	52	49	33	23
Advanced degree	10	20	27	29	16	13	9	7

* Small sample sizes are due to a low number of children producing spoken language during the 25-minute interaction.

Table 2. Median (and range) of age of identification, amplification and intervention in months by degree of hearing loss

	Identification	*Amplification*	*Intervention*
Mild (*n*=68)	1.5 (.5–45)	5 (1.5–45)	5 (1–47)
Moderate (*n*=93)	3 (.5–48)	6 (1–48)	7 (.5–48)
Severe (*n*=40)	8 (.25–43)	10.5 (2–44)	11.5 (1–44)
Profound (*n*=20)	3 (.5–31)	10 (.5–32)	11 (.5–32)
Cochlear implant (*n*=48)	2.5 (.5–21)	6 (1–23)	6 (.75-23)

children, 61.8% (*n*=165), had their hearing loss confirmed by 6 months of age. Twenty-three children had an acquired hearing loss. The mean age of hearing loss acquisition was 13 months with 52% (*n*=12) of the children having acquired their loss at or before 12 months of age.

Age of Intervention and Amplification

The age at which early intervention was initiated was available for 261 of the participants. The average age of intervention was 6.0 months (range: 2 weeks to 48 months). The age at which the child first received amplification was available for 257 of the participants. The average age of amplification was 5.0 months (range: 2 weeks to 48 months). For children whose loss was acquired, age of identification, amplification, and intervention was determined from the point that the hearing loss was acquired. Table 2 provides the median age of identification, intervention, and amplification for each of the hearing loss categories.

Ethnicity

Most of the participants were Caucasian, 76.2% (*n*=205). Of the remaining participants, 8.2% (*n*=22) were Caucasian and Hispanic, 7.8% (*n*=21) were Hispanic, 3.7% (*n*=10) were other ethnicities/races, 3.0% (*n*=8) were Asian American, and 1.1% (*n*=3) were African American.

Etiology

Etiology of hearing loss was available for 265 of the children. The etiology was reported to be unknown in 56.1% (*n*=151) of the cases. Genetic causes, including familial hearing loss and syndromes, accounted for 31.3% (*n*=83). The remaining etiologies included anoxia 1.1% (*n*=3), cytomegalovirus 2.6% (*n*=7), high fever 0.7% (*n*=2), meningitis 2.2% (*n*=6), ototoxicity 0.7% (*n*=2), prematurity 0.4% (*n*=1), and "other" 3.7% (*n*=10).

Presence of Additional Disabilities

This analysis only included children whose families and interventionists/ teachers reported no additional disabilities that interfered with speech and/or language development.

Gender

The participants in this study were 48% male (*n*=129) and 52% female (*n*=140).

Mode of Communication

All families included in the study reported they used spoken English when communicating with their child. Eighty-three percent of these families used primarily spoken language, and 17% indicated they were trying to use simultaneous communication (speech with sign language). Families who rarely or never used spoken language were excluded from the study as these children are likely to develop spoken language at different rates compared to children who are exposed to spoken language throughout their day.

Intervention Program

Eighty-eight percent (*n*=237) of the participants received or had received early intervention services through the Colorado Home Intervention Program (CHIP). CHIP is a family-centered early intervention program that aims to facilitate auditory, speech, language, and social-emotional development in children with hearing loss. Services are typically provided on a weekly basis in the home or other natural environment. The service provider may be a speech-language pathologist who specializes in hearing loss, a deaf educator, or a rehabilitation audiologist. During intervention sessions, the service provider works with the caregivers and child on developmentally appropriate activities providing parent education, coaching, and direct treatment. After 36 months of age, the children transitioned out of the CHIP program and into a variety of different preschool programs.

Procedures

Videotaped samples, 25 minutes in length, were recorded with the child and the primary caregiver. Sessions were recorded in the home for children younger than 36 months of age, and either in the school (with the child and the preschool teacher or parent) or in the home for children older than 36 months of age. The parents and teachers were instructed to interact with the children as they typically would. A team of graduate students studying linguistics phonetically transcribed each child's first 100 utterances into the Logical International Phonetics Program (LIPP) (Oller & Delgado, 1990), a computer program dedicated to phonetic transcription and analysis. If the child did not produce 100 utterances, the full 25-minute sample was transcribed. Only children who produced at least 10 different spoken words during the 25-minute sample were included in this study.

Using LIPP, consonant inventories were compiled for each sample. A consonant was included in the inventory if it was produced two or more times in a given transcript. A consonant could be included in the inventory even if it did not match the target phoneme of the word produced. For example, if a child produced [tɪg] for [dɪg], the /t/ was included in the inventory. The mean inter-coder reliability for the consonant inventory across a random sample of 26 transcripts was 90.63% (range: 68.75%–100%). Consonant inventories were examined within degree of hearing loss categories across a variety of age groups. The first age group at which 50% and 80% of the children produced a given phoneme was then determined.

Results

By 7 years of age, all of the consonants were produced by at least 50% of the participants. Across all degrees of hearing loss, stops, glides, and two of the three nasal consonants /m,n/ appeared first. Although /h,s,z/ were produced relatively early, the remaining fricative consonants and the affricates appeared to be the most difficult to produce for all of the hearing loss categories with /tʃ,dʒ,v,θ,ð,ʒ,ʃ/ generally not yet produced by 80% of children at 6 years of age. In evaluating consonant production by voicing, voiced stop consonants appeared before voiceless stop consonants; however, voiceless fricatives appeared prior to voiced fricatives.

In general, as severity of hearing loss increased, phonemes either emerged later or the point at which the majority of children produced the sounds was later. The children with mild and moderate hearing losses typically produced phonemes earlier compared to the children with severe to profound hearing loss who wore hearing aids or cochlear implants. It took the same amount of time or longer for 80% of the children with cochlear implants to produce most sounds when compared to the children with mild to profound losses who wore hearing aids. The exception to this pattern was /m,w,j,z,h/, which were produced by 80% of the children with cochlear implants earlier when compared to children with severe to profound hearing loss who used hearing aids.

The results provided in Appendix A are arranged by manner of production. The beginning of each solid bar represents the age at which at least 50% of the children produced a given phoneme and ends when at least 80% of the children produced the sound. Presentation of data in this manner allows the reader to see when, on average, children produce a given phoneme in spontaneous speech. It also provides benchmarks for when the vast majority of the children are producing a sound. The length of the bar provides a graphic representation of the amount of variability in age of acquisition for each phoneme with longer bars indicating a broader age range. In general, variability is greater for consonants that emerge later (e.g., /tʃ,r,ʃ/, which are not produced by half of the children until 33 months of age), and is less for those sounds produced earlier (e.g., /p,b,d,w/).

Mild Category

Sixty-eight children provided 232 samples for the mild category. Stops, glides, and two of the three nasal consonants were produced by at least 50% of the children by 15 months of age and by 80% of the children at or before 27 months of age. All phonemes except /ʒ/ were produced by 50% of the children by 5 years of age. By 6 years of age, only /tʃ,dʒ,θ,ʃ,ʒ/were not yet being produced by 80% of the children.

Moderate Category

Ninety-three children provided 306 samples for the moderate category. By 27 months of age, 80% or more of the children were producing all of the stop phonemes except /g/, all of the glides, and /n/, /m/, and /h/. By 48 months of age, 80% of the children had also added /g,s,l,r/ to their consonant repertoire. By 7 years of age, only /tʃ,dʒ,θ,ʃ,ʒ/ were not yet being produced by 80% of the children.

Severe Category

Forty children provided 109 samples for the severe category. All phonemes except /ð,dʒ,θ,ʒ/ were produced by 50% of the children by 5 years of age. By 48 months of age, there were still 12 consonants that were not produced by 80% of the children. By 7 years, only /ŋ,tʃ,dʒ,v/ were not yet being produced by 80% of the children.

Cochlear Implant Category

Forty-eight children provided 201 samples for the cochlear implant category. Samples were evaluated within this category based on the chronological age of the participant, not the participants' age post-implantation. Unlike the children in the mild to severe categories, only two consonants emerged as early as 15 months in 50% of the children, specifically /m,n/. However, like the children with severe loss who used hearing aids, all phonemes except /ð,dʒ,θ,ʒ/ were produced by 50% of the children with cochlear implants by 5 years of age. At 7 years of age, seven phonemes were not produced by 80% of the children, specifically /ŋ,tʃ,dʒ,θ,ʃ,ʒ,v/.

Profound Category

Language samples were available for 45 children with profound hearing loss, however 9 children could not be included in this study because they did not meet the study criterion of producing at least 10 different spoken words during the 25-minute interaction. This left an insufficient number of children within each age category to be able to consider the results by individual age groups. The children who had enough spoken language to be included in the analysis, as a group, demonstrated significant delay in the emergence of consonants. Some sounds with higher frequency auditory information such as /θ,s/ were still not produced by 50% of the children even by 8 years of age. There were very few consonants that reached the 80% criterion by 7 years of age, including what are typically early developing phonemes such as /t,d,k,g/.

On average, age of amplification and intervention were less than optimal (median = 10–11 months) for the children in the profound hearing loss group who wore hearing aids, setting their "hearing age" at almost 1 year below their chronological age. This does not, however, appear to explain their poor speech production, as children in the severe hearing loss group had comparable ages of amplification and intervention yet they produced considerably more consonant phonemes (specifically 80% or more of the children in the severe group produced 83% of English consonants by 7 years of age).

Discussion

The consonant inventories of 269 children with hearing loss were described in terms of two benchmarks; specifically, the age level at which each phoneme appeared in the spontaneous speech of 50% and 80% of the children. These benchmarks were provided within four degree-of-hearing loss categories. (The fifth group, profound hearing loss who did not use a cochlear implant, did not have a sufficient number of children who met the study criterion for spoken language use to be included in the analysis.) Consonants described in previous research as earlier-developing (e.g., stops, nasals, and glides) emerged and were produced by the majority of the children first, and consonants typically referred to as later-developing (fricatives and affricates) appeared later. Overall, as the degree of hearing loss increased, the benchmarks were reached at later ages. The age at which consonants emerged and were produced by 80% of the children with severe hearing loss who used hearing aids was similar to that of children with severe and profound hearing loss who wore cochlear implants.

Direct comparisons with previous studies that examined the age levels at which the majority of children with typical hearing can produce a given consonant is not possible due to differences in methodology. Specifically, the studies by Templin (1957), Sander (1972), and Smit et al. (1990) presented age levels at which the majority of children produced each of the consonants of English accurately in the context of a single-word articulation test and only included a phoneme as "produced" if it matched the target phoneme within the word. The current study, on the other hand, documented the production of a consonant in spontaneous speech and looked at an earlier stage of speech acquisition, i.e., the presence of a consonant within a child's inventory whether or not the phoneme matched the intended target.

Given that this study examined an earlier stage of consonant acquisition (i.e., presence of a sound within a child's phonetic inventory) compared to most studies of phoneme development, one would expect the ages of acquisition to be the same or lower. In general, the age level that the majority of the children who were deaf and hard of hearing produced the earlier developing consonants (/b,p,d,t,g,m,n,w,j,h,/) was comparable to previous data presented on children with typical hearing (Sander, 1972; Smit et al., 1990). On the other hand, the emergence of consonants such as /v,ʃ,dʒ,tʃ,θ,ð,ʒ/ that are reported to develop later in children with typical hearing appeared at even later ages in the children with hearing loss.

Young children with hearing loss are often described in terms of their "hearing age" (i.e., their chronological age minus their age at the time they received amplification). They are then compared to hearing norms based on this adjusted age level. On average, the hearing age of the children in the current study was 5 months below their actual age. The later developing consonants of English are typically produced accurately by children with typical hearing between 5 and 7 years of age (Sander, 1972; Smit et al., 1990). However, these consonants were not produced by 80% of the children with hearing loss (including those with mild hearing loss) at the age of 7. Even when considering an adjustment for hearing age, the children in this study were delayed in their acquisition of later-developing consonants relative to previous studies of children with typical hearing. This finding further supports the delay in speech development in children with hearing loss frequently cited in previous research (e.g., Ertmer & Goffman, 2011; Ertmer et al., 2012; Moeller et al., 2007, 2010; Robbins et al., 1991; Warner-Czyz & Davis, 2008; Warner-Czyz et al., 2010; Yoshinaga-Itano et al., 1992). Additionally, the findings of the current study are in agreement with others who have found the development of fricatives and affricates to be particularly late in children who are deaf and hard of hearing (Elfenbein et al., 1994; Moeller et al., 2007, 2010).

The finding that four to seven phonemes (depending on degree of hearing loss) were not present in the consonant inventory of 80% of the children by 7 years of age is important for speech-language pathologists and school administrators to keep in mind when determining if a child with hearing loss is eligible to receive speech/language services in an educational setting. Young children with typical hearing generally do not qualify for speech intervention if the phonemes they are producing in error are considered "later-developing." This is because there is evidence that the vast majority of children with typical hearing will develop these sounds naturally by 6 or 7 years of age.

In the present study, these later-developing consonants were still not present in many of the children at age 7, suggesting that children with hearing loss may need structured support to acquire these phonemes at the appropriate age so that they are on par with their peers who have typical hearing. Given that many of the 7-year-old children in the current study were not producing these later-developing phonemes argues against the "wait and see" approach, which is only evidence-based for children who have typical hearing. Lack of early attention to these sounds in children who are deaf or hard of hearing places them at risk for being set apart from their peers in terms of speech production and overall intelligibility by the first grade. In addition, the relatively late absence or distortion of these later-developing consonants can impact spelling, phonological awareness, and literacy (King & Quigley, 1985; Wauters, van Bon, & Tellings, 2006).

Although some consonants appeared later in the inventories of the children with hearing loss compared to previous reports of children with typical hearing, the general order of acquisition of the phonemes was similar. Like children with typical hearing, stops, glides, and nasals (with the exception of /ŋ/) emerged and were produced by the majority of the children first, whereas fricatives and affricates typically appeared later. This similarity in the order of phoneme acquisition to children with typical hearing has been noted by others who have examined the speech acquisition of children with hearing loss compared to children who have typical hearing (e.g., Flipsen, 2011; Moeller et al., 2007; Serry & Blamey, 1999).

Looking across degree-of-hearing-loss categories from mild to severe, there was a systematic increase in the age at which many of the phonemes emerged and were produced by a majority of the children. For example, /f/ was produced by 80% of the children with mild hearing loss by 48 months of age, which is comparable to the age level reported by Sander (1972) and Smit et al. (1990) for children who have typical hearing. However, this same phoneme was produced by 80% of the children with moderate and severe hearing loss by 60 and 72 months of age, respectively. This pattern of later phoneme acquisition as degree of hearing loss increased was apparent for many of the consonants and is in keeping with the findings of Markides (1970), who reported that children who are hard of hearing demonstrated more accurate speech production and increased speech intelligibility compared to children who are deaf and hard of hearing.

For approximately half of the consonants, the 80% benchmark was reached at the same age by children with severe hearing loss who used hearing aids and those with severe or profound hearing loss who used cochlear implants. Of the remaining half of the consonants, some developed earlier in children with severe hearing losses who wore hearing aids whereas others developed earlier in children with cochlear implants.

Limitations

There are a number of things to bear in mind in the interpretation of this study. First, the videotaped samples were categorized as containing either spoken language or babble/vocalizations based on the number of different spoken words produced. If children produced 10 or more different words during the 25-minute interaction, the sample was described as containing primarily spoken language, whereas samples that did not meet this criterion were excluded from this analysis. Therefore, the data discussed in this study may not be reflective of phoneme production trends in children with hearing loss who are not yet spontaneously producing spoken words in everyday interactions.

Two factors were identified that may have led to an underestimation of the number of consonants considered part of a child's phonetic repertoire. First, in an attempt to capture early speech production skills, only language samples that included 10 or more different spoken words were analyzed. If a child's language sample was at or near this relatively low threshold, yet the child was actually capable of producing considerably more spoken language, their full range of consonants may have not been captured. Additionally, the use of a spontaneous language sample may not have provided an opportunity for children to demonstrate all of the consonants in their repertoire. Some consonants appear less frequently in the English language and are found in words that are not commonly used by young children (e.g., /ʒ/). Thus, a child may have had additional phonemes in their consonant repertoire but did not have an opportunity to use them within the 25-minute sample.

A further consideration for interpretation is that children were assessed at designated testing ages. Development of phonemes was occurring throughout the period of birth to 84 months and testing at specific 6- and 12-month intervals would not be sensitive to changes between testing sessions. Finally, small sample sizes for some hearing loss categories at 15 and 21 months of age limits the generalization of results for these age groups.

The results of this study can help parents and interventionists understand the typical timelines for speech development in children with hearing loss. Thus, it can serve as a useful guide to assist listening and spoken language professionals in developing speech production goals for children who are deaf and hard of hearing. If a child is not progressing towards the production targets that are appropriate for his/her degree of hearing loss, it may be indicative of other factors that may be affecting development. For example, the child may not be appropriately amplified, the hearing loss may have progressed, or additional disabilities may be influencing development. Furthermore, the listening and spoken language professional may want to adjust their therapy strategies or discuss different techniques that the parents can use in the home to provide a more stimulating environment for speech development.

Conclusion

The present findings suggest that children with mild, moderate, or severe hearing loss who use hearing aids and children with cochlear implants acquire phonemes following a similar pattern to children with typical hearing. However, on average, the rate of development is delayed and the delay increases with degree of hearing loss. Approximately 30% of English consonants were not produced by at least 80% of the children, even by 84 months of age. The information presented in this article on the age at which children with hearing loss produce individual consonants will allow clinicians to compare the speech production skills of individual children to a group of children of the same age and with a similar degree of hearing loss.

Acknowledgments

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Appendix A. Results of Consonant Production

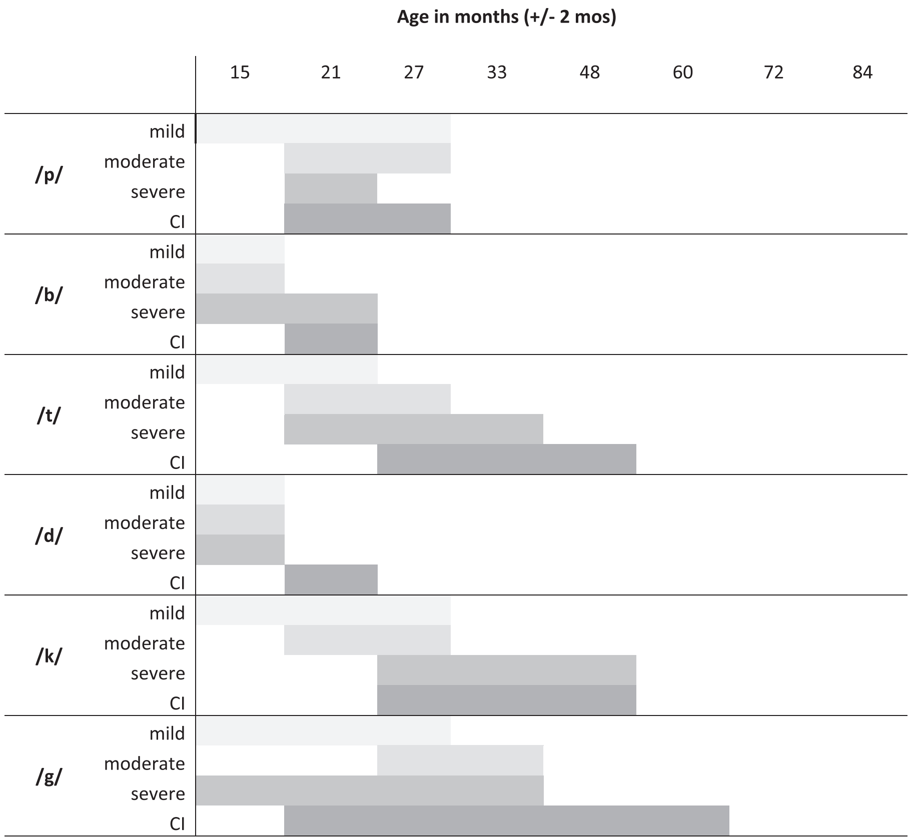

Chart 1. Development of stop phonemes. The beginning of each solid bar represents the age at which at least 50% of the children produced the sound and ends when at least 80% of the children produced the sound. Children with profound hearing loss who wore hearing aids are excluded due to small sample size.

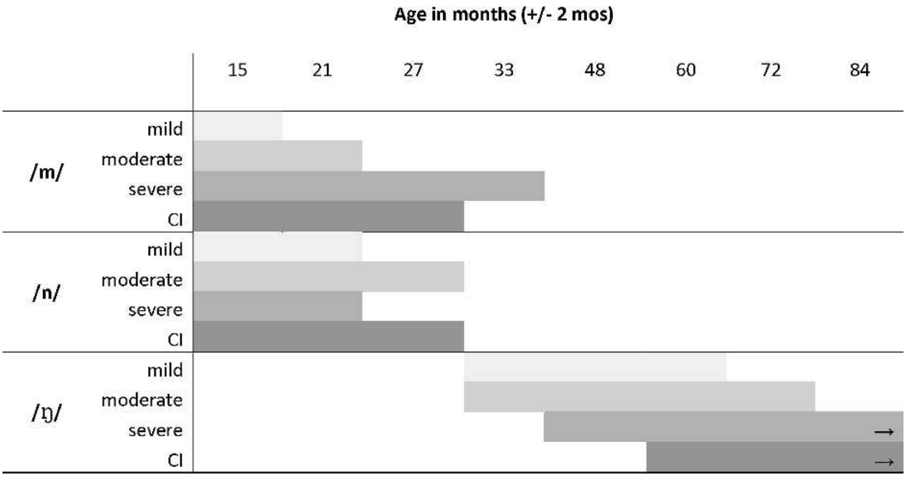

Chart 2. Development of nasal phonemes. The beginning of each solid bar represents the age at which at least 50% of the children produced the sound and ends when at least 80% of the children produced the sound. The arrow (→) indicates that 80% of the children were not yet producing the phoneme by 84 months of age. Children with profound hearing loss who wore hearing aids are excluded due to small sample size.

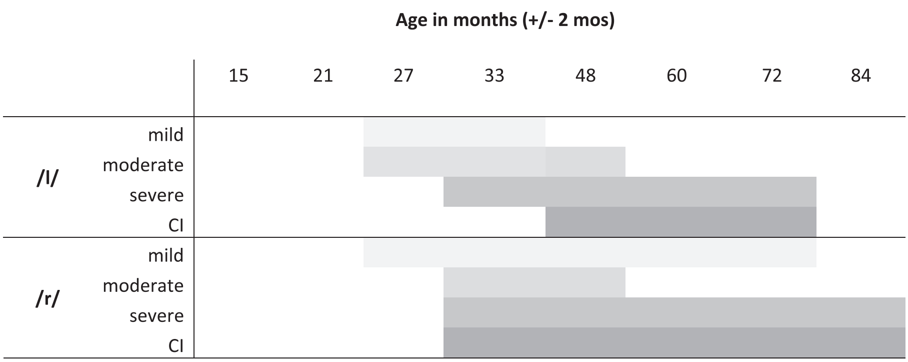

Chart 3. Development of liquid phonemes. The beginning of each solid bar represents the age at which at least 50% of the children produced the sound and ends when at least 80% of the children produced the sound. Children with profound hearing loss who wore hearing aids are excluded due to small sample size.

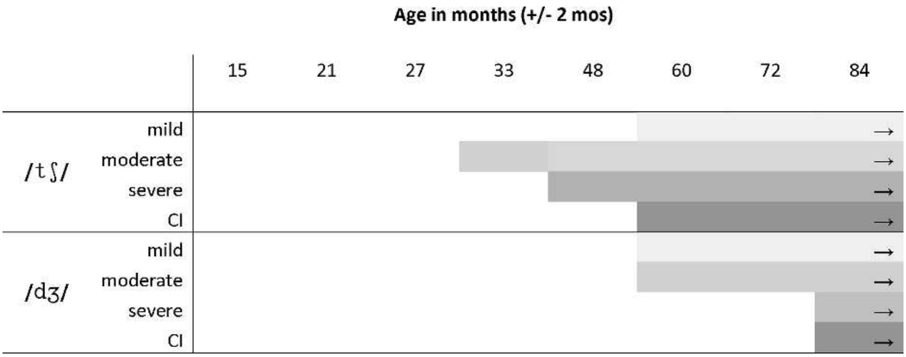

Chart 4. Development of affricate phonemes. The beginning of each solid bar represents the age at which at least 50% of the children produced the sound and ends when at least 80% of the children produced the sound. The arrow (→) indicates that 80% of the children were not yet producing the phoneme by 84 months of age. Children with profound hearing loss who wore hearing aids are excluded due to small sample size.

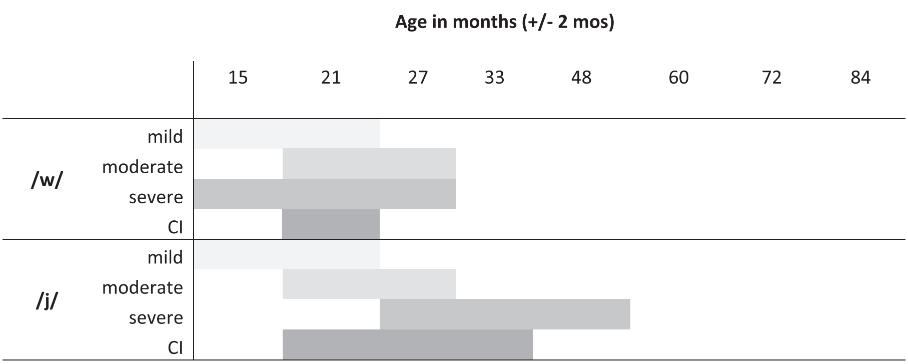

Chart 5. Development of glide phonemes. The beginning of each solid bar represents when at least 50% of the children produced the sound and ends when at least 80% of the children produced the sound. Children with profound hearing loss who wore hearing aids are excluded due to small sample size.

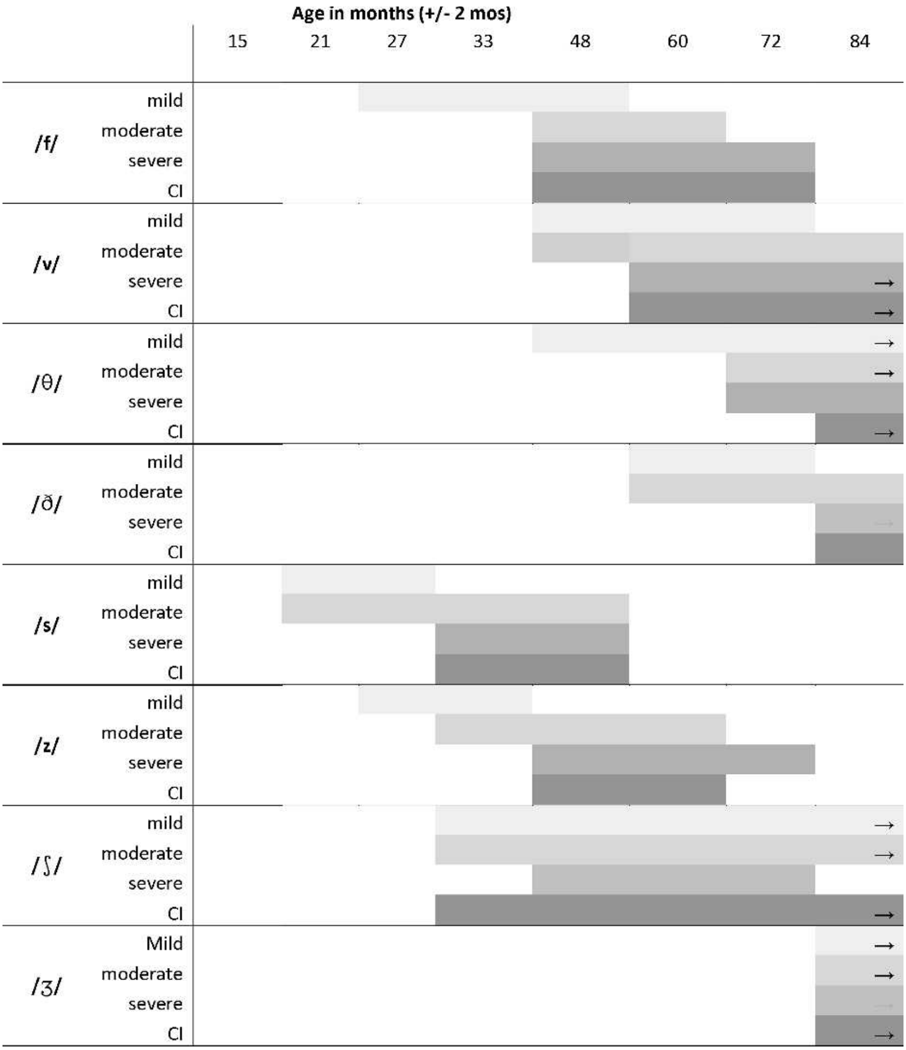

Chart 6. Development of fricative phonemes. The beginning of each solid bar represents when at least 50% of the children produced the sound and ends when at least 80% of the children produced the sound. The arrow (→) indicates that 80% of the children were not yet producing the phoneme by 84 months of age. Children with profound hearing loss are excluded due to small sample size.