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Deaf and Hearing American Sign Language–English Bilinguals: Typical Bilingual Language Development

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Abstract

Some studies have concluded that sign language hinders spoken language development for deaf and hard-of-hearing (DHH) children even though sign language exposure could protect DHH children from experiencing language deprivation. Furthermore, this research has rarely considered the bilingualism of children learning a signed and a spoken language. Here we compare spoken English development in 2–6-year-old deaf and hearing American Sign Language–English bilingual children to each other and to monolingual English speakers in a comparison database. Age predicted bilinguals' language scores on all measures, whereas hearing status was only significant for one measure. Both bilingual groups tended to score below monolinguals. Deaf bilinguals' scores differed more from monolinguals, potentially because of later age of and less total exposure to English, and/or to hearing through a cochlear implant. Overall, these results are consistent with typical early bilingual language development. Research and practice must treat signing-speaking children as bilinguals and consider the bilingual language development literature.

Introduction

This study presents data regarding the spoken English development of deaf and hearing American Sign Language (ASL)–English bilingual children. People using both a sign language and a spoken language are considered *bimodal bilinguals* because their two languages primarily occupy two different modalities: auditory/vocal and visual/gestural. We will also use the term "sign–speech" bilinguals in contrast to "speech–speech" bilinguals in this article, with speech–speech referring to bilinguals who use two spoken languages. Samples of spontaneous spoken language production from both groups of bilinguals were compared with each other and with those of hearing, monolingual English-speaking children. We discuss the similarities and differences in spoken language development across these three groups and how the results here should be used to inform language choices for deaf and hard-of-hearing (DHH) children.

One main argument we make in this paper is that DHH children learning both a signed and a spoken language should be considered bilinguals. While this may seem obvious, much of the previous literature about these children has not taken their bilingualism into consideration. Research has typically compared bilingual signing and speaking DHH children to those learning a single (spoken) language, often finding the signing-speaking children to be deficient (i.e., that the bilingual DHH children scored below monolingual English-speaking DHH children on standardized tests of spoken English, as in Geers et al., 2017; but see Fitzpatrick et al., 2016 for a systematic review finding that there is insufficient high-quality evidence to be conclusive). The results from these lines of research, in combination with other problematic scientific arguments and long-standing biases against sign languages, have been used by professionals to discourage sign language use with DHH children (as discussed in Hall, 2017; Hall et al., 2019; Henner & Robinson, 2023; Humphries et al., 2016; Lillo-Martin et al., 2021; Mauldin, 2016). In contrast, if we recognize that a child exposed to both a signed and a spoken language is bilingual, we can learn from the immense literature about speech–speech bilinguals and set realistic expectations for language development in two languages.

For instance, numerous studies have found that standardized tests in a single language underestimate speech–speech bilingual children's overall language abilities (Castilla-Earls et al., 2020; Thordardottir, 2015). Therefore, when research with DHH children fails to acknowledge language skills outside of the spoken modality, results are inherently biased against children whose language knowledge is distributed across a spoken and a signed language (e.g., see comments by Hall et al., 2019, regarding the study by Geers et al., 2017). Furthermore, a singular focus on spoken language as the only acceptable manifestation of verbal abilities ignores the importance of language, regardless of modality, to a child's cognitive and social–emotional development (Glickman & Hall, 2019).

The remainder of this introduction will set the stage for our study by discussing the factors that are expected to influence the language development of DHH children learning a signed and a spoken language. We will interweave evidence from speech–speech bilingualism research with the more limited research on sign–speech bilinguals specifically, and we will discuss results from research with hearing sign–speech bilingual children.

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We will end the introduction with our research questions and predictions.

Before we begin, we would also like to note that the current study focuses on children learning a natural sign language, ASL, and spoken English. However, there are additional ways in which DHH children can be considered bilingual. For example, some use a sign language and only the written form of a spoken language, and they are clearly also bilingual. Some may use multiple different sign languages or multiple different spoken languages. Furthermore, children exposed to a sign system (e.g., Signing Exact English) and a spoken language potentially could be considered bilinguals as well. This is because these children must learn two phonetic inventories, two vocabularies, potentially two grammars, as well as the pragmatics concerning which contexts map onto the use of each communication modality. Since sign systems are not natural languages, there will be some differences in language development based on the type of sign system a child is learning (Scott & Henner, 2020; Supalla, 1991). Nevertheless, the linguistic experiences of children learning a sign system along with a spoken language are comparable in many ways to those of bilinguals.

Factors that Influence Bilingual Language Development

Research with speech–speech bilinguals has found many input factors to be relevant to the pace of development in each language. For example, earlier ages of language exposure generally lead to higher proficiency in a given language (Unsworth, 2013). The manner in which the language input is divided is also important, with some researchers finding that children must receive a certain percentage of their input in a language to score comparably to monolinguals (Thordardottir, 2019). Similarly, we must also consider the cumulative amount of exposure a child has to each language, with more exposure leading to higher proficiency (Bedore et al., 2016). The number of people who use each language with a child can also be important, especially for the minority (home) language (Unsworth, 2016).

It can be presumed that input factors such as these are also highly relevant to sign–speech bilinguals. For example, only a very small proportion of DHH children are born into families in which a natural sign language is already used; according to Mitchell & Karchmer (2004), this percentage is not more than 5%. For other children, timing of initial sign language exposure, as well as quantity and quality of input can vary greatly. Some hearing parents opt to learn to sign, but it takes time before they are able to provide fluent sign input; meanwhile, the number of other signers the child might be exposed to (e.g., DHH mentors, early intervention providers, community members) will vary greatly. Many parents do not learn to sign (Gallaudet Research Institute, 2011), and their DHH children's first exposure to their sign language might occur at entry to school or often much later, when the child moves from a program providing spoken language exclusively, to one that uses a bilingual approach including sign language.

Sign–speech bilinguals also show variation in the age and quantity of exposure to their spoken language. Many DHH children receive cochlear implants to improve their access to sound, but the age of implantation varies from as young as 9 months (per 2020 FDA guidelines) to several years (Teagle et al., 2019). Following implantation, these children need aural rehabilitation services, which also contribute to the variation in input provided. Even for DHH children who have sufficient access to spoken language, it is different from that of children born with typical hearing—in age of onset, quality of sound (which is different from typical hearing), and amount of input (which can be exacerbated by factors such as implant failure, periods of nonuse, etc.). Furthermore, parental attitude toward deafness and sign languages is another factor that can affect the amount of exposure to each language that DHH children receive (Clark et al., 2013).

Broader societal attitudes toward bilingualism have also been found to affect patterns of linguistic development (Smithson et al., 2014). In the United States, the language use of speech–speech bilinguals has historically been characterized as "deficient" for the ways in which it differs from monolinguals, and systematic efforts have been made to assimilate children to a monolingual Standard American English ideal (Flores & Rosa, 2015). Children, especially those from first nations groups and immigrant groups, have been physically and emotionally punished for using a language other than English in the classroom and have sometimes been relegated to special education based on IQ tests administered in English, a language they may not yet have been fluent in (e.g., Hurstfield, 1975; Newland, 2022). Because of this subtractive approach to bilingualism, children's development in the majority language (in this case, English) often comes at the expense of the minority, or home language (Ebert, 2020).

Recent research is shifting from this deficit-based framework toward one that values the linguistic skills of bilinguals (Flores & Rosa, 2015). This modern approach also acknowledges that bilingualism is not double monolingualism, as famously stressed by Grosjean (1989) and echoed by many others; a bilingual's languages interact in complex ways. Thus, their language use may not look like that of a monolingual in either of their languages. Yet despite this shift in framing, the subtractive approach to bilingualism remains predominant in our society, especially for racialized and disabled children (Henner & Robinson, 2023).

DHH children have faced similar discrimination in American educational systems. Learning spoken English has long been valued above all other types of education, such as reading, math, science, and social studies (Booth, 2021, pp. 53–56). DHH students have experienced physical punishment and shaming for use of sign language in the classroom (Baynton, 1996). Sign languages are often viewed as animalistic and judgments of a DHH person's intelligence and worth are frequently based on their ability to emulate a hearing ideal of spoken language (Henner & Robinson, 2023; Holcomb & Lawyer, 2020). The American subtractive approach to bilingualism more broadly, as well as the low status of sign languages specifically, has led to many DHH children being denied sign language entirely, despite proclamations from the United Nations and the World Federation of the Deaf reaffirming the right to sign language for all DHH children (United Nations, 2006; World Federation of the Deaf, n.d.). This subtractive approach to bilingualism means that DHH children are at risk of losing fluency in their sign language as they become more proficient in a spoken language. It also means that their spoken language skills may look more monolingual-like if they become dominant in spoken language.

While American cultural and educational practices have been harmful to hearing children who use a language other than English at home, the stakes are even higher for DHH children. Because it is still difficult to predict which children will succeed with spoken language using modern hearing technology, withholding sign language denies some DHH children a strong foundation in *any* language at all (Hall et al., 2019). This language deprivation can lead to widespread deleterious consequences, such as emotional dysregulation and executive dysfunction (e.g., Gulati, 2019). The singular focus on speech for DHH children also ignores additional benefits of sign language use, such as development of self-acceptance and a deaf identity (Gale, 2021; Mayer & Leigh, 2010, p. 176).

Sign–Speech Bilingual Language Development in DHH Children

Many studies of language development in DHH children have included a heterogenous group of participants in terms of their background knowledge of a natural sign language. Most participants would have been first exposed to ASL (or another sign language or sign system) in primary school or perhaps preschool, with varying degrees of quantity and quality of input. It is clear that the earlier a child is exposed to fluent signed input, the more likely they will have better outcomes in their sign language (Henner et al., 2016, 2019; Hrastinski & Wilbur, 2016). Given the variability introduced by input variation, we will focus here on children who have had access to sign language input from birth. It is important for future research to develop better understanding of early language development in DHH children with later and more variable input (see, e.g., Berger et al., 2023; Caselli et al., 2021; Pontecorvo et al., 2023).

A few studies have specifically examined language development in DHH children who experienced fluent sign language input from birth, and who also accessed spoken language through cochlear implants. Hassanzadeh (2012) examined speech perception, speech production, and language development in spoken Persian for seven cochlear-implanted deaf children of deaf, signing parents, compared with data from deaf children with hearing parents. Hassanzadeh found that the children with early sign language exposure outperformed the children of hearing parents, and recommended that deaf children be encouraged to sign before implantation. Similarly, Davidson et al. (2014) looked at several measures of spoken English development in five deaf, cochlear-implanted children exposed to ASL from birth, and compared their results with those of 20 hearing children who also had been exposed to ASL from birth. They found that the two groups performed very similarly, and furthermore, that they scored at age-appropriate levels for monolinguals on standardized tests for which such comparisons were possible.

Goodwin & Lillo-Martin (2019) examined additional data from the five deaf, sign–speech bilingual children in Davidson's study, in comparison with seven hearing sign–speech bilinguals, focusing specifically on the development of English grammatical morphemes. They also observed no statistically significant difference in accuracy between the two groups. They did find that the deaf children seemed to make more errors than the hearing children on the use of regular plurals, which might be attributed to the lower acoustic salience of this grammatical morpheme in English.

While the studies summarized here have found high levels of performance in the spoken language of sign–speech bilinguals, it is important to point out that age-equivalency with monolinguals should not be the general expectation for either DHH or hearing bilinguals. As we have already noted, bilinguals typically progress along a different time scale compared with monolinguals in both of their languages and their languages may influence one another. Furthermore, for DHH children accessing spoken language through hearing technology, factors such as the timing and quality of input accessed using hearing technology, and the relative amount of input in each language, can be expected to have an effect. This can lead to hearing sign–speech bilinguals showing scores that are closer to those of monolinguals than DHH bilinguals do.

The study by Davidson et al. (2014) included one test of ASL development, which also indicated overall parallel performance between the deaf and hearing native signers. However, other studies examining specific areas of ASL development in sign–speech bilingual children have found differences in comparison to monolinguals, which can be attributed to the participants' bilingualism (Chen Pichler et al., 2018). For example, Palmer (2015) found that very young ASL–English bilinguals did not make use of the full range of word-order changing operations in ASL as a comparison group of deaf signers did. Similarly, Reynolds (2018) observed differences in the use of reference tracking devices in the narratives expressed in ASL by ASL–English bilinguals (deaf cochlear implant users and hearing native signers) compared with ASL-dominant deaf signers. These studies reinforce the conclusion that bilingual children are not just like monolingual children in either of their languages—even the one that they began to acquire first and use at home.

Sign–Speech Bilingual Language Development in Hearing Children

While research examining the development of spoken language by signing DHH children often overlooks the fact that they are bilingual, a related problem can be found in studies of language development in hearing children whose deaf parents use a sign language with them at home. In particular, some studies raised concerns that although these children have typical hearing, they would have difficulties with speech if the model of spoken language they received at home was from a deaf caregiver. This viewpoint continues to be seen in practice, as many families and speech–language pathologists continue to express concern about possible negative influences of the use of a natural sign language for hearing children, and they are over-referred for spoken language treatment (Chen Pichler et al., 2014).

In contrast, many studies have found that hearing sign–speech bilingual children's spoken language development is not delayed or harmed by their exposure to a sign language (for overviews, see Lillo-Martin et al., 2022; Quadros et al., 2016). Research has investigated the language development of sign–speech bilingual children for the insights that such studies can provide on the nature of bilingualism. For example, Petitto et al. (2001) observed three hearing children of deaf parents, who were learning both spoken French and the sign language used in Montreal, *Langue des signes québécoise*. They found that the children's early language milestones were equivalent in the two languages. Importantly, studies of sign–speech bilingual development in hearing children have consistently observed typical bilingualism effects (Lillo-Martin et al., 2016).

Before introducing the details of the current study, we provide some background on bilingual language sample analysis (LSA), as this is the approach we take.

Bilingual Language Sample Analysis

LSA involves the collection and analysis of language samples in order to measure aspects of a child's productive ability in a naturalistic environment. It is often seen as an integral part of language assessment for bilingual children (Castilla-Earls et al., 2020; Ebert, 2020). LSA has advantages over standardized quantitative approaches to language assessment for bilingual children, although the latter are still frequently used (Caesar & Kohler, 2007). Furthermore, LSA is not immune from the vulnerabilities when using comparisons between bilinguals and monolinguals, a point we will return to in the Discussion. Some of the benefits of LSA are that it can be considered ecologically valid and is appropriate for use with the youngest of children. Additionally, LSA can simultaneously provide information about multiple linguistic levels (e.g., phonology, vocabulary, morphology, and syntax) and can be conducted in both of a bilingual's languages.

Here we discuss basic outcomes from research using the same three language measures that we will present below for the ASL–English bilinguals in our current study. The first measure, vocabulary diversity (VocD), is a measure of the diversity of vocabulary items used that was developed to be less dependent on sample size than alternative measures, such as number of different words and type-token ratio. VocD has been found to increase developmentally from ages 18 to 60 months (Durán et al., 2004). The second measure, Mean Length of Utterance in Morphemes (MLUm), is a measure of syntactic complexity based on the average number of morphemes per utterance across a language sample. MLUm has been widely used across theoretical and clinical studies of language development and has been found to be sensitive to differences because of Specific Language Impairment/Developmental Language Disorder until around age seven (Rice et al., 2010). The last measure, the Index of Productive Syntax (IPSyn), is a checklist of 59 English grammatical constructions; children can score 0, 1, or 2 points for each item, depending on how many times the structure occurs in the sample (Altenberg et al., 2018). IPSyn can be used to understand a child's developing syntactic diversity. For typically developing monolingual children, IPSyn scores have been shown to plateau early in development, making this measure most appropriate for use in monolingual children up to age 4 years.

Research using LSA has generally found that speech–speech bilinguals tend to score below monolinguals on these three language measures, although the difference is not always statistically significant (Blom, 2010; Otarola-Seravalli, 2021; Paradis & Genesee, 1996). Input factors are important, with some studies showing that balanced bilinguals, or those with relatively equal amounts of exposure to each language, do not differ from monolinguals in either of their languages (Thordardottir, 2015). On the other hand, results differ for children who receive disparate amounts of input in each language and who thus become dominant in the language that they have greater exposure to. These children tend to look like monolinguals in their dominant language and to score below monolinguals in their nondominant language.

Generally, research on spoken language development using LSA with DHH children who use cochlear implants has found that they tend to score lower than hearing monolinguals on the number of different words produced (results not available for VocD specifically), MLUm and IPSyn (Geers, 2004; Tomblin et al., 1999; Yang et al., 2021). Some (but not all) research has found that when children with cochlear implants were matched to hearing peers based on the time since they received their implant (so-called "hearing age"), rather than based on their chronological age, there were no longer any differences between DHH and hearing children (Flipsen & Kangas, 2014; Tavakoli et al., 2015). Additionally, while some research has found that use of a signed system did not influence IPSyn scores specifically (Geers, 2004), other research has found that early exposure to a natural sign language may be beneficial (Davidson et al., 2014).

The Current Study

In this study, we analyze vocabulary diversity using VocD, sentence complexity using Mean Length of Utterance in morphemes (MLUm), and sentence diversity using the Index of Productive Syntax (IPSyn) in the longitudinal spontaneous spoken language produced by deaf and hearing ASL–English bilinguals between the ages of 2 and 6 years. The current study includes the largest such dataset on these two populations presented to date. We focus on three main research questions:

(1) Do deaf and hearing ASL–English bilinguals show increasing scores on English vocabulary diversity, syntactic complexity, and syntactic diversity from ages 2 to 6 years?
(2) Do deaf and hearing ASL–English bilinguals have similar scores on English vocabulary diversity, syntactic complexity, and syntactic diversity from ages 2 to 6 years?
(3) How do both groups of bilinguals' scores on the three language measures compare to a database of hearing, monolingual English-speaking children?

For research questions 1 and 2, we use a linear mixed-effects model to explore possible contributions of age and group to scores. We expect that age will significantly predict language scores, with increasing age associated with higher scores as all participants experienced additional cumulative exposure to spoken English with their increasing age. We also expect possible significant differences for hearing status. This is because the deaf children (1) began learning spoken English at a later age than the hearing children because of the inaccessibility of spoken language prior to cochlear implantation, (2) experienced degraded auditory input through their cochlear implants, which cannot perfectly replicate natural hearing, and (3) likely experienced some disruption in access to spoken language through periods of disuse of their cochlear implants.

For research question 3, we analyze Z-scores using the CHILDES KidEval monolingual database as the reference distribution of scores. We predict that both groups of bilinguals will tend to score lower than monolinguals on all language measures (i.e., have negative Z-scores). This is expected because previous research has demonstrated numerous ways in which bilingual language development differs from that of monolinguals, typically manifesting as lower scores on English language measures. Furthermore, we predict that the deaf bilinguals might differ more from the monolinguals because they likely have experienced a later onset of access to spoken language, as well as less overall English input, which may also have differed in perceptual quality from the hearing group. However, when the deaf bilinguals are compared with hearing children at a similar hearing age, we expect differences in scores to be reduced.

Method

Participants

All data were collected and managed in compliance with University IRB guidelines. We present data from two groups of ASL–English bilingual children between the ages of 20 and 71 months: six hearing children and six deaf children who used CIs. None of the participants were diagnosed with an additional disability. Both groups of bilinguals were drawn from a longitudinal corpus of ASL–English bilingual children collected over a period of years as part of a larger project on the development of ASL–English bilingualism, for which participants were recruited from the deaf community (Chen Pichler et al., 2016; Quadros et al., 2014).

All participating children had at least one Deaf parent and were exposed to ASL from birth. The hearing children were also exposed to English from birth by hearing family and community members, but spoken language was not accessible to the deaf children until after they received their cochlear implants. All deaf children received regular English speech and language therapy as recommended by their interventionists. Table 1 provides basic demographic information for all participants, and Table 2

Table 1. Participant information

Hearing status	Pseudonym	Sex	Maternal education[a]	Number of deaf/hearing parents	Language use at home[b] (%ASL/%English/%Mix)	Language use at school/daycare[b] (%ASL/%English/%Mix)	Other deaf family members[c]
Deaf	D1	M	16+	2(mother, father)/0	50/0/50	0/100/0	2 siblings
	D2	M	16+	2(mother, father)/0	50/0/50	0/50/50	1 sibling, grandparents
	D3	F	16+	2(mother, father)/0	75/5/20	0/100/0	None
	D4	F	16+	2(mother, father)/0	50/0/50	0/100/0	2 siblings
	D5[d]	M	16+	2(mother, father)/0	50/0/50	0/100/0	2 siblings
	D6	M	16+	2(mother, father)/0	50/0/50	0/100/0	1 sibling, grandparents
Hearing	H1[d]	M	16+	2(mother, father)/0	50/30/20	0/100/0	1 sibling, 1 grandparent
	H2	F	16	1(father)/1(mother-CODA[e])	Unknown	Unknown	Grandparents, aunt, uncle, cousins
	H3	M	16+	1(mother)/1(father)	40/20/40	0/100/0	Grandparents
	H4[d]	M	16+	1(mother)/1(father)	50/20/30	60/0/40	None
	H5	M	16+	2(mother, father)/0	80/10/10	0/100/0	None
	H6	M	16+	1(mother)/1(father)	75/15/10	0/100/0	None

Notes. [a]Maternal education is measured in years, with "16" indicating an undergraduate degree. [b]Parents were asked to report the proportion that American Sign Language (ASL), English, or a mix of ASL and English was used with their child at home and at school and/or daycare. [c]Family member(s) that the children had regular contact with. [d]Attended an ASL/English bilingual daycare or preschool before moving to an all-English program. [e]Mother's parents are deaf ASL signers.

Table 2. Audiological characteristics for deaf participants

Pseudonym	Age at first implant activation (months)	Age at second implant activation (months)	Pre-aided hearing level
D1	13	23	Severe to profound
D2	19	19	Profound
D3	18	42	Profound
D4	12	12	Profound
D5	16	42	Severe to profound
D6	12	17	Profound

provides audiological information for the deaf participants. For all the deaf participants, parental reports indicate that the children were deaf at birth.

All children used ASL in the home; some children also attended bilingual ASL–English (pre-)school programs for a period of time. While we do not include any measure of language dominance here, it is likely that many of the children may have had relatively balanced language skills or been ASL-dominant early in the observation period. This is when they were toddlers and likely spent more time in the ASL-rich home context. As the children entered preschool or kindergarten, their exposure to English likely increased, possibly leading to English dominance, especially for those children attending a monolingual English school. Three of the hearing participants and three of the deaf participants took part in a separate study that assessed their overall ASL and English skills when they were 5–1/2–6 years old (Davidson et al., 2014), using the ASL-Receptive Skills Test (ASL-RST; Enns & Herman, 2011) and the Preschool Language Scales, Fourth Edition (PLS-4; Zimmerman et al., 2002). On the PLS, five of the six participants scored within 1 standard deviation of the mean on both subscales (Expressive Communication and Auditory Comprehension); the sixth child, a deaf participant, had a standard score of 75 on the Auditory Comprehension portion of the test. On the ASL-RST, all participants scored at or above the mean standard score (of 100) with the exception of one hearing child, whose standard score was 97. Unfortunately, we do not have scores on such assessments for the other six participants.

Procedure

All children were recorded while interacting with researchers or family members during spontaneous play sessions of ∼1 hr. During these sessions, the child and interlocutor engaged in age-appropriate play with toys and/or books. Interlocutors were trained to encourage the child to lead the discussion. Naturally, the amount of language produced by children varied greatly across sessions.

Participants were invited to engage in weekly data collection sessions over a period of ∼2 years. Because of the significant imposition of such a study, participating families sometimes could not meet the expected schedule, but continued in the study as much as availability permitted. A few of the families agreed to remain in the study for roughly an additional year. The small size of the population from which the native signing children with CIs is drawn also means that some participants were only recruited at a later age. This necessary flexibility in data collection resulted in differential age ranges and frequency of samples available for the present study. In general, the project aimed to collect data in sessions which alternated between ASL as the target language, with deaf and fluent hearing signers as interlocutors, and English as the target language, with hearing English-speakers as interlocutors.

For the current analysis, all available English-target sessions up to one per month for each child within the age range 20–71 months were included, resulting in a total of 189 sessions. While ASL-target sessions were also collected as part of the larger project on ASL–English bilingualism, none of these sessions were analyzed here. Similarly, while many children used some ASL in English-target sessions, no ASL utterances or signs were included in the analyses discussed below. The different numbers of sessions that were available for each participant across different age ranges are shown in Table 3 below (see Supplementary Figure 1 for distribution of observations).

Table 3. Number and age range of observations per child

Hearing status	Pseudonym	Age range (months)	Number of observations
Deaf	D1	34–71	25
	D2	66–70	4
	D3	63–71	5
	D4	23–34	11
	D5	54–71	11
	D6	28–56	18
Total			74
Hearing	H1	24–67	24
	H2	27–64	22
	H3	24–40	12
	H4	36–71	20
	H5	23–60	25
	H6	22–41	12
Total			115

Table 4. Linear mixed effects models results

Predictors	Estimates	CI	*p*
VocD			
(Intercept)	19.28	9.43 to 29.14	<.001***
Age mths	.40	.19 to .61	<.001***
Group [hearing]	5.37	−7.51 to 18.26	.414
Age × Group	.04	−.26 to .34	.808
MLUm			
(Intercept)	1.13	−.17 to 2.44	.088
Age mths	.04	.02 to .06	.001**
Group [hearing]	−.65	−2.30 to 1.00	.442
Age × Group	.02	−.01 to .06	.121
IPSyn			
(Intercept)	22.00	13.99 to 30.02	<.001***
Age mths	.36	.22 to .51	<.001***
Group [hearing]	−17.38	−27.13 to −7.63	<.001***
Age × Group	.46	.27 to .65	<.001***

Note. MLUm, Mean Length of Utterance in Morphemes; VocD, vocabulary diversity; IPSyn, Index of Productive Syntax, $^{*}p < .05$. $^{**}p < .01$ $^{***}p < .001$.

All sessions were first transcribed using the ELAN transcription program (Crasborn & Sloetjes, 2008). The English transcriptions were produced by undergraduate research assistants who were trained to follow the English transcription conventions that were adopted by the lab, based on the conventions in the CHILDES/CHAT Manual (MacWhinney, 2000). At any point when a question arose as to the appropriate annotation, the questionable segment was discussed in the lab until a consensus was reached.

The ELAN transcripts were then checked by the lab manager and converted into CHAT format. The MOR function was then used to morphologically analyze all words within each transcript, and the morphologically analyzed transcripts were checked. This allowed us to use the KidEval utility within the Computerized Language Analysis program (Ratner & MacWhinney, 2016). KidEval automatically calculates various measures of spoken English language development and compares them to a hearing, monolingual English-speaking reference database constructed from the overall CHILDES database (https://childes.talkbank.org). KidEval compares each individual transcript to children of a similar age in the reference database, which is split into nine different 6-month age intervals between the ages of 18 and 71 months (e.g., 18–23 months, 24–29, etc.). KidEval provides the database group mean and standard deviation for each measure, as well as information about how much the comparison child's score differs from the database mean in terms of standard deviations. We analyzed vocabulary diversity using the VocD measure, syntactic complexity using MLUm, and syntactic diversity using IPSyn.

Results

Results are presented as responses to the three research questions raised earlier, starting with questions (1) and (2).

(1) Do deaf and hearing ASL–English bilinguals show increasing English vocabulary diversity, syntactic complexity, and syntactic diversity from ages 2 to 6 years?
(2) Do deaf and hearing ASL–English bilinguals have similar scores on English vocabulary diversity, syntactic complexity, and syntactic diversity from ages 2 to 6 years?

We addressed these questions using linear mixed effects models, with participants as a random effect (including by-participant intercepts and slopes), and hearing status as a fixed effect. We analyzed each measure using the glmmTMB package (Brooks et al. 2017) of R (R Core Team, 2021) running within RStudio (RStudio Team, 2019). We used the performance package (Lüdecke et al., 2021) to check model assumptions; we checked for normality using residuals and random effects, we checked for linearity, and we checked for homogeneity of variance. None of the model assumptions were violated. The full model did not converge for IPSyn, so we re-ran the model omitting by-participant slopes, and this second model converged. The R script used in our analysis is available in the Supplementary Material on OSF.

We summarize the statistical results in Table 4, and plot the overall distribution of raw scores in Figure 1. Plots of results by individual participant are provided with the full data set on OSF.

As shown in Table 4, age was a significant factor for all three measures. Group was not a significant factor for MLUm. Group was also not a significant factor for VocD, although the mean score for the hearing group was consistently higher than the mean score for the deaf group, and the variance is high. The interaction between age and group was not significant for either MLUm or VocD. For IPSyn, age, group, and the interaction between age and group were all significant.

(3) How do both groups of bilinguals' scores on the three language measures compare to a database of hearing, monolingual English-speaking children?

Z-scores were used to compare bilingual participants' English language skills to those of monolinguals. Z-scores indicate how far an individual score falls from the comparison mean in terms of the number of standard deviations, where a Z-score of −1 indicates that an individual score is 1 standard deviation below the mean, 0 indicates that an individual score is the same as the mean, and 1 indicates that an individual score is 1 standard deviation above the mean. The reference means and standard deviations are drawn from the KidEval reference database.

Figure 2 shows the distribution of Z-scores for participants on all three language measures by group. Assuming a normal distribution of monolingual scores in the KidEval database, we expect about 50% of monolingual scores to fall below the monolingual mean. The majority (74–95%) of Z-scores for both groups of bilinguals fell below the monolingual mean (i.e., $Z < 0$) on all three language measures, as shown in Table 5. It is important to note again, however, that the data are not cross-sectional; each

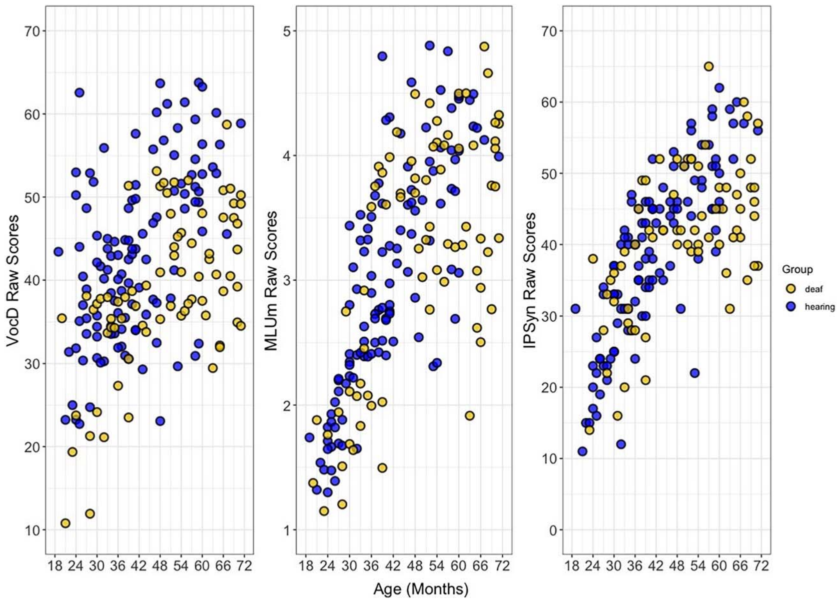

Figure 1. Spoken English Raw Scores by Age for American Sign Language–English Bilinguals. *Note.* VocD, vocabulary diversity; MLUm, Mean Length of Utterance in Morphemes; IPSyn, Index of Productive Syntax. Each child contributes more than one data point to each scatterplot.

Table 5. Distribution of *Z*-scores by group

Language measure		**Z < 0**		
	Monolingual expected	**Deaf bimodal bilingual (chronological age)**	**Deaf bimodal bilingual (hearing age)**	**Hearing bimodal bilingual**
VocD	50%	95%	72%	74%
MLUm	50%	84%	60%	86%
IPSyn	50%	84%	58%	83%
		Z < −1.5		
VocD	6.7%	30%	9%	7%
MLUm	6.7%	16%	1.5%	6%
IPSyn	6.7%	14%	6%	8%

Note. MLUm, Mean Length of Utterance in Morphemes; VocD, vocabulary diversity; IPSyn, Index of Productive Syntax.

bilingual participant contributes different numbers of scores to each group.

In order to get an idea of the magnitude of difference between the two groups of bilinguals and the monolingual scores in the KidEval database, we also looked at the percentage of scores that fell more than 1.5 standard deviations below the mean ($Z < -1.5$). There is no standard to rely on for potentially clinically significant scores on language samples of bimodal bilinguals, so we selected 1.5 SD as one of the options that is used for other standardized measures and one that would be more conservative in identifying potentially significant delays. Again, assuming a normal distribution for the monolingual database, about 6.7% of scores are expected to fall 1.5 standard deviations below the mean. The hearing bimodal bilinguals had roughly this number of scores on the measures VocD and MLUm, and a slightly higher number on IPSyn (see Table 5). However, there were a greater proportion of such scores for the deaf bilinguals on all three language measures.

In view of the fact that the deaf bimodal bilinguals received access to spoken language after CI activation, we determined each child's "hearing age" for every observation by using their activation date rather than their birthdate. We then compared the score for each session against the monolingual database for children in the same age band as the deaf participants' hearing age. The results of this comparison are also given in Table 5, under the heading "Deaf bimodal bilingual (hearing age)." Using the hearing age standard, the percent of scores below the mean is similar to or less than the percent for the hearing bimodal bilinguals. Looking at the percent of scores over 1.5 standard deviations below the mean, the deaf bilinguals are again similar to or less than the corresponding scores for the hearing participants.

Discussion

We analyzed spoken English data from the largest set of spontaneous speech samples from deaf and hearing ASL–English bilingual children to-date. We investigated which factors (age and hearing status) predicted English-language outcomes, as well as how the bilinguals compared with hearing, monolingual English-speaking children.

Using a generalized linear mixed effect model, we found that scores on English-language measures of vocabulary diversity (VocD), syntactic complexity (MLUm), and syntactic diversity (IPSyn) increased with age. This is unsurprising given that all participants had cumulatively more exposure to English as they got older. We also found that hearing status (deaf or hearing) significantly predicted scores on only one out of the three

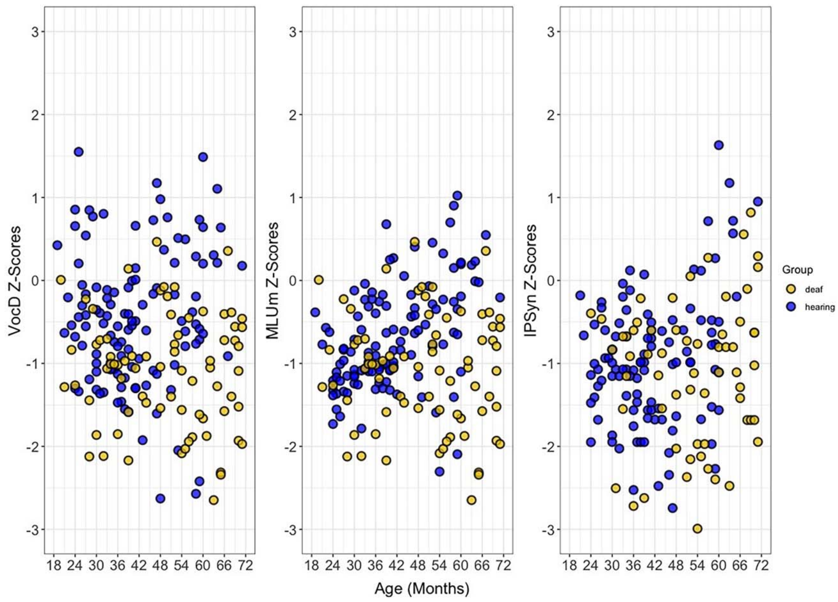

Figure 2. Spoken English Z-scores by Age for American Sign Language–English Bilinguals. *Note*. VocD, vocabulary diversity; MLUm, Mean Length of Utterance in Morphemes; IPSyn, Index of Productive Syntax. Each child contributes more than one data point to each scatterplot.

language measures, IPSyn, although a larger sample size might have led to significance for group on VocD as well (see Table 4). Potential differences between the results for the deaf and hearing groups would be consistent with what is understood about how input affects bilingual language development, since the deaf ASL–English bilinguals were exposed to English later than the hearing bilinguals (Unsworth, 2016). They also likely continued to have less exposure to English after cochlear implantation because of periods of processor disuse and differences in sound quality.

Turning to the Z-scores analyses, results were consistent with expectations based on previous studies with speech–speech bilinguals. When compared with chronological age cohorts of hearing, monolingual English speakers, both groups of ASL–English bilinguals tended to score below the monolingual mean at higher rates than would be expected for a group of monolinguals, based on a normal distribution. This is unsurprising given that the bilinguals received less exposure to spoken English than the monolinguals. In terms of the magnitude of this difference, the deaf bilinguals tended to score lower than 1.5 standard deviations below the mean more than would be expected for monolinguals on all three language measures. However, when we compared the deaf children to hearing monolinguals who matched their "hearing age" by taking into consideration the age of activation of their cochlear implants, they patterned closer to the hearing bilinguals.

For a full picture of the language skills of the participants, it would be vital to assess their ASL as well as their English. A similar approach has been argued for assessing bilingual children with other language pairs (Castilla-Earls et al., 2020). Unfortunately, it is much more challenging and time consuming to do analyses such as the ones presented here for ASL, using language sample analyses. There is no automated system for conducting language analyses, and no comparison group database against which to measure results. In ongoing work, we are developing and applying LSA techniques to data that we previously collected with deaf children of deaf parents (Lillo-Martin et al., 2017, 2021). Our preliminary conclusion from this work is that an ASL version of IPSyn is more sensitive to language development in children ages 2–5 years than is application of MLU to sign language data. There are also unfortunately few tests of ASL development for preschool/early school age children with large norming samples. One existing test is the ASL-Receptive Skills Test (Enns & Herman, 2011). As mentioned earlier, a subset of the current participants were given the ASL-RST, and performed age-appropriately.

While LSA is an important tool for assessing the language development of bilingual children, including bimodal bilinguals, it has limitations. In addition to the time and expertise that are needed to conduct LSA, it cannot capture the full extent of a child's linguistic abilities. Language samples provide a limited snapshot of a child's production capabilities, underestimating the child's full knowledge since a child might not happen to produce utterances of which they are capable during the observation period. In addition, a language sample study does not assess children's comprehension abilities, which may well supersede their production.

We do want to stress that the participants in this study had very good access to both ASL and English, and we recognize that this is not the case for all DHH children. Nevertheless, they also differed in factors such as number of deaf/signing family members, birth order, educational and/or child care experiences, etc. While such factors may also affect the timecourse of language development, given the small size of our sample it is not possible to draw any conclusions about how these factors might specifically have influenced the results of this study.

Implications

Children acquiring a sign language and a spoken language are bilingual, and therefore expectations regarding milestones of development in each language should consider this factor. With the recognition of their sign language, bilingual deaf children may be progressing in the development of their spoken language at a different pace compared with monolingual children. Thus, previous studies that used deaf children's slower pace of development in spoken language to justify excluding the use of sign language must be reexamined in light of all that is known about bilingual language development (see also Hall et al., 2019). Furthermore, the benefits of early bilingualism for DHH children far outweigh the potential risks of severe effects from language deprivation, and a typical bilingual difference in pace as compared with monolinguals should not be considered problematic.

This is not to say that all DHH children who are exposed to a natural sign language are developing language typically. Many of these children experience a period of no accessible input, which surely affects their language development, and the possible effects of lower quantity and quality of their signed input are currently unknown. Nevertheless, understanding the factors that are known to affect bilingual language development will help to calibrate expectations regarding the pace of achieving various milestones.

Given the prevalence of periods of language deprivation for DHH children, the magnitude of the consequences of this situation cannot be overstated. Early accessible language input is crucial for the development of multiple cognitive and social–emotional abilities, including executive function (Goodwin et al., 2021; Hall et al., 2018), Theory of Mind (Schick et al., 2007), and numeracy (Carrigan et al., n.d.; Langdon et al., 2020). Many parents are advised to pursue a monolingual spoken language approach initially, with the reassurance that their DHH child can learn a sign language later if it turns out to be desirable (Sugar, 2015). However, this approach ignores the serious consequences for children lacking early, accessible language input. Additionally, the view that sign language can be learned later overlooks the well-documented critical period for sign language development (Mayberry & Kluender, 2018).

What this discussion makes clear is that monitoring the development of both speech and sign is critically important. We stress that we do not advocate low expectations for deaf and hearing ASL–English bilinguals; rather, we ask that speech–language pathologists, early interventionists, educators, and other service providers draw on the knowledge base that has already been developed based initially on speech–speech bilinguals and apply this to sign–speech bilinguals. As such, we support the use of methods proven to be effective in evaluating bilinguals, such as using converging evidence from parent and teacher reports, LSA, and evaluation of learning potential using dynamic assessment (Castilla-Earls et al., 2020; Chen Pichler et al., 2014; Holcomb & Lawyer, 2020; Mann et al., 2014).

Because we need to assess skills in both of a child's languages, we also need to support the study of sign language development and deaf researchers creating knowledge of sign language acquisition, in order to have valid and reliable measures of ASL (Henner et al., 2019; Holcomb & Lawyer, 2020). Toward this end, we encourage cross-disciplinary research collaborations and the recruitment and support of deaf students in the audiology, speech language pathology, linguistics, education, and early intervention fields. Furthermore, more resources should be dedicated to assisting hearing parents and family members in learning a natural sign language, and serious efforts should be made to increase the inclusion of deaf mentors and deaf educators as role models (Cawthon et al., 2016; Clark et al., 2020; Gale, 2021; Hecht, 2020; Wilkinson & Morford, 2020).

Conclusion

We introduced the current study by proposing three research questions. These questions ask about two kinds of comparisons: first, between the deaf and hearing bilingual children; and second, between the bilinguals and monolinguals. Any differences observed between the deaf and hearing bilingual participants in their development of spoken English could be attributed to the later start, lower quantity, and different quality of the English input that the deaf children received using their cochlear implants as compared with the English input received via typical hearing for the hearing children. Possible differences between the bilinguals as a group compared with the monolinguals could be attributed to the fact that as bilinguals, they divide their time between two languages. This entails that the timing, amount, and quality of input for each language separately are likely to be less than what a monolingual would experience. As noted in the introduction, multiple studies of bilingual children attest that such differences contribute to differences in the pace of acquiring linguistic fluency including vocabulary diversity, syntactic complexity, and syntactic diversity. Additionally, a bilingual's production of both of their languages may differ from that of a monolingual because of interaction between the two languages in domains such as phonology and syntax (e.g., Serratrice, 2013). Hence, the mere exposure to a sign language is not clearly a causal factor when looking at differences in the pace of spoken language development between monolingual and bilingual DHH children.

Given the known and expected differences in the development of a majority language by bilingual children, we believe that overall group differences between the bilinguals and monolinguals in our study should not be worrisome. Differences in the pace of language development between bilinguals and monolinguals are not necessarily in themselves indications of language delay or deviance; rather, they are indications of bilingualism. Previous research with deaf children who had early experience with a natural sign language and attended schools providing instruction in ASL (Henner et al., 2019; Hrastinski & Wilbur, 2016) leads us to expect that these children will show good academic achievement in the community language. Moreover, they will experience the academic, social, and personal benefits of bilingualism (Holcomb & Lawyer, 2020). We support shifting from a subtractive approach to bilingualism wherein English development occurs at the expense of the minority language toward an additive approach to bilingualism in which children are supported in the development of both (or all) of their languages and one form of expression is not seen as superior to another.

It is important to remember that the participants in this study all had the benefit of early exposure to fluent ASL from their deaf, signing parents. Most DHH children have hearing parents who were unfamiliar with deaf culture and natural sign languages before their child was born. If these children are exposed to a sign language, they may become sign–speech bilinguals, but the input factors we discussed earlier—timing, quantity, and quality of accessible linguistic input—will likely influence the course of development of both their sign language and their spoken language. One recent study (Caselli et al., 2021) observed ASL vocabulary development in DHH children of hearing parents. They found that children whose exposure to ASL began by the age of 6 months showed ASL vocabulary sizes and rates of vocabulary growth resembling those of DHH children with deaf, signing parents. Children whose exposure began between 6 and 36 months had somewhat smaller vocabularies, an indication of the effect of input timing. However, they also made rapid gains.

For children acquiring both a sign language and a spoken language with more variable input, tracking progress in both languages becomes even more important, given the major impact that is likely to result from extended periods with no, little, or poor-quality accessible input. Data like that presented here can serve as a benchmark for the range of spoken language scores that might be expected for bilingual children, using those with full and early access to both languages as the appropriate standard. Educators and service providers can benefit from expanded information about typical bilingual developmental effects displayed by deaf and hearing ASL–English bilinguals.

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Data availability

All scores on language measures, plots of individual results, and the R script used for analysis are available at: https://osf.io/te7ma/?view_only=04aa001f9b9b4821b8e61b9439eeb1bf.

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