Deaf Children of Hearing Parents Have Age-Level Vocabulary Growth When Exposed to American Sign Language by 6 Months of Age

Naomi Caselli, PhD[1], Jennie Pyers, PhD[2], and Amy M. Lieberman, PhD[1]

Objective To examine whether children who are deaf or hard of hearing who have hearing parents can develop age-level vocabulary skills when they have early exposure to a sign language.

Study design This cross-sectional study of vocabulary size included 78 children who are deaf or hard of hearing between 8 and 68 months of age who were learning American Sign Language (ASL) and had hearing parents. Children who were exposed to ASL before 6 months of age or between 6 and 36 months of age were compared with a reference sample of 104 deaf and hard of hearing children who have parents who are deaf and sign.

Results Deaf and hard of hearing children with hearing parents who were exposed to ASL in the first 6 months of life had age-expected receptive and expressive vocabulary growth. Children who had a short delay in ASL exposure had relatively smaller expressive but not receptive vocabulary sizes, and made rapid gains.

Conclusions Although hearing parents generally learn ASL alongside their children who are deaf, their children can develop age-expected vocabulary skills when exposed to ASL during infancy. Children who are deaf with hearing parents can predictably and consistently develop age-level vocabularies at rates similar to native signers; early vocabulary skills are robust predictors of development across domains. *(J Pediatr 2021;232:229-36)*.

Language learning in early childhood is critical for communication and social interaction, but has even more far-reaching effects on child development. All languages, including sign languages like American Sign Language (ASL), can equally support healthy child development. Except in extreme cases of abuse, early exposure to language is virtually guaranteed for hearing children.[1] Most prelingually deaf and hard of hearing children, however, are at risk of limited access to language early in life, because they cannot hear spoken language and their parents generally do not know a sign language like ASL. Delayed first language acquisition has a host of negative consequences across domains.[2-10] As such, language—not simply hearing—is a critical outcome of any rehabilitation for children who are deaf.

Despite substantial advances in hearing technology and early intervention, most deaf and hard of hearing children do not develop age-expected spoken language skills.[11-20] Although some known factors can affect children's odds of learning spoken language (eg, age of implantation),[21] spoken language outcomes are nevertheless highly variable, unpredictable, and often below age-level even after following the American Academy of Pediatrics early intervention guidelines.[11-20,22] This raises the concern that without age-appropriate skills in another first-language (eg, ASL), early language delays may set the stage for further language and cognitive delays.

Children who are deaf born to parents who are deaf who use a sign language have unfettered access to language during infancy, and thus are spared the effects of language deprivation.[23-27] However, 95% of children who are deaf are born to hearing parents[28] who do not know a sign language when their child is born.[29] Many organizations in the US recommend that families consider learning ASL, but some argue that hearing parents are likely unable or unwilling to learn a new language to communicate with their child.[11] On the whole, sign language outcomes among children with hearing parents are variable.[30-34] The conditions necessary and/or sufficient for deaf and hard of hearing children to develop age-appropriate ASL skills remain unknown. We sought to determine what is the trajectory of ASL vocabulary acquisition for deaf and hard of hearing children with hearing parents and can deaf and hard of hearing children with hearing parents acquire age-appropriate ASL vocabularies when they begin acquiring ASL in infancy?

Methods

The Boston University Institutional Review Board approved this cross-sectional study. Inclusion criteria were parents who were hearing and had a deaf or hard of hearing child; children were learning ASL; and children were between 8 months

ASL	American Sign Language
CDaCI	Childhood Development after Cochlear Implantation

From the [1]Wheelock College of Education and Human Development, Boston University, Boston, MA; and [2]Department of Psychology, Wellesley College, Wellesley, MA

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and 5 years old. Because the target population is small, rather than setting a target sample size, our goal was to recruit as many participants as possible in the study period (June 2017 to December 2019). Three families with slightly older children requested to participate, and were included. The target population is hard to reach: deaf and hard of hearing children who use ASL are a subset of a low-incidence population, there is no registry from which to sample, and clinic-based sampling plans may systematically under-represent children who are learning sign language who may not use hearing technology or receive speech therapy. As such, we used snowball sampling and social media advertisements to recruit participants. Recruitment notices were also sent to ASL-based parent-infant programs. To confirm parents' basic knowledge of ASL, parents completed a 3-question vocabulary check, in which they watched a slow motion video of 3 ASL signs that new signers would likely know (MOTHER, NAME, and DEAF) and were asked to type in the meaning of the sign. If parents did not know any items, we called to confirm that families met the inclusion criteria.

We recruited 124 hearing parents with deaf and hard of hearing children from 28 US states and 2 Canadian provinces. Thirteen participated in the study twice while their child was still within the target age range. The average age was 35 months (median, 34 months; range, 9-67 months). We chose the age range to correspond with the age range of the assessment tool (the ASL-CDI 2.0). A total of 46 reports from children who had additional diagnoses related to language acquisition (eg, CHARGE syndrome, Down syndrome, or autism spectrum disorder; n = 35) and/or who were blind or had low vision (n = 30) were tested but excluded from the following analyses. Children with other diagnoses (eg, conditions that impact fine motor or visual motor coordination) were included. The rate of additional diagnoses in our sample mirrors other reports of the deaf and hard of hearing population.[35] The final sample included 88 reports from 78 children with hearing parents (55% female, 40% male, 6% did not report). The racial breakdown was 9% African American or Black, 6% Asian, 2% Native American, 78% White, and 1% multiracial (3% did not report). Participant ethnicities were 11% Hispanic/Latinx and 88% Not Hispanic/Latinx (1% did not report).

Reports were divided into 2 groups: those from children exposed to ASL between birth and 6 months (n = 69; average age of ASL exposure = 1.22 months) and those from children exposed after 6 months (n = 19; average age of ASL exposure = 22.5 months, range of ASL exposure = 6-36 months). We chose the 6-month cut-off because it is the earliest age at which children begin to learn word meanings, and current recommendations from the American Academy of Pediatrics for deaf and hard of hearing children suggest that they receive language intervention by age 6 months.[36]

Measures

Parents gave informed consent and completed an online questionnaire about the child's language background, then completed the ASL-CDI 2.0, an authorized ASL adaptation of the MacArthur Bates Communicative Development Inventory. The MacArthur Bates Communicative Development Inventories are a gold standard assessment of early language, have been used in thousands of studies of early language, including several studies of children who are deaf, and are widely used in clinical settings. Critically, validation work on this instrument indicates that hearing, signing parents can reliably complete the ASL-CDI 2.0.[37] In this assessment, parents viewed a video of each of 534 signs, and indicated whether their child did not know, understood, or understood and produced the sign. Parents could view an English translation of the sign as needed. All questions and instructions were presented in ASL and in written English. Parents completed the ASL-CDI 2.0 in 3 self-paced parts within one week. They were compensated $25 per section, plus a $15 completion bonus. Vocabulary scores were calculated as a proportion of the signs the child knew of the questions the parent answered due to missing data. Incomplete reports in which parents answered fewer than 30 items (6% of the test) were excluded (n = 3). Proportion of known signs on a subset of as few as 30 items on the MB-CDI are generally highly correlated with proportion of known signs on the whole test.[37,38] Using proportions rather than counts allows us to exclude signs the parent does not know from the child's score, which mitigates concerns that parents may indicate a child does not know a sign simply because the parent does not know the sign. The median number of answers the parents provided was 508 (minimum, 58; first quartile, 437.5). Data, with identifiable information redacted, are available at https://osf.io/s6y4w/.

Results

Children's language backgrounds varied (**Table I**). Some had no sources of ASL exposure other than a parent, and some had many signing family members and friends. Although a handful of primary caregivers (n = 6) learned ASL in childhood, most learned as adults.

We compared the participants in this study with a published normative dataset of deaf and hard of hearing children learning ASL under ideal conditions from their deaf signing parents ($n_{children}$ = 104, $n_{records}$ = 142).[37] These children generally acquire language along a similar trajectory as typically developing hearing children and provide a reference point for healthy ASL vocabulary acquisition.

Data Visualization

If deaf and hard of hearing children with hearing parents can successfully acquire ASL vocabulary, their development should overlap with the children with deaf signing parents completely (ie, approximately 68% of the data between ± 1 SD, equally distributed above and below the mean). This pattern was borne out when we plotted vocabulary size by age for the children who began learning ASL before 6 months; the distribution was nearly identical to that of deaf and hard of hearing children with deaf signing parents (**Figure 1**). This

Table I. Parent-reported language use and background variables for reports from deaf and hard of hearing children with hearing parents

Characteristics	Early	Late	X	t	df	P value
	(n = 69)	(n = 19)				
Dominant language during family activities			0.86		3	.84
ASL	7 (10%)	2 (11)				
English	7 (10)	2 (11)				
Mix of ASL and English	52 (75)	15 (79)				
Did not report	3 (4)	0				
Child's frequency of ASL use			0.59		3	.90
Always	23 (33)	6 (32)				
Often	26 (28)	6 (32)				
Sometimes	16 (23)	6 (32)				
Rarely	4 (6)	1 (5)				
Never	0	0				
Child's use of hearing technology			5.44		4	.25
Hearing aids	24 (35)	9 (47)				
Cochlear implants	6 (9)	2 (11)				
Both	18 (26)	3 (16)				
None	21 (30)	4 (21)				
Did not report	0	1 (5)				
Child's deaf family members			0.23		3	.97
None	39 (57)	10 (53)				
Siblings	12 (17)	3 (16)				
Extended family	9 (13)	3 (16)				
Did not report	9 (13)	3 (16)				
Child's participation in early intervention			5.49		2	.06
Currently enrolled	47 (68)	18 (95)				
Not currently enrolled	20 (29)	1 (5)				
Did not report	2 (3)	0				
Primary caregiver's level of education			<0.01		1	>.99
Some college	61 (88)	17 (89)				
No college	8 (12)	2 (11)				
Child's hearing level			1.82		1	.18
Mild/moderate	16 (23)	8 (42)				
Severe/profound	53 (77)	11 (58)				
Child's ability to understand spoken English (0-5)	2.09 ± 1.83	1.78 ± 1.83		0.66	27.6	.52
Age primary caregiver began learning ASL	23.6 ± 9.38	29.2 ± 5.99		1.47	32.6	.15
Primary caregiver's self-reported ASL skill (1-10)	5.45 ± 2.46	4.61 ± 2.13		−2.90	37.6	**.01**

Values are number (%) unless otherwise indicated or mean ± SD.
Significant *P*-values in bold.

provides initial evidence that deaf and hard of hearing children with hearing parents develop age-appropriate ASL vocabulary if exposed in infancy. For children who began learning ASL after 6 months, the distribution was more dispersed and shifted downward.

To examine the effects of age of exposure on vocabulary development, we calculated children's language age (age at test minus age of ASL exposure). The outcomes for children who began learning ASL before 6 months were even better when considering language age; almost all children fell within the expected range for their language age (**Figure 1**). The children who began learning ASL after 6 months still had a more dispersed distribution relative to the normative sample, and some had even larger vocabularies than the norming sample at the onset of learning which would indicate a more rapid pace of vocabulary acquisition when acquisition begins at an older age.

Statistical Analyses

Using the R packages lme4 and sjPlot, we analyzed vocabulary scores using mixed-effects linear regressions for expressive and receptive vocabulary as measured by the proportion of signs the child knew (**Table II**). *P* values were computed using the Kenward-Roger approximation for the degrees of freedom, and *P* values of less than .05 were used to determine significance. We compared vocabulary growth in the norming sample to each group of deaf and hard of hearing children with hearing parents (exposed before 6 months vs norming sample, and exposed after 6 months vs norming sample) using an age by group interaction. Group was dummy coded, with the normative sample as the reference group. The model also included random effects of child.

As expected, age was a robust predictor of expressive and receptive vocabulary. Group was not a significant predictor, with the exception of a difference in receptive vocabulary in early exposed children relative to the norming sample. However, the critical term in the regression is the interaction between groups and chronological age. If either group had slower than expected vocabulary growth, we would expect a significant interaction between age and group, that is, the effect of age would be weaker in that group compared with

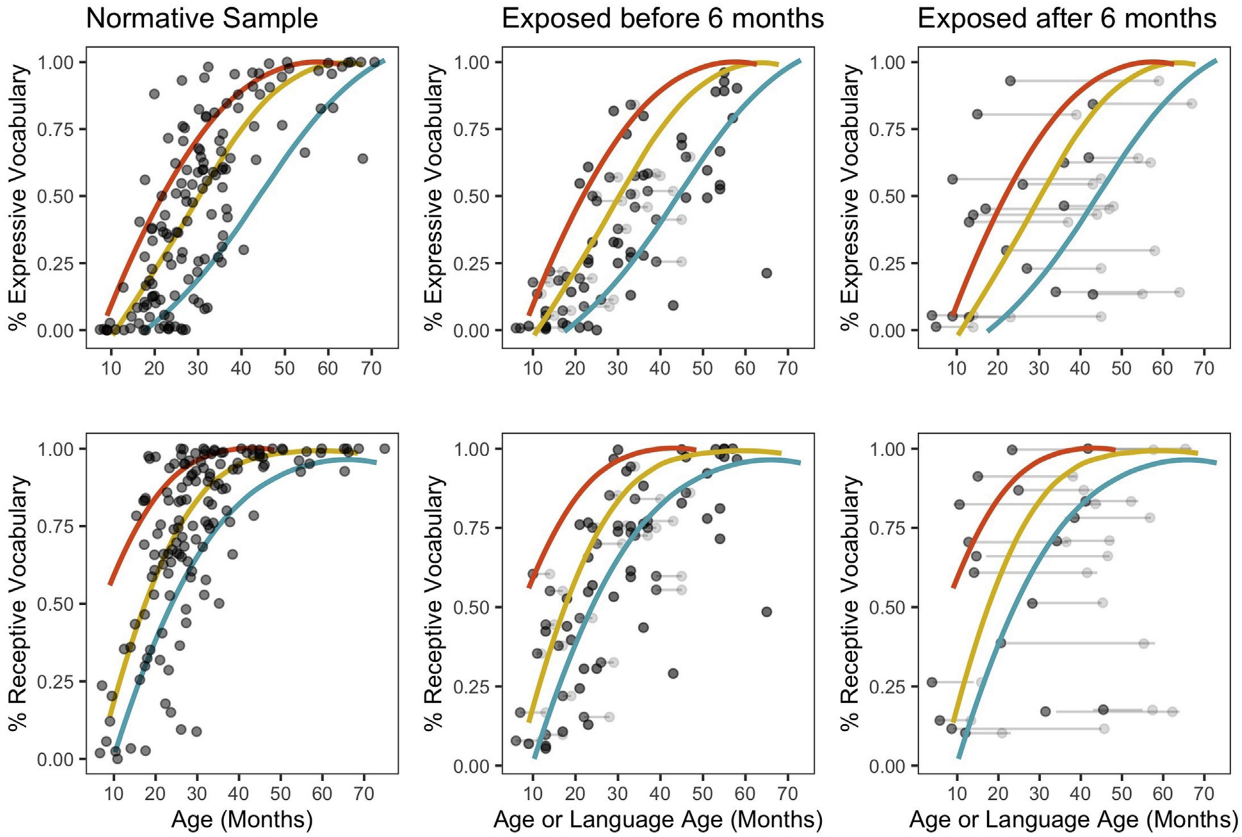

Figure 1. Deaf and hard of hearing children's ASL vocabularies by age (light grey) or language age (age–age of ASL exposure; dark grey). Red, yellow, and blue lines indicate the normal range (16th, 50th, and 84th percentiles) for deaf and hard of hearing children with deaf, fluent signing parents. Points jittered for anonymity.

the normative sample. In contrast, if children's vocabularies are developing at an age-appropriate rate, the interaction term between age and group would not be significant. In the early exposed group, an analysis revealed that vocabulary growth, as illustrated in the interaction between age and group, was not significantly different from the normative sample for either receptive or expressive vocabulary. In the later exposed group, the interaction term was not significant for receptive vocabulary, but was significant for expressive vocabulary. Together, our statistical analysis and visualization of the data suggest that early exposed deaf and hard of hearing children with hearing parents show ASL vocabulary sizes and rates of vocabulary growth that largely resemble those of deaf and hard of hearing children with deaf parents.

Table II. Model of proportion of signs known

	Expressive vocabulary size			Receptive vocabulary size		
Predictors	**Estimates**	**CI**	***P* value**	**Estimates**	**CI**	***P* value**
(Intercept)	−0.14	−0.23 to −0.04	**.004**	0.32	0.23 to 0.42	**<.001**
Age	0.02	0.02 to 0.02	**<.001**	0.01	0.01 to 0.02	**<.001**
Exposed before 6 months	0.02	−0.14 to 0.18	.80	−0.17	−0.33 to −0.01	**.03**
Exposed after 6 months	0.12	−0.24 to 0.49	.51	−0.15	−0.49 to 0.19	.39
Age * exposed before 6 months	−0.00	−0.01 to 0.00	.06	0.00	−0.00 to 0.01	.71
Age * exposed after 6 months	−0.01	−0.02 to −0.00	**.01**	−0.00	−0.01 to 0.00	.23
Random effects						
σ	0.01			0.05		
τ_{00}	0.03 Child			0.00 Child		
ICC	0.69			0.08		
N	182 Child			182 Child		
Observations	230			230		
Marginal R/Conditional R	0.551/0.863			0.435/0.479		

Reference group was deaf and hard of hearing children with parents who are deaf.
Significant *P*-values in bold.

Discussion

This study reports evidence that deaf and hard of hearing children with hearing parents can reliably develop chronological age-expected vocabulary skills given the right language learning environment. Although prior research with children with longer delays in age of ASL exposure has shown highly variable language outcomes among deaf and hard of hearing children with hearing parents, we found that children who begin learning ASL by 6 months old largely develop strong vocabularies at the same rate as native-signing children.[30-34]

Children exposed early to ASL generally successfully learned ASL vocabulary. Their expressive vocabularies were equivalent to those of native-signing children. They had statistically smaller receptive vocabularies relative to native-signing children, but as illustrated in the data visualization the difference is small, and the distribution largely mirrors the normative sample (**Figure 1**). These results counter the argument that hearing parents should not attempt to learn ASL because they cannot acquire the fluency to become strong language models. Hearing parents varied widely in their ASL fluency, and most reported only moderate skills. This variation makes the similarity in vocabulary acquisition between children of hearing and deaf parents all the more striking. Children's success in learning ASL may or may not be primarily attributable to parents' ASL proficiency; hearing parents may support their children's language development in many ways, both directly (learning and using ASL with their deaf or hard of hearing child) and indirectly (eg, enrolling their child in early intervention that uses ASL, using a fluent signing childcare provider, or seeking out a signing peer group).

Deaf and hard of hearing children who began learning ASL between 6 and 36 months of age had more variable, smaller expressive vocabularies than children with deaf signing parents, although the sample size in this group was relatively small (n = 19). However, when considering their "language age," their vocabularies were variable but often larger than expected (ie, a 4-year-old who had been learning ASL for 12 months knew more signs than the average 12-month-old infant in the normative sample). This pattern aligns with that reported in studies of individuals with long delays in first-language exposure and of international adoptees adopted between 2 and 5 years of age, for whom vocabulary acquisition is generally faster than that observed among infants.[39,40] Although language exposure was somewhat delayed, the children in this study all began learning ASL before age 3, which is earlier than children in most studies of delayed language exposure whose outcomes are generally poor.[2,6,39,41-43]

The success learning ASL stands in marked contrast to highly variable, generally poor outcomes with spoken English vocabulary acquisition reported in the literature. **Figure 2** illustrates published reports of expressive spoken English vocabulary size estimates for deaf and hard of hearing children that used the English MacArthur Bates Communicative Development Inventory: words and

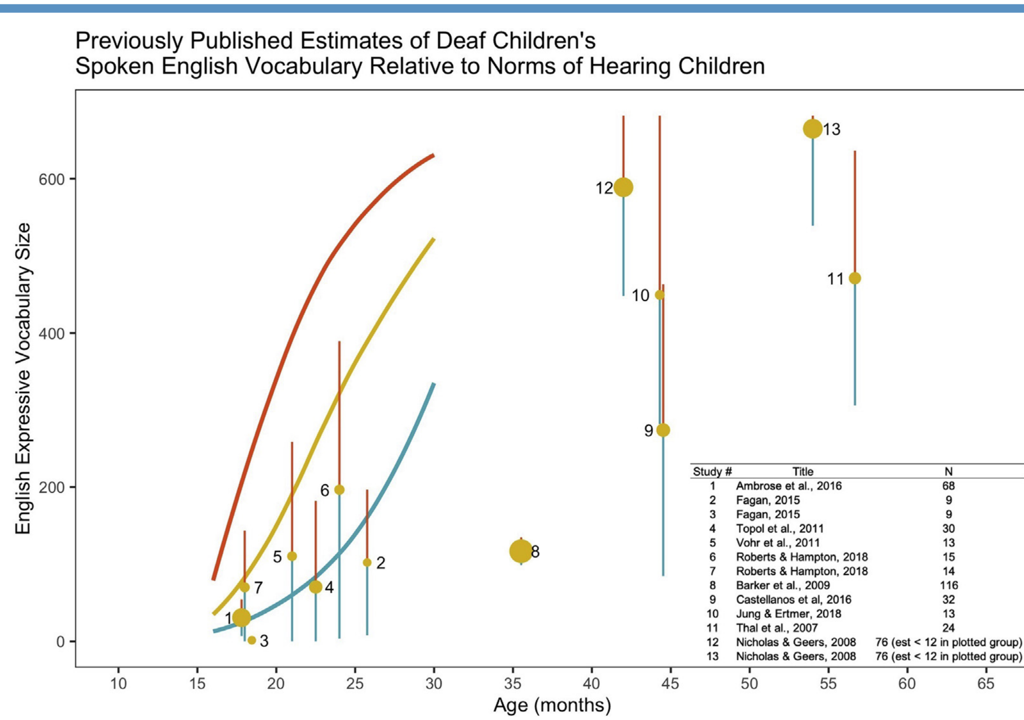

Figure 2. Deaf and hard of hearing children's English vocabularies (yellow dots and vertical lines) compared with hearing norms (growth curves).[44,45] Dot size corresponds to sample size. Yellow = mean or 50th percentile; blue = 1 SD below the mean or the 16th percentile; red = 1 SD above the mean or the 84th percentile.

sentences assessment.[4,5,46-53] With few exceptions,[54,55] deaf and hard of hearing children generally have smaller spoken English vocabularies than age-matched hearing peers.[56-71] ASL exposure seems to be a more reliable means of developing age-expected vocabularies than interventions focused on spoken English.

We could not determine whether early exposure to ASL is sufficient for optimal vocabulary development, or if families who begin using ASL before 6 months are unique in ways that make them better able to support ASL acquisition (eg, affinity for signing, or access to early intervention). More work is needed to determine the specific environmental conditions necessary for language success, including the threshold amount of ASL exposure needed, the proficiency of the language models, and the age of the child at first exposure. Additionally, the children in this study were predominantly white and well-educated, and may have disproportionately high access to resources (eg, high-quality early intervention), the children in this sample may be advantaged relative to the population of all deaf and hard of hearing children.

Although early vocabulary size is generally a robust predictor of many aspects of language proficiency, cognitive development, and academics, more work is needed to determine whether exposure to ASL during infancy can lead to typical development across these domains.[72-74] Individuals with severely delayed exposure to a first language can rapidly learn vocabulary but lag in other areas of language acquisition.[39]

Although hearing parents can successfully complete the ASL-CDI 2.0, and similar vocabulary checklists have been used with children of hearing parents in a number of other studies,[37,39] it remains possible that hearing parents underreport their children's vocabulary because of limitations in their own vocabularies.

Readers may be convinced that children can successfully develop ASL vocabulary skills, but fail to see the usefulness of ASL proficiency when most of the world uses a spoken language like English. First, learning ASL at an early age does not preclude learning English—in fact, preliminary evidence suggests that children with early exposure to ASL from parents who are deaf have comparable spoken English skills with their hearing peers.[75,76] Although the ability to use a majority language is undoubtedly useful, early mastery of any first language is critical for both communication and child development. Deaf and hard of hearing children are not guaranteed to master a first language if they are exposed to spoken language alone. Early exposure to ASL may offer families a reliable way to ensure timely language and cognitive development.

Despite substantial gains in technology and early intervention, limited language exposure during childhood often significantly harms deaf and hard of hearing children's development. There has been no documented language learning environment that reliably leads to age-appropriate development. Despite robust evidence for successful outcomes among deaf and hard of hearing children with deaf parents, concerns have persisted that deaf and hard of hearing children with hearing parents may not have such successful outcomes, and learning ASL may be prohibitive.[11] The evidence here may assuage concerns: deaf and hard of hearing children with hearing parents can consistently develop healthy ASL vocabularies, and—because there are no other environments that predictably lead to age-expected vocabulary growth—exposing children to ASL during infancy may well be worthwhile. ■

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Reprint requests: Naomi Caselli, Wheelock College of Education and Human Development, Boston University, 2 Silber Way, 3rd Floor, Boston, MA 02215. E-mail: nkc@bu.edu

Data Statement

Data sharing statement available at www.jpeds.com.

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