What Does Bimodal Bilingual Vocabulary Acquisition Look Like in Deaf Children with Hearing Parents?

Linghui Eva Gan, Angelica Llerena, Diane Lillo-Martin, and Deborah Chen Pichler

1. Introduction

Studies have estimated that more than 90% of deaf and hard-of-hearing children are born to hearing parents (hereafter DoH children; Mitchell and Karchmer 2004). Since their parents do not know a sign language, and their hearing levels restrict natural access to spoken language, many of these children experience early periods without full language access, until such time as they begin receiving exposure to signing and/or receive hearing technology permitting improved access to spoken language (Hall et al. 2017).

Many parents opt for an approach that focuses on the use of hearing technology and spoken language exclusively. However, these entail inevitable delays before children are able to develop spoken language, and while some eventually develop speech on par with their hearing peers, many do not (Ching et al. 2017; Hall et al. 2019). Exposure to a natural sign language could provide crucial early linguistic experience; however, pervasive effects of audism and linguicism mislead many parents and early intervention providers of deaf children into viewing early sign language exposure as an impediment to spoken language development (e.g., Geers et al. 2017; c.f. discussions in Humphries 1975; Bauman 2004; Pontecorvo et al. 2023, a.o.). In this study, we present evidence that counters this view, supporting bimodal bilingual acquisition - the use of both a spoken language and a sign language - as an optimal option for DoH children.

In particular, this study investigates vocabulary development by DoH children. Previous research demonstrates that children's vocabulary development is correlated with overall grammatical development. For example, Devescovi et

* Linghui Eva Gan, University of Connecticut, linghui.gan@uconn.edu; Angelica Llerena, University of Connecticut, asa24003@uconn.edu; Diane Lillo-Martin, University of Connecticut, diane.lillo-martin@uconn.edu; Deborah Chen Pichler, Gallaudet University, deborah.pichler@gallaudet.edu.

We extend our heartfelt appreciation to the participating families and the full FamilyASL research team. Research reported in this publication was supported by the National Institute on Deafness and Other Communication Disorders of the National Institutes of Health under Award Number R01DC016901. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

 Proceedings of the 50th annual Boston University Conference on Language Development, ed. Romi Hill et al., 248-257. Somerville, MA: Cascadilla Press.

al. (2005) show a positive correlation between lexical development and Mean length of Utterance (MLU) for hearing monolingual children (ages 1;06–2;06) learning English or Italian. Lillo-Martin et al. (in prep.) observe a similar positive correlation between MLU and lexical development for deaf children of deaf parents (ages 1;05–4;02), with exposure to ASL from birth.

The literature investigating vocabulary development of DoH children who sign is still limited. Among existing studies, it has been shown that with early access to both American Sign Language (ASL) and English, these bimodal bilingual children display age-appropriate vocabulary development in both ASL and English. For example, parent reports on the ASL adaptation of the MacArthur Bates Communicative Development Inventory (ASL-CDI 2.0) (Caselli et al. 2020) collected by Caselli et al. (2021) show that DoH children (ages 0;08–5;08) who were exposed to ASL before 6 months display age-appropriate receptive and expressive ASL vocabulary comparable to Deaf children of signing Deaf parents (hereafter DoD children). Pontecorvo et al. (2023) investigate the relationship between ASL vocabulary and spoken English vocabulary in DoH children (ages 0;08–5;00). They analyzed parental reports of the ASL-CDI 2.0 (Caselli et al. 2020) and the 100-item short form of the English-CDI (Fenson et al. 2000) and found a significant positive correlation between ASL vocabulary and spoken English vocabulary for these children. Furthermore, children with strong ASL vocabulary also tend to have age-appropriate English vocabulary comparable to monolingual hearing children. Berger et al. (2024) show that among DoH children (ages 0;08–5;00) whose parents are learning ASL and provide ASL input to them, there is a significant positive correlation between parent's ASL skills and child's ASL vocabulary for older and middle age groups of DoH children. However, they did not find a similar correlation for younger DoH children; some of those participants displayed age-appropriate ASL skills even if their parents' ASL was weaker. Note that all these studies are based on parental reports.

In this study, we use longitudinal production data and parental reports to investigate vocabulary development in both ASL and spoken English of bimodal bilingual deaf children with hearing parents. We also compare the ASL results from these participants with analogous production data from deaf children of deaf parents.

1.1. The family ASL project

This study is part of the Family ASL Project (https://slla.lab.uconn.edu/family-asl/). The goal of the project is to investigate the path of language development for ASL-exposed DoH children in ASL and English, as well as their hearing parents' learning of ASL. Unlike most deaf children with hearing parents, the hearing parents in this project are learning ASL as a second language (L2) and provide both English and ASL input to their children, so these children are developing as bimodal bilinguals (Lillo-Martin et al. 2023; Chen Pichler et al. 2024). During the course of the project, the families also receive support in their ASL development from an ASL specialist, including ASL lessons tailored to each family and introduction to visual strategies. While

the overall project covers a wide range of topics and participants, this paper focuses on vocabulary development for a subset of the children in the study.

2. Method

2.1. Participants

In this study, we focus on five DoH children who were the first qualified participants to complete the majority of the full year-long study. They were 26–49 months old during the period of observations (see Table 1). All these children have a CI or hearing aid, and all are exposed to English and ASL input over the course of the study. According to parent reports, their first exposure to signing was before 12 months.[1] In fact, all participants but Nayla were exposed to sign before 6 months. At the beginning of participation, the primary language used at home differs across families. Furthermore, we observed variation in language use based on the language samples submitted by the families over the course of the study.

Table 1. Participant information.

Child	Age range of observations (months)	# of language samples analyzed	Hearing devices	Age of first exposure to sign	Early input before joining the study (Primary/ Secondary)
Ellie	26 _ 36	9	Bilateral CI	2 months	Sign_supported English/ English, ASL
Imani	29 - 40	9	Unilateral CI	birth	Spoken English/ Sign-supported English
Nayla	31 - 40	9	Bilateral CI	8 months	Sign-supported English/ ASL
Haven	38 - 49	9	Bilateral CI	4 months	Sign-supported English/ Spoken English
Yeira	38- 48	8	Hearing Aid	birth	Sign-supported English/ Spoken English

[1] On this question we did not ask parents to differentiate between exposure to ASL versus sign-supported English.

2.2. Measures and analysis

We adopted two measures to evaluate vocabulary development in this report: language sample analysis and the Communicative Development Inventory (CDI). Both measures were applied to both ASL and English development.

For the first measure, we calculated the *number of word types* in language samples that were recorded by parents. Naturalistic language samples of children interacting with their parents were collected on a weekly basis. Most sessions include activities like playing with toys and reading books. As these sessions were recorded by parents, there were no experimenters involved. Families were encouraged to use whatever languages they are comfortable with. For most of the time, the families used a combination of ASL and spoken English.

Because annotation of the language samples is time-consuming, analysis at this stage was conducted on selected monthly sessions. We annotated both ASL and English for 5-minute segments of the selected sessions. ASL annotations follow the conventions of the SLAASh project (Hochgesang 2022), making use of ID glosses from ASL Signbank (Hochgesang et al. 2017-2025). The English annotations follow the CHAT format used in the CHILDES project (MacWhinney 2000).

Based on these annotations, we analyzed the 5-minute segments to assess the children's expressive vocabulary. Specifically, we calculated the number of word types (i.e., the unique vocabulary) produced in ASL and in English, respectively. For example, if the same word was used three times in a session in the same language, we only counted it as one word type for that language. Moreover, because we wanted to capture the participants' vocabulary development in each language, we counted vocabulary used in ASL and English separately. This means that potential translation equivalents expressed in ASL and English were counted twice instead of being treated as one lexical concept. For instance, MOM in ASL and English "Mom' are counted as two different word types, one for each language, even when produced simultaneously. The results were then analyzed using R (version 4.4.1; R Core Team 2025).

For comparison, we also calculated the number of word types in ASL produced by four similar-aged ASL-learning DoD children (ages 28–42 months) from a separate study (Lillo-Martin et al. 2024; in prep.). Specifically, we identified the range of ASL word types in their production data based on a 5-minute segment of each session. The range is decided by the highest and the lowest number of word types produced among the four DoD children at the same age point. Note that the language used in the DoD sessions was ASL only.

The second measure we adopted was the MacArthur-Bates Communicative Development Inventory (CDI). We collected parents' responses up to three times over the course of the study. For English, we used the short form of the English-CDI (Fenson et al. 2000), alternating between Forms A and B. For ASL, we used a 100-item adaptation of the ASL-CDI 2.0, also with two alternating forms (Anderson 2002; Caselli et al. 2020). In this study, we will only focus on the expressive CDI scores for both languages.

3. Results
3.1. Number of word types in language samples

Figure 1 illustrates the number of word types the five DoH children in our project produced compared with the DoD children. The range of ASL word types produced by the DoD children is shown by the grey shading. The solid dots represent the number of ASL words produced by the DoH children at different age points; the vertical bar of each dot represents the number of spoken English words they produced at the same age point; and the triangle represents the total combined vocabulary (i.e., ASL plus English) produced by the DoH children.

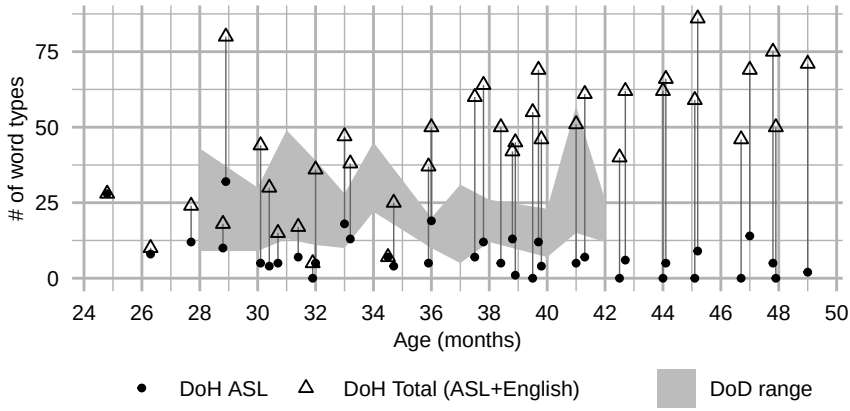

Figure 1. Number of word types produced by DoH children compared with DoD children. Figure created in R using the ggplot2 package (Wickham 2016).

If we compare just the ASL word types between the two groups, only a few of the DoH participants' observations (the solid dots) fall within the range of their DoD counterparts. Most of the DoH scores are lower, and there is no obvious increase over time. However, recall that these are bimodal bilingual children acquiring both English and ASL. If we consider the total word types combining English and ASL production, represented by the triangles, we observe an obvious increase over time. We conducted a correlation test using the cor.test function in R. As shown in Table 2, there is a statistically significant positive correlation between age and the total number of word types produced by the DoH children, with a moderate to strong correlation coefficient.[2] Their English word types, represented by the length of the vertical bars, also show an increase over time.

[2] The combined vocabulary types produced by the DoH children also appear to outperform the DoD children slightly. However, recall that for the DoH sessions, translation equivalents produced in ASL and English were counted twice, whereas the DoD sessions have ASL production only, so there is no such double crediting. For this reason, we choose to be cautious in making this comparison.

Table 2. Correlation between age and total vocabulary types of the DoH children.

Sample size	df	r	t-value	p-value	CI lower	CI upper
38	36	0.68	5.568	<.001	0.461	0.821

3.2. CDI scores

Figure 2 shows the ASL-CDI scores (on the left) and English-CDI scores (on the right) of the five DoH children. We can see that the overall CDI scores of both ASL and English increase for four of the five children, namely Ellie, Nayla, Imani, and Haven.[3]

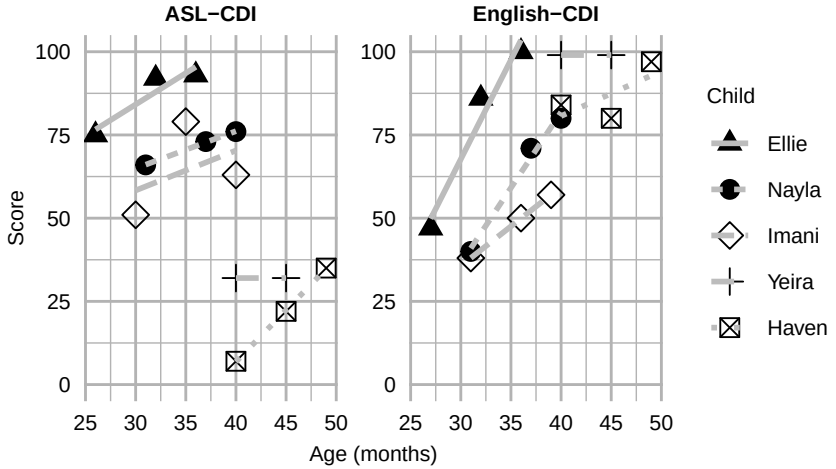

Figure 2. CDI scores of the DoH children. Figure created in R using the ggplot2 package (Wickham 2016).

Moreover, for these four children, the ASL-CDI scores show improvement over time, in contrast to the language sample results shown in Figure 1. In addition, for the three children who have higher ASL-CDI scores – Ellie, Nayla, and Imani – their scores are age-appropriate according to the norms based on DoD children learning ASL as reported by Caselli et al. (2020). Interestingly, the two outliers who have the lowest ASL-CDI scores – Yeira and Haven – also have the highest English-CDI scores. There could be multiple reasons behind this pattern, including differences in the proportion each language is used in the children's input. We will come back to this issue in the discussion.

[3] Yeira only has two data points available for each language.

4. Discussion

4.1. Language dominance and language input

We have seen from the CDI scores (Figure 2) that the participants differ in whether they display stronger scores in ASL or English. While we must exercise caution when comparing test scores across languages, based on the CDI scores, Yeira and Haven's English vocabulary scores are higher than their ASL vocabulary scores throughout all the observed age points; in contrast, Imani's ASL scores are higher than her English scores at all three observed age points. Ellie and Nayla both started with lower English-CDI scores than ASL-CDI scores, but their English seemed to catch up with ASL at the last observed age point. These results may indicate that the children have different patterns of language dominance (stronger ASL, stronger English, or balanced).

The children's differential language dominance may be related to the input that they received from their parents. We have some evidence of this from the language samples. We calculated the proportion of input utterances produced in ASL only (sign), English only (speech), or bimodally (ASL and English articulated simultaneously) in 10- to 15-minute segments of monthly language samples. As shown in Figure 3, Ellie, Nayla, and Imani were exposed to more ASL and bimodal input from their parents compared to Yeira and Haven, who were mostly exposed to spoken English.

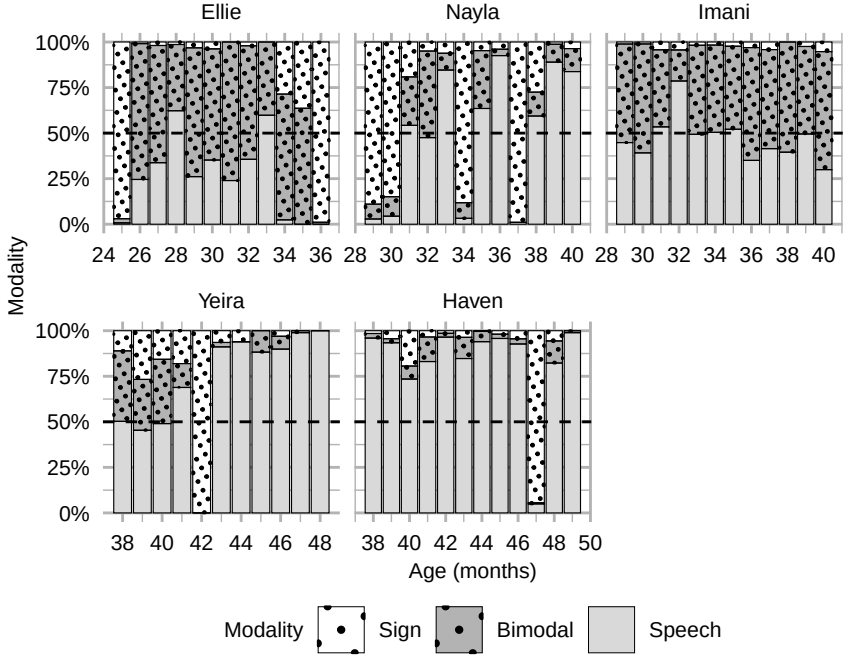

Figure 3. Distribution of input types in parents' language samples. Figure created in R using the ggplot2 package (Wickham 2016).

Caselli et al. (2021) found a difference in ASL development for DoH children whose sign exposure began before versus after the age of 6 months. In our sample, all participants other than Nayla had exposure before 6 months, and Nayla's exposure began between 6 and 12 months. Thus, for these participants, the amount of sign exposure over time seems to be more closely related to the relative strength of ASL development, rather than the age of first exposure.

4.2. English development in bimodal bilinguals

As we have observed in Figure 1, there is an increase in the number of English word types over time among the five participants. In other words, acquiring ASL does not hinder the acquisition of English for these bimodal bilinguals. This evidence counters the view that early sign language exposure impedes spoken language development (e.g., Geers et al. 2017; c.f. Pontecorvo et al. 2023 for a similar finding for ASL-English bilinguals).

4.3. Implications for future research

As these results show, we have observed different patterns based on our assessment of our participants' vocabulary development. During the language sample sessions, children were able to use the language they were most comfortable with at the time of data collection. This may have been a factor contributing to limited use of ASL by the English-dominant children, leading to the low number of ASL word types in their results. In contrast, the parental reports provide an overall picture of the children's production at specific age points. Since evaluation results vary based on the specific type of assessment conducted, using multiple measures is necessary to capture the overall picture of vocabulary development, particularly for bilingual children.

The data reported in this paper are based on observations of only 5-minute samples from 5 participants. To improve this limitation, we are working on expanding the data set to include longer segments and more participants. We are also conducting more detailed analyses of children's productive vocabularies in relation to their input from their parents.

5. Conclusions

In this study, we investigated the vocabulary development of five deaf children of hearing parents (DoH children) acquiring both ASL and English. We analyzed their expressive vocabulary development using two measures: language sample analysis of longitudinal naturalistic data and Communicative Development Inventory (CDI) parent reports. For the language samples, the number of different words produced by the DoH children in ASL was lower than that produced by deaf children with deaf parents (DoD children). However, the overall vocabulary development of the DoH children showed an increase over time, once the English and ASL word types are combined. Despite the low number of ASL word types in naturalistic production data, the DoH children do

show progress in acquisition of ASL and English over time as shown by their CDI scores. These findings reaffirm the importance of using multiple methods when assessing bilingual children's language development. The combined evidence presented here shows that the DoH child participants in our study are developing as bimodal bilinguals, and that their exposure to ASL does not hinder their English acquisition.

References

Anderson, D. 2002. "The MacArthur Communicative Development Inventory: Normative Data for American Sign Language." *Journal of Deaf Studies and Deaf Education* 7 (2): 83–106. https://doi.org/10.1093/deafed/7.2.83.

Bauman, H-Dirksen L. 2004. "Audism: Exploring the Metaphysics of Oppression." *The Journal of Deaf Studies and Deaf Education* 9 (2): 239–46. https://doi.org/10.1093/deafed/enh025.

Berger, Lauren, Jennie E. Pyers, Amy Lieberman, and Naomi K. Caselli. 2024. "Parent American Sign Language Skills Correlate with Child–but Not Toddler–ASL Vocabulary Size." *Language Acquisition* 31 (2): 85–99. https://doi.org/10.1080/10489223.2023.2178312.

Caselli, Naomi K., Amy M. Lieberman, and Jennie E. Pyers. 2020. "The ASL-CDI 2.0: An Updated, Normed Adaptation of the MacArthur Bates Communicative Development Inventory for American Sign Language." *Behavior Research Methods* 52 (5): 2071–84. https://doi.org/10.3758/s13428-020-01376-6.

Caselli, Naomi K., Jennie E. Pyers, and Amy M. Lieberman. 2021. "Deaf Children of Hearing Parents Have Age-Level Vocabulary Growth When Exposed to ASL by Six-Months." *The Journal of Pediatrics* 232 (May): 229–36. https://doi.org/10.1016/j.jpeds.2021.01.029.

Chen Pichler, Deborah, Mary Cecilia Conte, Patrice Creamer, et al. 2024. "Profile of a Family's Bimodal Bilingual Development." In *BUCLD 48: Proceedings of the 48th Annual Boston University Conference on Language Development*, edited by Hayat Abdullah Ali AlThagafi and Jupitara Ray. http://www.lingref.com/bucld/48/BUCLD48-12.pdf.

Ching, Teresa Y.C., Harvey Dillon, Laura Button, et al. 2017. "Age at Intervention for Permanent Hearing Loss and 5-Year Language Outcomes." *Pediatrics* 140 (3): e20164274. https://doi.org/10.1542/peds.2016-4274.

Devescovi, Antonella, Maria Cristina Caselli, Daniela Marchione, Patrizio Pasqualetti, Judy Reilly, and Elizabeth Bates. 2005. "A Crosslinguistic Study of the Relationship between Grammar and Lexical Development." *Journal of Child Language* 32 (4): 759–86. https://doi.org/10.1017/S0305000905007105.

Fenson, Larry, Steve Pethick, Connie Renda, Jeffrey L. Cox, Philip S. Dale, and J. Steven Reznick. 2000. "Short-Form Versions of the MacArthur Communicative Development Inventories." *Applied Psycholinguistics* 21 (1): 95–116. https://doi.org/10.1017/S0142716400001053.

Geers, Ann E., Christine M. Mitchell, Andrea Warner-Czyz, Nae-Yuh Wang, Laurie S. Eisenberg, and the CDaCI Investigative Team. 2017. "Early Sign Language Exposure and Cochlear Implantation Benefits." Article. *Pediatrics* 140 (1). https://doi.org/10.1542/peds.2016-3489.

Hall, Matthew L., Wyatte C. Hall, and Naomi K. Caselli. 2019. "Deaf Children Need Language, Not (Just) Speech." *First Language* 39 (4): 367–95. https://doi.org/10.1177/0142723719834102.

Hall, Wyatte C., Leonard L. Levin, and Melissa L. Anderson. 2017. “Language Deprivation Syndrome: A Possible Neurodevelopmental Disorder with Sociocultural Origins.” *Social Psychiatry and Psychiatric Epidemiology* 52 (6): 761–76. https://doi.org/10.1007/s00127-017-1351-7.

Hochgesang, Julie A. 2022. “SLAASh ID Glossing Principles, ASL Signbank and Annotation Conventions, Version 3.2. Figshare.” https://doi.org/10.6084/m9.figshare.12003732.v4.

Hochgesang, Julie A., Onno Crasborn, and Diane Lillo-Martin. 2017. “ASL Signbank.” https://doi.org/10.6084/m9.figshare.9741788.

Humphries, Tom. 1975. “The Making of a Word: Audism.” Unpublished manuscript.

Lillo-Martin, Diane C., Elaine Gale, and Deborah Chen Pichler. 2023. “Family ASL: An Early Start to Equitable Education for Deaf Children.” *Topics in Early Childhood Special Education* 43 (2): 156–66. https://doi.org/10.1177/02711214211031307.

Lillo-Martin, Diane C., Linghui Gan, Julie A. Hochgesang, and Deborah Chen Pichler. 2024. “Assessing the Development of ASL by Deaf Children: Longitudinal Spontaneous Production Data.” Stage presentation, FEAST 2024. Ann Arbor, USA.

Lillo-Martin, Diane C., Linghui Gan, Julie A. Hochgesang, and Deborah Chen Pichler. in prep. *Understanding Morpho-Syntactic Development in Children Acquiring American Sign Language: MLU and ASL-IPSyn*.

MacWhinney, Brian. 2000. “The CHILDES Project: Tools for Analyzing Talk (Third Edition): Volume I: Transcription Format and Programs, Volume II: The Database.” *Computational Linguistics* 26 (4): 657. https://doi.org/10.1162/coli.2000.26.4.657.

Mitchell, Ross E, and Michael A Karchmer. 2004. “Chasing the Mythical Ten Percent: Parental Hearing Status of Deaf and Hard of Hearing Students in the United States.” *Sign Language Studies* 4 (2): 138–63. https://muse.jhu.edu/pub/18/article/51652.

Pontecorvo, Elana, Michael Higgins, Joshua Mora, Amy M. Lieberman, Jennie E. Pyers, and Naomi K. Caselli. 2023. “Learning a Sign Language Does Not Hinder Acquisition of a Spoken Language.” *Journal of Speech, Language, and Hearing Research* 66 (4): 1291–308. https://doi.org/10.1044/2022_JSLHR-22-00505.

R Core Team. 2025. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. Vienna, Austria, Released. https://www.R-project.org/.

Wickham, Hadley. 2016. *ggplot2: Elegant Graphics for Data Analysis*. The Comprehensive R Archive Network. Released. https://ggplot2.tidyverse.org/.

Proceedings of the 50th annual Boston University Conference on Language Development

edited by Romi Hill, Xinhan Jiang, Danutham Worapipat, and Aditya Yedetore

Cascadilla Press Somerville, MA 2026

ISSN 1080-692X
ISBN 978-1-57473-047-0 (2 volume set, paperback)

Ordering information

To order a copy of the proceedings or to place a standing order, contact:

Cascadilla Press, P.O. Box 440355, Somerville, MA 02144, USA
phone: 1-617-776-2370, sales@cascadilla.com, www.cascadilla.com