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December 1, 2022

To the ASHFoundation Lessons for Success selection committee:

I am applying to participate in the 2023 Lessons for Success conference. I am a T32-funded postdoctoral fellow at the Waisman Center with Dr. Katherine Hustad and received my PhD in 2020 from the University of Memphis with Dr. D. Kimbrough Oller. My research seeks to identify vocal biomarkers of speech impairment in cerebral palsy (CP). My long-term goal is to develop scientifically validated clinical tools to inform early detection, prognosis, and treatment planning in children with CP as young as infancy. Regarding eligibility for this program, I was recently awarded a 2022 ASHFoundation New Investigator Research Grant as PI. The F32 award submitted as part of my application will be submitted December 8, 2022.

My research has two primary aims: 1) to improve the early detection of speech impairment in CP, and 2) to increase knowledge and awareness of communication impairments in CP. My first research aim directly contributes to my long-term research goal to develop scientifically validated tools for diagnosing speech impairment in CP and other neurodevelopmental disabilities, potentially even before the onset of first words. Through this work, I will require funding to conduct research using acoustic analysis, automated vocal detection, and psychometric validation of clinical diagnostic tools. My second research aim is geared to establish and build interdisciplinary research connections with community stakeholders (families and individuals with CP) and other medical health providers (e.g., neurologists, physical and occupational therapists, and educators). This research will require team science approaches and multi-site collaborations across research and clinical settings. Participation in the Lessons for Success conference will provide the necessary, intensive training to develop and manage large-scale grant proposals to support my programmatic line of research associated with these aims.

I am grateful for your consideration of my application for the Lessons for Success conference. Participation in this program will be foundational to my success as a competitive grant applicant and emergent independent investigator in CP, a vastly understudied population in the field of communication sciences and disorders. Please contact me at helen.long@wisc.edu with any questions.

Sincerely,

Helen Long

Helen Long, PhD, CCC-SLP
Postdoctoral Researcher
Waisman Center
University of Wisconsin-Madison

EXTRAMURAL RESEARCH GRANT PROPOSAL

Applicant	Helen Long, PhD
Grant mechanism	Ruth L. Kirschstein National Research Service Award (NRSA) Individual Postdoctoral Fellowship (Parent F32)
Sponsoring Agency	NIDCD
FOA	PA-21-048
Title	Multi-measure characterization of vocalizations in infants at risk for cerebral palsy
University site	University of Wisconsin, Waisman Center
Sponsor	Katherine C. Hustad
Submitted	12/8/2022

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December 1, 2022

Center for Scientific Review
National Institutes of Health
6701 Rockledge Drive MSC 7768
Bethesda, MD 20892-7768

Re: Assignment of “Multi-measure characterization of vocalizations in infants at risk for cerebral palsy”

Dear Sir or Madam:

I am pleased to submit a grant application for a NIH Ruth L. Kirschstein National Research Service Award (NRSA) Individual Postdoctoral Fellowship (F32) in response to **PA-21-048.**

I am requesting primary assignment to the **National Institute on Deafness and Other Communication Disorders (NIDCD)** and secondary assignment to the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD).

My letters of reference are from:

1. **D. Kimbrough Oller, PhD**
   Professor and Chair of Excellence
   School of Communication Sciences and Disorders
   The University of Memphis

2. **Mary Jo Cooley Hidecker, PhD, CCC-A/SLP**
   Associate Professor
   Department of Communication Sciences and Disorders
   University of Kentucky

3. **Sigan Hartley, PhD**
   Associate Professor and 100 Women Chair in Human Ecology
   Waisman Center
   University of Wisconsin-Madison

Please contact me by email with any questions at helen.long@wisc.edu.

Sincerely,

Helen Long

Helen Long, PhD, CCC-SLP
Postdoctoral Researcher
Waisman Center
University of Wisconsin-Madison

PROJECT SUMMARY/ABSTRACT

Speech impairments negatively impact well over half of all children diagnosed with cerebral palsy (CP), affecting social participation and quality of life throughout the lifespan. Prior work has evidenced the predictive nature of early speech and language performance on later communication outcomes in CP; however, very little is known about early vocal and speech development in this population under 24 months. This lack of knowledge is a fundamental barrier to identifying motor speech impairment in CP as early as possible. The proposed research aims to address this gap by examining the predictive nature of perceptual and acoustic measures for speech impairment in infants prospectively identified as being at risk for CP. My central hypothesis is that neurological damage associated with CP will affect the development of the motor speech system, resulting in atypical vocal features that are predictive of later speech disorders. The project will utilize an existing dataset of naturalistic parent-infant interaction laboratory audio recordings of 23 infants at risk for CP around 12 months of age. Infants will be grouped by later-identified speech outcomes based on their performance in a larger longitudinal study around 36 months. Specific Aim 1 will compare group-level performance across individual perceptual and acoustic measures derived from recordings. These include four perceptual measures of infant syllable categories (quasivowels, vowels, marginal syllables, and canonical syllables) and three acoustic measures (voice range density, periodicity, and harmonicity). We hypothesize that children with no speech motor impairment outcomes will have significantly higher values of well-formed syllable types across both perceptual and acoustic measures compared to those with speech motor impairment outcomes. Specific Aim 2 will quantify the predictive nature of perceptual and acoustic measures on speech outcomes in CP. Although this aim is exploratory in nature, we will model the best combination of predictors against outcome data. We predict that early vocal differences across the speech outcome groups will be revealed by a combination of both perceptual and acoustic measures. The proposed research has important implications for leveraging prelinguistic vocal markers to identify the earliest signs of speech impairment in CP, as young as infancy. This research can directly inform diagnostic and early intervention treatment planning to support communication outcomes in this population.

PROJECT NARRATIVE

Motor speech impairments are commonly observed in children with cerebral palsy (CP) which can impact social participation and quality of life, yet there is little evidence on the early vocal and speech development in this population under 24 months. This research will 1) compare perceptual and acoustic measures of infant vocalizations produced by 23 infants at risk for cerebral palsy in parent-infant naturalistic laboratory recordings around 12 months, and 2) quantify the predictive nature of these measures against their later-identified early speech outcomes. Findings from this research will provide essential information about early vocal predictors of speech impairment to support clinical diagnostic, prognostic, and treatment planning for children with CP, as young as infancy.

BIBLIOGRAPHY

1. Burnett, T. A., McCurdy, K. E., & Bright, J. C. (2008). Reflexive and volitional voice fundamental frequency responses to an anticipated feedback pitch error. *Experimental Brain Research*, *191*(3), 341–351. https://doi.org/10.1007/s00221-008-1529-z
2. Allen, P. J., & Burnett, T. A. (2011). Re-examining the effects of perturbation magnitude, direction, and duration on the pitch-shift reflex. *The Journal of the Acoustical Society of America*, *129*(4), 2454–2454. https://doi.org/10.1121/1.3588064
3. Macrae, T. (2013). Lexical and child-related factors in word variability and accuracy in infants. *Clinical Linguistics & Phonetics*, *27*(6–7), 497–507. https://doi.org/10.3109/02699206.2012.752867
4. Macrae, T., Tyler, A. A., & Lewis, K. E. (2014). Lexical and Phonological Variability in Preschool Children With Speech Sound Disorder. *American Journal of Speech-Language Pathology*, *23*(1), 27–35. https://doi.org/10.1044/1058-0360(2013/12-0037)
5. Oller, D. K. (1978). Infant vocalizations and the development of speech. *Allied Health and Behavioral Sciences*, *1*, 523–549.
6. Oller, D. K. (2000). *The emergence of the speech capacity*. Lawrence Erlbaum Associates.
7. Oller, D. K., Eilers, R. E., Neal, A. R., & Schwartz, H. K. (1999). Precursors to speech in infancy: The prediction of speech and language disorders. *Journal of Communication Disorders*, *32*(4), 223–245. https://doi.org/10.1016/s0021-9924(99)00013-1
8. Oller, D. K., Caskey, M., Yoo, H., Bene, E. R., Jhang, Y., Lee, C.-C., Bowman, D. D., Long, H. L., Buder, E. H., & Vohr, B. (2019). Preterm and full-term infant vocalization and the origin of language. *Scientific Reports*, *9*(1), 14734. https://doi.org/10/gnzf8m
9. Long, H. L., Oller, D. K., & Bowman, D. D. (2019). Reliability of listener judgments of infant vocal imitation. *Frontiers in Psychology*, *10*, 1340. https://doi.org/10.3389/fpsyg.2019.01340
10. Long, H. L., Bowman, D. D., Yoo, H., Burkhardt-Reed, M. M., Bene, E. R., & Oller, D. K. (2020). Social and endogenous infant vocalizations. *PLoS ONE*, *15*(8), e0224956. https://doi.org/10.1371/journal.pone.0224956
11. Long, H. L., Ramsay, G., Griebel, U., Bene, E. R., Burkhardt-Reed, M. M., & Oller, D. K. (under review). *Infants vocalize most during independent vocal play but produce their most speech-like vocalizations during vocal turn taking*. [Preprint].
12. Gipson, T. T., Ramsay, G., Ellison, E. E., Bene, E. R., Long, H. L., & Oller, D. K. (2021). Early vocal development in tuberous sclerosis complex. *Pediatric Neurology*, *125*, 48–52. https://doi.org/10.1016/j.pediatrneurol.2021.08.009
13. Long, H. L. (2020). *Endogenous and social factors influencing infant vocalizations as fitness signals* [Doctoral Dissertation, University of Memphis]. https://osf.io/cz7qe/
14. Long, H. L., Eichorn, N., & Oller, D. K. (2022). A Probe Study on Vocal Development in Two Infants at Risk for Cerebral Palsy. *Developmental Neurorehabilitation*, 1–8. https://doi.org/10.1080/17518423.2022.2143923
15. Koopmans, C., Sakash, A., Soriano, J., Long, H. L., & Hustad, K. C. (2021). Functional communication abilities in youth with cerebral palsy: Association with impairment profiles and school-based therapy goals. *Language, Speech, and Hearing Services in Schools*, 1–16. https://doi.org/10.1044/2021_LSHSS-21-00064
16. Long, H. L., Mahr, T. J., Natzke, P., Rathouz, P. J., & Hustad, K. C. (2022). Longitudinal change in speech classification between 4 and 10 years in children with cerebral palsy. *Developmental Medicine & Child Neurology*, *64*(9), 1096–1105. https://doi.org/10.1111/dmcn.15198
17. Long, H. L., & Hustad, K. C. (under review). *Longitudinal development of marginal and canonical babbling in ten infants at risk for cerebral palsy*.
18. Long, H. L., Oller, D. K., Romer, K., Friener, L., Warner, W., Spence, D., & Rhodes, L. N. (2020). Pre-speech and early speech development of young children diagnosed with cerebral palsy. *Developmental Medicine & Child Neurology*, *62*, 79–134. https://doi.org/10.1111/dmcn.14662
19. Long, H. L., Christensen, L., Hayes, S., & Hustad, K. C. (in preparation). *Vocal production in neurodevelopmental conditions at risk for speech disorders: A scoping review*.
20. Oller, D. K., & Eilers, R. E. (1988). The role of audition in infant babbling. *Child Development*, *59*(2), 441–449. https://doi.org/10.1111/j.1467-8624.1988.tb01479.x

21. Lynch, M. P., Oller, D. K., Steffens, M. L., Levine, S. L., Basinger, D. L., & Umbel, V. (1995). Onset of speech-like vocalizations in infants with Down syndrome. *American Journal of Mental Retardation*, *100*(1), 68–86.
22. Nyman, A., & Lohmander, A. (2018). Babbling in children with neurodevelopmental disability and validity of a simplified way of measuring canonical babbling ratio. *Clinical Linguistics and Phonetics*, *32*(2), 114–127. https://doi.org/10.1080/02699206.2017.1320588
23. Nathani, S., Ertmer, D. J., & Stark, R. E. (2006). Assessing vocal development in infants and toddlers. *Clinical Linguistics and Phonetics*, *20*(5), 351–369. https://doi.org/10.1080/02699200500211451
24. Lee, C.-C., Jhang, Y., Relyea, G., Chen, L.-M., & Oller, D. K. (2018). Babbling development as seen in canonical babbling ratios: A naturalistic evaluation of all-day recordings. *Infant Behavior and Development*, *50*, 140–153. https://doi.org/10.1016/j.infbeh.2017.12.002
25. Kent, R. D., & Kim, Y. J. (2003). Toward an acoustic typology of motor speech disorders. *Clinical Linguistics & Phonetics*, *17*(6), 427–445. https://doi.org/10.1080/0269920031000086248
26. Pennington, L., Lombardo, E., Steen, N., & Miller, N. (2018). Acoustic changes in the speech of children with cerebral palsy following an intensive program of dysarthria therapy*. *International Journal of Language & Communication Disorders*, *53*(1), 182–195. https://doi.org/10.1111/1460-6984.12336
27. Mou, Z., Teng, W., Ouyang, H., Chen, Y., Liu, Y., Jiang, C., Zhang, J., & Chen, Z. (2019). Quantitative analysis of vowel production in cerebral palsy children with dysarthria. *Journal of Clinical Neuroscience*, *66*, 77–82. https://doi.org/10.1016/j.jocn.2019.05.020
28. Allison, K. M., & Hustad, K. C. (2018). Acoustic predictors of pediatric dysarthria in cerebral palsy. *Journal of Speech, Language, and Hearing Research*, *61*(3), 462–478. https://doi.org/10.1044/2017_JSLHR-S-16-0414
29. Parkes, J., Hill, N., Platt, M. J., & Donnelly, C. (2010). Oromotor dysfunction and communication impairments in children with cerebral palsy: A register study. *Developmental Medicine & Child Neurology*, *52*(12), 1113–1119. https://doi.org/10.1111/j.1469-8749.2010.03765.x
30. Mei, C., Reilly, S., Reddihough, D., Mensah, F., & Morgan, A. (2014). Motor speech impairment, activity, and participation in children with cerebral palsy. *International Journal of Speech-Language Pathology*, *16*(4), 427–435. https://doi.org/10/gf6x3m
31. Sigurdardottir, S., & Vik, T. (2011). Speech, expressive language, and verbal cognition of preschool children with cerebral palsy in Iceland. *Developmental Medicine & Child Neurology*, *53*(1), 74–80. https://doi.org/10.1111/j.1469-8749.2010.03790.x
32. Mei, C., Reilly, S., Reddihough, D., Mensah, F., Green, J., Pennington, L., & Morgan, A. T. (2015). Activities and participation of children with cerebral palsy: Parent perspectives. *Disability and Rehabilitation*, *37*(23), 2164–2173. https://doi.org/10.3109/09638288.2014.999164
33. Mei, C., Reilly, S., Bickerton, M., Mensah, F., Turner, S., Kumaranayagam, D., Pennington, L., Reddihough, D., & Morgan, A. T. (2020). Speech in children with cerebral palsy. *Developmental Medicine & Child Neurology*, *62*(12), 1374–1382. https://doi.org/10.1111/dmcn.14592
34. Hustad, K. C., Sakash, A., Natzke, P. E. M., Broman, A. T., & Rathouz, P. J. (2019). Longitudinal growth in single word intelligibility among children with cerebral palsy from 24 to 96 months of age: Predicting later outcomes from early speech production. *Journal of Speech, Language, and Hearing Research*, *62*(6), 1599. https://doi.org/10.1044/2018_JSLHR-S-18-0319
35. Hustad, K. C., Sakash, A., Broman, A. T., & Rathouz, P. J. (2018). Longitudinal growth of receptive language in children with cerebral palsy between 18 months and 54 months of age. *Developmental Medicine and Child Neurology*, *60*(11), 1156–1164. https://doi.org/10.1111/dmcn.13904
36. McDaniel, J., & Gifford, R. H. (2020). Prelinguistic vocal development in children with cochlear implants: A systematic review. *Ear and Hearing*, *41*(5), 1064–1076. https://doi.org/10.1097/AUD.0000000000000829
37. Lang, S., Bartl-Pokorny, K. D., Pokorny, F. B., Garrido, D., Mani, N., Fox-Boyer, A. V., Zhang, D., & Marschik, P. B. (2019). Canonical babbling: A marker for earlier identification of late detected developmental disorders? *Current Developmental Disorders Reports*, *6*(3), 111–118. https://doi.org/10.1007/s40474-019-00166-w
38. Nyman, A., & Lohmander, A. (2018). Babbling in children with neurodevelopmental disability and validity of a simplified way of measuring canonical babbling ratio. *Clinical Linguistics and Phonetics*, *32*(2), 114–127. https://doi.org/10/gbvt2q
39. Allison, K. M., Annear, L., Policicchio, M., & Hustad, K. C. (2017). Range and Precision of Formant Movement in Pediatric Dysarthria. *Journal of Speech, Language, and Hearing Research*, *60*(7), 1864. https://doi.org/10.1044/2017_JSLHR-S-15-0438

40. Ansel, B. M., & Kent, R. D. (1992). Acoustic-phonetic contrasts and intelligibility in the dysarthria associated with mixed cerebral palsy. *Journal of Speech, Language, and Hearing Research*, *35*(2), 296–308.
41. Lee, J., Hustad, K. C., & Weismer, G. (2014). Predicting speech intelligibility with a multiple speech subsystems approach in children with cerebral palsy. *Journal of Speech, Language, and Hearing Research*, *57*(5), 1666–1678. https://doi.org/10.1044/2014_jslhr-s-13-0292
42. Kuhl, P. K., & Meltzoff, A. N. (1996). Infant vocalizations in response to speech: Vocal imitation and developmental change. *The Journal of the Acoustical Society of America*, *100*(4 Pt 1), 2425–2438. https://doi.org/10.1121/1.417951
43. Kent, R. D., & Murray, A. D. (1982). Acoustic features of infant vocalic utterances at 3, 6, and 9 months. *The Journal of the Acoustical Society of America*, *72*(2), 353–365. https://doi.org/10.1121/1.388089
44. Sussman, H. M., Minifie, F. D., Buder, E. H., Stoel-Gammon, C., & Smith, J. (1996). Consonant-Vowel Interdependencies in Babbling and Early Words: Preliminary Examination of a Locus Equation Approach. *Journal of Speech and Hearing Research*, *39*(2), 424–433. https://doi.org/10.1044/jshr.3902.424
45. Sussman, H., Domsch, C., Dalston, E., & Cacciatore, A. (1999). An Acoustic Analysis of the Development of CV Coarticulation. *Journal of Speech, Language, and Hearing Research*, *42*, 1080–1096. https://doi.org/10.1044/jslhr.4205.1080
46. Rvachew, S., Creighton, D., Feldman, N., & Sauve, R. (2002). Acoustic-phonetic description of infant speech samples: Coding reliability and related methodological issues. *Acoustics Research Letters Online*, *3*(1), 24–28. https://doi.org/10.1121/1.1429202
47. Rvachew, S., Creighton, D., Feldman, N., & Sauve, R. (2005). Vocal development of infants with very low birth weight. *Clinical Linguistics and Phonetics*, *19*(4), 275–294. https://doi.org/10.1080/02699200410001703457
48. Smith, A. L., & Hustad, K. C. (2015). AAC and Early Intervention for Children with Cerebral Palsy: Parent Perceptions and Child Risk Factors. *AAC: Augmentative and Alternative Communication*. https://doi.org/10.3109/07434618.2015.1084373
49. Singleton, N. C. (2018). Late talkers: Why the wait-and-see approach is outdated. *Pediatric Clinics of North America*, *65*, 13–29. https://doi.org/10.1016/j.pcl.2017.08.018
50. Levin, K. (1999). Babbling in infants with cerebral palsy. *Clinical Linguistics & Phonetics*, *13*(4), 249–267. https://doi.org/10.1080/026992099299077
51. Albert, R. R., Schwade, J. A., & Goldstein, M. H. (2018). The social functions of babbling: Acoustic and contextual characteristics that facilitate maternal responsiveness. *Developmental Science*, *21*(5), 1–11. https://doi.org/10.1111/desc.12641
52. Otapowicz, D., Sobaniec, W., Kułak, W., & Okurowska-Zawada, B. (2005). Time of cooing appearance and further development of speech in children with cerebral palsy. *Annales Academiae Medicae Bialostocensis*, *50 Suppl 1*, 78–81.
53. Lyytinen, P., Poikkeus, A. M., Leiwo, M., Ahonen, T., & Lyytinen, H. (1996). Parents as informants of their child's vocal and early language development. *Early Child Development and Care*, *126*(1), 15–25. https://doi.org/10.1080/0300443961260102
54. Ramsdell, H. L., Kimbrough Oller, D., & Ethington, C. A. (2007). Predicting phonetic transcription agreement: Insights from research in infant vocalizations. *Clinical Linguistics & Phonetics*, *21*(10), 793–831. https://doi.org/10.1080/02699200701547869
55. Warren, S. F., Gilkerson, J., Richards, J. A., Oller, D. K., Xu, D., Yapanel, U., & Gray, S. (2010). What automated vocal analysis reveals about the vocal production and language learning environment of young children with autism. *Journal of Autism and Developmental Disorders*, *40*(5), 555–569. https://doi.org/10.1007/s10803-009-0902-5
56. Pokorny, F. B., Schmitt, M., Egger, M., Bartl-Pokorny, K. D., Zhang, D., Schuller, B. W., & Marschik, P. B. (2022). Automatic vocalisation-based detection of fragile X syndrome and Rett syndrome. *Scientific Reports*, *12*, 13345. https://doi.org/10.1038/s41598-022-17203-1
57. Pokorny, F. B., Peharz, R., Roth, W., Zöhrer, M., Pernkopf, F., Marschik, P. B., Schuller, B. W., Morgan, N., Georgiou, P., Morgan, N., Narayanan, S., Metze, F., Amazon, A., Apple, eBay, Google, Microsoft, & et al. (2016). Manual versus automated: The challenging routine of infant vocalisation segmentation in home videos to study neuro(mal)development. *17th Annual Conference of the International Speech Communication Association, INTERSPEECH 2016*, *08-12-September-2016*, 2997–3001. https://doi.org/10.21437/Interspeech.2016-1341

58. Hustad, K. C., Gorton, K., & Lee, J. (2010). Classification of speech and language profiles in 4-year-old children with cerebral palsy: A prospective preliminary study. *Journal of Speech, Language, and Hearing Research*, *53*(6), 1496–1513.
59. Andersen, G., Mjøen, T. R., & Vik, T. (2010). Prevalence of Speech Problems and the Use of Augmentative and Alternative Communication in Children With Cerebral Palsy: A Registry-Based Study in Norway. *Perspectives on Augmentative and Alternative Communication*, *19*(1), 12. https://doi.org/10.1044/aac19.1.12
60. Khandaker, G., Muhit, M., Karim, T., Smithers-Sheedy, H., Novak, I., Jones, C., & Badawi, N. (2019). Epidemiology of cerebral palsy in Bangladesh: A population-based surveillance study. *Developmental Medicine & Child Neurology*, *61*(5), 601–609. https://doi.org/10.1111/dmcn.14013
61. Franklin, B., Warlaumont, A. S., Messinger, D., Bene, E., Iyer, S. N., Lee, C.-C., Lambert, B., & Oller, D. K. (2013). Effects of parental interaction on infant vocalization rate, variability and vocal type. *Language Learning and Development*, *10*(3), 279–296. https://doi.org/10.1080/15475441.2013.849176
62. Binos, P., Thodi, C., Vogazianos, P., Psillas, G., & Constantinidis, J. (2021). An acoustic and auditory analysis of vocants in infants with cochlear implants. *Logopedics Phoniatrics Vocology*, *46*(1), 28–34. https://doi.org/10.1080/14015439.2020.1724325
63. Stoel-Gammon, C. (1989). Prespeech and early speech development of two late talkers. *First Language*, *9*(6), 207–223. https://doi.org/10.1177/014272378900900607
64. Oller, D. K., & Delgado, R. E. (1999). *Logical International Phonetics Programs (Windows version) [Computer software]*. Intelligent Hearing Systems.
65. *MATLAB* (9.13.0). (2022). The Mathworks Inc.
66. Cooke, M., Mayo, C., & Villegas, J. (2014). The contribution of durational and spectral changes to the Lombard speech intelligibility benefit. *The Journal of the Acoustical Society of America*, *135*(2), 874–883. https://doi.org/10.1121/1.4861342
67. Story, B. H., & Bunton, K. (2016). Formant measurement in children's speech based on spectral filtering. *Speech Communication*, *76*, 93–111. https://doi.org/10.1016/j.specom.2015.11.001
68. Hillenbrand, J., & Houde, R. A. (1996). Acoustic Correlates of Breathy Vocal Quality: Dysphonic Voices and Continuous Speech. *Journal of Speech, Language, and Hearing Research*, *39*(2), 311–321. https://doi.org/10.1044/jshr.3902.311
69. Tchernichovski, O., Mitra, P. P., Lints, T., & Nottebohm, F. (2001). Dynamics of the vocal imitation process: How a zebra finch learns its song. *Science (New York, N.Y.)*, *291*(5513), 2564–2569. https://doi.org/10.1126/science.1058522
70. Takahashi, D. Y., Fenley, A. R., & Ghazanfar, A. A. (2016). Early development of turn-taking with parents shapes vocal acoustics in infant marmoset monkeys. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1693), 20150370. https://doi.org/10.1098/rstb.2015.0370
71. Tukey, J. W. (1953). The problem of multiple comparisons. *Priceton University*.
72. Grömping, U. (2009). Variable Importance Assessment in Regression: Linear Regression versus Random Forest. *The American Statistician*, *63*(4), 308–319. https://doi.org/10.1198/tast.2009.08199
73. McGraw, K. O., & Wong, S. P. (1996). Forming inferences about some intraclass correlation coefficients. *Psychological Methods*, *1*(1), 30–46. https://doi.org/10/br5ffs

FACILITIES AND OTHER RESOURCES

A. SCIENTIFIC FACILITIES CONTRIBUTING TO APPLICANT SUCCESS

University of Wisconsin-Madison (UW-Madison).
UW-Madison is a Research I university home consistently ranked as being among the top research universities in the nation. In 2019, UW-Madison was ranked 8th for National Research Expenditure and 2nd for Big 10 Research Expenditure (Data Digest 2020-2021). In fiscal year 2021, UW-Madison had an estimated $981M in federal research awards and $676M in non-federal research awards.

Waisman Center.
The Waisman Center's mission is to advance knowledge about human development, developmental disabilities, and neurodegenerative diseases through research, training, service, and community outreach. It is located 0.4 miles off the UW-Madison main campus near the university-affiliated hospital (UWHealth) campus. The Waisman Center is one of only 15 research centers in the United States that includes an Intellectual & Developmental Disabilities Research Center (IDDRC) and University Center for Excellence in Developmental Disabilities (UCEDD). It supports a wide range of research laboratories for biological and behavioral research, brain imaging, biomanufacturing, and clinical trials. It also supports high-quality clinical services across 11 clinics. The Waisman Center provides a superior intellectual environment, including 43 University of Wisconsin-Madison research faculty members, and 21 faculty affiliates representing 18 academic departments including Communication Sciences and Disorders, Pediatrics, and Psychology. It also provides training for more than 250 graduate and postgraduate students each year, providing a stimulating academic environment for research. I will continue to attend the weekly, 1-hour John D. Wiley Seminar series held by the Waisman Center. This seminar series features leading academic scientists in behavioral and biological state-of-the-art intellectual and developmental disabilities (IDD) research to support my exposure to and networking capacity in research across the field of intellectual and developmental disabilities.

Wisconsin Speech, Intelligibility, and Communication (WISC) Laboratory.
The proposed research will take place in the WISC laboratory housed in the Waisman Center of the University of Wisconsin-Madison, led by Dr. Katherine Hustad (Sponsor). The scoping research completed in this laboratory examines communication development in children with CP. The WISC laboratory is supported by two ongoing NIH R01-funded projects. It is a well-equipped research laboratory located on the fourth floor of the Waisman Center. It encompasses approximately 500 square feet of space. It includes a handicapped-accessible sound-attenuating recording studio fitted with state-of-the-art professional-quality digital audio and video recording equipment, children's furniture, and toys. The room includes a two-way mirror connected to a recording suite for management of the audio and video recording system. The WISC laboratory includes a laboratory assistant workstation room that houses five workstations with double monitor screens and noise cancelling headphones for coding and data extraction to support this proposal. Two of these workstations will be used to conduct the perceptual coding and acoustic analyses involved in this project. Finally, the WISC laboratory includes four shared office spaces. All existing data included in this proposal is stored in Dr. Hustad's laboratory which is ready for immediate coding analysis. The WISC laboratory staff includes the PI (Long), Sponsor (Hustad), 2 research speech-language pathologist project managers, a laboratory-dedicated data scientist (Mahr), 2-3 doctoral students, and 3-5 student research assistants. Laboratory meetings are held once weekly to discuss ongoing projects and laboratory logistics.

- Office: I have a dedicated workspace in one of the four shared office spaces in the WISC laboratory. The workspace occupies approximately 12x10 square feet on the fourth floor of the Waisman Center. The office is directly located across the hall from the recording suite and recording studio of the WISC laboratory, and is fully equipped with a desk, personal computer, office supplies, printer, wired internet, wireless internet capability, and remote and direct network access to the secure WISC laboratory servers. All internal and remote workstations at the Waisman Center are networked together and connect to the internet. I will continue to use this office for project management, data analysis, and manuscript writing for research conducted under this proposal.

- Computer: I have a password-protected laptop computer for literature review and manuscript writing and will use one of the secure WISC laboratory workstations (desktop with double monitor screens) for data

coding and analysis. All laboratory computers are connected via high-speed ethernet connections to the campus-wide computer system for internet access including World Wide Web resources, e-mail, and library resources. All departments have internal LAN-based intranet systems set up enabling disk sharing, automatic backup, and shared printer capabilities. All workstations and computers have the required equipment and software already installed.

B. INSTITUTIONAL INVESTMENT IN THE SUCCESS OF THE APPLICANT

Both UW-Madison and the Waisman Center are committed to support research and career training of postdoctoral researchers. UW-Madison has a robust postdoctoral association in which I am an active member (further described below in *Collegial Support)*. The Waisman Center has maintained a T32 postdoctoral training program since 1995 in intellectual and developmental disabilities. I was selected as one of two trainees for the 2021-2023 cohort of this highly competitive program which funded the first two years of my postdoctoral training with Dr. Hustad. Throughout the duration of the proposed project, both the University and the Waisman Center continue to offer a multitude of resources to support my research and career success. These resources are further described below.

Resources for Classes, Travel, or Training.

- Department of Statistics: The Department of Statistics is housed in the School of Computer, Data, and Information Sciences at UW-Madison. This department offers several courses available for postdoctoral students to register and audit to support research training. I plan to register for two statistics courses (STAT 240/340: Data Science Modelling I & II) to support my research as described in my training plan. The department offers several statistics resources for university faculty, staff, and students, including a Statistics Learning Center and Statistical Consulting Laboratory.

- Diversity, Equity, and Inclusion Training: I am an ongoing participant in the Delta Certificate Program at UW-Madison, as part of the Center for Integration of Research, Teaching, and Learning (CIRTL) network. This program applies evidence-based research to foster equitable and inclusive learning in research laboratory and classroom settings. I have already completed two workshops (Summer 2021: Inclusive Research Mentor Training, Spring 2022: Inclusive Professional Framework for Future Faculty). I intend to participate in at least one more workshop as part of this training. Participation in this program will ground my commitment to supporting diversity, equity, and inclusion in research mentorship and teaching.

- Grant Writing Bootcamp for Social Scientists: I will participate in a Grant Writing Bootcamp for Social Scientists sponsored by the UW-Madison Office of the Vice Chancellor for Research and Graduate Education. This workshop is held annually from July–February (twice monthly). It provides participants with information, feedback, and a structured timeline that will facilitate crafting a strong NIH research proposal. I intend to apply information learned in this bootcamp to my future grant writing of R21 and subsequent R01 proposals.

Collegial Support.

- Department of Communication Sciences and Disorders (CSD): The Department of CSD at UW-Madison is a top-ranked (#3 in the United States, US News & World Report, 2020) undergraduate and graduate program supporting students and trainees in the field of CSD. It is world-renowned for its accomplished faculty, high-quality learning, and productive research output. The department hosts a weekly research colloquium series throughout the academic school year in which students, postdocs, and internal and external faculty are invited to present their research on topics related to the speech, language, hearing, and swallowing sciences. Dr. Hustad is dually appointed through the Waisman Center and the Department of CSD. I will attend 2-3 research colloquium seminars each semester and actively network with internal and external presenting researchers.

- Office of Postdoctoral Studies: The Office of Postdoctoral Studies is dedicated to enhancing the postdoctoral training experience of over 750 postdocs at UW-Madison. I am an active member of the UW Postdoctoral Association, the postdoc-led organization based out of The Office. I served on the planning committee for the annual UWPA Research Symposium in 2021 and was selected as the postdoctoral representative for the University Committee on Disability Access and Inclusion (CDAI) since September

2022. Other opportunities and support mechanisms through the UWPA include a weekly newsletter with career planning, research, and teaching resources, regular research networking events, and scientific leadership training workshops. I will continue to remain an active participant in activities and workshops hosted by and shared through the Office.

- Institute for Clinical and Translational Research (ICTR): ICTR is an interdisciplinary institute at UW-Madison that facilitates the transformation of research into a continuum extending from investigation through discovery to translation into practice. It is based in the School of Medicine and Public Health and collaborates with its partner Marshfield Clinic and numerous other member sites across Wisconsin. Considerable resources are available from ICTR, such as biostatical planning and analysis support. Dr. Hustad is a member of ICTR and has full access to all benefits, including statistical consulting to support this proposal as needed.

Logistical Support.

- Information Technology (IT) support: The Waisman Center maintains a staff of three support personnel for IT management and troubleshooting. This includes support for computers, email, file sharing, printer issues, telephone services, and IT training and learning. The Waisman Center IT department administratively manages the WISC laboratory computers.

- Action Analysis Coding and Training (AACT) software: Customer service and logistical support for the AACT software program to be used in this proposal is available from the developer of the software (Dr. Rafael Delgado) I am already experienced and well trained on this software and do not anticipate requiring major support to trouble-shoot through problems that arise.

Financial Support.

- Friends of the Waisman Center: Travel and research funding is available via application through the Friends of the Waisman, a nonprofit organization dedicated to enhancing research activities at the Waisman Center. Conference poster printing is free for students and postdoctoral trainees of the Waisman Center through this organization.

- R01 funding for conference travel: Dr. Hustad (Sponsor) has two R01 grants currently funding WISC laboratory activities (R01DC015653, R01DC009411). These grants will support $1,000 per year for my conference travel.

- ASHFoundation New Investigators Research Grant: I received a highly competitive ASHFoundation New Investigators Research Grant of $10,000 in 2022. This award will span across the period of December 2022 to December 2023 (which encompasses a portion of the proposed project period). This award will be used for student research assistant funding and to fund the purchase of equipment and resources needed to support ongoing work in perceptual coding and acoustic analysis of infant vocalizations related to this proposal. These funds are not allowed to be used for conference travel.

EQUIPMENT

The Wisconsin, Intelligibility, Speech, and Communication (WISC) laboratory, led by the Sponsor of this proposal (Hustad), is already equipped with all up-to-date tools required to conduct the research project.

Computer and accessories.

- Five Dell desktop computers and one Macintosh computer are available in the WISC laboratory workstation room to conduct perceptual vocal coding and instrumental acoustic analysis. These computers each have a double monitor display, keyboard, and mouse. These computers are regularly updated to maintain the most recent Windows operating system by the Waisman Center IT department.
- Two pairs of Sony Noise Cancelling Headphones are also available in the WISC lab for dedicated use in this project.

Software.

- The Action and Analysis Coding and Training (AACT) software is already installed on all five desktop workstations for perceptual vocal coding and acoustic data extraction.
- MATLAB is installed on one workstation for acoustic analysis.
- R Studio will be used to conduct all statistical analyses. This open-source software is already installed on my personal and Dr. Mahr's secure workstations.
- Microsoft Office products (Word, Excel, etc.) will be used to write the manuscript resulting from the successful completion of this project. These products are already installed on all workstations in the WISC laboratory and personal computers of all team members involved in this proposal.

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Long, Helen Lauren

eRA COMMONS USER NAME (credential, e.g., agency login): hlong1

POSITION TITLE: Postdoctoral Trainee

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE	Completion Date	FIELD OF STUDY
Indiana University, Bloomington, IN, USA	BA	05/2010	Speech & Hearing Sciences; Slavic & Eastern European Languages and Culture
Florida State University, Tallahassee, FL, USA	MS	08/2012	Speech-Language Pathology
University of Memphis, Memphis, TN, USA	PhD	12/2020	Communication Sciences and Disorders
University of Wisconsin, Madison, WI, USA	Postdoc	In progress	Communication Sciences and Disorders

A. Personal Statement

I am applying for a 1-year NRSA Postdoctoral Fellowship (F32) for a third year of NRSA research training to support my training to become a productive, independent investigator in communication sciences and disorders. My programmatic line of research aims to identify prelinguistic vocal biomarkers of speech impairment in infants at risk for cerebral palsy (CP). My research questions are based in my clinical experience as a speech-language pathologist working with children with complex communication needs secondary to CP and other neurodevelopmental disabilities. I completed my doctoral training with Dr. D. Kimbrough Oller in typical infant vocal development. This experience instilled a strong theoretical framework to ground my study of prelinguistic vocal development in infants at risk for speech and language disorders. I am in my second year of T32 postdoctoral training with Dr. Katherine Hustad to develop my understanding of speech and communication developmental trajectories in children with CP. These experiences have built the foundation of my programmatic line of research to study vocal biomarkers of speech impairment in infants at risk for CP. I have contributed to 14 manuscripts (7 as first author) and 34 presentations (22 as first author) across 9 different national and international annual conferences. My predoctoral and postdoctoral research has primarily used longitudinal research designs and perceptual coding methods in parent-infant interactions from laboratory and home-based recordings. My work has also incorporated standardized assessment, educational data, and parent report questionnaires to study capacity, performance, and outcomes in CP. A key component of my work necessitates learning more objective methods of analysis, including instrumental acoustic analysis, as well as biostatistical modeling techniques to conduct rigorous research in this area. The proposed mentorship team are leading experts across the areas in which I seek training (acoustic analysis: Hustad, Bunton; statistical modeling: Hustad, Mahr). They are each well qualified and available to support this project during the proposed time frame. Receiving a third year of postdoctoral fellowship support to obtain the necessary research and professional training will ground my independence as a research investigator and strengthen my capacity to become a leading expert in early vocal and speech development in CP. Long-term, this work will support the future development of diagnostic tools for the early identification of speech and language impairments in CP.

1. **Long HL,** Bowman DD, Yoo H, Burkhardt-Reed MM, Bene ER, Oller DK. Social and endogenous infant vocalizations. PLoS One. 2020 Aug 5;15(8):e0224956. doi: 10.1371/journal.pone.0224956. PMID: 32756591; PMCID: PMC7406057.

2. Koopmans C, Sakash A, Soriano J, **Long HL**, Hustad KC. Functional Communication Abilities in Youth With Cerebral Palsy: Association With Impairment Profiles and School-Based Therapy Goals. Lang Speech Hear Serv Sch. 2022;53(1):88-103. doi: 10.1044/2021_LSHSS-21-00064. PMID: 34767477.
3. **Long HL**, Mahr TJ, Natzke P, Rathouz PJ, Hustad KC. Longitudinal change in speech classification between 4 and 10 years in children with cerebral palsy. Dev Med Child Neurol. 2022;64(9):1096-1105. doi: 10.1111/dmcn.15198. PMID: 35262181.
4. **Long, HL,** Eichorn, N, & Oller, DK. A probe study on vocal development in two infants at risk for cerebral palsy. Dev Neurorehab. 2022. doi: 10.1080/17518423.2022.2143923

B. Positions, Scientific Appointments, and Honors

Positions and Scientific Appointments

2021-	NICHD T32 Postdoctoral Fellow, Waisman Center, University of Wisconsin-Madison
2015-2020	Research Assistant, Origin of Language Laboratory, University of Memphis
2014-2021	Speech-Language Pathologist, Invo-Progressus Therapy
2012-2014	Speech-Language Pathologist, Easter Seals Massachusetts
2011-2012	Research Assistant, Experimental Child Phonetics Laboratory, Florida State University
2009-2010	Research Assistant, Voice Physiology Laboratory, Indiana University-Bloomington

Other Experience and Professional Memberships

2022-	Postdoctoral Representative, Committee on Disability Access and Inclusion
2021	Scientific Review Committee, American Academy for Cerebral Palsy and Dev. Medicine
2021-	Speech and Language Sciences Review Committee, ASHA Convention
2021-	Scholarship Review Committee, American Academy for Cerebral Palsy and Dev. Medicine
2020-	Ad hoc reviewer: American Journal of Speech-Language Pathology; Journal of Speech, Language, and Hearing Research; Journal of Communication Disorders; etc.
2020-	Co-founding collaborator, CSDisseminate
2019-2021	Member, International Congress of Infant Studies
2018-	Membership Committee/Member, American Academy for Cerebral Palsy and Dev. Medicine
2014-2015	Mentor, ASHA STEP Program
2013-	Member, American Speech-Language Hearing Association (CCC-SLP)
2009-2012	Member, National Student Speech-Language Hearing Association

Honors

2022	ASHFoundation New Investigators Research Grant
2022-	NIH Loan Repayment Award
2022-	Waisman Center Morse Society Scholar
2021	ASHA Pathways Program
2020	Graduate Student Association President Service Award, University of Memphis
2020	Celebrate Student Success Award, University of Memphis
2020	OrthoPediatrics™ Scholarship, American Academy for Cerebral Palsy and Dev. Medicine
2019	S.P. Wong Award for Best Presentation in Statistical Application, University of Memphis
2015-2016	Al Chymia Shriners Award, Shrine School SLP Department
2012	Red Apple Award for Outstanding School Personnel, Southborough Education Foundation
2012	Outstanding 2nd Year Master's Student Award, Florida State University
2011	Dr. Avery Vaughn Scholarship Fund for Excellence, Florida State University
2006-2010	H. Fullmer Faculty Scholarship Award, Indiana University

C. Contributions to Science

1. **Evolutionary origins of language and infant vocalizations as fitness signals.** My doctoral education with Dr. D. Kimbrough Oller provided a strong theoretical foundation in the infrastructural framework of infant prelinguistic vocal development. My doctoral dissertation used an evolutionary-developmental biology (evo-devo) lens to examine infants' capacity to vocally signal developmental information to caregivers. This work revealed three key findings. First, infant vocal imitation is rare in the first year but is highly salient to listeners, underscoring its potential to be used as a signal of information for caregivers.

Second, infants produce nonsocial vocalizations far more frequently than social ones, which suggests that independent vocal play is a primary driver in the development of articulatory properties of speech. Last, although infants vocalize the most during independent vocal play, we found that they produce their most developmentally advanced vocal forms during interactive periods, offering support for infants' capacity to signal developmental information to caregivers.

a. **Long HL,** Oller DK, Bowman DA. Reliability of listener judgments of infant vocal imitation. Front Psychol. 2019 Jun 11;10:1340. doi: 10.3389/fpsyg.2019.01340. PMID: 31244735; PMCID: PMC6579846.
b. **Long HL,** Bowman DD, Yoo H, Burkhardt-Reed MM, Bene ER, Oller DK. Social and endogenous infant vocalizations. PLoS One. 2020 Aug 5;15(8):e0224956. doi: 10.1371/journal.pone.0224956. PMID: 32756591; PMCID: PMC7406057.
c. Oller DK, Griebel U, Bowman DD, Bene E, **Long HL**, Yoo H, Ramsay G. Infant boys are more vocal than infant girls. Curr Biol. 2020 May 18;30(10):R426-R427. doi: 10.1016/j.cub.2020.03.049. PMID: 32428468; PMCID: PMC8204662.
d. Oller DK, Ramsay G, Bene E, **Long HL**, Griebel U. Protophones, the precursors to speech, dominate the human infant vocal landscape. Philos Trans R Soc Lond B Biol Sci. 2021 Oct 25;376(1836):20200255. doi: 10.1098/rstb.2020.0255. PMID: 34482735; PMCID: PMC8419580.

2. **Prelinguistic vocal development in clinical populations.** During my doctoral training, I independently sought experiences supporting my research training in early vocal development in infants at risk for speech and language disorders. The last paper in my dissertation examined canonical babbling in infants at risk for autism. Our findings suggested a potential robust internal motivation to produce a high rate of canonical syllables in both social and nonsocial contexts, even in the likely presence of autism. I also collaborated on a project evaluating vocal development in tuberous sclerosis. We found delayed canonical babbling and a low rate of their canonical syllable production compared to typical expectations. These findings indicate a critical need for further study of prelinguistic vocal patterns relative to later outcomes.

a. Gipson TT, Ramsay G, Ellison EE, Bene ER, **Long HL**, Oller DK. Early Vocal Development in Tuberous Sclerosis Complex. Pediatr Neurol. 2021 Dec;125:48-52. doi: 10.1016/j.pediatrneurol. 2021.08.009. Epub 2021 Sep 10. PMID: 34628143; PMCID: PMC8557126.

Other Publications

b. **Long, HL,** Ramsay, G, Griebel, U, Bowman, D, Burkhardt-Reed, MM, Bene, ER, & Oller, DK. Canonical Babbling in Vocal Turn Taking and Independent Vocal Play. [Preprint], doi.org/10.1101/2020.10.09.333872

3. **Speech, and communication development in cerebral palsy**. My postdoctoral training with Dr. Katherine Hustad has provided a unique opportunity to longitudinally examine speech and communication development in CP using archival, naturalistic laboratory recordings, educational data, and communication assessment data. My early work in this laboratory found variability in deficit profiles and school-based treatment goals across different levels of communication functioning in children with CP. We also recently found that speech performance improves over time in children with CP but those with severe impairments are more likely to remain stable. Our data suggests that children with mild-moderate speech and language impairments and CP have great potential to continue to make developmental and therapeutic communication gains. However, children with severe impairments are more likely to plateau in their speech development, thus requiring access to AAC as early as possible. These experiences have built the foundation to continue to develop a research program that blends my doctoral and postdoctoral training to study vocal behaviors predictive of speech impairment in CP, as young as infancy.

a. Koopmans C, Sakash A, Soriano J, **Long HL**, Hustad KC. Functional Communication Abilities in Youth With Cerebral Palsy: Association With Impairment Profiles and School-Based Therapy Goals. Lang Speech Hear Serv Sch. 2022;53(1):88-103. doi: 10.1044/2021_LSHSS-21-00064. PMID: 34767477.
b. **Long HL**, Mahr TJ, Natzke P, Rathouz PJ, Hustad KC. Longitudinal Change in Speech Classification Between 4 and 10 Years in Children with Cerebral Palsy. Dev Med Child Neurol. 2022;64(9):1096-1105. doi: 10.1111/dmcn.15198. PMID: 35262181.

4. **Prelinguistic vocal biomarkers in cerebral palsy.** Across my research experiences, I have maintained a strong focus on my programmatic line of research to study vocal biomarkers of speech impairment in CP. I independently initiated a case study on the emergence of mature CV-syllable forms in infancy (i.e., canonical babbling) during my PhD training. We found a low proportion of canonical syllables between 5-16 months in two infants with CP compared to ten typically developing infants, using all-day home recordings in CP.14 In my first year of postdoctoral work, I examined marginal and canonical babbling (i.e., immature and mature CV syllable forms) in ten infants at risk for CP and found a higher proportion of marginal syllables in infants with or with ongoing risk of CP, but a higher proportion of canonical syllables in infants whose motor delays later resolved. Throughout my doctoral and postdoctoral work, I have collaborated with a local neuromuscular clinic to study speech and language milestones in CP. We found that children with more severe communication impairments have achieved fewer prelinguistic vocal milestones. These studies offer preliminary support for directions of the ongoing study of vocal biomarkers of speech impairment in CP.
    a. **Long, HL,** Oller, DK, Romer, K, Friener, L, Warner, W, Spence, D, & Rhodes, LN. Pre-Speech and Early Speech Development of Young Children Diagnosed with Cerebral Palsy. [Abstract]. Dev Med Child Neurol, 2020 Oct;62,Suppl. 3:79-134. doi.org/10.1111/dmcn.14662

    Other Publications
    b. **Long, HL,** Eichorn, N, & Oller, DK. (In press). A Probe Study on Vocal Development in Two Infants at Risk for Cerebral Palsy. Developmental Neurorehabilitation. [Preprint], osf.io/ev397
    c. **Long, HL** & Hustad, KC. (Under Review). Longitudinal Development of Marginal and Canonical Babbling in Infants at Risk for Cerebral Palsy. [Preprint]. osf.io/2cvaq

5. **Open science practices in communication sciences and disorders.** A secondary line of research in which I have participated throughout my postdoctoral training is on the attitudes and behaviors associated with the use of open science practices in scientists within the field of communication sciences and disorders. Our work has revealed overall low knowledge, but high desire to understand and learn more about open science practices. One study looked specifically at the impact of different levels of open accessibility of manuscripts published in ASHA Journals. We found that fully open published versions of manuscripts and author-shared accepted versions both receive greater societal attention but only marginally greater scholarly attention than manuscripts published behind a paywall.
    a. El Amin, M, Borders, JC, **Long, HL,** Keller, MA, Kearney, E. Open Science Practices in Communication Sciences and Disorders: A Survey. Jour Sp Lang Hear Res. 2022 Epub ahead of print, [Preprint] doi: 10.1044/2022_JSLHR-22-00062

    Other Publications
    b. **Long, HL,** Drown, L, El Amin, M. (in press). The Effect of OpenAccess on Scholarly and Societal Metrics of Impact in the ASHA Journals. Jour Sp Lang Hear Res. 2022; 1-10. doi: 10.31219/osf.io/2ufte

Complete List of Published Work in MyBibliography:
https://www.ncbi.nlm.nih.gov/myncbi/1RMPzPxaXG8Qm/bibliography/public/

OMB No. 0925-0001 and 0925-0002 (Rev. 03/2020 Approved Through 02/28/2023)

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Katherine C. Hustad

eRA COMMONS USERNAME (credential, e.g., agency login): kchustad

POSITION TITLE: Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of Wisconsin – Eau Claire	B.A.	05/1990	Communication Disorders
University of Wisconsin – Madison	M.S.	05/1992	Speech-Language Pathology
University of Nebraska, Lincoln	Ph.D.	12/1999	Speech-Language Pathology

A. Personal Statement

My research program is focused on the study of communication development in children with cerebral palsy (CP). Specifically, my interests center on characterizing changes in speech production, speech intelligibility, language, cognition, and functional communication abilities among children with CP from early childhood into adulthood. One key facet of this work is that it involves multidimensional examination of a variety of complex communication-related variables as well as interactions among the different variables that have not previously been studied. A primary goal of my research program is to generate theoretically driven, data-based longitudinal models of speech and language development in CP that can be used to predict outcomes, test interventions, and guide treatment decisions. Ultimately, I hope to use these models of speech and language development to develop and test individually targeted communication interventions aimed at enhancing developmental trajectories and communication outcomes for this complex population of individuals

Dr. Long's research dovetails nicely with my own work in that her proposed studies address the predictive nature of early vocal and speech development in children with CP. However, the proposed research is fundamentally different in that it aims to examine pre-cursors to the production of spoken words, specifically very early vocal development as a means of identifying delays in speech motor development even before first words are expected. Dr. Long will use data from my lab, which was collected to study speech intelligibility. However, she will analyze these data in novel ways that have not been previously examined, in an effort to identify speech deficits at earlier ages than have ever been studied in CP. Dr. Long will conduct the proposed studies in my lab. She has full access to all of the resources of the Waisman Center and of my laboratory for this project. I will serve as a mentor and a consultant to support her independent research program. Key publications establishing my expertise in the study of speech in children with CP are as follows:

a. DuHadway CM, **Hustad KC.** Contributors to Intelligibility in Preschool- Aged Children with Cerebral Palsy. J Med Speech Lang Pathol. 2012 Dec;20(4):11. PMID: 25614727; PMCID: PMC4299463.
b. Lee J, **Hustad KC,** Weismer G. Predicting speech intelligibility with a multiple speech subsystems approach in children with cerebral palsy. J Speech Lang Hear Res. 2014 Oct;57(5):1666-78. doi: 10.1044/2014_JSLHR-S-13-0292. PMID: 24824584; PMCID: PMC4192090.
c. Allison KM, **Hustad KC.** Acoustic Predictors of Pediatric Dysarthria in Cerebral Palsy. J Speech Lang Hear Res. 2018 Mar 15;61(3):462-478. doi: 10.1044/2017_JSLHR-S-16-0414. PMID: 29466556; PMCID: PMC5963041.

d. Allison KM, Russell M, **Hustad KC.** Reliability of Perceptual Judgments of Phonetic Accuracy and Hypernasality Among Speech-Language Pathologists for Children With Dysarthria. Am J Speech Lang Pathol. 2021 Jun 18;30(3S):1558-1571. doi: 10.1044/2020_AJSLP-20-00144. Epub 2021 Mar 1. PMID: 33647216; PMCID: PMC8702867.

B. Positions and Honors

Positions

1992 - 1993	Speech - Language Pathologist, Community Services for Autistic Adults and Children, Rockville, MD.
1993 - 1994	Speech - Language Pathologist, Children's Seashore House, Philadelphia, PA.
1994 - 1996	Speech - Language Pathologist, Communication Aids and Systems Clinic, University of Wisconsin Hospitals and Clinics, Madison, WI.
1996 - 1999	Clinical Instructor, Barkley Memorial Speech, Language, and Hearing Clinic, University of Nebraska, Lincoln.
2000 - 2003	Assistant Professor, Department of Communication Sciences and Disorders, The Pennsylvania State University, University Park, PA.
2003 - 2009	Assistant Professor, Department of Communication Sciences and Disorders, University of Wisconsin – Madison
2009 - 2013	Associate Professor, Department of Communication Sciences and Disorders, University of Wisconsin - Madison
2010 - 2015	Director of Research and Education, Communication Aids and Systems Program, Waisman Center, University of Wisconsin - Madison
2011 - 2018	Co-Director, Clinical Translational Core, Waisman Center, University of Wisconsin – Madison
2012 - 2016	Associate Chair, Department of Communication Sciences and Disorders, University of Wisconsin - Madison
2016 - 2019	Chair, Department of Communication Sciences and Disorders, University of Wisconsin – Madison
2003 - present	Investigator, Waisman Center, University of Wisconsin - Madison
2013 - present	Professor, Department of Communication Sciences and Disorders, University of Wisconsin - Madison

Honors , Other Experience, and Professional Memberships

1990 - present	International Society for Augmentative and Alternative Communication, Member
1990 - present	United States Society for Augmentative and Alternative Communication, Member
1990 - present	American Speech-Language-Hearing Association (ASHA), Member
1992 - present	Certificate of Clinical Competence, American Speech-Language-Hearing Association
2007 - 2015	Associate Editor*, Augmentative and Alternative Communication*
2008 - present	Fellow, American Academy for Cerebral Palsy and Developmental Medicine
2009 - 2013	Associate Editor, *Journal of Speech, Language, and Hearing Research*
2010 - 2011	Ad Hoc Reviewer, Communication Disorders Review Committee, NIDCD, NIH.
2012 - 2014	Member, Research and Scientific Affairs Committee, American Speech, Language, and Hearing Association
2011 - 2012	Ad Hoc Reviewer, Special Emphasis Panel, Translational applications, NIDCD, NIH.
2014	Meritorious poster, American Speech, Language, and Hearing Association Annual Convention. Awarded to Meghan Darling-White, Ashley Oakes, and Katherine Hustad for "Characteristics of speech rate in children with cerebral palsy: A longitudinal study*".* November, 2014.
2015	Fellow, American Speech, Language, and Hearing Association
2012 - 2016	Standing panel member, Communication Disorders Review Committee, NIDCD, NIH.
2018	Distinguished Honors Faculty Award
2019	Editors Award for Article of Highest Merit, Journal of Speech, Language, and Hearing Research (Speech section). Awarded to Kristen Allison and Katherine Hustad for "Acoustic Predictors of Pediatric Dysarthria in Cerebral Palsy", published March 2018

2019 Meritorious poster, American Speech, Language, and Hearing Association Annual Convention. Awarded to Katherine Hustad, Tristan Mahr, & Phoebe Natzke for "Speech Intelligibility Acquisition in 3-year old Typically Developing Children". November, 2019.

2021 – 2023 Editor in Chief, American Journal of Speech Language Pathology

C. Contributions to Science

1. Interventions to improve speech intelligibility in individuals with dysarthria

My earliest research focused on testing the efficacy and effectiveness of augmentative and alternative communication (AAC) interventions for enhancing speech intelligibility in individuals with dysarthria and CP. Early R03 funding supported this work which focused specifically on examining the effects of speech supplementation strategies (e.g. topic cues, alphabet cues, and combined topic and alphabet cues) on intelligibility. These studies impacted the field in that they demonstrated very clearly that intelligibility gains of up to 40% could be achieved with AAC interventions that supplement speech. Studies also showed that specific changes to speech production features occurred with the implementation of alphabet supplementation (e.g. increased interword pauses, expanded vowel space areas) and that these changes accounted for the observed intelligibility enhancements. More recently we have begun examining the effects of speech supplementation strategies on the speech of children. Representative publications from this research are as follows:

a. **Hustad, K.C.,** Jones, T., & Dailey, S. (2003). Implementing speech supplementation strategies: Effects on intelligibility and speech rate of individuals with chronic severe dysarthria*. Journal of Speech, Language, and Hearing Research, 46,* 462-474.
b. **Hustad KC,** Jones T, Dailey S. (2003). Implementing speech supplementation strategies: effects on intelligibility and speech rate of individuals with chronic severe dysarthria. J Speech Lang Hear Res. Apr;46(2):462-74. PMID: 14700386.
c. **Hustad, K. C.,** & Lee, J. (2008). Changes in speech production associated with alphabet supplementation. *Journal of Speech, Language, and Hearing Research: JSLHR, 51(6), 1438-1450*.
d. Sakash, A., Mahr, T. J., Natzke, P., & **Hustad, K. C.** (2020). Effects of Rate Manipulation on Intelligibility in Children with Cerebral Palsy. *American Journal Of Speech-Language Pathology*, *29*(1), 127–141. [PMCID: PMC7231911]

2. Classification of communication profiles in children with cerebral palsy

Though my early work on adults with CP, I became interested in the course of development leading to adult outcomes. This interest gave way to a shift in my research program, initially fostered by a K23 award, to a focus on speech and language development in children with CP. Because children with CP are extremely heterogeneous and very little work had addressed communication development in this population, my group began a longitudinal study that was focused on development of a classification paradigm specific to communication abilities. Our communication classification model was developed using empirical data from 4- year old children with CP, and our current R01, in its third funding cycle, is focused on examination / expansion of that model in a longitudinal developmental context, examining children through the age of 15 years. To date our work has validated the profile group model, demonstrated that younger children (at 2 years of age) require special consideration and a different type of classification paradigm owing to developmental constraints, and that our classification model is superior to two other communication classification paradigms that were recently developed with regard to comprehensiveness of constructs captured and reliability. Representative publications from this research are as follows:

a. **Hustad, K. C.,** Gorton, K., & Lee, J. (2010). Classification of speech and language profiles in 4-year-old children with cerebral palsy: a prospective preliminary study. *Journal Of Speech, Language, And Hearing Research*, *53*(6), 1496–1513. [PMCID: PMC2962882].
b. **Hustad, K. C.,** Allison, K., McFadd, E., & Riehle, K. (2014). Speech and language development in 2-year- old children with cerebral palsy. *Developmental Neurorehabilitation*, *17*(3), 167–175. [PMCID: PMC3732544].
c. Allison, K. M., & **Hustad, K. C.** (2018). Data-Driven Classification of Dysarthria Profiles in Children With Cerebral Palsy. *Journal Of Speech, Language, And Hearing Research*, *61*(12), 2837–2853. [PMCID: PMC644031]
d. Soriano, JU, & **Hustad, KC.** (2021). Speech-language profile groups in school aged children

with cerebral palsy: Nonverbal cognition, receptive language, speech intelligibility, and motor function. *Developmental Neurorehabilitation,* 24(2), 118-129.

3. **Longitudinal development and prediction of speech and language outcomes in cerebral palsy**
My work on classification of speech and language profiles in children with CP also examines change over time. Specifically, we are examining growth curves for key speech and language variables in order to characterize rates and limits of change. We are also examining how profile group membership changes over time. This work has a strong statistical modelling component and includes the identification of early predictors of later outcomes. Results to date suggest that basic classification profiles shift in early speech and language development—from a 3-group classification model to a 4 group model—but that early classification is highly predictive of later classification group membership. In addition, age at which children begin speaking is highly predictive of intelligibility and maximum length of utterance at 4 years of age. Specifically, children who are speaking by 2 years of age have the best outcomes later in life. In addition, the age at which children cross a 50% intelligibility threshold is negatively correlated with intelligibility at 8 years of age such that children who cross the 50% threshold at younger ages have higher intelligibility later in life. Finally, our work to date has shown that growth in language comprehension development follows two discrete patterns, each of which comprises a latent class. Children who are unable to speak comprise their own class and show significant developmental delays in language comprehension growth. Children with CP who are able to speak (whether dysarthric or not) comprise a separate group and show a rate of growth over time that does not differ from typical developmental expectations. Representative publications are as follows:
   a. **Hustad, K. C.,** Allison, K. M., Sakash, A., McFadd, E., Broman, A. T., & Rathouz, P. J. (2017). Longitudinal development of communication in children with cerebral palsy between 24 and 53 months: Predicting speech outcomes. *Developmental Neurorehabilitation*, *20*(6), 323–330. [PMCID: PMC5409890]
   b. **Hustad, K. C.,** Sakash, A., Broman, A. T., & Rathouz, P. J. (2018). Longitudinal growth of receptive language in children with cerebral palsy between 18 months and 54 months of age. *Developmental Medicine And Child Neurology*, *60*(11), 1156–1164. [PMCID: PMC6175617].
   c. **Hustad, K. C.,** Mahr, T. J., Broman, A. T., & Rathouz, P. J. (2020). Longitudinal Growth in Single-Word Intelligibility Among Children with Cerebral Palsy From 24 to 96 Months of Age: Effects of Speech- Language Profile Group Membership on Outcomes. *Journal Of Speech, Language, And Hearing Research*, *63*(1), 32–48. [PMCID: PMC7213485]
   d. Long, H. L., Mahr, T. J., Natzke, P., Rathouz, P. J., & **Hustad, K. C.** (2022). Longitudinal change in speech classification between 4 and 10 years in children with cerebral palsy. Developmental Medicine & Child Neurology.

4. **Speech intelligibility in children with and without dysarthria**
An ongoing focus on speech intelligibility, variables that contribute to it, and its development has paralleled my work on speech and language classification. Our studies examining speech development in young children with CP have demonstrated that children with different speech profiles have different growth trajectories, that articulatory abilities seem to make the most impactful contribution to speech intelligibility, and that intelligibility scores differentiate between children with dysarthria and typically developing children very accurately at 5 years of age. Representative publications from this research are as follows:
   a. Lee, J., **Hustad, K. C.,** & Weismer, G. (2014). Predicting speech intelligibility with a multiple speech subsystems approach in children with cerebral palsy. *Journal Of Speech, Language, And Hearing Research*, *57*(5), 1666–1678. PMCID: PMC4192090.
   b. Natzke, P., Sakash, A., Mahr, T., & **Hustad, K. C.** (2020). Measuring Speech Production Development in Children With Cerebral Palsy Between 6 and 8 Years of Age: Relationships Among Measures. *Language, Speech, And Hearing Services In Schools*, *51*(3), 882–896. PMID: 32574125
   c. Soriano, JU, Olivieri, A, & Hustad, KC. (2021). Utility of the intelligibility in context scale for predicting speech intelligibility of children with cerebral palsy, *Brain Sciences, 11*(11), 1540.
   d. Allison KM, Russell M, **Hustad KC.** Reliability of Perceptual Judgments of Phonetic Accuracy and Hypernasality Among Speech-Language Pathologists for Children With Dysarthria. Am J Speech Lang Pathol. 2021 Jun 18;30(3S):1558-1571. doi: 10.1044/2020_AJSLP-20-00144. Epub 2021 Mar 1. PMID: 33647216; PMCID: PMC8702867.

5. **Services and interventions for children with neurodevelopmental disabilities**
   As part of the study of communication development in children with CP, we have also examined the specific services that children receive through educational and medical interventions. This work has shown that there seems to be a clear bias with regard to the types of interventions that children receive based on whether they are able to produce speech or not, without clear consideration for the quality and intelligibility of speech. Specifically, children who could benefit from the use of assistive technologies (AAC) and who have the ability to produce any speech at all appear to be systematically overlooked for interventions focusing on AAC. Ongoing work is seeking to track the point at which children are introduced to AAC and to advance professional education regarding the complementary roles of speech and AAC for fostering functional communication abilities. Representative publications from this research are as follows:
   a. **Hustad, K. C.,** Keppner, K., Schanz, A., & Berg, A. (2008). Augmentative and alternative communication for preschool children: intervention goals and use of technology. *Seminars In Speech And Language*, *29*(2), 83–91. [PMCID: PMC2493612].
   b. **Hustad, K. C.,** & Miles, L. K. (2010). Alignment between Augmentative and Alternative Communication Needs and School-Based Speech-Language Services Provided to Young Children with Cerebral Palsy. *Early Childhood Services (San Diego, Calif.)*, *4*(3), 129–140. [PMCID: PMC3243446].
   c. Smith, A. L., & **Hustad, K. C.** (2015). AAC and Early Intervention for Children with Cerebral Palsy: Parent Perceptions and Child Risk Factors. *Augmentative And Alternative Communication (Baltimore, MD: 1985)*, *31*(4), 336–350. [PMCID: PMC4628599]
   d. Koopmans, C., Sakash, A., Soriano, J., Long, H. L., & **Hustad, K. C.** (2022). Functional communication abilities in youth with cerebral palsy: Association with impairment profiles and school-based therapy goals. Language, Speech, and Hearing Services in Schools, 53(1), 88-103.

Complete list of published work in MyBibliography:
https://www.ncbi.nlm.nih.gov/sites/myncbi/katherine.hustad.1/bibliography/41150556/public/?sort=date&direct i on=descending

OMB No. 0925-0001 and 0925-0002 (Rev. 10/2021 Approved Through 09/30/2024)

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Bunton, Kate

eRA COMMONS USER NAME (credential, e.g., agency login): bunton

POSITION TITLE: Associate Professor, Department of Speech, Language, and Hearing Sciences

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of Iowa	BS	12/1990	Speech and Hearing Science
University of Wisconsin-Madison	MS	8/1993	Communication Disorders
University of Wisconsin-Madison	PhD	5/1999	Communication Disorders
University of Arizona	postdoc	8/2002	Speech and Hearing Science

A. Personal Statement

I have the expertise, training, and motivation necessary to successfully carryout the proposed project examining the relationship between perceptual and acoustic measures in vocal production in infants and young children. My expertise relates to vocal and speech production, specifically, the acoustic, aerodynamic, and articulatory (kinematic) study of production in infants as young as 4 months of age. As a co-PI or co-Investigator on several NIH and NSF funded grants, I have focused on understanding how the articulatory (movements of the tongue, lips, etc.), aerodynamic (air pressures and flows), and acoustic (sound) elements of the vocal tract affect speech sound production, and thus, intelligibility across the lifespan. I have successfully administered research protocols, collaborated, and produced over 34 peer-reviewed publications from each of these funded projects. The goal of my research is to develop a model that explains mechanisms underlying speech intelligibility deficits in children at risk for neuromotor impairment, which falls directly in line with the aims of Dr. Long's proposal. Also, the proposed research builds on my work documenting the development of early vocal and speech production in healthy infants and young children. Specifically, a primary arm of my research has sought to identify perceptual and acoustic correlates of velopharyngeal closure in real words versus infant babble. My experience and expertise in this area can directly support the proposed work characterizing of acoustic features in infant vocalizations. I am also a certified speech pathologist (25+years) with experience working clinically as part of an early intervention and cleft palate team. Thus, I am enthusiastic to co-sponsor clinical research conducted by early career scientists like Dr. Long with clearly defined implications for diagnosis and early intervention in developmental disabilities like cerebral palsy.

Citations:

a. Story BH, **Bunton K.** (2015). Formant measurement in children's speech based on spectral filtering. Speech Communication, 76, 93-111. doi: 10.1016/j.specom.2015.11.001. PubMed PMID: 26855461; PubMed Central PMCID: PMC4743040.
b. **Bunton K,** Story BH. (2016). Arizona Child Acoustic Database Repository. Folia Phoniatrica et Logopaedica, 68(3), 107-111. doi: 10.1159/000452128. Epub 2016 Oct 27. PubMed PMID: 27784009
c. Story BH, **Bunton K.** (2017). An acoustically-driven vocal tract model for stop consonant production. Speech Communication, 87, 1-17. doi: 10.1016/j.specom.2016.12.001. Epub 2016 Dec 9. PubMed PMID: 28093574; PubMed Central PMCID: PMC5234468.

d. Story BH, **Bunton K.** (2017). Vowel space density as an indicator of speech performance. Journal of the Acoustical Society of America, 141(5), EL458. doi: 10.1121/1.4983342. PubMed PMID: 28599542; PubMed Central PMCID: PMC5724721.

B. Positions, Scientific Appointments, and Honors

Positions and Scientific Appointments

2022-Present Director, Program for Excellence in Teaching and Learning, University of Arizona
2021 - Present Associate Department Head, Dept of Speech, Language, and Hearing Sciences, University of Arizona
2021 - Present Member, Cleft Palate Speech Outcomes Clinical Study Oversight Panel, NIDCR
2019 - 2022 Editor, Journal of Speech, Language, and Hearing Science
2018 - 2020 Guest Editor, American Journal of Speech-Language Pathology
2016 - Present Director of Graduate Studies, Dept of Speech, Language, and Hearing Sciences, University of Arizona
2010 - Present Associate Professor, Dept of Speech, Language, and Hearing Sciences, University of Arizona
2006 - 2010 Assistant Research Scientist, Dept of Speech, Language, and Hearing Sciences, University of Arizona
2002 - 2006 Assistant Research Scientist, Institute for Neurogenic Communication Disorders, University of Arizona
2000 - Present Licensed Speech Language Pathologist, State of Arizona
2000 - 2002 Post-Doctoral Fellow, Institute for Neurogenic Communication Disorders, University of Arizona
1999 - 2000 Research Associate, Waisman Center, University of Wisconsin-Madison
1996 – Present Member, American Cleft Palate-Craniofacial Association
1993 - Present Clinically Certified Speech Language Pathologist, American Speech, Language, and Hearing Association
1993 - Present Member, Speech Communication Technical Committee, Acoustical Society of America

Honors

2022 Teaching and Mentoring Award for Graduate Education, Graduate College, University of Arizona

C. Contributions to Science

1. I am using computational modeling to study how children produce speech during a period of rapid growth, ages 2-6 years. Although much is known about the acoustic characteristics of children's speech, there is comparatively little known about the mechanisms available to a child for producing sounds and how those mechanisms may differ from those of an adult system. This is a collaborative project with Dr. Brad Story (Dept of Speech, Language, and Hearing Sciences, University of Arizona). We have designed a protocol and are beginning longitudinal and cross-sectional data collection from children ages 2-6 years using a recently acquired a noninvasive 3D motion capture system (NDI Wave). This system allows for collection of movement data from the tongue, lip, and jaw during speech production. This new technology is an exciting advance over the more cumbersome and invasive systems used previously, and allows for studying children's speech production, which has historically been difficult. These data will be used to inform and verify modeling efforts. This project is significant, as it will provide new information about the acoustic, aerodynamic (airflow), and kinematic (movement) factors that guide speech production development in children.
    a. Story, BH, **Bunton K.** (2013, June). Production of child-like vowels with nonlinear interaction of glottal flow and vocal tract resonances. Journal of the Acoustical Society of America. Paper presented at the Joint Meeting of the Acoustical Society of America, International Congress on Acoustics, and the Canadian Acoustical Association, Montreal, Quebec, 5pSC2.
    b. Story BH, **Bunton K.** (2015). Formant measurement in children's speech based on spectral filtering. Speech Communication, 76, 93-111. doi: 10.1016/j.specom.2015.11.001. PubMed PMID: 26855461; PubMed Central PMCID: PMC4743040.

c. **Bunton K,** Story BH. (2016). Arizona Child Acoustic Database Repository. Folia Phoniatrics et Logopaedica, 68(3), 107-111. doi: 10.1159/000452128. Epub 2016 Oct 27. PubMed PMID: 27784009
d. Story BH, Vorperian HK, **Bunton K,** Durtschi RB. (2018). An age-dependent vocal tract model for males and females based on anatomic measurements. Journal of the Acoustical Society of America, 143(5), 3079. doi: 10.1121/1.5038264. PubMed PMID: 29857736; PubMed Central PMCID: PMC5966313.

2. A second research project is aimed at building a comprehensive account of the acoustic correlates of speech intelligibility. In short, the research goal is to identify those characteristics of the acoustic signal that pose the most difficulties for listeners in determining a speaker's intended message. Toward this goal, I am working with a computational model of speech production to simulate connected speech samples where specific acoustic features are varied systematically to determine how the changes in acoustics relate to listener identification. This project is being done in collaboration with Dr. Brad Story who developed the model and will provide information about which changes explain or underlie the identification and intelligibility of speech.
    a. Story BH, **Bunton K.** (2017). An acoustically-driven vocal tract model for stop consonant production. Speech Communication, 87, 1-17. doi: 10.1016/j.specom.2016.12.001. Epub 2016 Dec 9. PubMed PMID: 28093574; PubMed Central PMCID: PMC5234468
    b. Story BH, **Bunton K.** (2017). Vowel space density as an indicator of speech performance. Journal of the Acoustical Society of America, 141(5), EL458. doi: 10.1121/1.4983342. PubMed PMID: 28599542; PubMed Central PMCID: PMC5724721.
    c. Story BH, **Bunton K.** (2019). A model of speech production based on the acoustic relativity of the vocal tract. Journal of the Acoustical Society of America, 146(4), 2522. doi: 10.1121/1.5127756. PubMed PMID: 31671993; PubMed Central PMCID: PMC7064311.
    d. Story, BH, **Bunton, K.** (2021). Identification of voiced stop consonants produced by acoustically-driven vocal tract modulations. Journal of the Acoustical Society of America-Express Letters. doi:10.1121/10.0005917

3. A third project underway in my laboratory examines the time course for development of velopharyngeal function in infants and young children. This work is in collaboration with Dr. Jeannette Hoit (Department of Speech, Language, and Hearing Sciences, University of Arizona). We have collected longitudinal data on 92 infants beginning at four months of age and continuing until approximately two years of age using a noninvasive aerodynamic (airflow) approach. Preliminary data analysis shows significant individual variability in closure that may be related to acquisition of specific speech sounds and different syllable shapes. This dataset is being used to identify reliable to identify reliable acoustic and perceptual correlates of velopharyngeal status and has implications for development of clinical tools that could be used to identify the presence of velopharyngeal difficulties in infants and young children.
    a. **Bunton K,** Hoit JD, Gallagher K. (2011). A simple technique for determining velopharyngeal status during speech production. Seminars in Speech and Language, 32(1), 69-80. doi: 10.1055/s-0031-1271976. PubMed PMID: 21491360; PubMed Central PMCID: PMC3957481.
    b. **Bunton K.** (2015). Effects of nasal port area on perception of nasality and measures of nasalance based on computational modeling. Cleft Palate Craniofacial Journal, 52(1),110-4. doi: 10.1597/13-126. PubMed PMID: 24437587; PubMed Central PMCID: PMC4440335.
    c. **Bunton K,** Hoit JD. (2018). Development of Velopharyngeal Closure for Vocalization During the First 2 Years of Life. Journal of Speech, Language, and Hearing Research, 61(3), 549-560. doi: 10.1044/2017_JSLHR-S-17-0208. PubMed PMID: 29490338; PubMed Central PMCID: PMC6195065.
    d. **Bunton, K.** (2018). Update on Velopharyngeal Closure in Young Children. Perspectives of the ASHA Special Interest Groups, 3(5), 4-12. doi: 10.1044/persp3.sig5.4

Complete List of Published Work in MyBibliography:
https://www.ncbi.nlm.nih.gov/myncbi/1d1lzsuHgFX5G/bibliography/public/

OMB No. 0925-0001 and 0925-0002 (Rev. 12/2020 Approved Through 02/28/2023)

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
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NAME: Mahr, Tristan Jay

eRA COMMONS USER NAME (credential, e.g., agency login): tjmahr

POSITION TITLE: Assistant Scientist

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of Wisconsin–Madison	B.S.	05/2009	Linguistics
University of Wisconsin–Madison	M.S.	12/2013	Speech Language Pathology
University of Wisconsin–Madison	Ph.D.	08/2018	Communication Sciences and Disorders

A. Personal Statement

I support Dr. Hustad's lab as a data scientist. I prefer this title because it speaks to three competencies that I will use to support this project: 1) domain knowledge about speech and language development, 2) statistical modeling of longitudinal and linguistic data, and 3) programming and reproducible research. My background in linguistics and speech pathology gives me a base of prior knowledge about phonetic and phonological development and children with speech disorders. My Ph.D. research investigated the development of word recognition over the preschool years. Because I had to analyze change over time in the moment (from eyetracking-based word recognition data) and over the years (from longitudinal data), this research gave me the opportunity to learn many approaches to time series data, including mixed-effects models, generalized additive models and Bayesian regression models. My research also gave me experience in handling large datasets (millions of rows), developing software libraries to facilitate data analysis, and performing reproducible research with dynamic documents—that is, working so that research artifacts (figures, tables, in-text statistics) update automatically whenever the data change. I will consult with Dr. Long on the statistical analyses involved in her research proposal.

B. Positions, Scientific Appointments, and Honors

Positions and Scientific Appointments

2018 – Present	Assistant Scientist, Wisconsin Intelligibility, Speech, and Communication Lab [R01-DC009411, R01-DC015653], UW–Madison
2015 – 2018	Research Assistant, Little Listeners Lab [R01-DC012513], UW–Madison
2013 – 2015	Research Assistant, Learning to Talk Lab [R01-DC002932], UW–Madison
2013 – 2014	Sub. Speech-Language Diagnostician, Middleton Cross Plains School District, Middleton, WI

Honors

2019 Meritorious poster, American Speech, Language, and Hearing Association Annual Convention. Awarded to Katherine Hustad, Tristan Mahr, & Phoebe Natzke for "Speech Intelligibility Acquisition in 3-year-old Typically Developing Children". November, 2019.

2017 – 2018	Supported by NIH Training Grant to Susan Ellis Weismer: T32-DC5359, *Interdisciplinary Research in Speech–Language Disorders.*
2016	Jean Berko Gleason Award for highest scored student submission at the 41st Boston University Conference on Language Development.
2013 – 2015	Supported by NIH Training Grant to Maryellen MacDonald: T32-HD049899, *Training in Language: Acquisition and Adult Performance.*
2012	Students Preparing for Academic-Research Careers (SPARC) Award. Given by the American Speech-Language-Hearing Association.

C. Contributions to Science

1. **Speech intelligibility and speech rate in children with and without cerebral palsy:** In Dr. Hustad's lab, I have carried out the analysis of speech intelligibility and speech rate data for children with cerebral palsy (longitudinally) and children who are typically developing (cross-sectionally). I bring innovative statistical methods to bear on these datasets including nonlinear mixed models and flexible spline models for growth trajectories. One recent work showed a Bayesian framework for clinical forecasting by simulating plausible development trajectories based off a single assessment. Child speech is highly variable but I embrace the richness of these data. We have two additional in-press publications about developmental norms and percentile growth curves for articulation rate and intelligibility in typically developing children from 30 to 119 months in age.
   a. Long HL, **Mahr TJ,** Natzke P, Rathouz PJ, Hustad KC. Longitudinal change in speech classification between 4 and 10 years in children with cerebral palsy. Dev Med Child Neurol. 2022 Sep;64(9):1096-1105. doi: 10.1111/dmcn.15198. Epub 2022 Mar 9. PMID: 35262181; PMCID: PMC9339470.
   b. **Mahr TJ,** Soriano JU, Rathouz PJ, Hustad KC. Speech Development Between 30 and 119 Months in Typical Children II: Articulation Rate Growth Curves. J Speech Lang Hear Res. 2021 Nov 8;64(11):4057-4070. doi: 10.1044/2021_JSLHR-21-00206. Epub 2021 Sep 29. PMID: 34586882; PMCID: PMC9132150.
   c. **Mahr, T. J.,** Rathouz, P. J., & Hustad, K. C. (2020). Longitudinal Growth in Intelligibility of Connected Speech From 2 to 8 Years in Children With Cerebral Palsy: A Novel Bayesian Approach. *Journal of Speech, Language, and Hearing Research*.
   d. Sakash, A., **Mahr, T. J.,** Natzke, P. E., & Hustad, K. C. (2020). Effects of Rate Manipulation on Intelligibility in Children with Cerebral Palsy. *American Journal of Speech-Language Pathology*, 29, 127-141.

2. **Development of word recognition in toddlers and preschoolers:** My graduate research focused on studying word recognition in young children. In these experiments, we present an array of images on a screen, play a prompt to view one of the images (e.g., *find the dog*), and use eyetracking to record the child's gaze over time. That time-series data of how a child's gaze changes *in response to speech* measures word recognition. If we manipulate what the child sees or hears, we can study when or whether listeners integrate information during word recognition. The main finding of my research is that children act a lot like adult listeners, using information when it becomes available but they are more slow and less reliable, and that there is developmental continuity in word recognition from toddlerhood to adulthood. (That is, adults do not have any special skills compared to children; they just more developed lexicons.) To investigate these data, which deal with time-series during a trial and longitudinally, I had to work with a number of statistical approaches including mixed models, generalized additive models, nonlinear growth curve models, and Bayesian versions of these models.
   a. **Mahr, T. J.** (2018). *The development of word recognition in preschoolers.* (Doctoral dissertation). University of Wisconsin**–**Madison.
   b. **Mahr, T. J.,** & Edwards, J. R. (2018). Using language input and lexical processing to predict vocabulary size. *Developmental Science*. 10.1111/desc.12685.
   c. Law, F., II, **Mahr, T. J.,** Schneeberg, A., & Edwards, J. R. (2016). Vocabulary size and auditory word recognition in preschool children. *Applied Psycholinguistics*. 10.1017/S0142716416000126.
   d. **Mahr, T. J.,** McMillan, B. T. M., Saffran, J. R., Ellis Weismer, S., & Edwards, J. R. (2015). Anticipatory coarticulation facilitates word recognition in toddlers. *Cognition*, *142*, 345–350. 10.1016/j.cognition.2015.05.009.

3. **Open-source statistical computing:** My most impactful work, in terms of reach, is in open-source statistical computing. For instance, I am a coauthor of bayesplot R package, a library for visual diagnostics of Bayesian statistical models that receives 15,000 monthly downloads. I have written code tutorials on mixed-effects models and Bayesian regression models with thousands of reads as well. I have developed an interactive dashboard for computing intraclass correlations for estimating interrater reliability (ICCBot). I also have developed several “glue” packages. This is software that helps data flow through a scientific workflow. For example, I have written or contributed to R packages for cleaning data from Praat textgrids, E-Prime experiments, LENA time-series files, and iCoder and Tobii eyetracking files. These tools are open-source and used by a number of labs. My work with Dr. Hustad has led me to use more tools from corpus phonetics, and as a result, we developed and published a comparison of several different forced-alignment algorithms.
    a. **Mahr TJ**, Berisha V, Kawabata K, Liss J, Hustad KC. Performance of Forced-Alignment Algorithms on Children's Speech. J Speech Lang Hear Res. 2021 Jun 18;64(6S):2213-2222. doi: 10.1044/2020_JSLHR-20-00268. Epub 2021 Mar 11. PMID: 33705675; PMCID: PMC8740721.

SPECIFIC AIMS

Speech impairments negatively impact up to 80% of children with cerebral palsy (CP) which can reduce effective communication across environments throughout the lifespan.[29–32] However, speech impairments are often not formally diagnosed in CP until children are 4-5 years of age.[33] Recent work has shown that speech abilities at 2 years are highly predictive of communication outcomes at 5 and 8 years in children with CP.[34,35] Yet, there is little research examining early predictors of speech impairment in CP under 2 years.

Perceptual vocal coding is considered the gold standard method to study infant speech-like sounds according to how well they conform to general parameters of mature speech.[6] Vocal developmental delays are frequently observed in infants with later-identified communication disorders using these methods, indicating its ongoing utility for the early detection of impairment.[36–38] Instrumental acoustic analysis, on the other hand, is commonly used to quantitatively measure speech production in disordered populations to support objective comparison to typical speech.[25–28] Acoustically-derived measures have shown reduced vowel spaces and slow consonant-vowel (CV) formant transitions in children with dysarthria as young as 5 years of age.[27,28,39–41] Instrumental acoustic analysis has great potential to support a quantitative understanding of prelinguistic vocal behaviors in clinical populations, but has yet to be applied to the study of vocalizations in infants prospectively at risk for CP.[42–45] We posit that clinically meaningful differences in the prelinguistic vocal production of infants with different speech outcomes may be best revealed by a combination of acoustic and perceptual analyses.[46,47]

I am uniquely suited to develop my programmatic line of research examining vocal biomarkers of speech impairment in CP given my prior and ongoing training with Drs. D. Kimbrough Oller and Katherine Hustad, leading scientists in their respective fields of infant vocal development and communication development in CP. However, my preliminary work in this area has only used perceptual coding methods to study prelinguistic vocal production.[14,17,18] A third year of postdoctoral training is necessary to support my development toward becoming an independent investigator at an institution with very high research activity. Specifically, I require explicit training in instrumental acoustic analysis of infant vocalizations to expand my methodological tools for future research in this area and to further establish my expertise as an independent investigator. I also require advanced training in statistical modeling to learn rigorous methods for examining associations between prelinguistic variables and later speech outcomes. I have assembled a highly qualified mentorship team with the relevant expertise to support the proposed research aims and training goals, including the Sponsor (Hustad), acoustic analysis collaborator (Bunton), and statistical consultant (Mahr).

The primary objective of the proposed research is to examine the extent to which perceptual and acoustic measures of infant vocalization predict speech outcomes in CP. This project will use an existing longitudinal dataset of 23 infants at risk for CP. Perceptual and acoustic measures will be derived from laboratory audio recordings of parent-infant interactions at 12 months. Infants' speech outcomes will be classified using their ~36-month data. The central hypothesis of my work is that neurological damage associated with CP can negatively affect the development of the motor speech system during prelinguistic periods of development, resulting in atypical vocal features predictive of later impairment.

Aim 1. Compare perceptual and acoustic measures across speech outcomes in CP. Four perceptual measures and three acoustic measures will be used to conduct pairwise comparisons across the two speech outcome groups: SMI (speech motor impairment) and NSMI (no speech motor impairment). We predict that the NSMI group will show individual perceptual and acoustic values representative of more developmentally complex syllable types compared to the SMI group. These data will quantify the extent to which individual variables have the potential to be used as standalone predictors of speech outcomes in CP.

Aim 2. Identify acoustic and perceptual predictors of speech outcomes in CP. All perceptual and acoustic variables derived from recordings will be included in a set of statistical models to determine the extent to which the acoustic and perceptual variables jointly predict speech outcome groups. This aim is exploratory in nature; however, we predict that at least one perceptual and acoustic measure will significantly contribute to the model. Research from this aim seeks to identify the best combination of vocal predictors for speech impairment in CP.

Summary and future directions. The data and training obtained from the proposed research will support future work investigating prelinguistic biomarkers of speech impairment to improve early detection of communication outcomes in CP. Furthermore, it contributes to the long-term goal of my independent investigator career to develop critically needed diagnostic tools for speech and language impairment in CP. Importantly, the proposed work has clear clinical implications to inform treatment planning to support long-term communication outcomes and quality of life in children with CP.

RESEARCH STRATEGY

1. SIGNIFICANCE

Speech impairments negatively affect up to 80% of children with cerebral palsy (CP) which can reduce effective communication across environments and quality of life in these individuals throughout the lifespan.[29–32] Because of the protracted trajectory of typical speech development and the heterogenous nature of CP, formal speech diagnoses are often not made until 4-5 years of age.[33] Recent work has shown that speech abilities at 2 years are highly predictive of communication outcomes at 5 and 8 years in children with CP.[34,35] However, there is a paucity of research examining early predictors of speech impairment in CP under 2 years.

The uncertainty of the prognosis for speech and communication development in CP under 24 months has led to a critical mass of medical providers delaying speech referrals or treatment for augmentative and alternative communication.[48] The "wait-and-see" approach not only creates false hope for parents, but it can deleteriously impact long-term communication outcomes in children if early intervention is not initiated.[49] It is critical to expand the study of early vocal and speech development in CP under 24 months to identify biomarkers of speech impairment and its severity to support screening and diagnosis as young as infancy. I am uniquely suited to pursue this line of work given my training with Drs. D. Kimbrough Oller and Katherine Hustad; both are leading scientists in their respective fields of infant vocal development and communication in CP.

I recently led two pilot studies using perceptual coding of vocalization. These studies revealed preliminary evidence of anomalous prelinguistic vocal patterns in infants later diagnosed with CP.[14,17] Without question, perceptual listener coding is considered the gold standard method to empirically study infant vocal development.[46,50,51] The infraphonological framework of perceptual coding supports categorization of infant speech-like sounds according to how well they conform to phonatory, resonatory, and articulatory parameters of mature speech without presuming full command over phonemic units in infancy.[6] Studies using perceptual coding methods have repeatedly demonstrated delays in the emergence of prelinguistic vocal stages in children with speech, language, and hearing disorders, suggesting its ongoing utility for the early detection of impairment.[36–38] However, few studies beyond my own preliminary work have examined prelinguistic vocal behaviors in CP.[50,52] Perceptual methods of analysis demonstrate clear clinical implications with caregiver-reported information for clinical screening. Indeed, previous work has shown that both trained listeners and parents are highly reliable in their perceptual judgment of infant vocalizations.[9,53,54]

Instrumental acoustic analysis, on the other hand, is often used to quantitatively measure speech production in CP as an objective comparison to typical speech.[25–28] Reduced vowel space and slow consonant-vowel (CV) formant transitions, for example, are frequently observed in children and adults with dysarthria as young as 5 years of age.[27,28,39–41] Instrumental acoustic analysis has yet to be used to study vocalization in infants at risk for CP, and has great potential to support the quantitative analysis of primitive and adult-like sound forms in clinical populations.[42–45] Ultimately, clinical differences in the prelinguistic vocal production of infants with different speech outcomes may be best revealed by a combination of acoustic and perceptual measures.[46,47]

Infants at risk for CP and secondary motor speech impairment (e.g., pediatric dysarthria) are a particularly unique clinical group to study prelinguistic vocal behaviors. We operate under the assumption that early neurological damage to the speech subsystems around the time of birth can negatively affect the trajectory of prelinguistic vocal development to support functional speech. My central hypothesis is that neurological damage associated with CP will affect the development of the motor speech system, resulting in atypical vocal features that are predictive of later speech disorders. My preliminary work in this area has only used perceptual coding of infant vocalizations. Explicit training in instrumental acoustic analysis is critical to expand my methodological tools to study infant vocalization and to establish my independence as an expert researcher in this area. My postdoctoral mentor (Sponsor: Hustad) has extensive experience in the study of acoustic predictors of pediatric dysarthria in CP. My collaborating mentor (Bunton) also has extensive experience studying acoustic characteristics of normal and disordered child speech. Secondly, I am seeking training in rigorous statistical methodologies, particularly in biostatistical modeling of predictors for later outcomes. My statistical consultant (Mahr) is the data scientist in Dr. Hustad's laboratory and has broad knowledge in biostatistical modeling of longitudinal developmental trajectories, particularly involving speech variables associated with CP. Conducting the proposed work and training under the advisement of the proposed mentorship team will directly support my development as an independent investigator in these areas.

The primary objective of this research is to examine the extent to which perceptual and acoustic measures of infant vocalization predict speech impairment outcomes in CP. With the dawn of new automated technologies built to analyze both speech and infant vocalization,[55,56] the importance of incorporating acoustic measures into our assessment of vocal biomarkers is at an all-time high.[57] The successful completion of this project and the knowledge gained from a multi-measure characterization of perceptual and acoustic methods will directly inform future directions of research examining vocal biomarkers of speech impairment in CP. First, validating acoustic analysis against perceptual measures can inform the future development of automated methods to detect vocal patterns associated with later speech impairment. Second, comparing perceptual measures against acoustic analysis can offer quantitative validation for the future development of clinical tools utilizing listener-judgment and parent-report measures to screen for speech impairment in CP. The planned work has clear clinical implications to support diagnostic and early intervention treatment planning for improving communication outcomes in this population.

2. APPROACH

The proposed project will accomplish two aims: 1) compare group-level performance of perceptual and acoustic measures across speech outcomes in CP, and 2) identify the best combination of these measures to predict their speech outcome groups. These objectives will be achieved through the cross-sectional study of laboratory-based parent-infant (P-I) recordings of 23 infants around 12 months of age already available for immediate analysis. Later speech outcomes will be classified based on their ~36-month data. The first aim will involve pairwise comparisons of four perceptual and three acoustic measures between the two speech outcome groups. The second aim will involve statistical modeling of all variables to identify the best combination of predictors for later speech outcomes. These methods are further described below.

Recording dataset.

Twenty-three infants at risk for CP (Mean age: 12 months, SD: 1.0) will be included in the proposed project; their data are already available and ready for analysis. These infants were recruited through local and regional medical centers through the UW-Madison Waisman Center to participate in a longitudinal study of the emergence and acquisition of language and speech in CP (PI: Hustad, R01). My specific Research Aims have not been previously studied with these data. As part of recruitment for this longitudinal project, CP risk status was based on medical records and birth history. During participation, high quality audio recordings of naturalistic P-I interactions were collected during laboratory visits (mean duration: 12 minutes). During these sessions, parents were instructed to engage with their infant using toys, books, or simple games. The perceptual and acoustic measures will be derived from infant vocalizations produced during these recordings. Because of the longitudinal nature of the larger project, speech outcome data around 36 months is also available as an outcome variable of later-identified speech performance.

Speech outcome data.

Speech outcomes around ~36 months of age will be identified for each of the 23 infants. Outcomes will be measured using clinical judgment by a research speech-language pathologist (SLP) in the WISC laboratory. We will use a modified version of the speech-language profile group (SLPG) classification system,[58] originally created by Dr. Hustad (Sponsor) because these children are not yet 4-years-old. Specifically, the research SLP will observe naturalistic laboratory recordings of all 23 infants (around 36 months) and classify each child as having no speech motor impairment (NSMI) or a speech motor impairment (SMI), as described in **Table 1**. Clinical judgment will include 1) observation of the verbal motor production (general motor control, mandibular/labial facial control, lingual control, and oromotor integrity), and 2) an estimated rating of speech intelligibility. Previous research has suggested that children with CP who have at least 25% intelligibility between 24-36 months may be more likely to develop functional speech.[34] Thus, a 25% criterion for intelligibility will be used in conjunction with a subjective judgement of verbal speech motor performance to classify each child within one of the two categories. Prior epidemiological work has reported ~60-80% of young children with CP present with dysarthria

Table 1. Speech motor impairment (SMI) outcomes at 36 months

Category	*Description*
NSMI	No speech motor impairment observed as indicated by functional general motor control, mandibular/labial facial control, lingual control, and oromotor integrity. Intelligibility is comparable to typical expectations (>25%).
SMI	Speech motor impairment observed as indicated by reduced general motor control, mandibular/labial facial control, lingual control, or oromotor integrity. Reduced intelligibility (<25%) compared to typical expectations.

and reduced intelligibility,[33,59,60] thus we anticipate that a larger proportion of our sample will be classified as SMI than NSMI.

Perceptual measures.

a. Perceptual vocal coding

Four syllable categories will be used for coding vocalizations in real-time for all 23 infant recordings. I am well trained and experienced in this method of coding and will train a student coder to conduct this level of analysis (further described below). **Table 2** defines these four syllable categories by type (Vowel and CV) and formedness (i.e., developmental complexity). These four categories are well documented in the literature as speech-like vocalizations of interest in the study of prelinguistic development.[50,61–63] Keystroke coding will be used to identify time-stamped locations of syllables based on their respective category as they occur during real-time observation of each recording. The coder will be allowed to stop the audio to confirm their perceptual judgment of each syllable as needed. There will be a copy of the syllable category descriptions nearby the workstation to support coding fidelity. The sum of each category will be calculated from each recording to obtain total counts. Perceptual vocal coding is estimated to take approximately 20 minutes for each ~12-minute P-I recording (23 total). Ten hours of vocal coding are therefore built into the *Timeline* for the student coder.

Table 2. Syllable categories by type and formedness

Formedness	*Vowel type*	*CV type*
Primitive	**Quasivowel (QV):** Vowel-like sounds with a quasi-resonant nucleus with muffled resonance, often from a closed vocal tract at rest	**Marginal syllable (MB):** Consonant-like element with slow formant transition to vocalic nucleus
Adult-like	**Full vowel (FV):** Vowel sound with a fully resonant nucleus produced with an open vocal tract	**Canonical syllable (CB):** Consonantal element with adult-like formant transition to vocalic nucleus

- **Coding software:** The Action Analysis and Coding Training (AACT) software[64] will be used for perceptual vocal coding. AACT is a general-purpose software package developed for real-time and repeat-observation recording and analysis of infant vocalization and speech. I am already well acquainted with this software from my doctoral laboratory and have experience successfully training students. Therefore, I am immediately prepared to train a student coder on its use in the first two months of this project. A laboratory license of AACT is installed on two computers in the WISC laboratory for immediate use for this proposal.
- **Student coder:** One graduate student research assistant will be trained as the student coder for perceptual vocal coding. The training procedure is adapted from the training protocol used in my doctoral laboratory with Dr. Oller at the University of Memphis.[8] Vocal coding training is expected to last ~16 hours, split across 4 weeks of 4-hour increments. Each 4-hour training session will include direct instruction for using AACT, syllable category differentiation, coding practice, discussion of ambiguous information, and review of reliability training. Additional meetings will be scheduled to discuss discrepancies as needed to maintain the proposed timeline. I have previously successfully trained other student coders at the University of Memphis and Waisman Center on this protocol with excellent reliability.

b. Caregiver questionnaire item

As part of the larger longitudinal study, caregivers completed a communication questionnaire at each laboratory visit. Caregivers answered questions about their perception of their child's speech, language, communication, and participation capacity and performance. One item on this questionnaire asked caregivers whether their child was producing mature CV syllable combinations (i.e., representative of canonical babbling) at the time of the laboratory visit. Caregivers indicated their answer using a binary yes/no response. These data will also be included as a variable in Aim 2 to represent a parental screening measure of vocal complexity.

Acoustic measures.

Acoustic measures will be obtained from the same vocalizations produced in the P-I interaction recordings as described above. These vocalizations will be hand-extracted for analysis. For the purposes of acoustic analysis, vocalizations with overlapping caregiver speech will be excluded. All acoustic analyses will be performed using customized MATLAB[65] scripts developed by Dr. Bunton (collaborator) and colleagues. Three specific acoustic measures will be calculated in the proposed project: voice range density, periodicity, and harmonicity. These measures were selected based on prior work to provide a comprehensive profile of baseline pediatric acoustic modifications.[66] I will conduct all acoustic analyses with Dr. Bunton and Dr. Hustad's guidance and supervision to support my training goals. Formal acoustic analyses are estimated to take ~1 hour for each ~12-minute P-I recording. Therefore, forty hours of data extraction and instrumental

acoustic analysis are built into the Timeline. The three acoustic measures and their relevant methods of extraction are further described below:

a. **Voice range density:** A normalized voice range density plot (VRDn) will be created using f_o and SPL values extracted from syllable types. The fundamental frequency, f_o, will be determined with a cycle detection algorithm that measures the period of each consecutive glottal cycle in each file. The RMS value of the pressure signal (PRMS) will be calculated and converted to SPL. The f_o and SPL values will be normalized to their median values, and f_o will be converted to semitones. These values will be used to create a normalized VRD plot as described by Story and Bunton.[67] Each voice range density plot will be quantified by finding the area enclosed by a convex hull at a density level of 0.25, in units of dBHz. This area will be used as the quantitative measure of voice range density. A preliminary analysis of voice range density data of the two vowel types from one sample participant is presented below in *Pilot Data*.
b. **Periodicity:** A smoothed version of the cepstral peak prominence (CPPS) will be calculated using the methods described by Hillenbrand and Houde.[68] The CPPS indicates degree of periodicity present in the signal, as measured in dB. To calculate the CPPS, the real cepstrum (spectrum of a spectrum) will be first calculated and then smoothed with an averaging filter. A linear regression line will be fit to the smoothed cepstrum, and the amplitude of the peak and its location along the frequency axis will be identified with a peak detector. The difference between the peak value and the regression line at the same frequency will be logged as the value of CPPS. According to Hillenbrand and Houde,[68] a low number indicates a significant aperiodic spectral component (i.e., breathy or rough voice), whereas a high number indicates energy in the harmonic components (i.e., clear voicing).
c. **Harmonicity**: Wiener entropy will be calculated to measure spectral flatness of each syllable type. Wiener entropy is calculated as the logarithm of the ratio between the geometric and arithmetic means of the values of the power spectrum for different frequencies.[69,70] Entropy values that are close to zero will be used to indicate immature syllable types, while more negative values indicate more well-formed syllable types. Hypothetically, the well-formed types (FV and CB syllables) will have lower entropies than the primitive types (QV and MB syllables).

Table 3 presents a breakdown of all perceptual and acoustic measures to be used in this project.

Table 3. Perceptual and acoustic measures included

Perceptual		**Acoustic**
Vocal coding	*Questionnaire*	
QV FV MB CB	Presence or absence of canonical babbling (Aim 2 only)	VRDn CPPS Wiener entropy

Aim 1: Compare perceptual and acoustic measures across speech outcomes in CP

Purpose. Aim 1 will determine how individual perceptual and acoustic variables differ across the NSMI and SMI outcome groups. Comparing perceptual and acoustic measures will provide a broad view of significant differences within individual variables that may emerge across the two outcome groups.

Hypothesis. We predict that the NSMI group will show higher perceptual and acoustic values of well-formed syllable types. Conversely, the SMI group will show higher perceptual counts and acoustic values of primitive syllable forms.

Method & analysis plan. The 23 included children will be grouped by speech outcome: NSMI or SMI. Group-level differences will be compared within the four perceptual coding variables (QV, FV, MB, CB) and three acoustic variables (density area, CPPS, wiener entropy). To do this, we will conduct a series of pairwise t-tests comparing variables between each group, using familywise corrections for variables within each perceptual and acoustic category as appropriate.[71] These analyses will be used to determine whether any strongly significant differences emerge that have the potential to be used as standalone variables. Because of the dichotomous nature of the parent questionnaire data, this measure will not be statistically compared across groups in Aim 1. I will conduct these analyses with Dr. Mahr, the data scientist of Dr. Hustad's laboratory and statistical consultant of this proposal.

Potential problems & alternative strategies. Although we expect higher values across measures indicating greater complexity in the NSMI group, it is possible that we will see no significant differences between the two groups. If this occurs, we will use a multivariate approach that takes all measures into account to derive significant differences that may better differentiate groups.

Expected contributions of Aim 1. Information gained from Aim 1 is expected to identify the presence of any strongly significant variables that have potential to be used as standalone variables to predict speech outcomes in children with CP. Although Aims 1 and 2 are independent, these data may be used to inform analyses of Aim 2 to support the identification of the best combination of variables for predicting outcomes.

Aim 2: Quantify the predictive nature of perceptual and acoustic measures on speech outcomes in CP

Purpose. To determine which perceptual and acoustic measures of vocalizations are most predictive of speech outcomes in children with CP.

Hypothesis. This aim is exploratory in nature. We will model the best combination of predictors against outcome data. We predict that at least one perceptual measure and at least one acoustic measure will significantly contribute to the model.

Method & Analysis plan. Five perceptual measures (Four vocal categories and one parent questionnaire item) and three acoustic parameters will be included as predictor variables. We will conduct a set of statistical and scientific models to determine the presence of any highly significant correlations between predictor variables. We will use principal components to reduce dimensionality reduction if variables are too highly correlated. After reducing these data as appropriate, we will fit a series of logistic regression models to evaluate the strongest combination of predictors among the perceptual and acoustic measures, and whether they jointly predict outcomes.

Potential problems & alternative strategies. Aims 1 and 2 are independent of one another, thus, unexpected findings in Aim 1 will not directly impact the analysis of Aim 2. Should any problems arise with the logistic regression modeling, we may employ a stepwise regression approach to determine which acoustic and perceptual measures best predict outcome. In the case of too many highly correlated perceptual or acoustic measures, alternate statistical methods will be used, such as a random forest approach[72] to identify the most important contributors to speech outcomes.

Expected contributions of Aim 2. Information gained from the analyses conducted in Aim 2 is expected to determine the best combination of acoustic and perceptual variables that contribute to the prediction of later speech outcomes in children with CP.

Reliability.

All secondary calculations collected for reliability will follow the same above-described protocols (10 total, 5 different randomly selected recordings for both levels of analysis). **Perceptual measures.** I will serve as the reliability coder for the perceptual vocal coding of 20% of recordings. A two-way random (consistent raters, sample data) Interclass Correlation Coefficient (ICC)[73] will be used to assess inter-coder reliability of perceptual vocal coding counts across recordings. **Acoustic measures.** Dr. Bunton will conduct reliability measurement for instrumental acoustic analysis of 20% of recordings. Spearman correlations will be used to compare VRDn, CPPS, and Wiener entropy measures.

3. PRELIMINARY STUDIES & PILOT DATA

Preliminary Study. *Marginal and canonical babbling in ten infants at risk for cerebral palsy*[17]

I recently led a study examining marginal and canonical babbling in 10 infants prospectively at risk for CP around ~13 and ~16 months of age. Marginal babbling ratios (MBR) and canonical babbling ratios (CBR) were calculated to compare these ratios of vocalizations produced in laboratory recordings between two time points (**Fig1**). Individual differences were compared across 3 later-identified outcome groups: A CP group (confirmed CP diagnosis), a Risk group (ongoing motor delays and risk of CP), and a TDx group (motor delays later resolved). Higher MBRs were observed at both time points in the CP and Risk group infants. All TDx infants had a higher CBR at their second time point. These findings suggest that prolonged rates of marginal babbling may occur in infants at greater risk of impairment.

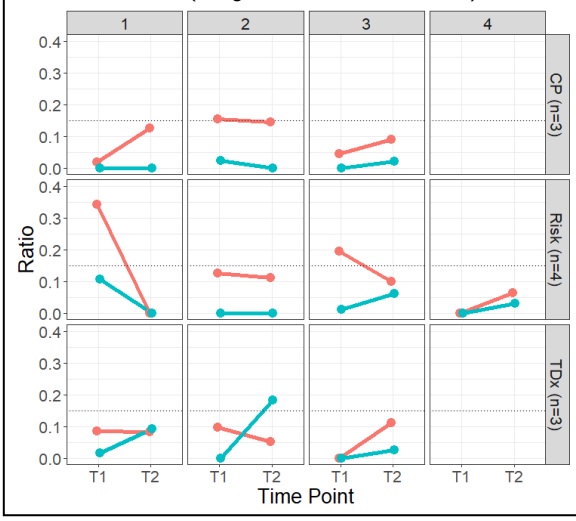


Fig1. MBRs (red) and CBRs (blue) of 10 infants at risk for CP. Higher MBRs observed in the CP and Risk groups. Higher CBRs at the second time point were observed in all 3 TDx infants. (Long & Hustad, under review)

Pilot data. *Perceptual coding and acoustic analysis of two vowel types for one infant*

We randomly selected a single participant (CP0) for pilot coding of the four perceptual vocal categories and voice range density. CP0 was a 13-month female infant who completed a 12-minute P-I interaction with her

mother in the laboratory. I completed perceptual coding of this audio recording in real-time (~15 minutes with occasional stopping to review). Dr. Bunton created the voice range density plots for this pilot analysis.

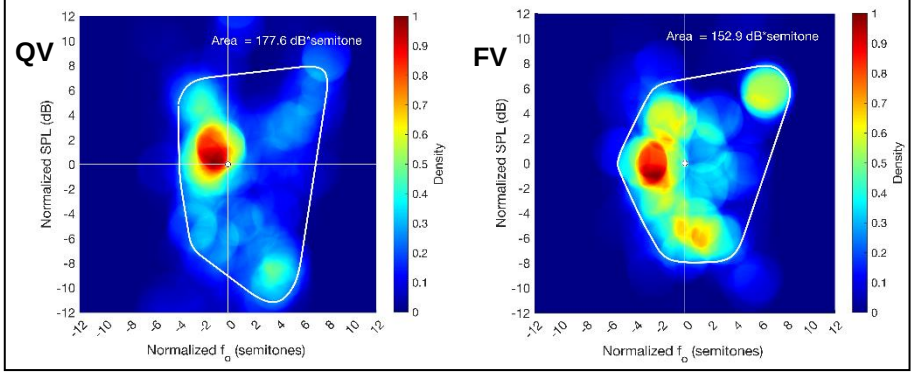
Perceptual coding: The total number of vocalizations produced by CP0 during this recording is presented in **Table 4**. CP0 produced a total of 95 speech-like syllables. CP0 produced more vowels (n = 78) than CV-syllable types (n = 17). Also, she produced more primitive (n = 56) than well-formed syllable types (n = 39). Although the present work will not use ratios, prior research has empirically determined a CBR of 0.15 (total canonical syllables divided by total syllables) as the criterion indicating infants' mastery of the canonical babbling stage.[23,24] In typical infants, this CBR is expected to be observed in laboratory recordings of infants between 7-10 months. CP0 had a CBR of 0.07 in this recording, suggesting delayed canonical babbling. All 23 infants (including CP0) will be coded by the student coder to obtain these four counts from each recording for comparison to acoustic measures.

Table 4. Perceptual coding of pilot data (CP0): Total counts

Type – Formedness	**Vocalization type**	**Count**
Vowel – Primitive	Quasivowel (QV)	46
Vowel – Well-formed	Full vowel (FV)	32
CV – Primitive	Marginal syllable (MB)	10
CV – Well-formed	Canonical syllable (CB)	7
Total		**95**

Acoustic analysis: We created normalized voice range density plots (VRDn)—as demonstrated by Story and Bunton[67]—of QV and FV syllables produced by CP0 in the same recording as described above (**Fig2**). The area (white hull) includes 75% of the tokens produced in that range. In a grid spanning from -12 to 12 semitones in the horizontal dimension, and from -12 to 12 dB in the vertical dimension, the number of [f_o, SPL] pairs present within a radius of 0.1 from every point in the grid were counted and assigned to the corresponding grid point as a density value. All density values were then normalized to the maximum density present across the grid so that the maximum density is always equal to 1.0. Plotted as a color map that varies from dark blue for low density, to red indicating high density, the VRDn indicates how the infant distributed their fundamental frequency and SPL across syllables. The left panel shows the density area of **QV syllables** (n = 40) at **177.6 dB*semitones**. The right panel shows the density area of **FV syllables** (n = 18) at **152.9 dB*semitones**. These data highlight a smaller density of FVs, suggesting greater control over the production of well-formed vowels. Greater variation is observed in the production of QVs, as indicated by the larger density area. Fewer syllables were included in the acoustic analyses because vocalizations with overlapping caregiver speech were excluded (n = 20). VRDn plots will be generated for infants within each outcome group across all four syllable types. Additional acoustic analyses will include measures of CPPS and wiener entropy to determine harmonicity of syllable types.

Fig2. Normalized vocal range profiles for QV and FV syllables of one infant



4. RESEARCH TIMELINE

Project activity	**Persons responsible**	**Bi-monthly project activity timeline**					
		1-2	**3-4**	**5-6**	**7-8**	**9-10**	**11-12**
Data extraction for acoustic analysis	Long, Student	X					
Student coder training	Long, Student	X	X				
SLP clinical judgment: Outcomes	Research SLP	X	X				
PI acoustic analysis training	Long, Bunton, Hustad	X	X	X			
Perceptual vocal coding	Student		X	X	X		
Acoustic analysis	Long		X	X	X		
Reliability coding and analysis (20%)	Long, Bunton			X	X	X	
Aim 1 & 2 data prep and stat. analysis	Long, Bunton, Mahr, Hustad				X	X	X
Manuscript prep and submit: JSLHR	Long, Bunton, Mahr, Hustad				X	X	X

PROTECTION OF HUMAN SUBJECTS

1. RISKS TO HUMAN SUBJECTS

a) Human Subjects Involvement, Characteristics, and Design

Overall study design: The data to be used in the proposed project is a secondary dataset collected as part of a larger, longitudinal study on communication development in cerebral palsy (CP). All recording data is housed in a secure laboratory server. Audio recordings of parent-infant interactions (mean: ~12 minutes) collected during laboratory visits will be used for analysis. Perceptual vocal coding and instrumental acoustic data extraction and analysis will be conducted using these recordings. Speech outcome data will be derived from ~36-month data of all 23 infants. Analyses will be conducted by the PI, student coder, and the mentorship team, all of whom have active HIPAA and CITI certification training.

Subject population: The study will include data from 23 infants between 11-14 months of age (~12 months) previously recruited for a risk of CP based on birth history.

Collaborating sites: All data was collected at the Waisman Center at the University of Wisconsin-Madison in Madison, WI. No collaborating sites participated in this longitudinal study.

b) Study Procedures, Materials, and Potential Risks

Planned research procedures: During prior participation, parents brought their infants to the laboratory to the Waisman Center for approximately 1-to-1.5-hour visits for data collection. Digital audio/video recordings were collected during these sessions. Audio of previously collected parent-infant interactions of the 23 infants will be analyzed using perceptual and acoustic methods. Speech outcomes will be identified using the most recent laboratory visits using clinical judgment by a certified speech-language pathologist.

Previously collected data sources: Data previously collected from an ongoing NIH-funded project (5R01DC009411-15; PI Hustad) will be used in this project. Included research material has already been obtained from infants at risk for CP, including recording audio of parent-infant interactions at the ~12 month and outcome time points. Identification numbers are already assigned to each infant which will be used to link infant data at all times of coding and analysis. Only the PI and laboratory research team members who have an explicit need to know the linkages between names and code numbers have access to this information.

Potential risks to subjects: There are no foreseeable risks associated with previous participation in this study. There are no known reports from families regarding damaging effects to their physical or emotional state because of their participation in this longitudinal study.

Alternative treatments and procedures: There are no alternative treatments or procedures involved in the present study because these data have already been collected.

2. ADEQUACY OF PROTECTION AGAINST RISKS

a) Informed Consent and Assent

Process for obtaining informed consent: Data from the included sample of infants has already been collected. During previous participation, all caregivers were given a thorough, verbal description of the goals of the longitudinal study, participation involvement, and tasks to be completed at laboratory visits. Caregivers provided written consent and ongoing assent for their infant to participate.

Waivers: No waivers of informed consent were used to collect data from participants.

b) Protections Against Risk

Planned strategies for protecting against risks: Risks to subject confidentiality are minimized by adopting suitable data storage procedures. All audio files and coded data are labeled with the infant identification numbers so that no identifying information is available during coding or analysis. The linkage between these numbers and identifying information for all infants is kept in a secure online database and in a locked file cabinet within a locked room in a different location from audio files. Digital audio recordings are maintained in a

secure laboratory server. Access to all online media is password protected using duo-authentication methods and restricted to only those individuals working on the research project. No identifying information regarding the identity of speakers will accompany any data reported from this project. Using these procedures, all reasonable precautions are taken to minimize linking any PHI to the research data.

Plans for ensuring intervention in the event of adverse effects: Because our project draws on existing databases of recordings, no adverse effects are anticipated.

Plans for handling incidental findings: Because our project draws on existing databases of recordings, no incidental findings are anticipated. Laboratory assistants and managers were present for the laboratory visit to discuss and manage incidental findings as they occurred in real time (e.g., suggesting referrals to appropriate medical providers).

c) Vulnerable Populations

Rationale for the involvement of infants: The proposed project involves vulnerable populations, specifically infants at risk for a developmental disability (CP). During their participation, all guidelines were followed to meet HHS regulatory requirements for parental permission and child assent (45 CFR 46.408) as described above and hereafter. IRB approval was received with annual review conducted throughout the duration of human subject participation. Parental informed consent was obtained by caregivers or legal guardians. Although infants were too young to formally obtain assent, infants' demeanor and activity levels were monitored during laboratory sessions to ensure comfort for continued participation. Breaks were provided as needed per parental request or infant discomfort.

3. POTENTIAL BENEFITS OF THE PROPOSED RESEARCH TO PARTICIPANTS AND OTHERS

Potential benefits of the research: Families received summary statements after each laboratory visit that provided information about their infant's performance in the laboratory tasks and speech and language development. Data and information collected from participants is used to conduct research studies and disseminate knowledge to improve our understanding of speech, language, and communication development and CP in children.

Reasonable risks to participant benefits: The risks to participants are negligible in relation to the anticipated benefits because data have already been collected, and risks during the time of participation were minimal. The potential benefits to families are outweighed by the minimal risks involved.

4. IMPORTANCE OF THE KNOWLEDGE TO BE GAINED

Importance of knowledge gained as a result of the proposed research: This project is expected to make significant contributions to our understanding of vocal biomarkers for speech impairment in CP. The inclusion of infants at risk for CP can lay foundations for more precise differential diagnosis of later speech impairment. The proposed project is expected to add to the existing literature on how infants with neurological damage gain control of the capacity to vocalize and develop speech. We expect that knowledge and dissemination of research completed under this proposal will inform our understanding of early identification for communication disorders.

Reasonable risks to knowledge importance: The potential benefits to the contributions to scientific research in developmental disabilities are outweighed by the minimal risks involved.

INCLUSION OF INDIVIDUALS ACROSS THE LIFESPAN

Existing Datasets or Resources. The proposed project includes existing data previously collected from 23 infants at risk for cerebral palsy (CP) between 11-14 months of age and their caregivers. This child age range was selected because previous research has suggested that prelinguistic vocal development is likely to occur in typical infants between 0-12 months, prior to the onset of first words. Infants at risk for developmental disabilities are likely to show delays in the emergence of prelinguistic vocal stages; thus, we seek to understand prelinguistic vocal performance at the latest possible age of typical infant development. The analysis of vocal behaviors during recordings of parent-infant interactions is critical to mimic the kinds of naturalistic interactions during which infants are likely to produce their most speech-like vocalizations.

Existing speech outcome data collected around 36 months of age is also available for analysis from all 23 infants. Speech outcome data collected in toddlerhood is critical to frame our prelinguistic vocal behavioral findings against developmental outcomes at an older time point. The approximate 36-month time point was selected as an approximate age when typical children are likely to be combining intelligible phrases of speech. This age is also the latest possible time point at which we have available data for inclusion in this study. Caregiver ages will vary.

RECRUITMENT AND RETENTION

The study uses data from an existing cohort; therefore, no recruitment and retention plans are required.

INCLUSION OF WOMEN AND MINORITIES

Distribution of subjects. The proposed research will involve the use of existing datasets that were previously approved by human subjects' committees and funded by federal grants at the Waisman Center of the University of Wisconsin-Madison. Families were recruited to participate through the Waisman Center clinics and regional birth-to-three programs in Madison, Wisconsin, as well as social media outlets and word of mouth.

- Women: Our study includes 23 infants at risk for CP between 11-14 months of age and their caregivers. This sample includes 11 females and 12 males. All caregivers (n = 23) who participated in the parent-infant interaction were female. No infant was excluded from participating based on sex.

- Minorities: Minorities were included to the extent possible, consistent with demographics of the Madison, Wisconsin areas (78% not Hispanic/Latino, 9% Hispanic/Latino, 13% not reported; 74% white, 13% more than one race, 13% not reported). The original study did not collect race/ethnicity data of caregivers. No infant or family was excluded on the basis of racial/ethnic group membership.

Rationale for selection. All efforts were made to originally enroll an equal number of male and female infants and those from diverse racial/ethnic groups across the various recruitment methods.

Proposed outreach programs. No proposed outreach programs are included in this project, as it draws from existing datasets.

Included and excluded groups. There were no race or ethnicity exclusions for the study.

- Inclusion criteria: The inclusion criteria for the larger longitudinal study required that infants: 1) have motor delay or a medical diagnosis related to birth complications associated with CP, 2) have hearing within normal limits per parent report, and 3) be from a monolingual English-speaking home.

- Exclusion criteria: Infants who did not have motor delay or a diagnosis related to CP were excluded. Children with a medically diagnosed hearing loss were also excluded as a known confound in the study of vocal development.

RESPECTIVE CONTRIBUTIONS

Research proposal development.
I developed and wrote the research proposal and training plan for this fellowship with the guidance of my sponsor, Dr. Hustad, and collaborator, Dr. Bunton. The idea for the proposed project was based on feedback and comments from peer review of a manuscript currently under review,[17] in which acoustic measurements of infant vocalizations were discussed. Dr. Hustad and I initially conceived and outlined the plan for this project together. Dr. Bunton supported the planning and writing descriptions of acoustic variables. Dr. Bunton also conducted the preliminary analysis of the voice range density ploy pilot data. Dr. Mahr also provided expert statistical guidance for planning and writing descriptions of the proposed statistical analyses of both Aims 1 and 2. Together with my mentorship team, we refined and agreed upon the hypotheses, methods, and predicted outcomes presented in this research proposal. This was completed through regular virtual or in-person meetings through intellectual discussion, assigned readings, and shared materials.

Data coding and extraction.
- Perceptual vocal coding: I will conduct the coding training for the graduate student coder. The student coder will conduct 100% of the perceptual vocal coding of all 23 recordings. I will complete 20% reliability coding (5 randomly selected recordings).
- Acoustic analysis: I will work with the student coder to extract infant syllables in recordings for acoustic analysis under the supervision of Dr. Bunton. Drs. Bunton and Hustad will provide explicit training for instrumental acoustic analysis. I will conduct all acoustic analyses of all infant recordings to support my training goals. Dr. Bunton will complete 20% reliability for the acoustic analyses (5 randomly selected recordings).

Data analysis.
Dr. Hustad will provide guidance and supervision of data management of perceptual coding and acoustic data. Dr. Mahr will supervise and help conduct the formal statistical analyses of both Aims 1 and 2. Specifically, he will support the development of analysis code and confirm correct procedural analysis and data interpretations.

Manuscript writing.
I will be responsible for preparing and submitting the manuscript from this proposal as first author. Drs. Hustad and Bunton will explicitly support the writing and revision of sections involving methodology, data interpretations, and clinical implications. Dr. Mahr will explicitly support the writing and revision of sections involving statistical analysis, results, and data interpretations sections. All mentors will review and provide feedback on all sections of the manuscript across all submission and revised versions. All members of my mentorship team will receive co-authorship for this manuscript.

Technical support.
Drs. Hustad, Bunton, and Mahr will help troubleshoot any problems that arise with the instrumental acoustic analyses and statistical analyses during our regularly scheduled meetings. Dr. Hustad and the Waisman Center IT department will support ongoing maintenance of laboratory facilities, equipment, and software.

External feedback and support.
Throughout the duration of the project, I will be the principal investigator (PI) with regular supervision and in consultation with my mentorship team. I will also solicit ongoing feedback through several outlets to support the progress of this work. First, I will meet weekly with laboratory members of Dr. Hustad's team to discuss project specifics regrading data coding, analysis, and manuscript writing. I will also seek interdisciplinary feedback through presentation at intramural research colloquia and conference talks.

SELECTION OF SPONSOR AND INSTITUTION

Selection of Sponsor.
I am presently a second year T32 postdoctoral trainee at the Waisman Center of the University of Wisconsin. As part of this research project, I am proposing to maintain my primary postdoctoral research mentor (Sponsor: Hustad) at the same institution to obtain additional postdoctoral training in acoustic analysis and statistical modeling. Extending my training specifically in Dr. Hustad's laboratory is vital to conducting the proposed research for two major reasons:

1) Dr. Hustad is the leading expert of longitudinal speech and communication development in children with CP. CP is a vastly understudied clinical population in the field of communication sciences and disorders, thus, there exist few NIH-funded researchers to support my highly specialized area of research. Continuing my postdoctoral training under Dr. Hustad's mentorship will establish my developing expertise in 1) relating early vocal performance to later speech outcomes, and 2) conducting longitudinal, large-scale research in CP, in which experiential knowledge can only occur in a 1-year time frame with an existing, longitudinal dataset. Dr. Hustad is highly supportive of my research goals and provides regular support, guidance, and feedback on my research during our weekly one-on-one meetings and weekly laboratory meetings to support my career. The statistical consultant of this project (Mahr) is the dedicated data scientist in Dr. Hustad's laboratory and is already familiar with the data structure and elements involved to support data analysis in this proposal.

2) Dr. Hustad maintains the largest, longitudinal recording databases in the world of infants at risk for CP. This database includes high quality, naturalistic laboratory recording data already collected to be analyzed in the proposed research (23 infants around 12 months of age) as part of a larger, longitudinal study (R01 DC009411, PI: Hustad). Collecting this amount of data in a new dataset is estimated to take over 3 years with infants at risk for CP (a condition that only occurs in ~2-3 out of 1000 live births). The proposed research is necessary to identify the best combination of perceptual and acoustic measures to predict later speech outcomes in this population. Dr. Hustad will provide relevant expertise in speech acoustics in CP to support interpretations of associations found between our prelinguistic and outcome data. For these reasons, maintaining Dr. Hustad as a primary mentor and Sponsor of this research is a logical decision. Findings from research conducted in this proposal, using the existing database available in Dr. Hustad's laboratory, will directly inform my future research directions as an independent investigator in my area of study.

Selection of Institution.
The Waisman Center is an ideal location to continue my ongoing postdoctoral training for my programmatic line of research identifying vocal biomarkers of speech impairment in infants at risk for CP. It is a research institution devoted to conducting biological and behavioral research in intellectual and developmental disabilities (IDD). The Center houses faculty from over 18 academic departments at the University of Wisconsin-Madison, including the School of Communication Sciences and Disorders, School of Medicine and Public Health, and the Department of Psychology. The Center is well established as a collaborative environment for its faculty affiliates, their students, and staff, including postdoctoral researchers. Four laboratories within the Waisman Center specialize in infant developmental research, and two laboratories specialize in topics in cerebral palsy, including the Sponsor (Hustad). I have already engaged ongoing mentorship relationships and aim to continue intellectual discussion with Dr. Doug Dean in infant neuroimaging, Dr. Bernadette Gillick in pediatric neuromodulation in CP, and Dr. Jenny Saffran in infant word learning. I intend to continue to take advantage of the many opportunities for interdisciplinary training from these leading experts. The Waisman Center hosts weekly research seminars throughout the academic year presented by international scientists, an interdisciplinary poster fair, and community outreach workshops in topics relating to my research and other IDD areas. The large interdisciplinary presence across areas related to my research evidence a strong capacity to support my research and training in early vocal and speech development in cerebral palsy (CP).

Extending my training under the guidance of Dr. Hustad at the world-renowned Waisman Center of the University of Wisconsin-Madison will maximally enhance my skills and prepare me to become an independent investigator in my highly specialized area of research.

TRAINING IN THE RESPONSIBLE CONDUCT OF RESEARCH

Ethical and scientifically responsible research is of paramount importance to conducting human subjects research in my area of interest, which includes infants and clinical populations. Training in the responsible conduct of research (RCR) is an ongoing process, in which I intend to continue my education throughout my career as a mentored and independent investigator. I plan to participate in the following training activities to support this goal during the period of the proposed research.

Waisman Center Ethics and Professional Development (WEPD) seminar series.
The WEPD seminar provides training in research ethics to support the independent professional development of doctoral and postdoctoral trainees at the Waisman Center. I will participate in all scheduled WEPD seminars throughout the duration of the proposed research.

- Format: Face-to-face lecture and small group discussion with ~10 participants each academic school year.
- Subject Matter: Individual seminar session topics vary each year. Topics have historically included areas such as research misconduct, conflicts of interest, consent and assent, socially responsible science, scientific rigor and reproducibility, inclusive professional frameworks, team science, and data integrity.
- Faculty Participation: Each WEPD seminar session is led by a Waisman Center faculty member. Dr. Hustad (Sponsor) leads at least one session discussion per year.
- Duration of Instruction: Each seminar session lasts approximately one hour.
- Frequency of Instruction: The WEPD cohort meets at least two times a month throughout the academic school year, across approximately 15 sessions (total: ~15 contact hours).

Professional Research Education Program (PREP).
The PREP aims to support faculty, staff, and students at the University of Wisconsin-Madison in conducting safe, compliant, and inclusive human subjects research and connect the research community to campus resources. I will participate in two PREP workshops during the proposed research timeframe.

- Format: The workshop formats are live lecture and discussion sessions in a face-to-face or live virtual format.
- Subject Matter: Workshop topics vary each year. Previous workshop topics have included consent considerations, research with minors, school-based research, and status relationships.
- Faculty Participation: PREP is organized by a cross-campus working group, including members from the Clinical Research Office, Institute for Clinical and Translational Research, IRB office, Office of Research Compliance, and the School of Medicine and Public Health.
- Duration of Instruction: Workshop sessions are 1-2 hours in length (total: ~4 contact hours).
- Frequency of Instruction: PREP offers 8-10 synchronous, live webinars or in-person events per year.

Ongoing certifications.
I have maintained active Collaborative Institutional Training Initiative (CITI) program certification since 2015. This tri-annual training covers topics including misconduct policies, research ethics of working with children and special populations, data management, conflicts of interest, and HIPAA privacy guidelines. I have successfully completed the Basic or Refresher courses in Social & Behavioral Research every three years.

Since 2010, I have also maintained active Health Insurance Portability and Accountability Act (HIPAA) training on the guidelines for protection of patient health information. This annual training includes a 20-25-minute course of online video and reading material with a final multiple-choice assessment. HIPAA training is critically relevant to my ethical conduct and practice as a clinical researcher.

BACKGROUND AND GOALS FOR FELLOWSHIP TRAINING

My long-term goal is to become an independent investigator and expert in the early detection of speech impairments in neurological disorders like cerebral palsy (CP). To continue my progress toward this goal, I am pursuing a third year of postdoctoral research training in acoustical methods of analysis and their theoretical frameworks, and statistical modeling of variables to predict communication outcomes. I am also seeking additional professional training to support my learning of diversity, equity, and inclusion in research, grant writing, and responsible conduct of research. The knowledge and experience gained from this proposal will allow me to successfully compete for an early career R21 and subsequent R01 awards to develop scientifically validated diagnostic tools for the early detection of speech and language impairments in CP and other neurodevelopmental disabilities, as young as infancy.

A. DOCTORAL DISSERTATION AND RESEARCH EXPERIENCE

Undergraduate and graduate research. My research training began in my undergraduate program at Indiana University-Bloomington. I supported data collection and analysis in studies examining the effects of delayed auditory feedback on the pitch-shift reflex as a research assistant in the Voice Physiology laboratory with Dr. Theresa Burnett.[1,2] Through this work, I learned about the potential for empirically studying vocal predictors of disorders with secondary vocal tremor like ataxia, Parkinson disease, and multiple sclerosis. Following my undergraduate studies, I began a Master's program in speech-language pathology to obtain comprehensive clinical training in communication disorders. During this time, I supported the data collection and analysis of research in lexical and phonological variability in infants and preschool children conducted by Dr. Toby Macrae in the Experimental Phonetics laboratory.[3,4] These research experiences fostered a strong interest in studying early speech and word learning in children with speech sound disorders.

Development of clinical research questions. My research questions were developed during my clinical experiences as a speech-language pathologist. While working in a school for children with significant medical disabilities including CP, I had the opportunity to diagnose and treat children with complex communication impairments from preschool to high school ages. I often sought research in early speech and AAC developmental trajectories in CP to inform my diagnosis and prognosis of their speech development. However, I discovered scant evidence on the early identification of speech disorders in this population and minimal resources on decision-making for treatment directions in CP, a disorder known for its variability in level of impairment. These experiences helped formulate my early research questions aimed at identifying biomarkers of impairment in children at risk for speech motor impairment secondary to CP. These real-world inquiries grounded my programmatic line of research in the early detection of speech impairment in infants and young children with CP and other neurological disorders.

Doctoral training in typical and atypical infant vocal development. My doctoral education next provided a strong theoretical foundation in the infrastructural framework of typical infant prelinguistic vocal development. My primary mentor was Dr. D. Kimbrough Oller, a leading researcher in this area whose work has long informed the study of prelinguistic vocal behaviors in children with speech, language, and hearing disorders since the 1970's.[5–8] I received unique training in perceptual research methods using laboratory and home-based recordings to study infant vocalizations. My doctoral dissertation used an evolutionary-developmental biology (evo-devo) lens to examine infants' capacity to vocally signal developmental information to caregivers. This work revealed three key findings. First, infant vocal imitation is rare in the first year but is highly salient to listeners, underscoring its potential to be used as a signal of information for caregivers.[9] Second, infants produce nonsocial vocalizations far more frequently than social ones, which suggests that independent vocal play is a primary driver in the development of articulatory properties of speech.[10] Last, although infants vocalize the most during independent vocal play, we found that they produce their most developmentally advanced vocal forms during interactive periods, indicating infants' capacity to signal developmental information to caregivers.[11] This experience provided invaluable training in longitudinal infant data collection, perceptual vocal coding of infant vocalizations, and multi-site, team-based management of R01 grant projects. I contributed to 9 manuscripts (4 as first author) and 21 conference presentations in Dr. Oller's laboratory.

- *Dissertation clinical and research implications.* The work completed during my doctoral dissertation has direct clinical implications to support the ongoing study of vocal biomarkers of atypical development. Specifically, this work suggests that typical infants possess an innate drive to produce their most advanced vocal forms during social interaction. This implies that atypically developing infants may be less likely to produce

advanced vocal forms in interaction. For this reason, my research continues to utilize naturalistic, parent-child interactions to study vocal behaviors in infancy for signs of atypical development. Additional research from my doctoral laboratory using these methods also evidenced observable delays in the emergence of prelinguistic stages across several clinical populations, including tuberous sclerosis,[12] autism,[13] and a case study in cerebral palsy.[14] These studies offer preliminary support to continue my independent line of research examining vocal biomarkers of speech impairment in CP.

Postdoctoral training in speech and communication development in CP. Following my doctoral training, I was accepted to a highly competitive T32 postdoctoral training program through the Waisman Center of UW-Madison, a leading research center in intellectual and developmental disabilities. I sought to expand my training with Dr. Katherine Hustad—the foremost expert in speech and communication development in CP. This experience has provided a rich environment to expand my knowledge on childhood outcomes in CP. I have had the unique opportunity to longitudinally examine speech and communication performance using laboratory recordings, educational data, and communication assessment data. My early work in this laboratory found variability in deficit profiles and school-based treatment goals in children with CP across different levels of communication functioning.[15] Another paper that has received attention across medical providers found that speech performance improves over time in children with CP but those with severe impairments are more likely to remain stable.[16] Our data suggests that children with mild-moderate speech and language impairments and CP have great potential to continue to make developmental and therapeutic communication gains. However, children with severe impairments are more likely to plateau in their speech development, thus requiring access to AAC as early as possible. Since joining Dr. Hustad's laboratory in 2021, I have already contributed to 5 publications (3 as first author, 3 more in preparation) and 13 conference presentations. These experiences have built the foundation to continue to develop a research program that blends my doctoral and postdoctoral training to study vocal behaviors predictive of speech impairment in CP as young as infancy.

Preliminary work in my programmatic line of research: Prelinguistic vocal biomarkers in CP. Across my research experiences, I have maintained a strong focus on my programmatic line of research to study vocal biomarkers of speech impairment in CP. I independently initiated a case study on the emergence of mature CV-syllable forms in infancy (i.e., canonical babbling) during my PhD training. We found a low proportion of canonical syllables between 5-16 months in two infants with CP compared to ten typically developing infants, using all-day home recordings in CP.[14] In my first year of postdoctoral work, I examined marginal and canonical babbling (i.e., immature and mature CV syllable forms) in ten infants at risk for CP and found a higher proportion of marginal syllables in infants with and at ongoing risk for CP, but a higher proportion of canonical syllables in infants whose motor delays later resolved.[17] In an external collaboration with a regional CP clinic, we are preliminarily finding that prelinguistic vocal milestones are significantly delayed in older children with CP who have more severe communication impairments.[18] Finally, I am leading a scoping review examining vocal development in infants at risk for neurodevelopmental disabilities and motor speech impairments. We found only 10 previous studies in CP (median publication year: 1999) despite the exponential advancement of technology to measure infant vocalization.[19] These findings reveal substantial research gaps in this area, indicating much room to develop a long and successful line of research devoted to my aims.

B. TRAINING GOALS AND OBJECTIVES

I have three research training goals and three professional training goals to support my development as an independent investigator of vocal biomarkers of speech impairment in CP. Activities to support meeting these goals and objectives are further elaborated below.

Research Training Goals

1. Acquire expertise in instrumental acoustic analysis of infant vocalization

A longstanding body of work has used perceptual, listener judgment of infant vocalizations to study prelinguistic development.[20–24] To date, my own research has solely used this method of data coding and analysis to support cross-study comparison of both typical and atypical infant vocal development. However, instrumental acoustic analysis is often used in the CP literature to quantitatively measure speech production for objective comparison to typical speech.[25–28] Presently, there is limited research investigating the acoustics of infant vocal behaviors and none of these studies have examined infants at risk for CP. Incorporating instrumental acoustic analysis into the study of prelinguistic vocal behaviors in this population has great potential to support quantitative analysis of immature sound forms across different levels of complexity. Explicit

training in these methods is critical to expand my methodological tools to further establish my independence as an expert researcher in this area.

Kate Bunton, PhD will provide explicit training in **instrumental acoustic analysis** of infant vocalizations as the external collaborator of this project. Dr. Bunton is an expert investigator in the study of intelligibility correlates of kinematic, aerodynamic, and acoustic characteristics of normal and disordered child speech with over 39 publications in this area. Few researchers have studied acoustic variables of infant vocalization. Dr. Bunton is an ideal mentor for training in infant vocal acoustics because of her experience conducting research analyzing perceptual and acoustic correlates in real words versus infant babble. Broadly, her research aims to develop models explaining mechanisms underlying speech intelligibility deficits in children at risk for neuromotor impairment. Thus, our research goals are directly aligned to advance this research agenda and to expand my own expertise in these areas.

- **Dr. Bunton** will travel to the Waisman Center for a **2-day, in-person training** within the first two months of the award to provide hands on training to initiate acoustic analysis of infant vocalizations as described in this proposal. She will meet with me and Dr. Hustad to guide set-up and training in instrumental acoustic analysis.
- I will meet regularly with **Dr. Bunton** for **one-on-one and small group training** (with Dr. Hustad) in acoustic analysis. During the first 6 months of the project timeline, we will meet one-on-one, biweekly, in a virtual format for regular training and to discuss ongoing logistics for acoustic extraction and analysis methods. During the last 6 months of the project timeline, we will meet one-on-one, once monthly, in a virtual format for ongoing training and consultation in these methods.

Katie Hustad, PhD (Sponsor) will provide relevant expertise in **acoustic analysis of articulatory characteristics** of speech in young children with CP. Dr. Hustad has extensive experience analyzing acoustic variables in young children with CP. Her expertise will directly support building an association between the early vocal variables and later speech outcomes.

- **Dr. Hustad** and I will meet for **one-on-one, weekly in-person meetings** throughout the duration of the project to discuss ongoing progress of vocal perceptual coding, and instrumental acoustic analysis. She will provide feedback and guidance on acoustic measurement and relate these measures to the later identified outcomes. We will review prior work together on acoustically inferred articulatory, velopharyngeal, and laryngeal characteristics of speech in children with CP and discuss how these characteristics are aligned with our observations and expectations in the present dataset. We will also discuss these topics during weekly laboratory meetings in the context of this project and other related research studies conducted in the laboratory by other team members.
- **Dr. Hustad**'s extensive experience in administering longitudinal research studies is essential to **managing ongoing aspects of the project**, including data management, data collection, organization and analysis of data, and manuscript preparation. She will supervise and consult with me in all these areas across one-on-one meetings, and laboratory meetings. Dr. Hustad will remain available for additional guidance as needed.

<u>2. Expand theoretical knowledge of pediatric motor speech models</u>

Drs. Hustad (Sponsor) and **Bunton** (collaborator) will co-lead my training to develop a deeper understanding of **theoretical models** of the development of speech subsystems as it relates to CP.

- During my one-on-one meetings with **Dr. Hustad**, we will conduct **independent readings** of research examining acoustic variables using a multiple speech subsystems approach. Dr. Hustad has pioneered this line of research in children with CP, in which later speech intelligibility is evaluated using a prediction model of acoustic measures to represent speech subsystems. Becoming familiar with this work will help me develop a deeper understanding of theoretical implications for developmental changes in the speech subsystem. We will discuss these topics during weekly laboratory meetings in the context of this project and other related research studies conducted in the laboratory by other team members.
- During my one-on-one meetings with **Dr. Bunton,** we will conduct **independent readings** of her and other prior research of speech subsystems and their developmental implications for typical and atypical development. Specifically, developing a deeper understanding of her work and related research will inform my future work associating the development of phonetic inventories and speech subsystems. This will also support my understanding of acoustic correlates of the various subsystems, including velopharyngeal closure, and other phonatory and articulatory characteristics.

I will present at and attend at least two scientific conferences to gain knowledge in theoretical models of pediatric motor speech disorders to gain knowledge of current theoretical frameworks that can be applied to my research directly from experts in pediatric motor speech disorders.

- I will attend the **Motor Speech Conference** to gain knowledge in speech motor control, theoretical models of speech, and motor speech disorders. This 3-day conference attracts participation from national and international experts conducting research in these topics. Furthermore, this conference includes a mentorship program in which trainees are matched with an experienced research mentor throughout the duration of the conference. I will participate in this mentorship program with the goal to engage in intellectual discussion, receive informal training, and develop research connections with experts in theoretical models of pediatric motor speech development.
- I am also a regular attendee of the **American Academy of Developmental Medicine & Child Neurology (AACPDM)** annual meeting. I will also submit to present this research and attend the AACPDM conference to continue to develop my understanding of the diagnosis of CP and its broad implications for speech and communication development in this disorder. Attending the AACPDM annual meeting will support building interdisciplinary collaborations with scientists conducting infant research in CP and other related areas to my own.
- Funding permitted, I will submit to present and attend the **American Speech-Language Hearing Association (ASHA)** annual convention. The ASHA conference broadly attracts scientists and clinicians in the field of communication sciences and disorders. I will plan to attend seminars and poster presentations discussing pediatric motor speech models and communication and speech development in cerebral palsy. I intend to engage in intellectual discussion and connect with experts to build research connections for future collaborations. The ASHA Convention also offers several opportunities for early career research including the Mentoring Academic-Research Careers (MARC) program.

<u>3. Learn and apply statistical modeling of perceptual and acoustic predictors and speech outcomes</u>

I require additional training to develop my expertise in **biostatistical analysis of predictors for later speech outcomes**. My prior statistical experience in this area has studied longitudinal developmental trajectories of variables using generalized estimating equations. Increasing my proficiency in statistical modeling for developmental outcomes will support my independence and developing expertise in the study of vocal biomarkers for speech disorders in CP and other neurological disorders.

- I will meet with **Dr. Mahr** and **Dr. Hustad** for monthly **consultation meetings** to discuss the statistical plan and subsequent analyses of the proposed project for Aims 1 and 2 during the first six months of the proposed timeline. During the data analysis period of the second half of the timeline of this project, I will meet with Drs. Mahr and Hustad weekly to plan and conduct analyses in R and interpret findings together. Dr. Mahr is the dedicated data scientist in Dr. Hustad's laboratory; therefore, he is already familiar with my work, the proposed dataset, and the statistical plan for this project. Dr. Mahr and I will also discuss ongoing project logistics in our weekly laboratory meeting.
- I will register for **STAT 240: Data Science Modeling I** (Fall) to support my training of statistical modeling within a broader biostatistical context. This course introduces reproducible data management, modeling, and analysis through a practical, hands-on case studies approach. Topics include the use of an integrated statistical computing environment, data wrangling, the R programming language, data graphics and visualization, random variables and concepts of probability, data modeling, and report generation using R Markdown with applications to a wide variety of data to address open-ended questions. This course is required in order to register for STAT 340.
- I will register for **STAT 340: Data Science Modeling II** (Spring) to further extend my training in biostatistical modeling. This course teaches students how to apply statistical methods to learn from data. Topics include one- and two-sample inference; an introduction to Bayesian inference and associated probability theory; linear and logistic regression models; the bootstrap; and cross-validation. An integrated statistical computing environment is used to explore and analyze data, develop models, make inferences, and communicate results in a reproducible manner through a project-oriented approach to learning.

Professional Training Goals

<u>1. Increase knowledge of practices to support diversity, equity, and inclusion in research and teaching</u>

- I am an ongoing participant in the **Delta Program** at UW-Madison, as part of the Center for Integration of Research, Teaching, and Learning (CIRTL) network. The Delta Program applies evidence-based knowledge to foster equitable and inclusive learning in research laboratory and classroom settings. I have already

completed two ~6-hour workshops (Summer 2021- Inclusive Research Mentor Training; Spring 2022- Inclusive Professional Framework for Future Faculty) with the Program. I will participate in one additional workshop from the Delta Program. Through participating in this program, I aim to establish my commitment to supporting diversity, equity, and inclusion through my research mentorship and teaching experiences.

2. Enhance knowledge in responsible conduct of research

- I will participate in the **Waisman Center Ethics and Professional Development seminar series** to support my ongoing training in the responsible conduct of research. This seminar occurs annually for doctoral students and postdoctoral trainees at the Waisman Center. It occurs at least two times per month (~16 one-hour sessions) each academic school year led by different Waisman faculty for in-person lecture and small-group discussion. Topics of each session include consent and assent, socially responsible science, scientific rigor and reproducibility, and inclusive professional frameworks.
- I will also participate in two workshops hosted by the **Professional Research Education Program**, a cross-campus working group designed to support scientists at UW-Madison conduct safe, compliant, and inclusive research and to connect the research community to campus resources. Workshops at 1-2 hours in length and involve live, in-person or virtual lecture and break-out group discussion on topics related to the responsible conduct of human subject research.

3. Improve grant writing skills

- I will participate in a **Grant Writing Bootcamp for Social Scientists** sponsored by the UW-Madison Office of the Vice Chancellor for Research and Graduate Education. The Bootcamp is held annually from July through February (twice monthly). It provides participants with information, feedback, and a structured timeline for crafting a strong NIH research proposal. Participants are expected to develop an external grant application during this bootcamp; thus, I will begin to develop an early career R21 for a future research faculty position. During this time, I will also begin to investigate non-federal research foundations such as the ASHFoundation (ASHA) and the AACPDM to plan for future grant proposals.

- I intend to participate in the **ASHA Lessons for Success Program**. This program provides intensive grant writing training to early career scientists in communication sciences and disorders. Lessons for Success involves a combination of lectures, mock reviews, and small-group sessions. This 2.5-day program occurs in-person at the ASHA National Office in Maryland (all travel is covered by the program). I have already applied to participate in the 2023 cohort; however, if I am not selected this round, I will reapply to participate during the proposed award period.

Other Training Goals

Mentored job search: Drs. Hustad and Bunton will provide guidance and feedback throughout my training plan to support my job search and preparation of materials to obtain a tenure-track Assistant Professor research faculty position. Guidance will be provided on a range of academic activities, including scholarly publishing, grant writing, setting up a lab, developing coursework, and negotiating start-up packages and salaries. The knowledge and experience gained from the F32 will be critical for obtaining a position as an independent investigator at a Research I university.

C. ACTIVITIES PLANNED UNDER THIS AWARD

Percent effort across activities: 12 months proposed effort

60% Research

- Data coding and analysis: 40%; Mentoring research assistant: 5%; Manuscript writing and submission: 15%

25% Research Training

- Meetings with Dr. Bunton: 5%; Meetings with Dr. Hustad: 5%; Meetings with Dr. Mahr: 5%; Scientific conferences: 5%; Statistical coursework: 5%

15% Professional Training

- DEI workshop: 3%, Grant writing workshop and preparation: 4%; RCR Training: 3%; Waisman Center interdisciplinary research seminars: 2%; UWPA research symposium: 1%; Job search preparation: 2%

Training Activity Timeline

Training activities	Bi-monthly project activity timeline					
Research Training	**1-2**	**3-4**	**5-6**	**7-8**	**9-10**	**11-12**
Biweekly training meetings with Dr. Bunton	X	X	X			
Monthly training meetings with Dr. Bunton				X	X	X
Weekly training meetings with Dr. Hustad	X	X	X	X	X	X
Monthly statistical consultation with Dr. Mahr	X	X	X			
Weekly statistical analysis consultation with Dr. Mahr				X	X	X
STAT 240: Data Science Modelling I	X	X	X			
STAT 340: Data Science Modelling II				X	X	X
Submit talk to Motor Speech Conference		X				
Submit talk to ASHA Convention				X		
Submit talk to AACPDM annual meeting					X	
Professional Training						
RCR trainings	X	X	X			
Grant writing bootcamp			X	X	X	X
ASHA Lessons for Success program					X	
DEI workshop: Delta Program			X	X		
Apply for faculty positions	X	X				
R21 outline preparation for faculty position					X	X

Summary. My long-term career goal is develop scientifically validated clinical diagnostic tools to support the early detection of speech impairment in CP and other neurodevelopmental disabilities. The proposed F32 award will provide the training necessary to launch my independent line of research integrating knowledge in acoustic analysis and statistical modeling to successfully generate research examining vocal biomarkers of speech impairment in CP. Training with the proposed mentorship team will provide the ideal level of support to support my developing expertise to support my programmatic line of research. Research conducted under this proposal is necessary to drive the directions of future early career R21 and R01 proposals aiming to support this goal. Specifically, we must engage a multi-measure approach to study prelinguistic vocal behaviors to support early detection of speech impairments to inform treatment decision making for clinicians to improve communication outcomes in CP.

INSTITUTIONAL ENVIRONMENT AND COMMITMENT TO TRAINING

RESEARCH PROGRAM

The **Waisman Center** is an interdisciplinary research institute that conducts biological and behavioral research in intellectual and developmental disabilities (IDD). The Waisman Center is part of the University of Wisconsin-Madison, a Research I institution highly ranked by the National Institutions by US News & World Report with research expenditures of approximately $1.2 billion. The Waisman Center is dedicated to support postdoctoral researchers and has maintained an NICHD T32 postdoctoral training program in intellectual and developmental disabilities since 1995. I was selected as a participant in the 2021-2023 cohort of this highly competitive program which funded the first two years of my NRSA postdoctoral training.

The Waisman Center houses the **Wisconsin Intelligibility, Speech, and Communication (WISC) laboratory**, led by the Sponsor of this proposal, Dr. Katherine Hustad. I will have completed 2 years of postdoctoral training with Dr. Hustad and the WISC laboratory prior to beginning the proposed research project. My first two years of postdoctoral training focused on learning about speech and communication development in older children with CP. The WISC laboratory team includes the Sponsor (Hustad), data scientist (Mahr), PI (Long), 2 research speech-language pathologist project managers, 2-3 doctoral students, and 3-5 graduate and undergraduate research assistants. The laboratory team meets weekly to discuss ongoing project logistics, and to present and discuss internal research projects. I also meet weekly one-on-one with Dr. Hustad for mentorship and feedback on my work.

OPPORTUNITIES FOR INTELLECTUAL INTERACTION

The **Waisman Center** offers a multitude of interdisciplinary resources for postdoctoral researchers, faculty, staff, and students. The **Department of Communication Sciences and Disorders** is well represented at the Waisman Center which also hosts several opportunities for intellectual interaction.

- The John D. Wiley Seminar Series is hosted throughout the academic school year, where internal faculty and international researchers are invited to present their research. Following each seminar, presenters facilitate lively discussions of their research with audience members across the biological and behavioral sciences.
- I am a nominated member of the Waisman Center Morse Society, a multidisciplinary group of ~12 graduate students and postdoctoral researchers engaged in IDD research activities led by two Waisman Center faculty. The Morse Society meets monthly to engage in intellectual discussion, debate, and idea generation of clinical and translational research topics in a collaborative setting.
- An annual poster fair is held at the Waisman Center to give faculty, students, and postdoctoral researchers the opportunity to present their recent research advances and to build conversation across scholars associated with the Center.
- A weekly professional research colloquium seminar is hosted by the Department of Communication Sciences and Disorders, in which Dr. Hustad is dually appointed. I have previously presented at and attended this seminar and aim to continue my participation in this colloquium to contribute to ongoing research conversations in the field of communication sciences and disorders. Seminars are held once a week during the academic school year.
- In connection with the Department of Pediatrics, Pediatric Grand Rounds is a weekly multidisciplinary and interprofessional conference series that is open to the public. It is designed to share knowledge across clinical healthcare and implementation topics. These one-hour talks occur live in a virtual or in-person format, 2-3 times per month. Previous topics related to my research have included Genomics in Cerebral Palsy; Health Equity; and Advancing Research in CP: Integrating Real Feedback from Real Participants and Their Families.

FACILITIES AND OTHER RESOURCES FOR CAREER ENHANCEMENT

The **Office of Postdoctoral Studies** at UW-Madison supports over 750 postdoctoral trainees conducting research across the university. It strives to enhance the postdoctoral experience by providing access to robust professional development training to support our development as competitive academic candidates. A weekly bulletin is sent to all postdoctoral trainees advertising resources developed for—or available to— postdoctoral

researchers. Several resources for career enhancement available through the Office of Postdoctoral Studies include:

- The UW Postdoctoral Association hosts an annual postdoctoral research symposium that highlights research conducted by postdoctoral trainees across the university. I served on the planning committee for this symposium in 2021. I plan to present my research at this symposium in the future and build research connections with postdocs in related fields during the proposed research project.
- The Postdoctoral Training Course in Scientific Leadership offers formal training in the development of leadership and management skills in the context of a scientific career. The course is specifically designed for postdoctoral researchers and consists of six, three-hour sessions offered once per month for six months. I plan to apply to participate in this program to support my career enhancement.
- Individual career advising for one-on-one discussion with the Office Career Development Manager. Topics for advisement include researching career options, effective job search strategies, networking tips/discussion, CV and/or cover letter feedback, interview preparation, and job offer/salary/benefits negotiation.
- The Postdoc Career Group is an ongoing discussion group for postdocs to explore career development topics. Sessions are only open to postdocs and led by a certified Career Development Facilitator. This group regularly hosts guest experts and provides best practices for negotiating the transition from postdoctoral training to professional career success.
- Career Planning Workshops are small group sessions that provide career development education specifically tailored to the needs of postdocs. Between six to ten sessions are held annually. Previous workshop topics have included “Building personal connections,” “Applying for faculty positions,” “Negotiation,” “Networking success secrets,” and “Becoming a better mentor.”
- The For Future Faculty Series is a platform through the Office built to distribute upcoming workshops (virtual and in-person) and discussion panels hosted by the university, affiliated institutes, and external funding mechanisms. Previous offerings have been hosted through the National Postdoctoral Association; National Institutes of Health Office of Intramural Training & Education; the Center for the Integration of Research, Teaching and Learning; and the UW–Madison Writing Center, among others. Topics have included, “Understanding institutional fit,” “Preparing your job application materials,” “Conducting your job search,” “Developing your research program,” and “Advancing your teaching skills.”

The **Institute of Clinical and Translational Research** (ICTR) is an interdisciplinary institute at UW-Madison centered around building capacity in translational science. Its primary objectives are to train the next generation of biomedical and behavioral scientists, provide investigators and clinicians with the next generation of critical technological and scientific resources, and create novel solutions to disseminate innovations to improve healthcare. ICTR has many education and training opportunities available to investigators, including postdoctoral researchers.

- A variety of courses, workshops and presentations are available through ICTR. Specific topics related to clinical and translational research include study design, grant and manuscript writing, overviews of conducting clinical and translational research, stakeholder engagement, biomedical informatics, and qualitative research methods. Many of these resources are housed online, either as training modules or as archived videos and readings. In-person trainings and workshops are also held each year, including a K-Grant Writing Group, a Dissemination & Implementation Research Short Course, and the Culturally Confident Engagement for Translational Research: Building Trust Curriculum Workshop.
- ICTR facilitates a Mentor-Mentee training program to enhance mentorship skills in scientists in the clinical and translational sciences. This program is co-created through the Center for the Improvement of Mentored Experiences in Research at UW-Madison with the goal to promote cultural change that values excellence in research mentoring. The mentorship training curriculum addresses topics such as aligning expectations, addressing equity and inclusion, assessing understanding, and fostering independence.

PROJECT TIMELINE

Timeline	**Bi-monthly activity timeline (12 months)**					
Research activity	**1-2**	**3-4**	**5-6**	**7-8**	**9-10**	**11-12**
Student extracts syllable segments for acoustic analysis	X					
PI trains student research assistant for perceptual coding	X	X				
Speech outcome classification by research SLP	X	X				
Bunton trains PI for acoustic analysis	X	X	X			
Student conducts perceptual coding		X	X	X		
PI instrumental acoustic extraction		X	X	X		
PI reliability perceptual coding (20%)			X	X		
Bunton reliability acoustic analysis (20%)			X	X		
Aim 1 & 2 data preparation				X	X	
Aim 1 & 2 statistical analysis				X	X	X
Manuscript preparation				X	X	X
Manuscript submission: JSLHR						X
Submit conference talks (MSC, AACPDM, ASHA)		X		X	X	
HIPAA/CITI certification and IRB renewal	X			X		
Training activity						
Weekly training/consultation with Dr. Hustad	X	X	X	X	X	X
Bi-weekly acoustic training with Dr. Bunton	X	X	X			
Monthly acoustic training/consultation with Dr. Bunton				X	X	X
Monthly statistical consultation with Dr. Mahr	X	X	X			
Weekly statistical analysis consultation with Dr. Mahr				X	X	X
RCR trainings	X	X	X			
Grant writing bootcamp			X	X	X	X
ASHA Lessons for Success workshop					X	
DEI workshop: Delta Program			X	X		
Research faculty position planning						
Prepare research faculty position application materials	X	X				
Apply for faculty positions in CSD departments	X	X				
Begin outline for NIDCD early career R21					X	X

PI: Principal investigator; **SLP:** Speech-language pathologist; **JSLHR**: Journal of Speech, Language, and Hearing Research; **MSC:** Motor Speech Conference; **AACPDM**: American Academy of Cerebral Palsy and Developmental Medicine; **ASHA**: American Speech-Language Hearing Association; **HIPAA**: Health Insurance Portability and Accountability Act; **CITI**: Collaborative Institutional Training Initiative Program; **IRB**: Institutional Review Board; **RCR**: Responsible Conduct of Research; **DEI**: Diversity, equity, and inclusion; **UW-OPS**: University of Wisconsin Office of Postdoctoral Studies; **CSD**: Communication sciences and disorders; **NIDCD**: National Institute of Deafness and Other Communication Disorders

Helen Long, PhD, CCC-SLP
Postdoctoral Researcher
University of Wisconsin-Madison

Year 1: Postdoctoral Researcher (third year) 2023-2024	
Teaching (<5%)	• 1-2 guest lectures as requested

Research (75%)	**Grants**
	• Research eligible early career grant mechanisms for Assistant Professor position (K23, R21) and begin outline for grant submission
	
	Research
	• Continue to track and monitor research pipeline
	• Train and mentor 1 student for vocal coding of archival recordings
	  • Submit IRB or modifications as needed
	• Participate in laboratory meetings
	  • Present current data 1-2x each academic semester
	• Submit to and present at relevant research conferences
	  • ASHA – Submit 1-2 abstracts
	  • AACPDM – Submit 1 abstract
	  • Motor Speech Conference – Submit 1 abstract
	• Start outlining plan for faculty start-up fund budget, equipment, and resources needed
	• Participate in departmental events and seminars
	• Mentor 1-2 undergraduate or graduate student research projects
	• Participate in Responsible Conduct of Research (RCR) training
	
	Publications
	• Prepare 2-3 first-authored manuscripts for publication
	  • Early speech and language milestones in CP
	  • Vocal behaviors of anarthric children with CP at 50 months
	  • Communication profiles of children with CP and restricted speech intelligibility growth
	• Collaborate on 1-2 postdoc laboratory manuscripts as needed

Service (5%)	• Peer review 2-4 manuscripts within area of expertise as invited • Participate in 1 conference review committees as invited • Continue to serve as postdoctoral representative for UW-Madison Committee for Disability Access and Inclusion

Year 2: Assistant Professor (first year) 2024-2025	
Teaching (40%)	• Prepare and teach two courses (1 Spring, 1 Fall) • Attend junior teaching training

Research (50%)	**Grants**
	• Write and submit one NIH early career grant applications (K23 or R21, etc.)
	
	Research
	• Begin writing laboratory manual and expectations document for students
	• Purchase equipment and build out laboratory recording studio
	• Write and submit IRB for laboratory and clinical data collection
	• Initiate university and community collaborations
	  • Hospital CP clinic
	  • Interdisciplinary university institute
	• Build departmental relationships
	  • Brainstorm future grant collaborations
	• Hire 1-2 research assistants to assist with data collection
	• Begin recruitment for laboratory and clinic studies
	• Submit to and present at relevant research conferences
	  • ASHA
	  • AACPDM
	  • Ongoing search for new options as appropriate
	• Participate in departmental events and seminars
	
	Publications
	• Prepare 1-2 first-authored manuscripts for publication
	• Support 1-2 manuscripts with external collaborators

Service (10%)	• Mentor 2-5 undergraduate or graduate student research projects • Peer review 2-3 manuscripts within area of expertise as invited • Serve on 1 university committee • Participate in scientific review committees for conferences as requested

Year 3: Assistant Professor (second year) 2025-2026	
Teaching (40%)	• Teach two courses (1 spring, 1 fall) • Adjust as appropriate from course feedback • Prepare second year P&T portfolio • Attend UDL workshop

Research (50%)	**Grants**
	• Revise and resubmit 1 major grant application if not previously awarded (K23 or R21, ASHFoundation, etc.)
	• Seek out and submit to private foundation funding
	  • CP Research network
	  • CP Alliance
	• Plan and outline departmental co-PI collaboration grant proposal
	
	Research
	• Ongoing research laboratory building and management
	• IRB renewal and updates
	• Continue to build university and community collaborations
	• Strengthen departmental relationships
	• Manage 1-2 research assistants' laboratory duties
	• Continue recruitment for laboratory and clinic studies
	• Submit to and present at relevant research conferences
	  • ASHA
	  • Motor Speech Conference
	  • Ongoing search for new options as appropriate
	• Participate in departmental events and seminars
	
	Publications
	• Prepare 1-2 first-authored manuscripts for publication
	• Support 1-2 manuscripts with external collaborators

Service (10%)	• Mentor 2-5 undergraduate or graduate student research projects • Peer review 2-3 manuscripts within area of expertise as invited • Serve on 1 university committee • Participate in scientific review committees for conferences as requested

Year 4: Assistant Professor (third year) 2026-2027	
Teaching (35%)	• Teach two courses (1 spring, 1 fall) • Adjust as appropriate from course feedback • Prepare third year P&T portfolio, review with mentoring committee • Attend early faculty teaching training

Research (50%)	**Grants**
	• Revise and resubmit 1 major grant application if not previously awarded (K23 or R21)
	• Seek out and submit to private foundation funding
	  • ASHFoundation
	  • AACPDM
	• Write and submit departmental co-PI collaboration grant proposal
	
	Research
	• Ongoing research laboratory management
	• IRB renewal and updates
	• Participate in interdisciplinary events with university and community collaborations
	• Manage 1-2 research assistants' laboratory duties
	• Continue recruitment for laboratory and clinic studies
	• Submit to and present at relevant research conferences
	  • ASHA
	  • ICIS
	  • Ongoing search for new options as appropriate
	• Participate in departmental events and seminars
	
	Publications
	• Prepare 2-3 first-authored manuscripts for publication
	• Support 1-2 manuscripts with external collaborators

Service (15%)	• Mentor 2-5 undergraduate or graduate student research projects • Peer review 2-3 manuscripts within area of expertise as invited • Serve on 1 university committee • Participate in scientific review committees for conferences as requested

Year 5: Assistant Professor (fourth year) 2027-2028	
Teaching (35%)	• Teach two courses (1 spring, 1 fall) • Adjust as appropriate from course feedback • Prepare fourth year P&T portfolio, review with mentoring committee • Attend teaching strategies workshop

Research (50%)	**Grants**
	• Outline and prepare R01 grant application
	• Seek out and submit to private foundation funding
	  • Pedal with Pete
	  • ASHFoundation
	• Revise and resubmit departmental co-PI collaboration grant proposal
	
	Research
	• Ongoing research laboratory management
	• IRB renewal and updates
	• Participate in interdisciplinary events with university and community collaborations
	• Manage 1-2 research assistants' laboratory duties
	• Continue recruitment for laboratory and clinic studies
	• Submit to and present at relevant research conferences
	  • ASHA
	  • AACPDM
	  • Ongoing search for new options as appropriate
	• Participate in departmental events and seminars
	
	Publications
	• Prepare 2-3 first-authored manuscripts for publication
	• Support 1-2 manuscripts with external collaborators

Service (15%)	• Mentor 2-5 undergraduate or graduate student research projects • Peer review 2-3 manuscripts within area of expertise as invited • Serve on 1 university committee • Apply to serve as editor for ASHA Journals • Participate in scientific review committees for conferences as requested

Research Statement

Name: Helen Long, PhD, CCC-SLP
Education: BA in Speech & Hearing Sciences, Indiana University-Bloomington (2010)
MA in Communication Sciences and Disorders, Florida State University (2012)
PhD in Communication Sciences and Disorders, University of Memphis (2020)
Postdoc at Waisman Center, University of Wisconsin-Madison (2021-present)
Current Affiliation: Waisman Center, University of Wisconsin-Madison
Current Position: T32 Postdoctoral Researcher

1. Major research goals: The primary goal of my research is to leverage prelinguistic vocal markers to identify the earliest indicators of speech impairment in infants at risk for cerebral palsy (CP) and related neurodevelopmental disabilities. My central hypothesis is that neurological damage resulting in a CP diagnosis will affect the development of the motor speech system, resulting in atypical prelinguistic vocal features that will be predictive of later motor speech disorders. This population has not been systematically investigated in this area yet remains at great risk for impairment that will have a profound impact on their quality of life. A secondary goal of my research is to increase knowledge and awareness of communication impairments in CP. Speech-language pathology is an underrepresented area in CP early detection and care teams, and an often-misunderstood area of development in general medicine. I aim to improve interprofessional practices aiming to improve long-term participation through building multidisciplinary collaborations across members of CP care teams. Ultimately, the long-term goal of my work is to develop scientifically validated clinical tools to improve 1) evidence-based decision-making for earlier detection in infancy, 2) more accurate prognoses, and 3) treatment planning in CP. This work is critical to support communication outcomes in this population.

2. Major methods to address research goals: My research utilizes a multi-measure approach to examine quantitative and qualitative aspects of longitudinal vocal and early speech development in CP. This includes human coding of vocalizations produced during naturalistic interactions in laboratory and home recordings for gold standard analysis of vocal complexity. I also use parent-report based tools and standardized assessment to study early vocal and speech development. I am presently seeking postdoctoral support to receive training in instrumental acoustic analysis to expand my methodological toolbox for studying biomarkers of speech impairment. In the future, I intend to continue building collaborations to study 1) how gross and fine motor impairment impacts early vocal communication in interaction, and 2) the parallel emergence of vocal milestones with feeding/swallowing development in CP. This work will benefit from collaborating with researchers in physical therapy, occupational therapy, and pediatric dysphagia. This research will support the development of validated communication assessment tools for children with motor impairment. Throughout my career, I aim to continue to build interdisciplinary collaborations across the allied health professions to support this population.

3. Funding sources: The aims of my research are in line with the funding priorities of the NIDCD, NICHD, and NINDS. In my first 3-5 years as research faculty, I will apply for early career (R21) and training (K23) grants through these mechanisms to establish my independent career aiming to improve early detection of communication disorders in CP. Work funded through these awards will inform the development of subsequent R01 applications. I also intend to apply for funding through the ASHFoundation, the American Academy of Cerebral Palsy and Developmental Medicine, and the Cerebral Palsy Alliance Research Foundation.

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Long, Helen Lauren

eRA COMMONS USER NAME (credential, e.g., agency login): hlong1

POSITION TITLE: Postdoctoral Trainee

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Indiana University, Bloomington, IN, USA	BA	05/2010	Speech & Hearing Sciences; Slavic & Eastern European Languages and Culture
Florida State University, Tallahassee, FL, USA	MS	08/2012	Speech-Language Pathology
University of Memphis, Memphis, TN, USA	PhD	12/2020	Communication Sciences and Disorders
University of Wisconsin, Madison, WI, USA	Postdoc	In progress	Communication Sciences and Disorders

A. Personal Statement

I am applying to the Lessons for Success Program to support my development as a productive early career research investigator. My programmatic line of research aims to identify prelinguistic vocal biomarkers for speech impairment in infants at risk for cerebral palsy (CP). My research questions are based in my clinical experience as a speech-language pathologist working with children with complex communication needs secondary to CP or autism. I completed my doctoral training with Dr. D. Kimbrough Oller to study typical infant vocal development. This training instilled a strong theoretical framework to study prelinguistic vocal behaviors and to assess for signs of later speech and language disorders. I am conducting my postdoctoral training with Dr. Katherine Hustad to gain comprehensive training in speech and communication development in children with CP. Our research to date has longitudinally studied functional communication, school-based treatment goals, and changes in speech impairment classification in school-aged children with CP. These experiences provided the foundation to build a programmatic line of research combining my doctoral and postdoctoral training to study vocal biomarkers of speech impairment in infants at risk for CP. I have contributed to 14 manuscripts (7 as first author) and 35 presentations (22 as first author) across 9 different national and international annual conferences. My predoctoral and postdoctoral research has used longitudinal research methods involving human coding of infant vocalizations produced during parent-infant interactions in laboratory and home-based recordings. My work has also incorporated standardized assessment, educational data, and parent report questionnaires to study performance and outcomes in CP. A key component of my work necessitates intensive grant preparation to fund and successfully manage longitudinal studies of infants at risk for speech impairment and CP from 0-5 years of age. My research thus far has received attention from funding mechanisms such as the ASHFoundation, NIH Loan Repayment Program, and a highly competitive T32 training program at the Waisman Center. The Lessons for Success Program will ensure a smooth transition from my postdoctoral training to my early stage faculty career as a I develop my research program. As a previous participant of the 2021 ASHA Pathways Program, I aim to continue to develop a strong research foundation with first-rate mentorship through ASHA's training resources and from successful researchers in our field. The Lessons for Success Program will provide invaluable training to become a competitive grant applicant for R01 funding and ultimately achieve academic independence.

A recently awarded project that I wish to highlight is:

New Investigators Research Grant, ASHFoundation Long (PI) 12/2022 – 12/2023
Prelinguistic vocal behaviors in infants at risk for cerebral palsy under 24 months
The goal of this one-year project is to examine prelinguistic vocal behaviors and their association with language performance in infants at high risk for cerebral palsy.
Role: PI

Citations

1. **Long HL,** Bowman DD, Yoo H, Burkhardt-Reed MM, Bene ER, Oller DK. Social and endogenous infant vocalizations. PLoS One. 2020 Aug 5;15(8):e0224956. doi: 10.1371/journal.pone.0224956. PMID: 32756591; PMCID: PMC7406057.
2. Koopmans C, Sakash A, Soriano J, **Long HL**, Hustad KC. Functional Communication Abilities in Youth With Cerebral Palsy: Association With Impairment Profiles and School-Based Therapy Goals. Lang Speech Hear Serv Sch. 2022;53(1):88-103. doi: 10.1044/2021_LSHSS-21-00064. PMID: 34767477.
3. **Long HL**, Mahr TJ, Natzke P, Rathouz PJ, Hustad KC. Longitudinal change in speech classification between 4 and 10 years in children with cerebral palsy. Dev Med Child Neurol. 2022;64(9):1096-1105. doi: 10.1111/dmcn.15198. PMID: 35262181.
4. **Long, HL,** Eichorn, N, & Oller, DK. (In press). A probe study on vocal development in two infants at risk for cerebral palsy. Developmental Neurorehabilitation. [Preprint], osf.io/ev397

B. Positions, Scientific Appointments, and Honors

Positions and Scientific Appointments

2021-	NICHD T32 Postdoctoral Fellow, Waisman Center, University of Wisconsin-Madison
2015-2020	Research Assistant, Origin of Language Laboratory, University of Memphis
2014-2021	Speech-Language Pathologist, Invo-Progressus Therapy
2012-2014	Speech-Language Pathologist, Easter Seals Massachusetts
2011-2012	Research Assistant, Experimental Child Phonetics Laboratory, Florida State University
2009-2010	Research Assistant, Voice Physiology Laboratory, Indiana University-Bloomington

Other Experience and Professional Memberships

2022-	Postdoctoral Representative, Committee on Disability Access and Inclusion
2021	Scientific Review Committee, American Academy for Cerebral Palsy and Dev. Medicine
2021-	Speech and Language Sciences Review Committee, ASHA Convention
2021-	Scholarship Review Committee, American Academy for Cerebral Palsy and Dev. Medicine
2020-	Ad hoc reviewer: American Journal of Speech-Language Pathology; Journal of Speech, Language, and Hearing Research; Journal of Communication Disorders; etc.
2020-	Co-founding collaborator, CSDisseminate
2019-2021	Member, International Congress of Infant Studies
2018-	Membership Committee/Member, American Academy for Cerebral Palsy and Dev. Medicine
2014-2015	Mentor, ASHA STEP Program
2013-	Member, American Speech-Language Hearing Association (CCC-SLP)
2009-2012	Member, National Student Speech-Language Hearing Association

Honors

2022-	NIH Loan Repayment Award
2022-	Waisman Center Morse Society Scholar
2021	ASHA Pathways Program
2020	Graduate Student Association President Service Award, University of Memphis
2020	Celebrate Student Success Award, University of Memphis

2020 OrthoPediatrics™ Scholarship, American Academy for Cerebral Palsy and Dev. Medicine
2019 S.P. Wong Award for Best Presentation in Statistical Application, University of Memphis
2015-2016 Al Chymia Shriners Award, Shrine School SLP Department
2012 Red Apple Award for Outstanding School Personnel, Southborough Education Foundation
2012 Outstanding 2nd Year Master's Student Award, Florida State University
2011 Dr. Avery Vaughn Scholarship Fund for Excellence, Florida State University
2006-2010 H. Fullmer Faculty Scholarship Award, Indiana University

C. Contributions to Science

1. **Evolutionary origins of language and infant vocalizations as fitness signals.** My doctoral education with Dr. D. Kimbrough Oller provided a strong theoretical foundation in the infrastructural framework of infant prelinguistic vocal development. My doctoral dissertation used an evolutionary-developmental biology (evo-devo) lens to examine infants' capacity to vocally signal developmental information to caregivers. This work revealed three key findings. First, infant vocal imitation is rare in the first year but is highly salient to listeners, underscoring its potential to be used as a signal of information for caregivers. Second, infants produce nonsocial vocalizations far more frequently than social ones, which suggests that independent vocal play is a primary driver in the development of articulatory properties of speech. Last, although infants vocalize the most during independent vocal play, we found that they produce their most developmentally advanced vocal forms during interactive periods, offering support for infants' capacity to signal developmental information to caregivers.
    a. **Long HL,** Oller DK, Bowman DA. Reliability of listener judgments of infant vocal imitation. Front Psychol. 2019 Jun 11;10:1340. doi: 10.3389/fpsyg.2019.01340. PMID: 31244735; PMCID: PMC6579846.
    b. **Long HL,** Bowman DD, Yoo H, Burkhardt-Reed MM, Bene ER, Oller DK. Social and endogenous infant vocalizations. PLoS One. 2020 Aug 5;15(8):e0224956. doi: 10.1371/journal.pone.0224956. PMID: 32756591; PMCID: PMC7406057.
    c. Oller DK, Griebel U, Bowman DD, Bene E, **Long HL**, Yoo H, Ramsay G. Infant boys are more vocal than infant girls. Curr Biol. 2020 May 18;30(10):R426-R427. doi: 10.1016/j.cub.2020.03.049. PMID: 32428468; PMCID: PMC8204662.
    d. Oller DK, Ramsay G, Bene E, **Long HL**, Griebel U. Protophones, the precursors to speech, dominate the human infant vocal landscape. Philos Trans R Soc Lond B Biol Sci. 2021 Oct 25;376(1836):20200255. doi: 10.1098/rstb.2020.0255. Epub 2021 Sep 6. PMID: 34482735; PMCID: PMC8419580.

2. **Prelinguistic vocal development in clinical populations.** During my doctoral training, I independently sought experiences supporting my research training in early vocal development in infants at risk for speech and language disorders. The last paper in my dissertation examined canonical babbling in infants at risk for autism. Our findings suggested a potential robust internal motivation to produce a high rate of canonical syllables in both social and nonsocial contexts, even in the likely presence of autism. I also collaborated on a project evaluating vocal development in tuberous sclerosis. We found delayed canonical babbling and a low rate of their canonical syllable production compared to typical expectations. These findings indicate a critical need for further study of prelinguistic vocal patterns relative to later outcomes.
    a. Gipson TT, Ramsay G, Ellison EE, Bene ER, **Long HL**, Oller DK. Early Vocal Development in Tuberous Sclerosis Complex. Pediatr Neurol. 2021 Dec;125:48-52. doi: 10.1016/j.pediatrneurol. 2021.08.009. Epub 2021 Sep 10. PMID: 34628143; PMCID: PMC8557126.

    Other Publications
    b. **Long, HL,** Ramsay, G, Bowman, D, Burkhardt-Reed, MM, & Oller, DK. Canonical Babbling in Vocal Turn Taking and Independent Vocal Play. [Preprint], doi.org/10.1101/2020.10.09.333872

3. **Speech, and communication development in cerebral palsy**. My postdoctoral training with Dr. Katherine Hustad has provided a unique opportunity to longitudinally examine speech and communication development in CP using archival, naturalistic laboratory recordings, educational data, and communication assessment data. My early work in this laboratory found variability in deficit profiles and school-based

treatment goals across different levels of communication functioning in children with CP. We also recently found that speech performance improves over time in children with CP but those with severe impairments are more likely to remain stable. Our data suggests that children with mild-moderate speech and language impairments and CP have great potential to continue to make developmental and therapeutic communication gains. However, children with severe impairments are more likely to plateau in their speech development, thus requiring access to AAC as early as possible. These experiences have built the foundation to continue to develop a research program that blends my doctoral and postdoctoral training to study vocal behaviors predictive of speech impairment in CP, as young as infancy.

a. Koopmans C, Sakash A, Soriano J, **Long HL**, Hustad KC. Functional Communication Abilities in Youth With Cerebral Palsy: Association With Impairment Profiles and School-Based Therapy Goals. Lang Speech Hear Serv Sch. 2022;53(1):88-103. doi: 10.1044/2021_LSHSS-21-00064. PMID: 34767477.
b. **Long HL**, Mahr TJ, Natzke P, Rathouz PJ, Hustad KC. Longitudinal change in speech classification between 4 and 10 years in children with cerebral palsy. Dev Med Child Neurol. 2022;64(9):1096-1105. doi: 10.1111/dmcn.15198. PMID: 35262181.

4. **Prelinguistic vocal biomarkers in cerebral palsy.** Across my research experiences, I have maintained a strong focus on my programmatic line of research to study vocal biomarkers of speech impairment in CP. I independently initiated a case study on the emergence of mature CV-syllable forms in infancy (i.e., canonical babbling) during my PhD training. We found a low proportion of canonical syllables between 5-16 months in two infants with CP compared to ten typically developing infants, using all-day home recordings in CP. In my first year of postdoctoral work, I examined marginal and canonical babbling (i.e., immature and mature CV syllable forms) in ten infants at risk for CP and found a higher proportion of marginal syllables in infants with or with ongoing risk of CP, but a higher proportion of canonical syllables in infants whose motor delays later resolved. Throughout my doctoral and postdoctoral work, I have collaborated with a local neuromuscular clinic to study speech and language milestones in CP. We found that children with more severe communication impairments have achieved fewer prelinguistic vocal milestones. These studies offer preliminary support for directions of the ongoing study of vocal biomarkers of speech impairment in CP.
    a. **Long, HL,** Oller, DK, Romer, K, Friener, L, Warner, W, Spence, D, & Rhodes, LN. Pre-Speech and Early Speech Development of Young Children Diagnosed with Cerebral Palsy. [Abstract]. Dev Med Child Neurol, 2020 Oct;62,Suppl. 3:79-134. doi.org/10.1111/dmcn.14662

    Other Publications
    b. **Long, HL,** Eichorn, N, & Oller, DK. (In press). A Probe Study on Vocal Development in Two Infants at Risk for Cerebral Palsy. Developmental Neurorehabilitation. [Preprint], osf.io/ev397
    c. **Long, HL** & Hustad, KC. (Under Review) Longitudinal Development of Marginal and Canonical Babbling in Infants at Risk for Cerebral Palsy. [Preprint]. osf.io/2cvaq

5. **Open science practices in communication sciences and disorders.** A secondary line of research in which I have participated throughout my postdoctoral training is on the attitudes and behaviors associated with the use of open science practices in scientists within the field of communication sciences and disorders. Our work has revealed overall low knowledge, but high desire to understand and learn more about open science practices. One study looked specifically at the impact of different levels of open accessibility of manuscripts published in ASHA Journals. We found that fully open published versions of manuscripts and author-shared accepted versions both receive greater societal attention but only marginally greater scholarly attention than manuscripts published behind a paywall.
    a. **Long, HL,** Drown, L, El Amin, M. The effect of open access on scholarly and societal metrics of impact in the ASHA Journals. Jour Sp Lang Hear Res. 2022; 1-10. Epub ahead of print, doi: 10.1044/2022_JSLHR-22-00062

    Other Publications
    b. El Amin, M, Borders, JC, **Long, HL,** Keller, MA, Kearney, E. (In press). Open Science Practices in Communication Sciences and Disorders: A Survey. Journal of Speech, Language, and Hearing Research. [Preprint] doi: 10.31219/osf.io/jwba3

Complete List of Published Work in MyBibliography:
https://www.ncbi.nlm.nih.gov/myncbi/1RMPzPxaXG8Qm/bibliography/public/

D. Additional Information: Extramural Research Support Currently Under Review

F32 (DC: Not yet assigned) Helen Long (PI) *Submitting* 2022/12/08
Multi-Measure Characterization of Vocalizations in Infants at Risk for Cerebral Palsy
The goal of this research is to compare perceptual and acoustic measures of infant vocalizations in infants at risk for CP and identify the best combination of predictors for later-identified speech outcomes.
Role: PI

E. Additional Information: Extramural Research Support Currently Not Funded

F31 DC018468 Helen Long (PI) 2019/04/08
Infant Vocal Development of Clinical Populations in Social and Non-Social Contexts
The goal of this research proposal was to longitudinally assess the effect of parent interaction and endogenous activity on prelinguistic vocal development in typically developing infants as well as those in two clinical populations, autism and cerebral palsy.
Role: PI

New Century Scholars Doctoral Scholarship, ASHFoundation Helen Long (PI) 2019/05/08
Infant Vocal Development in Typically Developing and Clinical Populations
This research plan sought to evaluate the influence of parent interaction and endogenous vocal activity on prelinguistic vocal development in infants at 6, 9, and 12 months of age.
Role: PI

PhD Student Scholarship, CAPCSD Helen Long (PI) 2019/11/15
Prelinguistic Speech, Language, and Communication Profiles in Infants At-risk for Cerebral Palsy
This research proposal aims to compare early prelinguistic speech, language, and communication development in young children diagnosed and at-risk for CP to typically developing children using valid parental report assessments already designed for clinical use.
Role: PI

F. Additional Information: Intramural Research Support

N/A