Personal Statement

I am a clinical research scientist specializing in the emergence of **prelinguistic vocal development in young children at risk for neurodevelopmental disabilities like cerebral palsy (CP).** My long-term goal is to improve early detection of speech impairments in children at risk for disorders affecting motor speech abilities as an independent research scientist.

My early professional career (2012-2014) began as a speech-language pathologist (SLP) working with children who had complex communication needs secondary to developmental disorders like autism or cerebral palsy. This clinical experience fundamentally shaped my research questions that led me to become a research scientist. The required two years of Master's level training to become an SLP was supported entirely by student loans. As a doctoral student (2015-2021), I studied social and nonsocial factors influencing infant vocalizations as developmental fitness signals for caregivers and contributed to nine publications[28,31–38] (four as first author[28,31,32,35]). My dissertation mentor, Dr. D. Kimbrough Oller is a leading scientific researcher in the field of infant vocal development with more than 30 publications in this area since the 1970's.[10,39,40] During my doctoral training, **I gained a foundational understanding of prelinguistic vocal development** using an evolutionary-developmental biology (evo-devo) perspective to study typically developing infants and several developmental disorders (autism,[28] tuberous sclerosis[37]) including a preliminary case study on two infants at-risk for cerebral palsy.[35] During this time I had the opportunity to work on several grant funded projects (R01 DC015108, R01 DC011027, R01 HD046947, PI: Oller) and to independently write a predoctoral NIH grant (F31 DC018468, PI: Long, not funded). I also **independently initiated an ongoing research collaboration** with a neuromuscular clinic and have maintained this collaboration since 2018 even after beginning my postdoc program. This was an invaluable experience in building community research connections. I have presented this research across four national conferences.[41–44]

Immediately following my doctoral training, I was awarded a highly competitive postdoctoral fellowship in a **T32 clinical research postdoctoral program** at the Waisman Center of the University of Wisconsin-Madison (2021-2023). Through this experience I aim to continue my study of vocal development in infants at risk for cerebral palsy. The Waisman T32 postdoctoral research training program is **designed to foster research success through mentorship and training of promising early career research scientists** in intellectual and developmental disabilities. **My short-term goals** as a postdoctoral trainee are to 1) receive mentorship from associated faculty to build my programmatic line of research, 2) increase my publication record as an early career scientist, and 3) receive additional training in external grant writing and professional development. Meeting these goals will contribute to the success of **my long-term career goals** to 1) obtain a tenure-track research faculty position and 2) develop an independent clinical research laboratory to study vocal development in children with neurodevelopmental disorders.

For my postdoctoral experience I selected Dr. Katherine Hustad as my mentor. Dr. Hustad is one of the top scientists studying communication development in cerebral palsy. **My primary research throughout the course of the LRP contract will evaluate prelinguistic vocal developmental patterns in children at risk for CP using longitudinal data from Dr. Hustad's laboratory**, further discussed in *Research Activities*. I am working on several projects within and outside of my postdoc lab to support my publication productivity and research collaboration efforts, including 1) a longitudinal study examining speech impairment classification in cerebral palsy, 2) a pre-post study on the effectiveness of augmentative and alternative (AAC) training for speech-language pathologists with a Waisman Center-affiliated AAC clinic, 3) a systematic review on babbling in neurodevelopmental disorders with the UW-Madison Libraries, and 4) an evaluation of functional communication, speech and language school-based treatment goals for children with CP[45] (in press).

In summary, **I am committed to a research career evaluating prelinguistic and early speech patterns in neurodevelopmental populations and the implications of these patterns on motor speech development**. The necessary clinical training to support my research questions was made possible by the provision of student loans; thus, the LRP award will provide the opportunity to shift my focus from the burden of student loan debt to the ongoing study of my research questions. By studying the trajectory of prelinguistic vocal abilities in these populations during the first few years of life, we have the potential to improve early detection, clinical intervention, and long-term participation outcomes for children with complex communication needs.

Research Activities

Over the course of the LRP contract I will complete the second and third years of postdoctoral research training with 100% of my efforts dedicated to research. My research proposal will evaluate prelinguistic vocal development in children with cerebral palsy using a longitudinal dataset of recordings already available in my postdoctoral laboratory. All research activities will take place in the Wisconsin Intelligibility, Speech, and Communication (WISC) Lab (PI: *Hustad*) in the Waisman Center at the University of Wisconsin-Madison.

1. BACKGROUND

Up to 80% of children with cerebral palsy (CP) present with speech impairments which can affect communication effectiveness, educational participation, and social interaction throughout the lifespan.[1] Speech and language impairments can be identified in children with CP as young as two years of age.[2,3] However, speech impairments can be difficult to predict at earlier ages due to the wide variability in severity profiles of CP.[4,5] There is limited evidence on the patterns of prelinguistic development in this population under 24 months of age.[6–9]

There exists a longstanding line of research on typical prelinguistic vocal development and its stages prior to the emergence of first words around 12 months.[10–13] Mastery of increasingly advanced vocal stages evidences greater control over the phonatory, articulatory, and intonational domains prior to the onset of first words around 12-15 months.[11] Reaching vocal milestones such as the onset of *canonical babbling*—i.e., production of syllables with a fully resonant vowel and quick transition (<250ms) between the consonant and vowel, e.g., [baba]—between 7-10 months of age is a robust predictor of typical speech development.[14,15] Many studies have consistently demonstrated canonical babbling delays in neurodevelopmental disorders such as autism,[16] Down syndrome,[7,17] and apraxia of speech.[18,19] The current studies on vocal development in CP utilizes cross-sectional research designs observing canonical babbling only.[6–9]

At present, there has been no longitudinal investigation of babbling emergence or within-stage vocal characteristics in CP. Earlier vocal stages such as *marginal babbling* are considered infrastructural, i.e., crucial to the development of more advanced stages and word production.[14,20,21] Marginal babbling is defined as production of "immature" syllables with a slow transition (perceived as >250ms) between the consonant-like element (i.e., margin) and vowel.[22] It is imperative to observe infrastructural stages across the first year to observe how early vocal patterns can influence the emergence of first words. Furthermore, despite there being several known levels of advancing complexity within the canonical babbling stage[23]—i.e., reduplicated babbling (e.g., [bababa]) and variegated babbling (e.g., [badaga])—it is unclear to what extent neurological damage from CP may influence infants' ability to combine mature syllables.

There is a great need for a large-scale longitudinal investigation of prelinguistic vocal development in children at risk for CP under 24 months of age to identify clinical predictors of later speech impairments. Identifying prelinguistic clinical predictors is critical for informing speech and language diagnostic and intervention planning as early as possible to improve communication outcomes. **The following Specific Aims will be addressed in this research proposal using a longitudinal dataset of ~23 infants at risk for CP:**

> **Aim 1:** Identify vocal stage onset age ranges for marginal babbling, canonical babbling, and first words through longitudinal observation of infants at risk for CP.
>
> **Aim 2:** Explore marginal babbling and canonical babbling placement characteristic types in infants at risk for CP.
>
> **Aim 3:** Examine the range of canonical syllable complexity in infants at risk for CP.

Summary. My research proposal will longitudinally evaluate prelinguistic vocal stage onset, vocal type characteristics, and canonical babbling complexity in infants between 5-25 months at risk for CP ("CP risk"). **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 production features that will be predictive of later motor speech disorders. This research has the potential to contribute to the early identification of speech impairments in CP to inform speech and language diagnostic and treatment planning and to improve long-term communication and participation outcomes in this population.

2. APPROACH

Dataset. For all Aims in this proposal, professional quality **laboratory recordings of 23 infants between 5-25 months of age are available for immediate coding and analysis**. These 23 infants were recruited through local and regional medical centers through the Waisman Center's Clinical Translational Core to participate in an ongoing longitudinal project in my postdoc laboratory on the Study of the Emergence and Acquisition of Language and Speech in infants and young children at risk for CP between 0-5 years ("**SEALS project**," 5R01DC009411-14, PI: *Hustad*). CP risk status was based on medical records and birth history. During participation in the SEALS project, families brought the participating infant to the laboratory every 1-2 months for assessment. During these laboratory visits, recordings of naturalistic parent-infant interactions were also collected (mean duration: 12 minutes). For these interactions, parents were instructed to engage with their infant using toys, books, or simple games. ~6 recordings exist per infant between 5-25 months of age. The Aims in this proposal will use these pre-existing parent-infant interaction recordings for analysis. **A total of 144 recordings are available for analysis** of Aims 1-2. Because the SEALS project is ongoing, ~3-4 infants and ~4-5 recordings per infant are expected to be added for final analysis. My specific Research Aims have not been previously studied with these data and my predoctoral work has provided me unique training to analyze prelinguistic vocal behaviors captured in these recordings.

Coder training. I am presently creating modules for coder training for the vocal types described in this proposal. These modules are adapted from the training protocol used in my doctoral laboratory (OLL Lab, PI: Oller). Specifically, I will train 2-3 graduate student assistants who have had at least one course in phonetic transcription as "**coders**". The use of training modules will ensure a standardized procedure for subsequent coding in my postdoctoral and future independent laboratory settings. These modules include 15–30-minute videos and knowledge checks on the theoretical framework for the natural logic of infant vocalizations and typical prelinguistic vocal stages,[11] thorough descriptions of vocal types with examples, an introduction to the coding software,[24] and explicit training on real-time coding methods.

Coder practice and listener calibration. Following engagement with the training modules, coders will practice coding three 15-min laboratory recordings. Their results will be compared with a "key" developed from my coding as a gold standard. Discrepancies between student coding and the key will be highlighted for individual coders, and a second round of practice coding will ensue. This will continue until coders reach a criterion of not more than 10% discrepancy from the key on the targeted categories. The primary training goals are to calibrate coders' perception of 1) articulatory placement characteristics and vocal stage categories, 2) criteria for judging infant vocal utterances versus syllables, 3) speech-like vocalizations apart from cry, laugh, and vegetative sounds, and provide experience with independent judgment of ambiguous utterances. The procedure of coding training in my predoctoral laboratory goes remarkably fast (~21 hrs. distributed over three weeks), because most categories are intuitive, i.e., they must be recognized by caregivers (even if only tacitly) to scaffold expectations of the child at each stage of development; thus, coder training is expected to take 2-4 weeks before formal coding of material discussed in this research proposal.[25]

Infant Vocal Type coding. Using a coding scheme adapted from my doctoral laboratory (Origin of Language Laboratory (OLL), University of Memphis, PI: *Oller*), coders will identify infant vocalizations observed in recordings across two real-time passes: 1) marginal and canonical syllable vocal types and characteristics and words (Aims 1 & 2), and 2) canonical syllable complexity types (Aim 3). In the first observation pass, a total of eight Vocal Types and MB and CB articulatory characteristics will be coded to yield a total count of each vocal type produced per recording (**Vowel, MB-labial, MB-coronal, MB-dorsal, CB-labial, CB-coronal, CB-dorsal,** and **Word**). Specifically, individual marginal babble ("**MB**") and canonical babble ("**CB**") syllables will be point-based coded for labial, coronal, and dorsal articulatory characteristics, as well as any words produced. Syllables with only vowel or vowel-like resonance (i.e., no consonantal element) will also be coded for comprehensive inclusion of all vocal types. Aim 1 will collapse the MB and CB articulatory characteristic types to study onsets of marginal babbling, canonical babbling, and first word stages. Aim 2 will use all eight categories to examine marginal and canonical babbling articulatory characteristics. The second coding pass of canonical babbling complexity types is discussed in *Approach: Aim 3*. Coding will be completed using *Noldus: The Observer XT* software.[24] The Observer XT is a general-purpose software package used for point-based (location in time) and state-event (duration in time) recording and analysis in behavioral research. The Observer XT is already available for use in the WISC Lab. I have already coded a small portion of data for preliminary analysis of Aims 1 and 2 using this software, discussed in *Preliminary Data*.

Aim 1: Identify vocal stage onset age ranges for marginal babbling, canonical babbling, and first words through longitudinal observation of infants at risk for CP.

Rationale. The onsets of canonical babbling (~6-10 months) and first words (~12-15 months) are known predictors of typical speech development. To our knowledge there is no research evaluating the emergence of *marginal babbling*, the stage prior to the onset of canonical babbling. We seek to longitudinally examine the onsets of three increasingly advanced vocal stages over time (marginal babbling, canonical babbling, first words) to observe developmental patterns and the implications of these patterns on subsequent stages.

Hypothesis 1: The CP risk infants will show delays in expected ages of onset for all three vocal stages as a result of motor deficits associated with neurological damage from CP.

Aim 1 Approach. For Aim 1, the eight coded vocal categories will be collapsed into four primary Vocal Types: Vowel, MB, CB, and Word to represent all major vocal types expected to be occur throughout the first and second years of life. The sum of each Vocal Type count will be divided by the total count of syllables/words to yield four **Vocal Type ratios** per recording. A sample schematic is provided in **Table 1** for Vocal Type coding and ratio calculations across Aims 1 and 2. Ratios were selected as the measure for development because they are the most common method of observation of prelinguistic vocal emergence.[7,17,22,26]

Table 1. Vocal coding schematic of a sample recording: Aims 1 & 2. Ratios are calculated as the sum of each Vocal Type divided by the total count of syllables and words per recording.

Aim 1 Vocal Type	Type count	Aim 1 ratio	Aim 2 Vocal Type	Type count	Aim 2 ratio
Vowel	23	0.45	**Vowel**	23	0.45
MB	21	0.41	**MB-labial**	7	0.14
			MB-coronal	9	0.18
			MB-dorsal	5	0.10
CB	6	0.12	**CB-labial**	2	0.04
			CB-coronal	3	0.06
			CB-dorsal	1	0.02
Word	1	0.02	**Word**	1	0.02
Total	*51*	*1.0*	*Total*	*51*	*1.0*

Onset criteria. A canonical babbling ratio ("CBR") of 0.15 is widely accepted as the level at which infants can be judged to have reached the *onset* of the canonical babbling stage, indicating within-stage vocal mastery. The canonical babbling stage onset is commonly known to occur in typically developing ("**TD**") children between 6-10 months of age.[16,27] There is no set criterion for the onset of marginal babbling, but prior research describes its occurrence between 4-8 months of age in TD children.[11,12] Thus in this proposal, **marginal babbling ratios (MBRs) and CBRs of 0.15 or higher will be used as the criteria for onset** (i.e., mastery) of each respective stage. The onset of first words is widely known to occur in typical development between 12-15 months of age. Thus, **the onset criteria for the word stage will be any ratio >0,** indicating at least 1 word was spoken in a recording. **Table 2** summarizes each stage's predicted age range and onset criteria. An onset beyond the last age month of a stage may suggest potential delays in later vocal development. Comparing the onset of each of the three specified vocal stages will offer insight into the implications of delays in earlier stages.

Table 2. Summary of Vocal Type expected age ranges and measurement criteria for onset.

Vocal Stage	Expected ages of onset	Onset criteria
Marginal babbling	4-8 months	0.15 marginal babbling ratio (MBR)
Canonical babbling	6-10 months	0.15 canonical babbling ratio (CBR)
First words	12-15 months	>0-word ratio

Analysis plan. Student coders will observe recordings and code infant vocalizations for each of the eight vocal types. Coders will be assigned to observe longitudinal recordings of individual children. Each student will serve as a reliability coder for at least 10% of all recordings. With the assistance of my statistical mentor (*Mahr*), we will use a generalized mixed effects logistic regression model to estimate average marginal and canonical babbling and word rates using age, Type, and age by Type interaction. This model will account for individual-level variation and their growth trajectories. An alternative analytic approach is to retrospectively group infants by speech impairment type and compare group-level onset age differences.

Feasibility and timeline. Since April 2021, I have met with Dr. Hustad for twice weekly lab meetings and since August 2021 I have met with Dr. Hustad for once-a-week, one-on-one meetings to discuss data collection and analysis of material related to this proposal. To demonstrate feasibility of this project and progress, we have submitted an abstract of our preliminary findings associated with Aim 1 to the Motor Speech Conference in 2022 (discussed in *Preliminary Data*). The timeline for Aim 1 shown in **Table 5** of the *Training and Mentoring Plan* is feasible because there is no primary data collection. The training for student coders of Aim 1 is on track to be completed by spring of Year 1. We project to have our first Aim 1 manuscript submitted by fall of Year 2 and our second manuscript by the fall of Year 3. The first manuscript will report vocal stage onsets directly from our findings of Aim 1 and the second manuscript will compare the emergence of known

early speech and language milestones to vocal stage onsets observed from coding in this research proposal. I plan to present data from Aim 1 at the American Academy of Developmental Medicine and Child Neurology annual meeting in Years 1 and 3.

Aim 2: Explore marginal babbling and canonical babbling placement characteristic types in infants at risk for CP.

Rationale. Prelinguistic babbling is a critical step in the emergence of speech in children. Babbling is characterized by the sensorimotor exploration of various aspects of the vocal domain, including articulatory posturing. In typical development, we would predict high variability in the use of marginal and canonical syllable placement characteristic types as infants experiment with the range of articulatory posturing.[28] It is necessary to examine the articulatory placement characteristic types of prelinguistic vocalizations in infants at risk for CP to study the potential effects of motor damage on prelinguistic control of the oral mechanism. Results from Aim 2 will contribute to scientific knowledge on the early impact of the motor speech system. Identifying prelinguistic markers of later speech impairments is imperative for informing speech and language diagnostic and treatment planning to improve communication outcomes.

Hypothesis 2: The CP risk infants will show low variability in the use of marginal and canonical syllable placement characteristic types as a result of motor deficits associated with neurological damage from CP.

Aim 2 Approach. The broad-scale placement characteristic coding (MB- and CB-labial, coronal, dorsal) from the first coding pass described above in *Infant Vocal Type coding* will be used for Aim 2. The eight characteristic-levels and counts shown in **Table 1** (Vowel, MB-labial, MB-coronal, MB-dorsal, CB-labial, CB-coronal, CB-dorsal, and Word) will be used to observe the frequency and variability of placement characteristic types produced over time. Observing the emergence of each articulatory characteristic type across marginal babbling and canonical babbling levels will allow a more fine-grained observational analysis of prelinguistic motor development in infants at risk for CP.

Analysis Plan. With the assistance of my statistical mentor (*Mahr*), we will use a linear discriminant analysis (LDA) to find a linear combination of articulatory characteristic features that characterizes or separates children into later-identified speech impairment severity levels. LDA is used to estimate the probability that any combination of variables belongs to a certain class, making this analysis technique an appropriate method to predict later speech impairments based on the frequency of different characteristic types across two prelinguistic vocal stages. Alternative approaches include completing a factor analysis to describe the variability of characteristic types used by children over time, or to use the Aim 2 ratios in **Table 1** to complete a similar generalized mixed effects logistic regression model from Aim 1 to estimate average marginal and canonical babbling characteristic type and word rates using age, Type, and age by Type interactions.

Feasibility and Timeline. Using the same dataset as Aim 1, Aim 2 focuses on within-stage marginal and canonical babbling characteristics produced over time by young children with CP. Coding of Aim 2 is on track to be completed by spring of Year 1 because coding of this Aim will occur in the same pass as Aim 1. Aim 2 is a logical extension of Aim 1, though Aim 2 is independent of Aim 1. Discussions and readings on articulatory placement characteristics will be incorporated into the one-on-one meetings with Dr. Hustad across Years 1-2 in preparation for the Aim 2 manuscript. One manuscript is expected from Aim 2 on articulatory placement characteristics in CP. The timeline for completion of this manuscript is expected by the spring of Year 2. I will present preliminary results from this work at the American Speech-Language Hearing Association annual meeting in fall of Year 2.

Aim 3: Examine the longitudinal development of canonical syllable complexity in infants at risk for CP.

Rationale. There is a growing literature base on canonical babbling emergence in CP. Within the canonical babbling stage, there are known syllable complexity stages—reduplicated babbling (e.g., [baba]) and variegated babbling (e.g., [bada])—indicative of advanced vocal development and the capacity for recombination of syllables prior to the emergence of first words.[23,29] To date, no research has evaluated utterance-level canonical syllable complexity types in children with CP. Observing canonical syllable complexity in utterance-level material is important to identify breakdowns in the emergence of complex syllables that have the potential to be combined into words in later development. In typical development we would predict proportions of more advanced complexity types to increase over time.

Hypothesis 3: The CP risk infants will show delays in the emergence of utterance-level canonical syllable complexity as a result of motor deficits associated with neurological damage from CP.

Aim 3 Approach. Coders will complete a second pass of observation for utterance-level canonical *Complexity Types* (singleton, vowel-mixed, reduplicated, and variegated) in recordings from Aims 1 and 2 that include at least one canonical syllable. **Table 3** presents a definition summary and example vocalizations for each increasingly advanced Complexity Type. Singletons and the reduplicated and variegated stages are well documented in the literature.[23,30] I have added a Vowel-Mixed category in my coding scheme to include multisyllabic utterances containing noncanonical syllables. Because *The Observer XT* coding software allows point-based coding, coders can quickly skim each recording to the time-stamped location of previously identified canonical syllables from Aims 1 & 2 to code Complexity Types and do not have to listen to recordings in their entirety for a second time.

Table 3. Utterance-level canonical syllable complexity types. Utterances are defined as the production of single- or multi-syllabic vocalizations without pause and immediate transitions between syllables.

Complexity Type	Definition	Example
Singleton	An utterance including a **single** consonant-vowel (**CV**) syllable	[ba] or [da]
Vowel-Mixed	An utterance including a **vowel** or vowel-like syllable **and CV** syllable	[aba] or [ada]
Reduplicated babbling	An utterance including **two or more repeated CV** syllable **types**	[baba] or [dada]
Variegated babbling	An utterance including **two or more CV** syllable **types**	[bada] or [badaga]

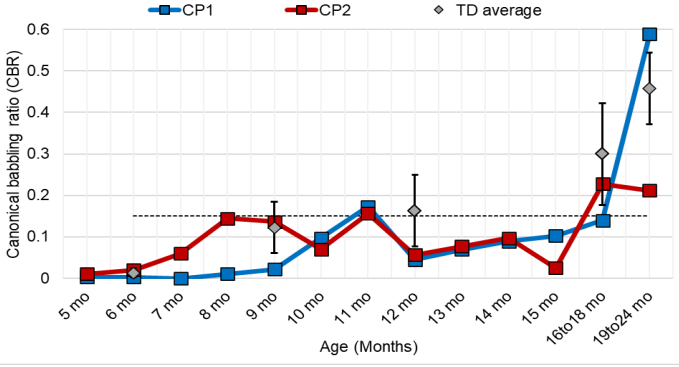
Analysis plan. With the assistance of my statistical mentor (*Mahr*) for Aim 3, we will use a generalized mixed effects logistic regression model to estimate average singleton, vowel-mixed, reduplicated, and variegated babbling Complexity Types using age, Type, and age by Type interactions. This model will be compared to previously reported onset age ranges for singletons, reduplicated, and variegated babbling. An alternative analytic approach to Aim 3 is to retrospectively group infants by speech impairment type to compare group-level differences in the emergence of Complexity Types.

Feasibility and timeline. Aim 3 is a logical extension, though independent, of Aims 1 and 2, to look within a specific vocal stage (canonical babbling) at the capacity for recombination of syllables in children with CP (beyond articulatory characteristics). The timeline for coding Aim 3 is expected to be completed by spring of Year 2. The duration of the coding pass will take significantly less time because coders will use the time-stamped locations of canonical syllables coded in the first pass to code complexity types. Two manuscripts are expected from this Aim. One manuscript will explicitly model canonical babbling complexity in children with CP using the analysis described above. A second manuscript will draw from the archives of these children parent report responses on emergence of syllable recombination and canonical babbling complexity types to compare parent report to laboratory coding to measure the utility of parent report as a clinical tool for identifying potential risk for speech delays or disorders. Results will be presented at the Motor Speech Conference and International Congress of Infant Studies (ICIS) annual meetings in Years 2 and 3.

3. PRELIMINARY DATA

Canonical babbling case study. At the end of my doctoral work, I conducted a longitudinal multiple case study examining the emergence of canonical babbling and its *consolidation* (i.e., the longitudinal trend for infants to produce a monotonic proportion of syllables within a specific stage) in two infants at-risk for CP between 5-16 months. I also compared their development to ten typically developing infants at five age points. **Fig1** shows neither of the at-risk infants evidenced a clear onset (.15 CBR) of canonical babbling by 12 months, but rather evidenced an unexpected pattern of babbling emergence and possible regression at 12 months compared to linear growth in the TD group. Both infants at risk were later diagnosed with CP and speech impairments by the second year of life. This paper highlights the need to study a larger sample size of infants at risk for CP to examine longitudinal emergence of canonical babbling with respect to its surrounding stages (marginal babbling and first words) to inform our understanding of the implications of earlier emerging stages on more advanced developmental stages.

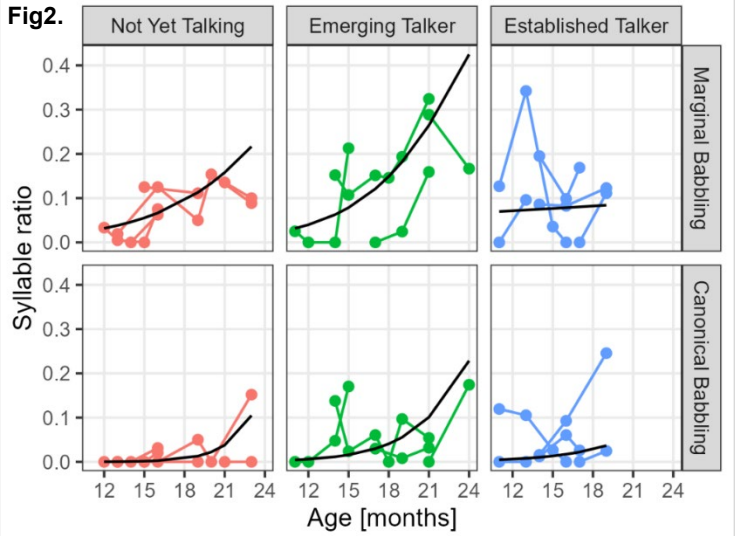
Fig1. Canonical babbling ratios of two infants at risk for cerebral palsy compared to ten typically developing infants



(Long, Eichorn, & Oller, under review)

Marginal and canonical babbling in three groups. Since beginning my postdoctoral experience, I have begun an initial investigation of marginal and babbling development in a subset of 14 infants from the SEALS project dataset. These 14 infants were retrospectively classified into three speech developmental group types based on speech performance at 3 years of age: Not Yet Talking (n=5), Emerging Talkers (n=4), and Established Talkers (n=5). The retrospective identification of speech performance allows us to observe longitudinal speech developmental patterns to understand trajectories of prelinguistic development in this population. **Fig2** indicates all groups showed delays in the emergence of marginal and canonical babbling and none of the three groups consistently met the .15 criterion for onset of the canonical babbling stage. Preliminary differences observed between the three groups highlight the potential for identifying longitudinal prelinguistic vocal patterns in this population to inform earlier detection of speech impairments. These data are in submission for presentation at the 2022 Motor Speech Conference.

Fig2.



(Long, Mahr, & Hustad, in preparation)

4. SCIENTIFIC CAREER GOALS

In achieving each of the three Aims, scientific knowledge is advanced toward identifying prelinguistic markers of speech impairments in children with CP, a disorder known for its wide variability of severity profiles and diagnostic uncertainty in infancy. Thus, this research not only has the potential to inform speech diagnostics in this population, but also the diagnosis of CP as a primary diagnosis at even earlier ages. Findings from this research proposal will provide the foundation for my programmatic line of research on the early detection of speech impairments in children with developmental disabilities to inform speech and language diagnostic and treatment planning to ultimately improve treatment outcomes later in life. Future directions include 1) studying parent-infant interactions and the impact of infant-directed speech on later speech outcomes, 2) developing a prelinguistic classification system in children at risk for CP as a clinical tool to classify developmental progress based on observed delays in infancy and beyond, and 3) developing early intervention treatments supporting in parallel speech development and augmentative and alternative communication (AAC) in infants identified as being at risk for speech impairments. The research activities described in this proposal—coupled with my training alongside the leading experts in prelinguistic vocal development (PI: *Oller*) and communication development in CP (PI: *Hustad*)—will support my success toward becoming an independent clinical researcher evaluating pre-speech and early speech development in neurodevelopmental disorders like cerebral palsy in a tenure-track faculty position.

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43. Long, H. L., Allen, E., Friener, L., Eichorn, N., & Oller, D. K. (2020). Assessing language emergence in cerebral palsy using the LENA Developmental Snapshot. *American Speech-Language Hearing Association Annual Convention (Cancelled)*.
44. Long, H. L., Friener, L., Rhodes, L. N., Romer, K., & Oller, D. K. (2021, November 19). Early speech and language developmental milestones in children with cerebral palsy between 1-4 years. *American Speech-Language Hearing Association Annual Convention*.
45. 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*.

Training and Mentoring Plan

Research Training Program. The focus of my research training plan is to foster development of an independent research career. The primary goal of my postdoctoral program is to develop my expertise in research methods evaluating early communication development in children with CP. During Years 1-3, I will be a postdoctoral researcher funded under a **T32 postdoctoral training program** (5T32HD007489, PI: Hartley) and laboratory internal grants (5R01DC009411, PI: Hustad) with 100% dedicated research time. The Waisman Center T32 is a well-established program funded through NIH since 1995 aimed at training promising early career scientists in interdisciplinary and translational biobehavioral research methods.

Mentoring Plan. My mentors and I have developed a tailored program of training to support my successful transition to an independent research career. My primary mentor throughout my postdoctoral program will be **Dr. Katherine Hustad**, an expert research scientist in communication development in young children with CP. I will also receive statistical mentorship from **Dr. Tristan Mahr** (Data Scientist, WISC Lab). The WISC Lab studies longitudinal research in cerebral palsy (CP) in early development. My predoctoral training in typical prelinguistic vocal development and implications of atypical patterns provides an additional perspective to study infant and toddler ages in this population. Throughout my postdoc I aim to broaden my skillset to study neurodevelopmental disorders and learn methods for characterizing and analyzing speech. This research proposal will support my learning of how to apply these skills to children with CP. The following goals and developmental activities will contribute to my growth as an independent scientist in my area of interest:

A. Establish expertise in the study of communication development in cerebral palsy

1. Systematic review on vocal development in CP and other neurodevelopmental disorders
   - Critically review the extant literature on prelinguistic, speech, and language development in CP
   - Ongoing manuscript writing including literature review for papers from Specific Aims (See Table 4)
2. Advance the development of my thematic research program addressing prelinguistic vocal development in children with CP
   - Specific Aims outlined in *Research Activities* target currently identified critical areas of study
   - Systematic review findings will guide the development of additional research questions
   - Semiweekly laboratory meetings will contribute to the development of future research questions
   - Participate in scholarly activities supporting my development as a research scientist (See Table 5)
   - Semiweekly meetings with Dr. Hustad to review my progress and adapt ongoing goals

B. Develop expertise in longitudinal statistical modeling for speech and language data

1. Build knowledge in fundamental longitudinal data analysis and modeling procedures
   - Study the conceptual framework for analyzing longitudinal data
   - Participate in beginner and intermediate R and SPSS training for developmental psychologists
2. Conduct and interpret longitudinal statistical analyses in R and SPSS
   - Implement learned R and SPSS skills for data analysis including plotting and modeling techniques
   - Monthly consultation meetings with Dr. Mahr and weekly laboratory discussion on appropriate analysis methods

C. Expand repertoire of research methods for the study of communication development in CP

1. Learn research methods evaluating early speech and language development and the implications of neurological damage on the emergence of these systems
   - Longitudinal evaluation of speech developmental patterns in children with CP between 4-10 years
   - Learn how to parse longitudinal data into intermediate research projects for cross-sectional study
   - Submit and initiate K99/R00 grant to gain training on experimental methods for improving speech intelligibility and clinical outcomes in children with speech impairments
2. Participate in interdisciplinary activities at the Waisman Center to support the foundations of my research questions evaluating the implications of CP as a primary diagnosis on speech development
   - Observe, shadow, and collaborate with associated interdisciplinary clinics, e.g., NICU follow-up clinic, Communication Aids and Systems Clinic (CASC), and Developmental Disabilities clinic
   - Contribute to roundtable discussions on the implications of CP on neuromotor development

Progress monitoring and evaluation. Dr. Hustad will supervise and monitor the development of my research studies with scaffolded support throughout my postdoctoral training. This will include the development of research questions, study designs, hypothesis predictions, data analysis, and interpreting results. Currently I have regular interaction with Dr. Hustad through our weekly lab meetings and twice monthly one-on-one meetings. We will continue these interactions throughout my postdoc to discuss ongoing project management and to redirect any anticipated problems. My progress on the goals listed in the *Mentoring Plan* above will be reviewed informally in our one-on-one meetings and formally in our annual progress report meeting.

Plans for Successful Transition to Independence. At the end of Year 2, I will apply for an NIH K99/R00 Pathway to Independence award to receive additional postdoctoral training on clinical trial experimental methods and to support the timely transition to an independent, tenure-track research career. If I am unable to obtain external funding, I will apply for research faculty positions at research intensive universities during Year 3. Additional activities to support my transition to independence include scaffolded support from my primary mentor and participation in a scientific leadership workshop through the UW-Madison postdoctoral association (UWPA). I will also participate in regular events sponsored by the UWPA on presenting research, interview skills, developing job application materials, and developing an independent laboratory.

Research Timeline

Table 4. Publication Plan. Timeline of each manuscript in dark gray. LRP contract period in light gray.

Aim	Manuscript Topic	Submitting Journal	Y1	Y2	Y3
1	Vocal stage emergence in CP	Inf. Behavior & Dev.			
1	Early speech and language milestones in CP	AJSLP			
2	Articulatory placement characteristics in CP	Clin. Ling. & Phonetics			
3	Canonical babbling complexity in CP	Infancy			
3	Comparing vocal complexity to parent report	JSLHR			

JSLHR: Journal of Speech, Lang., & Hearing Research; AJSLP: American Journal of Speech-Lang. Pathology

Table 5. Career Development Timeline. Timeline of each activity in dark gray. LRP contract period in light gray.

Specific Aim 1	FY1	SY1	FY2	SY2	FY3	SY3
Coder training development						
Secondary coder training						
Vocal type coding of recordings: Pass 1						
Data analysis/manuscript preparation						
Specific Aim 2						
Vocal type coding of recordings: Pass 1						
Data analysis/manuscript preparation						
Specific Aim 3						
Vocal type coding of recordings: Pass 2						
Data analysis/manuscript preparation						
Training						
Performance review and feedback from mentors						
Grant writing seminar						
UWPA Scientific Leadership Workshop						
Shadow/Observe Waisman Center CP Clinics						
Professional Development						
Ethics and Prof. Dev. Seminar (RCR Training)						
Scientific Conferences (1-2 per year)						
K99/R00 preparation and submission						
Apply for faculty positions*						

**I will apply for a K99/R00 grant to extend my postdoctoral training an additional 2 years and to support the first 2 years as an independent researcher. If funding is not awarded, I will apply for faculty positions during Y3.*

Research Environment

I am currently a postdoctoral researcher at the Waisman Center of the top-ranked University of Wisconsin-Madison (UW-Madison). My research mentor is Dr. Katherine Hustad in the Wisconsin Intelligibility, Speech, and Communication (WISC) laboratory. I am an appointee of the Waisman Center T32 postdoctoral program (5T32HD007489, PI: Hartley) and plan to apply for grant funding to extend my postdoctoral training.

Mentorship Team. Katherine Hustad, PhD, CCC-SLP is my primary postdoctoral mentor and the Principal Investigator (PI) of the WISC Laboratory. Dr. Hustad is a Professor of Communication Sciences and Disorders in the Department of Communicative Disorders and the Waisman Center at UW-Madison. Dr. Hustad's programmatic research studies speech, language, cognitive, and communication development in children with cerebral palsy (CP) across childhood using observational and experimental research methods. Her work has been NIH funded since 2003 (4 NIH R01 grants, 1 additional R01 under review; 1 R03 grant; 1 K23 grant) with over 80 publications. Tristan Mahr, PhD, will serve as a secondary mentor providing training in statistical analysis. Dr. Mahr has been a data scientist in the WISC Laboratory at the Waisman Center since 2018 and 17 publications. Dr. Mahr has an extensive background in Bayesian statistics, functional programming, and mixed effects models to support the longitudinal research in this proposal.

University of Wisconsin-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. UW-Madison has a Postdoctoral Association (UWPA) Office dedicated to enhancing the postdoctoral training experience of more than 115 postdocs at UW-Madison. Opportunities through the UWPA include an annual UWPA research symposium (2021 committee member), engagement opportunities to build professional connections and collaborations with other researchers, and scientific leadership training workshops.

The **Waisman Center** is a comprehensive, multidisciplinary, academic center with faculty from more than 25 affiliated UW departments conducting biological and behavioral research in human development, developmental disabilities, and neurodegenerative diseases. As a T32 trainee, I regularly attend interdisciplinary research and training activities through the Waisman Center including the weekly John D. Wiley research seminar series featuring presentations from renowned behavioral and biological scientists in intellectual and developmental disabilities (IDD), twice monthly Brain Imaging and IDD Discussion Series, and twice monthly Ethics and Professional Development seminar. The Waisman Center is 0.4 miles off the UW-Madison main campus. I have a private, locked office space in the Center equipped with a dedicated computer, wired internet, printing, and office supplies that will remain available to me throughout my time as a T32 trainee. Travel and research funding is available through the T32 funding and the Friends of the Waisman program, a nonprofit organization dedicated to enhancing research activities at the Waisman Center.

The **Wisconsin Intelligibility, Speech, and Communication (WISC) Laboratory** (PI: Hustad) is housed within the Waisman Center at UW-Madison. The scoping research completed in this laboratory studies communication development in children with CP. The WISC Lab is a well-equipped research laboratory space which includes a recording suite, recording studio, and workspace rooms with two ongoing NIH-funded projects (5R01DC009411 and 5R01DC015653). The recording suite will be used for data collection from children; it is fitted with state-of-the-art professional-quality digital audio and video recording equipment, children's furniture, and toys. The laboratory staff includes the PI (*Hustad*), two research speech-language pathologist project managers, a laboratory-dedicated data scientist (Mentor: *Mahr*), two postdoctoral scientists (including me), and 5-10 student research assistants a year. I have a shared office space available in the WISC Laboratory equipped with a personal desk, laboratory computer, wired internet, remote and direct access to the secure WISC Lab server, and office supplies that will remain available to me throughout my time at UW-Madison. Laboratory meetings are held twice weekly to discuss ongoing research projects and laboratory logistics. Research and travel funding support is also available through Dr. Hustad's ongoing research grants.

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 USERNAME (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	BA	05/2006	Speech & Hearing Sciences; Slavic & Eastern European Languages and Culture
Florida State University, Tallahassee, FL	MS	08/2012	Speech-Language Pathology
University of Memphis, Memphis, TN	PhD	12/2020	Communication Sciences and Disorders
University of Wisconsin, Madison, WI	Postdoctorate	In progress	Communication Sciences and Disorders

A. Personal Statement

I am a T32 Postdoctoral Trainee in the Waisman Center at the University of Wisconsin-Madison. My research evaluates prelinguistic vocal development in children with cerebral palsy (CP). Throughout my postsecondary education I studied in the field of communication sciences and disorders and have broad knowledge in linguistics and psychology. During my undergraduate and Master's level training I studied voice physiology with Dr. Teresa Burnett (Indiana University) and experimental phonetics with Dr. Toby Macrae (Florida State University) as a laboratory assistant. During my clinical Master's program in speech-language pathology (SLP), I required student loan assistance to advance my training in speech and language disorders. This degree was integral to my development as a research scientist and provided specialized experience as an SLP working with children who have disabilities to support the synthesis of my programmatic line of research.

As a doctoral student I received formal research training in longitudinal and observational research methods studying infant vocal development in typical and disordered populations. My dissertation evaluated the role of social and nonsocial factors influencing infant vocalizations as signals of developmental fitness. This research offered perspective on the frequency of social and nonsocial vocal behaviors and the importance of independent vocal play in prelinguistic vocal development. I contributed to nine publications out of my predoctoral laboratory (four as first author).

I am presently a successful recipient of the Waisman Center T32 postdoctoral program. Dr. Katherine Hustad is a logical postdoctoral mentor to advise my clinical research training in neurodevelopmental disorders because of her significant research contributions in communication development in CP. The primary goal of my postdoctoral program is to apply my doctoral training in infant vocal development to study prelinguistic vocal patterns for the early identification of speech impairments in CP. The UW-Madison Waisman Center offers a multitude of opportunities to build connections with successful research scientists in intellectual and developmental disabilities to support my transition into a tenure-track research faculty position.

In summary, I have the clinical training previously supported by student loans, specialized research experience, and lifelong motivation to build an impactful, clinical research career studying prelinguistic vocal development in children with neurodevelopmental disorders like CP to support early diagnostic and intervention decision making to ultimately improve their communication outcomes later in life.

An ongoing appointment that I would like to highlight is:
5T32HD007489-27 (NICHD)
Hartley (PI), Role: Trainee
08/02/21-08/01/23
Post-Doctoral Training in Intellectual and Developmental Disabilities Research

B. Positions, Scientific Appointments, and Honors

Positions and Scientific Appointments

2021-	Postdoctoral Research Trainee, Waisman Center, University of Wisconsin, Madison, WI
2021-	Scientific Review Committee, American Academy for Cerebral Palsy and Dev. Medicine
2020-	Co-Founding Creator, CSDisseminate
2019-	Member, International Congress of Infant Studies
2018-	Membership Committee, American Academy for Cerebral Palsy and Dev. Medicine
2017-2018	Instructor, School of Comm. Sciences and Disorders, University of Memphis, Memphis, TN
2016-2017	Teaching Assistant, School of Comm. Sciences and Disorders, Univ. of Memphis, Memphis, TN
2015-2020	Research Assistant, Origin of Language Laboratory, School of Comm. Sciences and Disorders, University of Memphis, Memphis, TN
2014-2021	Speech-Language Pathologist, Invo-Progressus Therapy, Memphis, TN
2013-	Member, American Speech-Language Hearing Association
2012-2014	Speech-Language Pathologist, Easter Seals Massachusetts, Worcester, MA
2011-2012	Graduate Research Assistant, Experimental Phonetics Laboratory, School of Comm. Sciences and Disorders, Florida State University, Tallahassee, FL
2010-2012	Teaching Assistant, Distance Learning Program, School of Comm. Sciences and Disorders, Florida State University, Tallahassee, FL
2009-2010	Undergraduate Research Assistant, Voice Physiology Laboratory, Department of Speech and Hearing Sciences, Indiana University, Bloomington, IN
2009-2012	Member, National Student Speech-Language Hearing Association

Honors

2020	Graduate Student Association President Service Award, UofM, Memphis, TN
2020	Celebrate Student Success Award, University of Memphis, Memphis, TN
2020	OrthoPediatrics™ Scholarship, American Academy for Cerebral Palsy and Developmental Medicine
2019	S.P. Wong Award for Best Presentation in Statistical Application, UofM, Memphis, TN
2012	Red Apple Award for Outstanding School Personnel, Southborough Education Foundation, Southborough, MA
2012	Outstanding 2nd Year Master's Student Award, Florida State University, Tallahassee, FL
2011	Dr. Avery Vaughn Scholarship Fund for Excellence, Florida State University, Tallahassee, FL
2006-2010	H. Fullmer Faculty Scholarship Award, Indiana University, Bloomington, IN

C. Contributions to Science

1. **Infant vocalizations as fitness signals:** My doctoral dissertation evaluated the role of social and endogenous factors influencing infant vocalizations as "fitness" signals, i.e., indicators of developmental wellbeing. Specifically, I investigated the reliability of listener judgments of the degree of infant vocal imitativeness as a measure of the saliency of potential vocal fitness signals. I found high intra- and inter-rater agreement among listeners, suggesting vocal imitation has the potential to be used as a signal of fitness in early development. I also quantified the extent to which infants produce social and endogenous (i.e., nonsocial) vocalizations across contexts. The findings highlight a potentially robust internal social motivation for vocalization, even in the presence of likely social-cognitive differences such as risk for autism. This line of research offers perspective on the ways in which social and endogenous factors reveal natural selection pressures on fitness signaling in the human infant.

a. **Long, H.L.,** Oller, D.K., & Bowman, D. (2019). Reliability of listener judgments of infant vocal imitation. Frontiers of Psychology, *Developmental Psychology, 10,* 1340. doi.org/10.3389/fpsyg.2019.01340
b. **Long, H. L.,** Bowman, D., Yoo, H. J., Burkhardt-Reed, M. M., Bene, E. R., & Oller, D. K. (2020). Social and endogenous infant vocalizations. *PLoS ONE, 15*(8), e0224956. doi.org/10.1371/journal.pone.0224956

Other Publications (under peer review)

c. **Long, H. L.,** Ramsay, G., Bowman, D., Burkhardt-Reed, M. M., & Oller, D. K. (under review). Social and endogenous motivations in the emergence of canonical babbling in infants at low and high risk for autism. *BioRxiv,* [Preprint]. doi.org/10.1101/2020.10.09.333872

2. **Evolutionary origins of language:** In addition to the publications listed above, I have also contributed to projects studying the evolutionary origins of language. This line of research is founded in the notion that the stages of prelinguistic vocal abilities follow a natural logic of development foundational to advanced linguistic skills in humans. In these studies, we observed newborn and even preterm infants produce high rates of vocalizations which serve as an early foundation for vocal language. Gesture is often thought of as a foundation for language; however, we found that infants produce far higher rates of vocalization than gesture, supporting the theory that language is founded in the vocal domain. Across sexes, we observed a greater tendency for higher vocal rates in males at earlier ages but no sex differences in canonical babbling development, suggesting a robust mechanism for prelinguistic vocal emergence.

a. Burkhardt-Reed, M. M., **Long, H. L.,** Bowman, D. D., Bene, E. R., & Oller, D. K. (2021). The origin of language and relative roles of voice and gesture in early communication development. *Infant Behavior and Development*, *65*, 101648. doi.org/10.1016/j.infbeh.2021.101648
b. Oller, D. K., Ramsay, G., Bene, E. R., **Long, H. L.,** & Griebel, U. (2021). Protophones, the precursors to speech, dominate the human infant vocal landscape. Theme Issue in *Philosophical Transactions of the Royal Society B: Biological Sciences*, *376*(1836), 20200255. doi.org/10.1098/rstb.2020.0255
c. Oller, D. K., Griebel, U., Bowman, D. D., Bene, E. R., **Long, H. L.,** Yoo, H., & Ramsay, G. (2020). Infant boys are more vocal than infant girls. *Current Biology, 30*, R417-29. doi.org/10.1016/j.cub.2020.03.049
d. Oller, D. K., Caskey, M., Yoo, H. J., Bene, E. R., Jhang, Y., Lee, C.-C., Bowman, D., **Long, H. L.,** Buder, E. H., & Vohr, B. (2019). Preterm and full-term infant vocalization and the origin of language. *Scientific Reports, 9,* 14734. doi.org/10.1038/s41598-019-51352-0

3. **Prelinguistic vocal development in neurodevelopmental conditions.** The last paper in my dissertation examined social and endogenous motivations in the emergence of advanced vocal forms in infants at low and high risk for autism. The findings highlight a potentially robust internal motivation for the production of advanced vocal forms like canonical babbling, even in the presence of likely social-cognitive differences such as risk for autism. I supported the data analysis and manuscript writing of a project evaluating canonical babbling in tuberous sclerosis where we observed a delayed canonical babbling onset and low overall production of canonical syllables. Finally, I independently initiated a longitudinal observation of canonical babbling emergence in two infants at risk for CP between 5-16 months of age. We observed a delayed onset of canonical babbling beyond 12 months and variability in consolidation, i.e., the continued increasing rate of canonical syllable production compared to a typically developing control group. These findings support the continued need to study the impact of potential motor speech disorders on prelinguistic and early speech development.

a. 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. doi.org/10.1016/j.pediatrneurol.2021.08.009

Other Publications (under peer review)

b. **Long, H. L.,** Ramsay, G., Bowman, D., Burkhardt-Reed, M. M., & Oller, D. K. (under review). Social and endogenous motivations in the emergence of canonical babbling in infants at low and high risk for autism. *BioRxiv,* [Preprint]. doi.org/10.1101/2020.10.09.333872

c. **Long, H. L.,** Eichorn, N., & Oller, D. K. (under review). A probe study on vocal development in two infants at risk for cerebral palsy.

4. **Early speech and language milestones in cerebral palsy:** This line of research evaluates parent report of speech and language milestones expected to be reached by 36 months in typical development in children with CP between 1-5 years of age. Data collection for this project is ongoing through a research collaboration I independently initiated with a local neuromuscular clinic during my predoctoral program. Overall, we have observed significant speech and language delays across all ages, indicating a greater impact on both speech and language in CP across all levels of severity than may have been previously assumed. I have presented preliminary data on this project at several conferences, and I plan to expand this dataset during my postdoctoral fellowship and publish two forthcoming manuscripts.

    a. **Long, H. L.,** Oller, D. K., Romer, K., Friener, L., Warner, W., Spence, D., & Rhodes, L. N. (2020, September 23-26). *Pre-speech and early speech development of young children diagnosed with cerebral palsy.* Poster presented at the American Academy of Cerebral Palsy and Developmental Medicine 74th Annual Meeting.
    b. Hidecker, M. J. C., & **Long, H. L.** (2020, September 23-26). *When to refer: Early indicators for communication concerns in cerebral palsy*. Seminar presented at the American Academy of Cerebral Palsy and Developmental Medicine 74th Annual Meeting
    c. **Long, H. L**., Oller, D. K., Friener, L., Romer, K., & Rhodes, L. N. (2020, August 7-8). *Mastery of prelinguistic milestones in young children with cerebral palsy.* Poster presented at the Cerebral Palsy Early Detection and Implementation Conference.
    d. **Long, H. L.,** Friener, L., Rhodes, L. N., Romer, K., & Oller, D. K. (2021, November 18-20). *Early speech and language developmental milestones in children with cerebral palsy between 1-4 years.* Poster presented at the American Speech-Language Hearing Association Annual Convention, Washington, D.C.

Complete List of Published Work in MyBibliography:

https://www.ncbi.nlm.nih.gov/myncbi/1RMPzPxaXG8Qm/bibliography/public/