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From Speech Processing to Print Representations: The Development of Phonemic Awareness in Young Children

By

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Doctor of Philosophy

Psychology

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MEd, Georgia State University, 2006

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Advisor: Laura L. Namy, PhD

An abstract of

A dissertation submitted to the Faculty of the

James T. Laney School of Graduate Studies of Emory University

in partial fulfillment of the requirements for the degree of

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Abstract

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The National Institutes of Health (NIH) has deemed illiteracy a national health crisis based on reading proficiency rates among American children. In fact, according to the Nation's Assessment of Educational Progress (NAEP) (2015), only 36% of fourth graders are reading at a level of "proficient" or higher, and approximately 10% of children in America will require intervention (Catts & Hogan, 2003). Six pre-reading skills have been identified as most crucial to reading mastery and predict future reading outcomes. Of those skills, phonological awareness is the strongest independent predictor of early reading outcomes. One specific component of phonological awareness, phonemic awareness --the ability to parse spoken word forms into individual sound units-- is the most predictive of future reading outcomes.

Limited research has addressed the *development* of such component skills. This is due in part to poor integration of efforts between basic research on cognitive developmental processes and more applied research in educational psychology and early childhood education. Investigation of developmental trajectories has also been constrained by the field's reliance on *oral production* measures of phonemic awareness that cannot easily be administered with children under five- years-old and

therefore are not sensitive to early implicit or emerging knowledge. The current studies attempt to redress these limitations by recruiting approaches from the cognitive development literature to derive *receptive* measures of early precursors to reading sub-skills.

The goals of this dissertation are to elucidate the early development of phonemic awareness, to address the extent to which performance-based factors (i.e., using production-based measures) may result in underestimates of children's early phonemic awareness skills, and to identify the cognitive, environmental, and sociocultural factors that may contribute to development of these abilities and skills. The first study examines phonemic awareness development in 2.5- and 3.5-year-old children utilizing newly developed *receptive* measures of phonemic awareness. The second study elucidates how working memory, the home language and literacy environment, and socioeconomic status relate to receptive phonemic awareness development. Implications for both theory and practice in early language and pre-reading development are discussed, including implications for early intervention and early childhood education reform efforts.

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ACKNOWLEDGEMENTS

"If we stand tall, it is because we stand on the backs of those who came before us."

~West-African Proverb

The above quote perfectly summarizes my sentiments of both gratitude and pride as I conclude my graduate school journey at Emory University in the Department of Psychology. I will remain forever grateful for the exquisite educational and scientific training opportunities I received, while being immersed in inquiry, discourse, and collaborative efforts with some of the most brilliant and forward-thinking minds of our times. Each of the faculty of the Cognition and Development Program, as well as many in other programs within the department, played critical roles in shaping me as both a scholar and practitioner. From the onset of recruitment weekend, the Cognition and Development Program Faculty saw promise in my starry-eyed ambitions to build a bridge between basic science and educational practice for the sake of both scientific and societal good. They have nurtured my ideas and ambitions over the past 7 years, and played formative roles in shaping the questions that I ask and the approaches to my research. For all of this, I am grateful.

The first person and faculty member I must acknowledge is my advisor and mentor, Laura L. Namy, PhD. Laura's role as my mentor began prior to my entry into Emory when I was a graduate student at Georgia State in what was then the Department of Educational Psychology and Special Education. In the fall of 2008, I took my first cognitive and developmental psychology class in the psychology department at GSU titled "Cognitive and Linguistic Development". I was completely engaged in the course material, and was determined that I must make a switch in my research training trajectory. After searching, I found Laura and she agreed to meet with me for a coffee chat. What I remember most about that first meeting was the sense of pride and ownership that Laura communicated about her approach to mentorship. Even though she is an internationally renowned scholar, it was clear to me in that moment that Laura took her job as graduate faculty mentor as seriously as any of her other responsibilities. She suggested that I volunteer in her lab for a semester to ensure that this transition was one I would like to make and to gauge a potential mentor-mentee fit. I did, and applied to Emory that year. The rest is history. Laura has played a primary role in scaffolding my academic voice, and methodological acumen. She has facilitated my transition from education and educational psychology to the cognitive and developmental sciences in a way that has allowed me to leverage what I have learned in each field in a complimentary way. Over the past 7 years, I have never doubted that Laura has had anything other than my best interest at heart. She has helped me to navigate both graduate school and life as graduate student and mommy gracefully and realistically, while still holding me to the utmost of standards. I appreciate her nurturing, yet direct approach to mentorship, as it has truly facilitated my success, allowing me to beat the graduate school retention statistical odds as a mother and a woman of color. She has been by my side through both exciting happy times, like the birth of my 3rd child as I was entering the program in 2009, and less than ideal times, like the death of my father in 2011 and my divorce in 2012. I am forever thankful to Laura for recognizing my intellectual capacity, nurturing it beyond what I could have imagined for myself, allowing me to think outside of a traditional box, and believing in me. She has been both a mentor and friend, and I know that I would not have likely reached this pivotal milestone without her brilliance, guidance, dedication, commitment, humor, love, and support.

I must also acknowledge the members of my Dissertation Committee and Faculty Advisory Committee (FAC). I feel ever so fortunate to have benefited from the intellectual talents, and contributions to my work and scientific development over the years from: Robyn Fivush (Dissertation Committee and FAC), Scott O. Lilienfeld (Dissertation Committee and Qualifying Exam Committee), Lynne C. Nygaard (Dissertation Committee and FAC), Nicole Patton Terry (Dissertation Committee), and Irwin D. Waldman (FAC).

As one of the most established and respected developmental memory researchers in our field, Robyn Fivush, PhD has played an instrumental role in supporting and shaping my work. From her dynamic developmental memory course, to her one-on-one mentorship meetings when needed, Robyn has helped to shape the way in which I frame developmental questions, and has provided me with a solid foundation in basic cognitive science upon which I know I will continue to build. I am also grateful to Robyn for her supportive and family-friendly mentorship style. It has been evident from the onset that she too believed in my capacity as a scholar, and I am forever grateful for her encouragement, realistic yet high expectations, and continual support and guidance over the past 7 years.

The majority of my first interactions with Scott O. Lilienfeld, PhD were at the phase of my qualifying exam, when he was appointed as the clinical faculty member for my quals committee. To this day, I appreciate the rigor that he brought to my qualifying exam experience, and the ways in which he has pushed for me to bolster my quantitative analysis skills in a supportive and encouraging fashion. Scott, in collaboration with my advisor Laura, also provided me with a professional writing opportunity to draft rubrics for the instructors manual for end-of-chapter questions in one of their collaborative textbooks. I am grateful to Scott for being one of the faculty members in the Psychology Department who is a voice for ethical and best practices, and for the ways in which he has shaped my academic training at Emory. I feel fortunate for having the opportunity to experience his scientific legacy first-hand.

When I entered Emory it was clear from the onset that although Laura was my advisor, Lynne C. Nygaard, PhD was someone whom I could equally count on for guidance and support. Lynne has played a critical role in my graduate school experience. She provided keen insights and asked thought-provoking questions in language group, and even created the auditory stimuli for my dissertation study. She also allowed me to crash in her lab when I wanted to work by a window, and if I needed a listening ear, all I had to do was ask. Lynne's warmth and sense of humor have seen me through many challenging days. We have experienced many wonderful times at Emory over the past 7 years, and I am forever grateful that she claimed me as one of her own throughout the tenure of my graduate school career at this institution.

Nicole Patton Terry, PhD, Associate Professor of Educational Psychology, Special Education, and Communication Sciences at Georgia State University, Executive Director of the Urban Child Study Center, and research scientist at the Haskins Laboratories at Yale University, has been a mentor and friend since 2006 when she entered GSU as an assistant professor and I was entering as doctoral student and cross-departmental faculty member in the College of Education. Nicole's research in early language and reading development, sociocultural theories and practices, and early intervention has significantly shaped my research interests and passions. She was a member of my advisory committee at GSU prior to my transfer to Emory, and I am thankful to my current advisor, Laura L. Namy, and the James T. Laney Graduate School for recognizing the contributions and utility of Nicole's expertise to my graduate training experience. Nicole too, has been extremely supportive and accessible throughout my time as a graduate student at both institutions. We have journeyed through motherhood together, and she has also shaped my intellect and critical thinking in more ways than she is likely aware. I am appreciative to Nicole for reinforcing that it is not only acceptable to remain engaged in both research and practice, but for modeling this ideology herself. I respect and admire the fearlessness and ease with which she seamlessly flows between higher education, Capitol Hill, and a preschool classroom in a low-income community. She is a true model for what she has termed "implementation science", and I am eternally grateful for her grounded and multi-dimensional mentorship approach, as well as the impact and influence that she continues to have on my academic and professional trajectories, and the lives and educational outcomes of young children throughout our nation.

I would also like to thank Irwin Waldman, PhD for his time and guidance as a member of my Faculty Advisory Committee (FAC), and for respecting and supporting my multidisciplinary training plan. From his linear and multiple regression course, to one-on-one mentorship conversations, Irwin has played a significant role in my graduate school experience. I appreciate his continual acknowledgement of my scientific writing strengths, and his straight forward feedback and advice. Irwin too believed in me and continued to push me toward excellence. I am thankful to have experienced him as a professor and mentor during my time at Emory, and to him I am also grateful.

I would also like to thank other Cognition and Development Program faculty who have shaped my research interests, developed my knowledge base, and encouraged me along the way. Philippe Rochat, PhD has been a consistent supportive voice in the department and my academic program. He always encouraged me, and often engaged with me in philosophical conversations pertaining to my work that caused me think more broadly and within a variety of sociocultural and other contexts. I feel fortunate to have been in the last cohort that was required to take the History of Psychology course that he co-taught with Patricia Brennan, PhD. This course gave me an appreciation for my academic roots, and helped me to think broadly about where I stand as a cognitive and developmental scientist in the context of history. Likewise, I would like to thank Phillip Wolff, PhD for his enlightening Concepts course, and Patricia Bauer for broadening my understandings of cognitive development by allowing me to attend the ERP group she facilitates. She also co-taught the developmental memory course that I took with Robyn Fivush, and I feel thankful to have learned under her legacy and expertise during my time at Emory.

I would be remiss not to acknowledge my first doctoral advisor at GSU, Mary Beth Calhoon, PhD (now at The University of Miami), who first suggested that I take the psychology course that sparked my interest in cognition and development. She also recognized my analytical strengths and encouraged me to take more advanced statistics coursework than what was required by my program at the time. Mary Beth, in conjunction with Nicole Patton Terry, taught me most of what I know about reading and intervention work. Mary Beth also provided me with my first opportunity to give a talk at a renowned conference in the reading and special education fields, and held my hand every step of the way as I made last minute edits to my presentation the night before my big talk. I still remember the accolades I received from some very well-known scholars in our field after that talk. I have Mary Beth to thank for giving me my first forte into my work, and building my confidence as a young scholar. When I transferred to Emory, she was very supportive, and even came to visit me in my lab a few years ago while she was in town. I am grateful to Mary Beth for investing three years in me as my doctoral advisor, and for recognizing that the questions I started asking called for a different educational and scientific trajectory. She whole-heartedly supported my decision to pursue a different, but complimentary scientific path, and I am forever grateful for this.

I have to thank Rihana Shiri Mason, PhD (now Associate Professor of Psychology at Emmanuel College in Franklin Springs, GA.), the psychology professor who taught the “Cognitive and Linguistic Development” course that I took at Georgia State University in 2008, and changed my academic trajectory forever. Through her introduction to classic developmental researchers like Hart and Risley, Rihana’s course allowed me to see the disconnectedness between educational psychology and cognitive developmental psychology. This course fueled my interest in bringing these two

disciplines together for the benefit of children's early language and literacy outcomes. Rihana and I have remained in contact throughout the years, and I remain forever grateful to her for planting the seeds of inquiry that have fueled my dissertation and will continue to influence my future work in the field.

I would also like to thank one very special undergraduate research assistant, Arielle Friehling. Now a law student at Harvard University, Arielle played a formative role in the development of my dissertation study. Her background in both psychology and linguistics was extremely valuable in the development of my auditory stimuli. Additionally, Arielle was a brilliant thought partner, and I believe that we were equally excited about the possibilities that could arise from my dissertation research. Arielle successfully completed an honors thesis using my dissertation design, and even ran a few longitudinal subjects to run some exploratory analyses. She is an excellent experimenter and played a critical and collaborative role in data collection for my project. I consider Arielle as not only a mentee, but also a colleague and collaborator. I feel very fortunate to have crossed paths with her during her undergraduate career at Emory.

As a non-traditional student, I must also thank those who have supported my professional training and experiences along the way. I want to thank the faculty of Georgia State University's College of Education for my 3-year appointment as a cross-departmental faculty member, particularly Dr. Candace Stevenson who encouraged me to pursue doctoral studies at the completion of my master's degree, and Dr. Joya Carter Hicks (now at Kennesaw State) who in conjunction with Dr. Stevenson hired me for the faculty position. I gained valuable experiences in mentorship and adult learning in this role that remain relevant today.

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As I complete my doctoral training, I have been extremely fortunate to secure a dream role as Director of Research and Innovation at an historic, renowned Atlanta-based non-profit organization. In this role I will have the opportunity to combine my passions

of both basic and applied research with partnership development, and embark upon innovative change efforts at both organizational and systems levels. I want to thank our Chief Academic Officer, Sondra Mims, Executive Director, Comer Yates, and Human Resources Director, Iris Goodson for inviting me into this organizational family, and for fostering an environment that feels like an extension of higher education, with an even broader purpose and mission. They have collectively created and sustained an organizational culture that holds research, continual education, and professional learning at its core, making it possible for me to complete this last stretch in my doctoral training with less pressure and stress. I now also have the added benefit of knowing that completion of my degree will have a direct impact on the lives children throughout our state and nation. I want to specifically thank Sondra Mims for envisioning this role, and for entrusting me to continue to carry our organizational torch of building bridges between research and practice, as has been the case since our organization's founding in 1938. I feel fortunate to work among so many bright and passionate colleagues, and want to specifically thank Jessica Bergeron, Aaron Spitalnick, and Jennifer Wolford for giving me such a warm induction into the organization and for being such fun collaborators. I also want to thank my administrative assistant, Pam Crocket, for keeping me organized and always greeting me with a smile in the morning. I look forward to the future opportunities that are ahead as we continue to broaden our base of research, policy, and community partners.

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I must thank my father, and ophthalmologist, the late Charles Edward Biscoe, MD., for instilling a love and appreciation of science and inquiry in me at a very young age. I still remember him taking time to bring pig eyes to my science classes in elementary school for us to dissect, his insistence that my younger sister and I read and watch National Geographic and similar scientific programming, and the way in which he seemed to turn every conversation into an exercise in philosophy or inquiry. He supported my research and interests until the day that he took his last breath, and I feel fortunate to have had him close by, in my home, during his last two years on this earth. He was an excellent grandfather and was honest about both his strengths and his faults. He had high standards, and always pushed me toward what he termed “Biscoe Excellence”. I miss him dearly, and I know that he would be proud to see me reach this pivotal milestone in my life.

I owe equal, if not more, tribute to my mother, and developmental psychologist, Belinda P. Biscoe Boni, PhD, for her role in shaping who I have become as a scholar, practitioner and mother. Like my father, she always instilled a love of science in me as a child, and exposed me early in life to the importance of community involvement, non-profit work, and systems level change. I remember playing in her office many evenings as she toiled away on some huge federal grant or other impactful project. I owe my entrepreneurial spirit, and multidimensional thought processes to my mother. As her biography was read aloud during her induction into the Oklahoma Higher Education Hall of Fame this past fall semester, I remember thinking to myself that I can only hope to achieve her level of impact and influence one day. My mother has been an excellent role model as a mother, scholar, researcher, non-profit entrepreneur, and community organizer. I feel fortunate that she instilled and upheld the values of education, empathy, communication, and community service in our family that I am passing on to my own children. I love her dearly, and I feel proud to call her my mommy. I also want to thank her husband, and my step father, Bill Boni, for believing in me and consistently encouraging me to complete my degree program. Each time I talked to him over the past couple of years he began by asking how my PhD progress was coming along. I appreciate his motivation and support along the way.

I must also acknowledge my childhood nanny, the late Katherine Miller. Katherine was like a grandmother to me, and co-raised me from the time I was 6-weeks-old until I was 12-years-old. Katherine didn’t even complete a high school education, but she always made sure that I completed my homework and read books over the summer, and she constantly involved me in many community-based and cultural activities. I feel so fortunate to have had such a loving and consistent force in my life during my formative years, as my mother was pursing her own PhD during my early years in development. Katherine’s fair, empathetic, hard-working, and loyal spirit most definitely shaped the person I have become today. She left this earth my senior year of undergrad. I will always cherish the last evening I spent with her only a few weeks before her sudden passing, and I know that she would be proud to see me reach this point in my educational journey.

I want to thank the matriarch of our family, and my maternal grandmother, Mrs. Luetta Marks-Perry, affectionately called “Gigi” by my children, for her love and support during my entire life and throughout the process of completing my dissertation. As a graduate of Spelman College and a retired elementary and middle school teacher of 34 years in the Atlanta Public Schools, I know that the passion for education that I gleamed from my mother, actually started with her. At 85 years of age, my grandmother proudly shares how old she is and tells publishing-worthy stories about the days of segregation and the roots of educational inequality in our nation's south. She and my late step-grandfather, Captain Clarence Perry, (a graduate of Morehouse College who was among the first black officers to integrate the Atlanta Police Department), were active in educational advocacy and reform efforts, even if through their own everyday work and challenges. I am forever grateful for the strong foundation rooted in education that my grandmother, even as a young mom at the age of 18, provided for my mother, so that my mother could eventually provide that same foundation for my sister and me. My grandmother has created a legacy that will last in our family for generations. I love her dearly, and I am proud to call her one of my closest friends and our Gigi.

Last, but certainly not least, I must thank my three children, Imani Nicole, Kaden Jason, and Amina Patrice Kenner. From the moment I laid eyes on each of them my life changed for the better. When my oldest was born my mother said: *"Now that you have chosen to become a mother, you have chosen to wear your heart outside of your body for the remainder of your life."* This statement is so very true. In all that I do, my first thought is my children. All that I am and all that I have accomplished, I owe to them. Imani, Kaden, and Amina have made me view life through a lens that I didn't know existed prior to motherhood. They have selflessly shared their mommy with graduate school, entrepreneurial efforts, community service, work, and even my escapes to my garden in our backyard, without a single gripe. They are constant reminders of the values of strength, fairness, empathy, and kindness, as well as the joy that life was designed to bring to each one of us, each day. I could not have asked for more empathetic, beautiful, witty, or brilliant children, and I know that they will each leave a significant and unique imprint on this earth. I love them each dearly. They are the absolute light of my life, and I feel blessed that they chose me to be their mommy.

Each of the people mentioned in these acknowledgements have contributed to life experiences that led me up to this exact moment in time. I know that I only stand tall because I stand on the backs of them all. Their wisdom, experience, guidance, inspiration, love, and support have seen me to, and through, this once in a lifetime academic journey.

DEDICATION

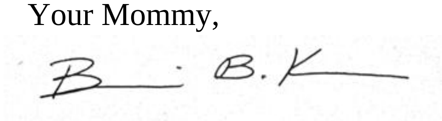
I dedicate this dissertation to my children: Imani Nicole, Kaden Jason, and Amina Patrice Kenner…

"Your work is to discover your work and then with all your heart to give yourself to it."
~Buddha

Thank you each for simultaneously being, and inspiring, my life's work. May this work have a lasting positive impact on each of your lives, and the lives of all children, for the betterment of society.

With All My Love,

Your Mommy,



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CHAPTER 1: Introduction

1.1 Background and Literature Review

Reading is an ability upon which many life skills depend in modern, industrialized societies (Moats, 1999). It is a skill that must be explicitly taught (NRP, 2000), and a failure to master the foundational skills of reading early in life significantly decreases the likelihood of learning them at all (Moats, 1999). It is a complex task that involves word recognition processing in both the auditory (i.e., hearing word forms) and visual (i.e., recognizing printed word forms) modalities (Cunningham & Stanovich, 1993), as well as mapping between them. Although most children learn to read, many fail to become proficient readers. In fact, according to the Nation's Assessment of Educational Progress (2015), only 36% of fourth graders are reading at a level of "proficient" or higher, and approximately 10% of children in America have difficulty learning to read at all and will require intervention (Catts & Hogan, 2003).

Collaborative research efforts spearheaded by Congress sought to investigate the components that comprise skilled reading (National Reading Panel, 2000) in an effort to identify best practices in reading *instruction*. Based on findings from this initiative, the Panel identified five components of reading that should receive emphasis in reading instruction. Referred to as "The Five Big Ideas", the following competencies comprise skilled reading: phonemic awareness, alphabetic principle, fluency, vocabulary, and comprehension. Phonemic awareness is the ability to identify and manipulate individual sounds within words, but does not necessarily imply an understanding of sound-grapheme mappings. The alphabetic principle, also known as phonics, refers to the ability to map speech sounds onto graphemes and use this knowledge to decode text and to spell. Fluency refers to the ease with which one reads connected text with speed, accuracy, and expression. Vocabulary, or the ability to understand and use words, is connected to comprehension, the ability to gain meaning from text. The "Five Big Ideas" provides a framework for recommendations and best-practices for optimal reading instruction delivery. Nonetheless, the panel also recommended that additional research efforts should be aimed toward studying the *development* of skilled reading (NRP, 2000).

In an attempt to address this need, the National Early Literacy Panel (NELP) was convened in 2002 to research best practices in the intervention, assessment, instruction, and development of pre- reading skills in children from birth through age five. The panel identified six key beginning reading *precursors* that were highly predictive of future literacy outcomes: Alphabet Knowledge, Phonological Awareness, Rapid Automatic Naming (RAN) of Letters or Digits, RAN of objects or colors, Writing or Name Writing, and Phonological Memory (National Institutes for Literacy, 2008). Of these skills, phonological awareness – awareness of the sound structure of words— is the strongest independent predictor of early reading outcomes (see Goodman, Libenson, & Wade-Woolley, 2010 and Wagner & Torgesen, 1987).

Within phonological awareness there are five distinct *sub-components* that contribute uniquely to early reading acquisition: rhyming, syllabication, word awareness, sentence awareness, and phonemic awareness, or the ability to parse word forms into individual sound units. Phonemic awareness consistently emerges as a key precursor to early reading development. Although phonemic awareness does not imply an understanding of sound-grapheme mappings, it appears to be an important prerequisite to creating these mappings by requiring children to analyze and break complete word forms into constituent parts. Until children are able to identify individual phonemes and recognize the part-whole relation between phonemes and words, they cannot begin to recruit sound-grapheme mappings in the service of reading. Accordingly, although all five of the aforementioned skills are related to early reading, *phonemic awareness* has consistently been found, over nearly four decades of research, to be the most predictive of future reading outcomes in children both with (Bradley & Bryant, 1981, 1983; Metsala, 1999; Scarborough, 1998;) and without (Fox & Routh, 1975; Muter, Hulme, Snowling, & Taylor, 1998; Stanovich, Cunningham, & Cramer, 1984; Verhagen, Aarnoutse, and van Leeuwe, 2009) reading disabilities.

For example, using a mix-methods four-year longitudinal training study, Bradley and Bryant (1983) explored the relation between phonemic awareness and later academic abilities. They measured phonemic awareness by presenting 4- and 5-year-old English speaking children with a sound categorization task prior to exposure to any formal reading instruction. Four years later, children were given various academic measures in reading, spelling, and math. Initial analyses indicated a significant relationship between sound categorization and both reading and spelling in 4- and 5-year old children.

Muter and colleagues (1998) examined the relation between phonemic awareness and rhyme sensitivity in thirty-eight non-reading 3.5-to 4.5-year-old English speaking children and their subsequent beginning reading skills at 5.5- and 6.5-years-old. Phonemic awareness was measured at three time points using a phoneme identification task and a phoneme deletion task. During the phoneme identification task the experimenter presented children with a series of pictures with one syllable names containing 3 phonemes and supplied the first two phonemes of the word. The children were then asked to "finish" the word by producing the final phoneme. During the phoneme deletion task, children were shown pictures of common objects and asked to say the word after deleting the first phoneme, e.g., "'cat' without the /k/ says /æt/ ". Children were also given a simple rhyming task. Results from this study revealed that phonemic awareness, but not rhyme awareness, at Time 1 was a strong predictor of beginning reading outcomes at time 3.

More recently, Verhagen, Aarnoutse, and van Leeuwe (2009) employed a longitudinal design measuring the relation between phonemic awareness and reading in 238 Dutch speaking 5.5-year-old children. Using a Phonemic Analysis Task, experimenters produced both real words and pseudowords and asked children to produce only the first or last phoneme in each word. The authors found that phonemic awareness in both Kindergarten and First grade was predictive of word reading at the end of second grade. These studies provide strong evidence for the influence of the smaller units of phonological awareness on reading success, specifically phonemic awareness.

1.2 Theories of Phonological Awareness Development

Prevailing models of phonological awareness posit that phonemic awareness is a skill that develops later in ontogeny than many other aspects of pre-reading (such as RAN of letters and objects) and is the final precursor necessary to begin skilled reading. The overarching belief to date is that phonological awareness begins at the word level and that development is characterized by incremental sensitivity to smaller units of sound discrimination with age (i.e., from word awareness to syllable and/or rhyme awareness, and finally to the level of the individual phoneme). Accordingly, phonemic awareness --involving discrimination at the level of the smallest meaningful unit has traditionally been conceptualized as a sub-skill of phonological awareness that emerges during the school-aged years in tandem with explicit, formal reading instruction.

For example, Anthony, Lonigan, Driscoll, Phillips, and Burgess' (2003) model of skilled reading development posits a continuum of skill development moving from larger to smaller linguistic units, i.e., from word awareness in preschool through onset-rime awareness to phoneme awareness in early school-age. Similarly, Goswami (1990) posited that phonemic awareness develops in consecutive phases with gradual awareness of progressively smaller word components (i.e., Phase 1 – rhyme and alliteration awareness during the preschool years followed by Phase 2 - phoneme level knowledge and phonemic awareness during the early school-aged years, and ultimately Phase 3 – fluent skilled reading).

Although the evidence to date regarding the late development of phonemic awareness is consistent with these key theories (Carroll, Snowling, Stevenson, & Hulme, 2003; Liberman, Shankwiler, Fischer, & Carter, 1974; Lonigan et al., 1998; Wakerlee-Hollman et. al., 2015), most of the traditional measures used to assess phonemic awareness are *production* or performance measures, requiring oral responses, tapping, or counting, which cannot easily be administered with children under five-years-old. For example, children might be asked to perform *phoneme segmentation* in which they must verbally parse a word, such as “cat”, into the individual phonemes “/k/ /æ/ /t/”. Conversely, *phoneme blending* requires children to listen to the parsed phonemes /k/ /æ/ /t/ and verbally produce the whole-word form. Alternatively, children may be asked in a syllable production task to tap or clap the number of syllables heard in a word. Success on these tasks is contingent upon performance factors and comprehension of verbal instructions that are not directly relevant to phonological awareness (Castles, Wilson, & Coltheart, 2011). This raises the possibility that task demands in standardized measures may mask earlier competence in phonemic awareness that might be indexed using more developmentally appropriate and sensitive measures. Indeed, Gombert (1992) raised the question of whether there might be a dissociation between comprehension and production within various aspects of language, including phonetic discrimination. Gombert distinguished two types of phonological awareness, epilinguistic awareness --a more implicit awareness of the sound systems of language, and metalinguistic awareness --the ability to explicitly manipulate and make meaning from the sound systems of a language. Gombert posited that metalinguistic knowledge is most closely connected to literacy.

1.3 Measures of Phonological Awareness

Although the National Early Literacy Panel made significant progress identifying *which* pre- reading skills are most crucial to reading mastery and predict future reading outcomes, few studies have employed empirical approaches to investigate and document the development of such precursory skills, particularly in children under 3-years-old (Lonigan et al., 1998; Anthony, Lonigan, & Burgess, 2002). Tracking the development of reading sub-skills *before* the preschool years has the potential to provide a deeper understanding of the developmental processes contributing to receptivity to early reading instruction, as well as a means for early identification of children at-risk for reading failure.

The fact that there is such limited research addressing the developmental trajectory of reading sub-skills prior to the preschool years is attributable to multiple factors. First, there is a discontinuity between the theories and approaches guiding research in cognitive developmental psychology, and those guiding work in educational psychology and early childhood education. Reading research in cognitive developmental psychology places an emphasis on the mechanistic processes and precursors involved in reading development, and uses highly controlled experimental designs to answer questions aimed at teasing apart and tracking such processes. In contrast, research in educational psychology typically places an emphasis on identifying the components of reading itself, as well as areas such as reading instruction strategies, and intervention. Quasi-experimental and pre-test/post-test designs are often used to explore these issues. Second, many of the measures used to assess sub-skills such as phonemic awareness (Liberman, Shankwiler, Fischer, & Carter, 1974; Lonigan et al., 1998) are *production* measures, requiring oral responses, tapping, or counting, which cannot easily be administered with children under five-years-old. Success on these tasks is contingent upon performance factors and comprehension of verbal instructions that are not directly relevant to phonological awareness (Castles, Wilson, & Coltheart, 2011). Furthermore, because these tasks require an explicit analysis of word forms, they may not be sensitive to implicit or emerging knowledge. It may be that, as with many aspects of language acquisition, comprehension precedes production and, consequently, lack of production does not imply lack of comprehension.

Empirical work in the developmental speech perception literature may provide insights into how to assess early precursors to reading sub-skills *receptively*. For example, researchers have developed sensitive implicit measures to inventory the types of phonological contrasts to which infants are sensitive at different points in development. Children's early emerging sensitivity to phonemic content of words may link directly to children's subsequent ability to analyze words into component sounds (Kuhl et al., 2005; Werker & Tees, 2002). Indeed, promising results have emerged from Cardillo (2010) who reported the striking finding that 7-month-old native phonemic discrimination predicted phonological awareness at 5 years of age. However, a more detailed, empirical exploration of the developmental trajectory of specific precursors to early reading acquisition and later proficient reading is lacking. The proposed research will investigate developmental precursors to phonemic awareness, the reading sub-skill found to be most predictive of reading acquisition. I propose to do so by marrying theories and methods from two primary literatures – the developmental speech perception literature and the educational psychology literature on early reading. I utilize Karmiloff-Smith's (1992) Representational Redescription model of cognitive development as a theoretical framework for potentially describing the mechanistic processes underlying the development of skilled reading.

1.4 Theoretical Framework

The Representational Redescription Model

Annette Karmiloff-Smith's (1992) Representational Redescription (RR) Model of cognitive development may serve as a logical theoretical framework for describing the mechanistic processes underlying the development of skilled reading. This model, which describes the process by which knowledge transitions from implicit to explicit, may explain how children's implicit, perceptual processing of phonemes gives way to explicitly *analyzing* speech units meaningfully, to ultimately mapping spoken words to print representations.

Levels of Representational Redescription

The Representational Redescription model posits that cognitive development occurs within the context of four levels of knowledge representation and re-representation: Implicit (I), Explicit-1 (E1), Explicit-2 (E2), and Explicit-3 (E3).These levels are reiterated continually, within and across domains of knowledge, throughout ontogeny. Therefore, children's representations can be stored within any or all of these levels for any given broad domain (e.g., literacy) or micro-domain (e.g., reading, writing, or spelling) at any specific point in development.

Level I, the implicit level, is identified as the procedural level. At Level I, children encode information received from the environment in procedural form that can be utilized but not explicitly manipulated. For example, infants can implicitly process and discriminate the phonemes in their native language early in development but are not consciously aware of this ability. Representations stored at this level, though flexible in some respects, are generally inaccessible to conscious awareness and do not cross into other cognitive domains.

Level E1 marks the beginning of representational flexibility, the ability to analyze and manipulate knowledge. Level E1 representations do not contain as many details as the original implicitly stored representations. Similarities or associations may be formed among these representations.

However, they are not yet consciously or verbally accessible. For example, children whose speech representations are at Level E1 may begin to manipulate words and sounds in seemingly explicit ways such as alliterative play or rhyming. However this does not mean that they yet have conscious awareness of the fact that they are producing alliteration or rhyme. The shift from Level I to Level E1 is important because it distinguishes the RR model from other cognitive developmental models that posit a simple dichotomy of implicit procedural knowledge and verbally accessible declarative knowledge.

Level E2 is characterized by conscious access to representations that are not yet available to verbal report. For example, a child whose phonemic awareness representations are at this level may be able to distinguish the individual phonemes within words and indicate this understanding when presented with a receptive task, but may not yet be able to demonstrate this understanding in a task that requires *verbal* production of individual phonemes.

Level E3 in the RR model is characterized by representational formats that are both consciously and verbally accessible. Representations that have reached this level of access have not only become consciously accessible, but can also be subjected to verbal report. This, I am arguing, is the level at which conventional production tasks assess pre-reading competence, while masking earlier, less readily articulated knowledge.

The purpose of the current study is not to show a direct mapping of pre-reading competencies to the specific levels of development in the RR Model. Rather, I outline the details of the phases in this particular model as one theoretical framework that could potentially explain my broader argument that pre-reading development occurs in a gradual process as opposed to a dichotomy of implicit awareness to explicit awareness, as is typically presented in the literature. I propose that there are levels of explicit awareness involved in pre-reading skills that have not yet been adequately examined in the existing literature. Employing *receptive* measures of phonemic awareness tasks could allow us to index stored phonemic representations that may not be accessible through more established production tasks, but could be accessible through non-verbal behavioral measures at another representational level. To potentially gain access to the more intermediate phases of pre-reading development that fall between implicit understanding and full, explicit, verbal demonstration of knowledge, this study will explore measures of explicit but *receptive* phonemic awareness and compare them to measures of explicit and *productive* phonemic awareness which would reflect different levels of explicit awareness as suggested in the RR model. If beginning skilled reading follows a gradual developmental process, then conscious, *though not necessarily verbally accessible*, explicit representations of speech sound-to-print mappings should emerge as precursors to conscious, explicit speech-to-print representations that can be verbally accessed and eventually identified as early reading.

1.5 Goals of Dissertation

The goals of this dissertation are to elucidate the early development of phonemic awareness, one of the pre- reading skills most predictive of early reading achievement, and to address the extent to which performance-based factors (i.e., using production-based measures) may result in underestimates of children's early phonemic awareness skills, and to investigate the cognitive, environmental and sociocultural factors that may contribute to the development of such skills. To achieve these goals, I approach this work with several primary aims nested within two separate manuscripts. Manuscript 1 has the following aims:

1) **To investigate the developmental progression of phonemic awareness, both receptively and productively, in 2.5- and 3.5-year old children**. Prior literature has posited that phonemic awareness abilities (segmenting and blending) do not emerge until the late preschool years. However I posit that this assumption is an artifact of the production-based nature of tasks used to measure this skill. If phonemic awareness abilities in fact do not emerge until the late preschool years, then children younger than 4.5-years-old should not exhibit any conscious understanding of phonemic awareness, even through the use of receptive measures. However, if phonemic awareness develops in a progression from receptive abilities to productive abilities, then we may find tentative evidence of emerging phonemic awareness as early as 2.5 years and expect to find evidence of receptive but not productive competence in 3.5-year old children who have acquired phonemic awareness but are not yet able to fully access their knowledge in the service of completing production-based measures of this skill.

2) **To determine whether *receptive* phonemic awareness abilities are consistent across blending (i.e., /k/ /æ/ /t/ → cat) and segmenting (i.e., cat → /k/ /æ/ /t/) tasks**. In traditional production-based phonemic awareness tasks, children are typically successful on blending tasks earlier in ontogeny than on segmenting tasks. If phonemic awareness follows a developmental progression of blending followed by segmenting, and these experimental receptive measures are tapping into emergent phonemic awareness abilities, then we should see successful performance on receptive blending tasks earlier in development than on segmenting tasks. However, if these measures do not follow the same developmental progression it is possible that what is being measured in production tasks are additional skills above and beyond phonemic awareness. Productive segmenting task performance could be relying on additional task- related factors such as the verbal proficiency to comprehend the task instructions, working memory, or the ability to verbally produce a response.

The second manuscript serves as both a validation of the measures and developmental trajectory examined in the first manuscript by extending the receptive phonemic awareness paradigm to include 4.5-year-old participants who have begun to exhibit proficiency on the production based phonemic awareness measures, and an examination of cognitive, environmental, and sociocultural factors that may contribute to the development of these receptive abilities prior to formal school-age years and the introduction of formal reading instruction. The aims of the second manuscript are as follows:

1) **To investigate the developmental progression of phonemic awareness, both receptively and productively, in 2.5-, 3.5-, and 4.5-year-old children**. Prior literature has posited that phonemic awareness abilities (segmenting and blending) do not emerge until the late preschool years. However we argue that this assumption is an artifact of the production-based nature of tasks used to measure this skill. Our preliminary research indicates receptive evidence of phonemic awareness in the absence of productive evidence. However the receptive evidence indicated only *emerging* knowledge at 2.5 and 3.5 years of age. To fully validate the measures and the developmental trajectory, we propose to compare 2.5 and 3.5-year-olds to 4.5-year-olds. We predict that by 4.5 years, children will show clear and compelling evidence of mastery of both blending and segmenting in the receptive tasks, but only emerging evidence in the standardized productive measure.

2) **To examine the contribution of individual differences in overall cognitive functioning to children's receptive phonemic awareness development from 2.5- to 4.5-years of age.**

   Prior literature has demonstrated that performance on productive measures of phonemic awareness often co-varies with children's cognitive abilities, particularly verbal working memory, even when controlling for IQ. If our receptive phonemic awareness tasks are indexing a pre-cursory, emergent form of traditional productive phonemic awareness tasks, we predict that performance on our receptive phonemic awareness measures will co-vary with individual differences in working memory, even when controlling for IQ.

3) **To examine the contribution of the home language and literacy environment and socioeconomic status on 2.5-, 3.5-, and 4.5-year-old children's phonemic awareness development.** The relationships between environmental and socioeconomic factors on the one hand and children's language and literacy development on the other are well established. Although passive indicators of the home language and literacy environment (e.g., the frequency with which a child observes a parent reading for pleasure) are not typically predictive of oral language development or early literacy (Burgess, S. R., Hecht, S. A., & Lonigan, C. J. (2002), active, *informal* parental language literacy teaching behaviors (e.g., shared book reading) are predictive of oral language development and vocabulary development, and active, *formal* parental language and literacy teaching behaviors are predictive of early literacy development (e.g., word reading and invented spelling; Sénéchal and LeFevre, 2014). Sénéchal and LeFevre (2014) did not find relations between any *informal* parental teaching behaviors and phonemic awareness. There is, however, evidence for a relationship between what Burgess and colleagues (2002) referred to as the Limiting Literacy Environment (e.g., number of books in the home or frequency of visits to the library) and phonological awareness development in other domains besides phonemic awareness development (i.e. rhyme awareness; Raz & Bryant, 1990). To the extent that phonemic awareness is developing across the toddler and preschool years, I hypothesize that various active parental behavior indices of the home language and literacy environment (both informal and formal), as well as elements of the Limiting Literacy

Environment, will be related to performance on the experimental *receptive* measures of phonemic awareness under investigation in the first experiment. As has been found in prior literature (Raz & Bryant, 1990), we anticipate that measures of the Limiting Literacy Environment, and consequently emerging phonemic awareness will vary with socioeconomic status.

1.6 Implications

The experiments in the following manuscripts will investigate the developmental progression of receptive and productive phonemic awareness in 2.5-, 3.5-, and 4.5-year-old children, will determine whether such phonemic awareness abilities are consistent across blending and segmenting tasks, and will investigate the relationship between phonemic awareness and various environmental and sociocultural factors. If these receptive measures do indeed index emerging phonemic awareness not captured by traditional production measures, the results would have several implications. First, this work could inform the development new cognitive and developmental theories that more accurately capture how phonemic awareness skills develop across early ontogeny, prior to the introduction of formal reading instruction. Second, the receptive phonemic awareness measures developed could eventually be utilized to detect children at risk for reading difficulty at an earlier point in development than is currently feasible. Third, this work has potential to inform best practices in terms of early childhood education, and intervention mechanisms at child, family, program, and community levels.

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CHAPTER 2

Phonemic Awareness Development in 2.5- and 3.5-year-old Children: An Examination of Emergent, Receptive, Knowledge and Skills

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2.1 Abstract

The National Institutes of Health (NIH) has deemed illiteracy a national health crisis based on reading proficiency rates among American children. In 2002, the National Early Literacy Panel identified six pre-reading skills that are most crucial precursors to reading mastery and predict future reading outcomes. Of those skills, phonological awareness, and in particular phonemic awareness, is the strongest independent predictor of early reading outcomes. However, limited research has addressed the *development* of these component skills due in part to the fact that many of the measures used to assess sub-skills such as phonemic awareness are *oral production* measures that cannot easily be administered with children under the age of five, and are not designed to detect implicit or emerging knowledge.

To address this limitation, we developed and administered two receptive measures of phonemic awareness to 2.5- and 3.5- year old children. We found evidence for the emergence of this component skill earlier in ontogeny than is currently acknowledged in the literature. Overall, children performed at above chance rates on measures of receptive phonemic awareness at the level of the individual phoneme as early as 2.5-years-old. Results are discussed in terms of the need for a paradigm shift in prevailing models of how phonological awareness develops, as well as the potential to identify children at-risk for reading failure at an earlier point in ontogeny than is currently feasible.

2.1 Background

Reading is an ability upon which many life skills depend in modern, industrialized societies. It is a skill that must be explicitly taught (NRP, 2000), and a failure to master the foundational skills of reading early in life significantly decreases the likelihood of learning them at all (Moats, 1999). It is a complex task that involves word recognition processing in both the auditory (i.e., hearing word forms) and visual (i.e., recognizing printed word forms) modalities (Cunningham & Stanovich, 1993), as well as mappings between them. Although most children learn to read, many fail to become proficient readers. In fact, according to the most recent Nation's Assessment of Educational Progress (2015), only 36% of fourth graders are reading at a level of "proficient" or higher. Further, it is estimated that approximately 10% of children in America have difficulty learning to read at all and will require intervention (Catts & Hogan, 2003).

The congressionally spearheaded research efforts that have emerged over the last two decades, such as the National Reading Panel (NRP; 2000) and the National Early Literacy Panel in 2002, indicate our nation's acknowledgment of the literacy crisis we face. Although these efforts yielded robust progress in our knowledge and understandings of effective reading instruction, interventions, assessments, and of the components of skilled reading, there is still much to be learned about the *development* of these component skills prior to the school-age years and the introduction of formal reading instruction.

The National Early Literacy Panel identified at least six components of skilled reading: - Alphabet Knowledge, Rapid Automatic Naming (RAN) of Letters or Digits, RAN of objects or colors, Writing or Name Writing, Phonological Memory, and

Phonological Awareness (National Institute for Literacy, 2008). Of these skills, phonological awareness – awareness of the sound structure of words— is the strongest independent predictor of early reading outcomes (see Goodman, Libenson, & Wade-Woolley, 2010; Wagner & Torgesen, 1987).

Within phonological awareness there are five distinct *sub-components* that contribute uniquely to early reading acquisition: rhyming, syllabication, word awareness, sentence awareness, and phonemic awareness, or the ability to parse word forms into individual sound units, as displayed in figure 1.

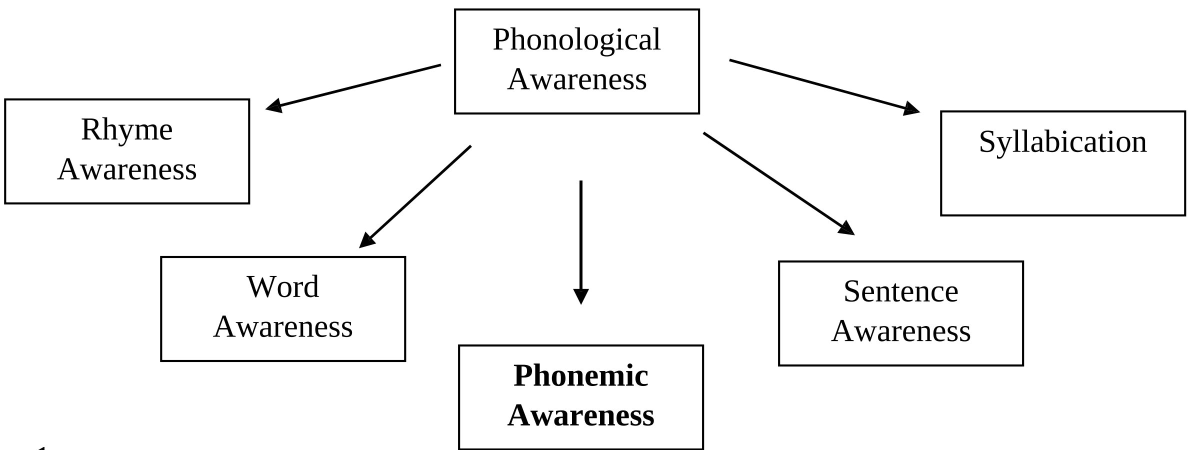

Figure 1.
Five Sub-components of Phonological Awareness

Although phonemic awareness does not imply an understanding of sound-grapheme mappings, it appears to be an important prerequisite to creating these mappings because it requires children to analyze and break complete word forms into constituent parts. Until children are able to identify individual phonemes and recognize the part-whole relation between phonemes and words, they cannot begin to recruit sound-grapheme mappings in the service of reading. Accordingly, although all five of the aforementioned skills are related to early reading, *phonemic awareness* has consistently been found, over nearly four decades of research, to be the strongest precursor to, and predictor of, reading achievement. These findings apply to children both with (Bradley & Bryant, 1981, 1983; Metsala, 1999; Scarborough, 1998) and without reading disabilities (Anthony & Lonigan, 2004; Fox & Routh, 1975; Muter, Hulme, Snowling, & Taylor, 1997; Stanovich, Cunningham, & Cramer, 1984; Verhagen, Aarnoutse, and van Leeuwe, 2009; Wackerle-Hollman et. al., 2015). Given that phonemic awareness has consistently emerged as a critical precursor to skilled reading, it is imperative to examine the development of this component skill. A more robust understanding of the developmental trajectory of and mechanisms underlying phonemic awareness could allow us to view reading readiness through a more developmentally appropriate lens in both research and practice settings.

Theories of Phonological Awareness Development

Prevailing models of phonological awareness posit that phonemic awareness is a skill that develops later in ontogeny than many other aspects of pre-reading (such as RAN of letters and objects) and is the final precursor necessary to begin skilled reading. The overarching belief to date is that phonological awareness begins at the word level and that development is characterized by incremental sensitivity to smaller units of sound discrimination with age (i.e., from word awareness, to syllable and/or rhyme awareness, and finally to the level of the individual phoneme). Accordingly, phonemic awareness, involving discrimination at the level of the smallest meaningful unit, has traditionally been conceptualized as a sub-skill of phonological awareness that emerges during the school-aged years in tandem with explicit, formal reading instruction.

For example, Anthony, Lonigan, Driscoll, Phillips, and Burgess' (2003) model of skilled reading development posits a continuum of skill development moving from larger to smaller linguistic units from word awareness in preschool through onset-rime awareness to phoneme awareness in early school-age. Similarly, Goswami (1990) posited that phonemic awareness develops in consecutive phases with gradual awareness of progressively smaller word components (i.e., Phase 1 – rhyme and alliteration awareness during the preschool years followed by Phase 2 - phoneme level knowledge and phonemic awareness during the early school-aged years, and ultimately Phase 3 – fluent skilled reading).

Although the evidence to date regarding the late development of phonemic awareness is consistent with these key theories, most of the traditional measures used to assess phonemic awareness (Liberman, Shankwiler, Fischer, & Carter, 1974; Lonigan et al., 1998; Wakerlee-Hollman et. al., 2015) are *production* or performance measures, requiring oral responses, tapping, or counting, which cannot easily be administered with children under five-years-old. For example, children might be asked to perform *phoneme segmentation* in which they must verbally parse a word, such as "cat", into the individual phonemes "/k/ /æ/ /t/". Conversely, *phoneme blending* requires children to listen to the parsed phonemes /k/ /æ/ /t/ and verbally produce the whole-word form. Alternatively, children may be asked in a syllable production task to tap or clap the number of syllables heard in a word. Success on these tasks is contingent upon performance factors and comprehension of verbal instructions that are not directly relevant to phonological awareness (Castles, Wilson, & Coltheart, 2011). This raises the possibility that task demands in standardized measures may mask earlier competence in phonemic awareness that might be indexed using more developmentally appropriate and sensitive measures. Indeed, Gombert (1992) raised the question of whether there might be a dissociation between comprehension and production within various aspects of language, including phonetic discrimination. Gombert distinguished two types of phonological awareness, epilinguistic awareness --a more implicit awareness of the sound systems of language, and metalinguistic awareness --the ability to explicitly manipulate and make meaning from the sound systems of a language. Gombert posited that metalinguistic knowledge is most closely connected to literacy.

Measures of Phonological Awareness

Few studies have examined the *development* of phonemic awareness, particularly during the toddler and preschool years (Anthony, Lonigan, Driscoll, Phillips, & Burgess, 2003; Goswami, 1990; Lonigan et al., 1998), likely due to a lack of developmentally appropriate measures. The few studies that have examined phonemic awareness development in toddler and preschool-aged children employed measures at multiple levels of specificity and did not necessarily index phonemic awareness at the level of the individual phoneme. For example, Lonigan and colleagues (1998) administered a phoneme blending task to 2- through 5-year-old children which required children to combine word elements to verbally produce a new word (e.g. “This is a cow and this is a boy. What word do you get when you put cow…boy…together?” or “What do you get when you put /b/ /a/ /t/ together?”). In the same study, the experimenters administered a phoneme elision task in which children were asked to say a word by eliminating a specific sound or set of sounds (e.g. “ Say ‘doorbell’. Now say ‘doorbell’ without saying ‘bell’.” or “Say ‘time’. Now say ‘time’ without saying ‘/m/’.”).

Results from this work revealed that children’s phonological sensitivity was below chance at 2- and 3-years-old. The authors note that only approximately 3% and 11% of 2- and 3-year-old participants, respectively, performed at above chance levels on the phoneme discrimination elision task, and only approximately 3% and 21% of 2- and 3-year-old participants, respectively, performed at above chance rates on the phoneme discrimination blending task. Poor performance for the 2- and 3-year-old children was not especially surprising. However it is unclear whether this is due to lack of capacity to engage in phonological awareness or to developmentally inappropriate performance demands that do not relate directly to competence.

Little research has addressed the challenges associated with utilizing developmentally appropriate assessment tools to measure pre-reading skills in very young children. One recent endeavor, however, indicated both feasibility of and greater sensitivity of receptive measures of pre-reading relative to productive measures. Wakerlee-Hollman and colleagues (2015) developed and revised four measures of phonological awareness in an effort to validate additional measures of phonological awareness that were aligned to Response To Intervention (RTI) models in schools, and would adequately support the screening and/or diagnoses of 3- to 5-year-old children, prior to school entry. Two of these measures were production-based (Syllable Segmenting and Sound Blending) and two were receptive (Rhyming and Alliteration). They found that the receptive measures yielded higher overall performance and argued that this difference in performance between measures appeared to be related to greater comprehension of task requirements for the receptive measures. Whereas performance on the production based measures elicited dichotomous response patterns with children either responding at ceiling or at floor, receptive measures seemed to capture natural variability in children's performance.

Findings such as these suggest that when phonological awareness tasks require an explicit analysis of word forms, they may not be sensitive to implicit or emerging knowledge. It may be that, as with many aspects of language acquisition, comprehension precedes production and, consequently, lack of performance does not imply lack of competence. These findings underscore the importance of identifying developmentally appropriate measures to accurately assess and examine early phonological awareness development, particularly the smaller units of phonological awareness such as phonemic awareness, utilizing measures that do not rely upon production.

Early Development of Phonological Awareness

Although explicit phonological awareness appears not to develop until much later, infants acquire implicit knowledge of the phonological inventory, phonological contrasts, and phonotactic constraints in their native language before their first birthdays. Children’s early emerging sensitivity to phonemic content of words may link directly to children’s subsequent ability to analyze words into component sounds. (Kuhl et al., 2005; Werker & Tees, 2002). Indeed, promising results have emerged from Cardillo (2010) who reported the striking finding that 7-month-old native phonemic discrimination predicted 5-year-old phonological awareness. However, a more detailed, empirical exploration of the developmental trajectory of specific precursors to early reading acquisition and their relation to later reading is lacking. Paradigms that have been employed to assess phonemic knowledge in infancy are, by necessity, implicit in nature. This empirical work in the developmental speech perception literature may provide clues regarding how to assess early precursors to reading sub-skills *receptively*. For example, researchers have developed sensitive implicit measures to inventory the types of phonological contrasts to which infants are sensitive at different points in development.

The current study investigates developmental precursors to phonemic awareness, the reading sub-skill found to be most predictive of reading acquisition using experimenter-developed receptive measures of phonemic awareness and comparing them to more standardized production measures. We predict that receptive measures will reveal phonemic awareness at significantly higher rates and earlier ages than standardized production measures typically reveal. The notion that early implicit knowledge becomes increasingly more explicit across development is well-established in the cognitive development literature and was perhaps most compellingly conveyed through Karmiloff-Smith’s (1992) Representational Redescription model. of cognitive development as a theoretical framework for potentially describing the mechanistic processes underlying the development of skilled reading.

The Representational Redescription Model

Annette Karmiloff-Smith’s (1992) Representational Redescription (RR) Model of cognitive development has the potential to describe the mechanistic processes underlying the development of skilled reading. This model, which characterizes the process by which knowledge transitions from implicit to explicit, may explain how children move from early implicit perceptual processing of phonemes to explicitly *analyzing* speech units meaningfully, to ultimately mapping spoken words to print representations.

The RR model postulates that early implicit knowledge, with use, becomes increasingly more explicitly available to the child. However the process of achieving explicit awareness is a graded one on this account. The earliest emergence of explicit knowledge may involve generating associations and connections without conscious awareness. For example, children may begin to manipulate words and sounds in seemingly explicit ways such as alliterative play or rhyming. However this does not mean that they yet have conscious awareness of the fact that they are producing alliteration or rhyme. This earliest stage of explicit knowledge may subsequently give rise to even more explicit representations that enable children to analyze the individual phonemes within words and indicate this understanding in a receptive, but not a productive task. According to the RR model, only after attaining these intermediate stages would a child reach the fully conscious verbally accessible level of explicit awareness to support tasks that require *verbal* production of individual phonemes. Additionally, the RR Model argues that with explicitization comes cognitive flexibility. This flexibility is present within knowledge domains (e.g. reading), “sub-domains” (e.g.Phonological Awareness) and “micro-domains” (e.g. Phonemic Awareness or syllabication), and is not necessarily linear. Therefore, it is possible that a skill such as phonemic awareness could be emerging simultaneously in development with skills such as syllabication or rhyming, for example.

2. 3 Goal of the Current Study

The goal of the current study is investigate the possibility that there may be emerging phonemic awareness at younger ages than previously shown that is not yet verbally accessible, but nonetheless evident when using developmentally appropriate receptive performance measures. This would be consistent with the RR Model as an account of the development of phonemic awareness. We propose that there are levels of explicit awareness involved in pre-reading skills that have not yet been adequately examined in the existing literature, and that appear considerably earlier in development than previously detected. Employing *receptive* measures of phonemic awareness tasks could allow us to index stored phonemic representations that may not be accessible through more established production tasks, but could be accessible through non-verbal behavioral measures at another representational level.

To potentially gain insight into earlier, less explicit levels of pre-reading development, this study will explore measures of *receptive* phonemic awareness and compare them to a measure of *productive* phonemic awareness which would reflect different levels of explicit awareness according to the RR model. If beginning skilled reading follows a gradual process, then conscious, *though not necessarily verbally accessible*, representations of speech sound-to-print mappings should emerge as precursors to explicit speech-to-print representations that can be verbally accessed and eventually give rise to early reading.

As such, the goals of this study are to elucidate the early development of phonemic awareness, one of the pre- reading skills most predictive of early reading achievement in the literature, and to address the extent to which performance-based factors (i.e., using production-based measures) may result in underestimates of children's early phonemic awareness skills. This work could eventually lead to detection of children at risk for reading difficulty at an earlier point in development than is currently feasible. To achieve these goals, we approach this work with two?? primary aims:

1) **To investigate the developmental progression of phonemic awareness, both receptively and productively, in 2.5- and 3.5-year old children**. Prior literature has posited that phonemic awareness abilities (segmenting and blending) do not emerge until the late preschool years. However we propose that this assumption is an artifact of the production-based nature of tasks used to measure this skill. If phonemic awareness abilities in fact do not emerge until the late preschool years, then children younger than 4.5-years-old should not exhibit any conscious understanding of phonemic awareness, even through the use of receptive measures. However, if phonemic awareness develops in a progression from receptive abilities to productive abilities, then we may find tentative evidence of emerging phonemic awareness as early as 2.5 years and expect to find evidence of receptive but not productive competence in 3.5-year old children who have acquired phonemic awareness but are not yet able to fully access their knowledge in the service of completing production-based measures of this skill.

2) **To determine whether *receptive* phonemic awareness abilities are consistent across blending (i.e., /k/ /æ/ /t/ → cat) and segmenting (i.e., cat → /k/ /æ/ /t/) tasks**. In traditional production-based phonemic awareness tasks, children are typically successful on blending tasks earlier in ontogeny than on segmenting tasks. If phonemic awareness follows a developmental progression of blending followed by

segmenting, and these experimental receptive measures are tapping into emergent phonemic awareness abilities, then we should see successful performance on receptive blending tasks earlier in development than on segmenting tasks. However, if these measures do not follow the same developmental progression it is possible that what is being measured in production tasks are additional skills above and beyond phonemic awareness. Productive segmenting task performance could be relying on additional task- related factors such as the verbal proficiency to comprehend the task instructions, working memory, or the ability to verbally produce a response to a task.

2.4 Method

Participants:

Twenty-five 2.5-, and 25 3.5-year-old children from diverse socio-economic, racial, and ethnic backgrounds, both male and female, participated in a cross-sectional study for a total of 50 child participants. There were a total of 31 female and 19 male participants. Per parent report, approximately 14% of our sample identified their children as Hispanic. The racial makeup of our child sample is as follows: American Indian – 2.0% (1 participant), Asian – 4.0% (2 participants), Black – 16.0% (8 participants), White – 66% (33 participants), Asian and White – 10% (5 participants), Black and White – 2% (1 participant).

Measures:

We employed one standardized production-based measure of phonemic awareness and two receptive phonemic awareness measures that were developed for this study to assess both segmenting and blending constructs. All three measures (one productive and two receptive) were administered to 3.5 year olds, however only the receptive measures were employed with 2.5 year olds. Pilot testing indicated that 2.5 year olds had difficulty completing the production-based measure, and exhibited distress due apparently to incomprehension of instructions during these tasks. The standardized production measure and experimental receptive measures are described below.

Stimuli and Materials

Auditory Stimuli:

Auditory stimuli consisted of single syllable, minimally paired words spoken one individual phoneme at a time. The items were drawn from the MacArthur-Bates Communicative Development Inventory to ensure familiarity with the words. Word pairs included some with word- initial- (e.g. '/c/ /a/ /t/' and '/b/ /a/ /t/') and some with word-final- (e.g. '/b/ /o/ /t/ and /b/ /o/ /l/') phoneme discriminations. The recorded speaker was a middle-aged Caucasian American female with a neutral, Midwest accent. The speaker produced each sound clearly, taking care to not place emphasis on any one phoneme. A complete list of the minimal pairs employed in this study are listed in Appendix A.

Picture Cards:

Picture cards were developed to correspond to each auditory stimulus. The experimenters pilot tested 2.5-year-old children's ability to recognize the images depicted by eliciting labels for each picture. Only picture stimuli that received 100% labeling accuracy during piloting were used.

Procedure

Productive Measure: DIBELS Phoneme Segmentation Fluency

Phoneme *segmentation* is one of the most common measures of phonemic awareness represented in the literature, and routinely utilized in practice to assess pre-reading skills. Accordingly, we administered the Phoneme Segmentation task of the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) as a standardized test of *productive* phoneme segmentation competencies. The test assesses children's ability to segment three- and four-phoneme words into their individual phonemic components. The experimenter presents the child with a word and asks the child to verbally produce the component sounds of the word. For example, if the experimenter says the word "cat" the child is expected to respond with the phonemes "/k/ /æ/ /t/". The experimenter began with one training trial in which the child was asked to listen to a sample word such as "Sam". The experimenter says: "I'm going to say a word. After I say it, you tell me the sounds in the word. So if I say 'Sam' you say '/s/ /a/ /m/'. Let's try one. Tell me the sounds in 'mop'". The child is expected to produce the sounds '/m/ /o/ /p/'. If the participant answers correctly, the experimenter says: "Very good. The sounds in 'mop' are /m/ /o/ /p/." If the participant answers incorrectly, the experimenter says: "The sounds in 'mop' are /m/ /o/ /p/. Your turn, tell me the sounds in 'mop'." Following the training trial, the experimenter says: "Good. We're going to do some more." The experimenter then presents a series of words for 1 minute. Participants are allowed 3 seconds to respond to each presented word. If they do not respond within 3 seconds they receive 0 points for that particular word. Participants receive 1 point for each phoneme correctly pronounced within 1 minute. A segmentation fluency score is determined by calculating the proportion of correct phonemic responses produced in 1 minute to the total phonemes present in the task set. The total number of correctly produced phonemes are tallied to create a standard score. DIBELS is norm referenced on kindergarten children, and according to the administration handbook, children are expected to produce at least 33 correct phonemes in 1 minute by winter of their kindergarten year. Children who produce fewer than 28 correct phonemes by winter of the kindergarten year are identified as requiring intensive intervening instruction.

Receptive Phonemic Awareness Measures:

Receptive measures of both phoneme segmentation and phoneme blending were designed to measure children’s abilities to parse words into individual phonemes, and to blend individual phonemes to form whole words, respectively. Neither measure required that children be able to produce an oral response, and both initial and final phoneme discrimination stimuli were developed for the task. Figure 2 is a pictorial representation of both the receptive phoneme segmenting and blending task presentations. Procedures for each task are explicated below.

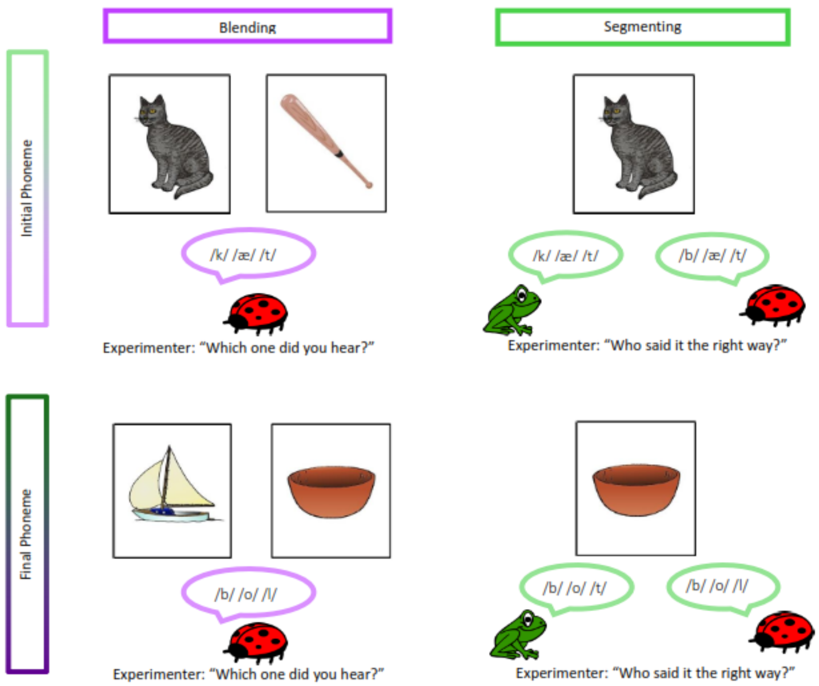

Figure 2:

Receptive, Initial and Final Phoneme Blending and Segmenting Discrimination Tasks

Receptive Measure: Segmentation

The receptive Segmentation task was designed to measure children's ability to parse words into individual phonemes without having to orally produce a response. Children were presented with a picture of a familiar object (e.g., a cat) and were told that two stuffed animal puppets, Lulu the Ladybug and Francine the Frog, were trying to break the name for that object into pieces. The experimenter asked the child to help by picking the puppet who breaks the word into pieces the right way. For example, when presented with the picture of a cat, Lulu might "say" /k/ /æ/ /t/ and Francine /b/ /æ/ /t/. Pre-recorded sound sequences were played over a computer speaker and paired with each puppet one at a time. Children were asked to point to, or touch, the stuffed animal that said the sounds the “right way.” Participants received two training trials during which feedback was provided.

Training trials began with an introduction to the two puppets, Lulu and Francine. Children were allowed to play with the puppets for approximately 1 minute to lessen any effects of being distracted by them as novel objects in the sessions. After 1 minute, the experimenter explained the task stating: “We’re going to play a game with some pictures. You’re going to see a picture of a word. Then Lulu and Francine are going to try to break the word into pieces. You’re going to help me decide who breaks the word up the right way. Let’s practice one.” The experimenter then presents a training picture card: ‘pot’, and says: “This is a ‘pot’. Lulu calls the pot: (the experimenter plays the sounds associated with Lulu – e.g., ‘/p/ /o/ /t/’)…and Francine calls the pot: (the experimenter plays the sounds associated with Francine – e.g., ‘/g/ /u/ /m/’). Who said it the right way?” During training trials, the experimenters used words that were in stark contrast to ensure understanding of the task. If a child made an error, the experimenter corrected the child saying: “Let’s listen again. This is a ‘pot’. Lulu calls the pot ‘/p/ /o/ /t/’ and Francine calls the pot ‘/g/ /u/ /m/’. I think Lulu’s sounds more like ‘pot’”. After receiving 2 training trials, and feedback if needed, test trials began.

Test trials were completed without feedback and consisted of minimal pairs including 4 trials that required word-initial phoneme discrimination, and 4 trials that required word-final phoneme discrimination. Order of presentation of word-initial and word-final phoneme stimuli was randomized. The verbiage was the same for test trials as training trials, minus any feedback for errors. The experimenter responded to both correct and incorrect responses by saying “Thank you.”, and then continued to the next trial.

Receptive Measure: Blending

The receptive Blending task was designed to measure children’s ability to blend individual phonemes to form whole words without having to orally produce a response. Participants were told that Lulu the Ladybug was going to say some broken words, and that the experimenter needed help figuring out what was she was saying. For example, the child may have heard “/k/ / æ / /t/” and then was simultaneously presented with a picture of a cat and a picture of a bat. The experimenter asked the child to touch the picture for the word that the puppet produced. If children are able to blend together each phoneme to form a complete word, they should choose the picture of the cat and not the bat.

As in the segmenting task, children received two training trials and feedback during the training for incorrect responses. Training trials began with an introduction to the puppet, Lulu the Ladybug. The child was then presented with two picture cards whose names have contrasting sound structures, e.g., ‘pot’ and ‘door’. The experimenter said: “This is a ‘pot’ and this is a ‘door’. The experimenter then played the target sound sequence: ‘/p/ /o/ /t/’, and said: “Which one did you hear?” If the child picked the picture of the door, instead of the pot, the experimenter provided feedback saying: “Let’s listen again. Lulu said ‘/p/ /o/ /t/’. That sounds like ‘pot’." After receiving 2 training trials, and feedback if needed, test trials began.

Testing trials were administered without feedback and included minimal pairs, 4 trials that required word-initial phoneme discrimination and 4 trials that required word-final phoneme discrimination. The verbiage was the same for test trials as training trials, minus any feedback for errors. The experimenter responded to both correct and incorrect responses by saying “Thank you.”, and then continued to the next trial.

Additional Measure: Vocabulary

The Peabody Picture Vocabulary Test, 4^{th} Edition (PPVT-4) was utilized as a proxy for general intelligence to be used as a co-variate in the analyses. The PPVT-4 is a receptive vocabulary measure that is normed on children ages 2.5- years through adults, is known to be highly correlated with general intelligence measures, and is therefore consistently used in developmental and early reading literatures as a proxy for IQ. Administration of the PPVT-4 is as follows: Children are shown a page with four pictures presented in quadrants and asked to point to the picture depicting a target vocabulary word (see Appendix B). For example, the experimenter says: “I’m going to show you some pictures and ask you to point to one. Let’s try one. Show me ‘baby’. The participant is expected to point to the picture of the baby. The participant completes two practice trials and then continues until reaching a ceiling by missing 8 or more words within a set of words.

Task order:

Tasks were presented based on the order of presentation that proved most feasible given children's attention spans during pilot testing with an eye towards prioritizing completion of the receptive segmenting and blending tasks. As a result, order of presentation of the receptive tasks was counterbalanced but these tasks were always completed prior to the productive segmenting task. The PPVT was administered at the end of the session. As noted previously, 2.5 year olds did not complete the production task. The majority of participants also completed a working memory measure that is not being analyzed for this study.

2. 5 Results

Productive Measure: DIBELS Phoneme Segmentation Fluency Results:

As noted in the method section, this task was only administered to 3.5-year-old participants, because pilot testing indicated that 2.5-year-olds had difficulty completing this production-based measure, and exhibited distress due apparently to incomprehension of instructions. This task is normed on children 5.0 years and older. Therefore, we compared performance on this task to both floor (i.e., 0 correct trials or phonemes per minute) and the kindergarten benchmark of 33 correct trials or phonemes per minute. We found that 3.5-year-old participants performed significantly above floor (M = 4.92, SD = 7.56); $t(23) = 3.19$, $p < .01$; d = .92), yet significantly below the Kindergarten benchmark of 33 correct phonemes per minute, with some variability in performance (*range* = 0-26; $t(23) = -18.2$, $p < .001$; d = -5.25).

Receptive Measure: Segmenting Results

Figure 3 represents the mean proportional rates of correct responses on the Receptive Phonemic Awareness Segmenting task for 2.5- and 3.5-year-old children, shown separately for initial-phoneme and final-phoneme discrimination trials. First, we assessed the accuracy of children’s performance on the receptive segmenting task by conducting comparisons to chance (.5 given the two alternative forced-choice paradigm).

Next, we explored how performance varied as a function of phoneme contrast placement (initial v. final phoneme discrimination) and age (2.5-year-olds v. 3.5-year-olds).

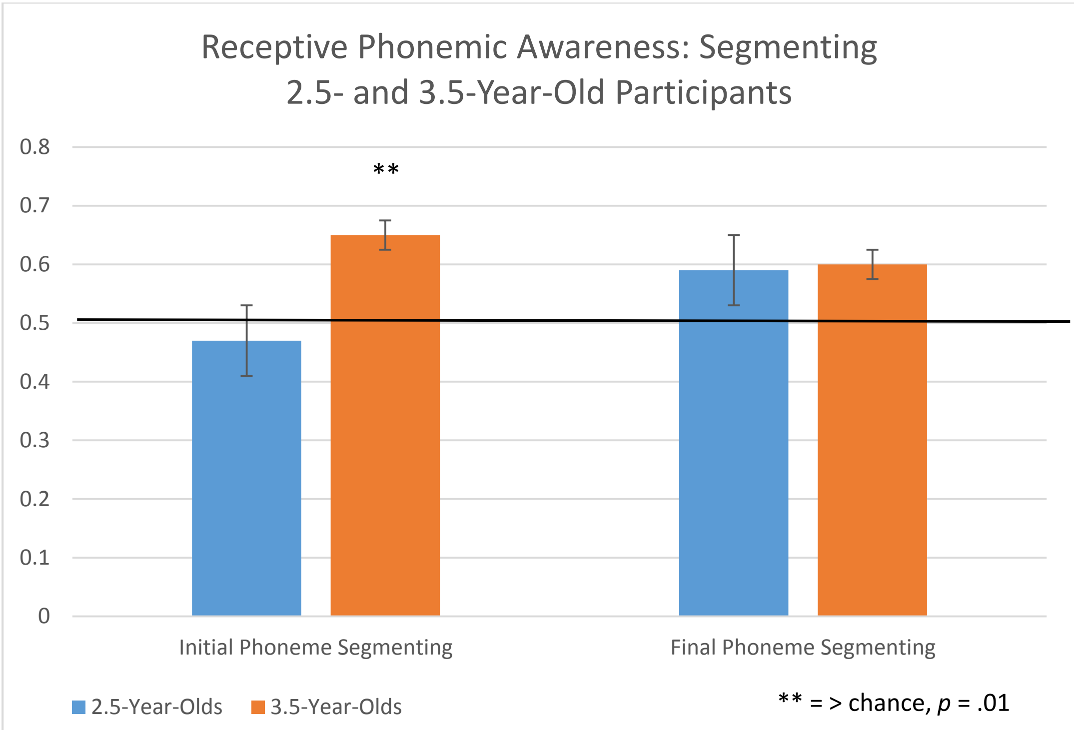

Figure 3

2.5-year-old and 3.5-year-old proportion of correct responses within initial- and final-phoneme segmenting conditions (chance = .50).

Comparisons to Chance:

To assess children's overall performance on the receptive phoneme segmenting measure, we conducted comparisons to chance.

First, we conducted an overall comparison to chance at each age, collapsing across initial and final phoneme segmenting trial types. Performance did not differ from chance in 2.5-year-old participants (M = .54, SD = .12, $t(24) = 1.43$, p > .05). However, 3.5-year-old participants selected the correct response at rates that exceeded chance (M = .63, SD = .23; $t(24) = 2.77$, $p = .01$; d = .80).

Next, we examined performance for each trial type at each age. Not surprisingly, 2.5-years-old children's performance did not differ from chance rates on either initial- (*M* = .47, *SD* = .25) or final- (*M* = .59, *SD* = .32) phoneme discrimination conditions (*t*'s (24) = -.59 and 1.40 for initial and final phoneme trials respectively, both p's >.05). At 3.5 years, children's performance exceeded chance on *initial* phoneme segmenting (*M* = .65, *SD* = .28; *t*(24) = 2.68 , *p* = .01; d = .76) but not on final phoneme segmenting, (*M* = .60, *SD* = .34; *t*(24) =1.48, *p* > .05).

Condition Comparisons by Age:

We conducted a 2 (initial- v. final-phoneme) X 2 (2.5- v. 3.5-year-olds) repeated measures ANCOVA, using trial type (initial- v. final-phoneme segmenting trials) as a within-subjects factor, age as a between-subjects variable, and vocabulary scores from the PPVT-4 as a covariate, to explore how performance varied as a function of phoneme contrast placement. The model yielded no significant effects of either age or phoneme contrast placement, and no interactions. Additionally, there was no effect of the PPVT on performance (*F*(1,47) = .78, *p* = .38).

Receptive Measure: Blending Results

Figure 4 depicts the mean proportion of correct responses on the Receptive Phonemic Awareness Blending task for 2.5-, and 3.5-year-old children, shown separately for initial-phoneme and final-phoneme discrimination trials. First, we assessed the accuracy of children’s performance on the receptive blending task by conducting comparisons to chance. Next, we examined how performance varied as a function of phoneme contrast placement (initial v. final phoneme discrimination) and age (2.5-year-olds v. 3.5-year-olds).

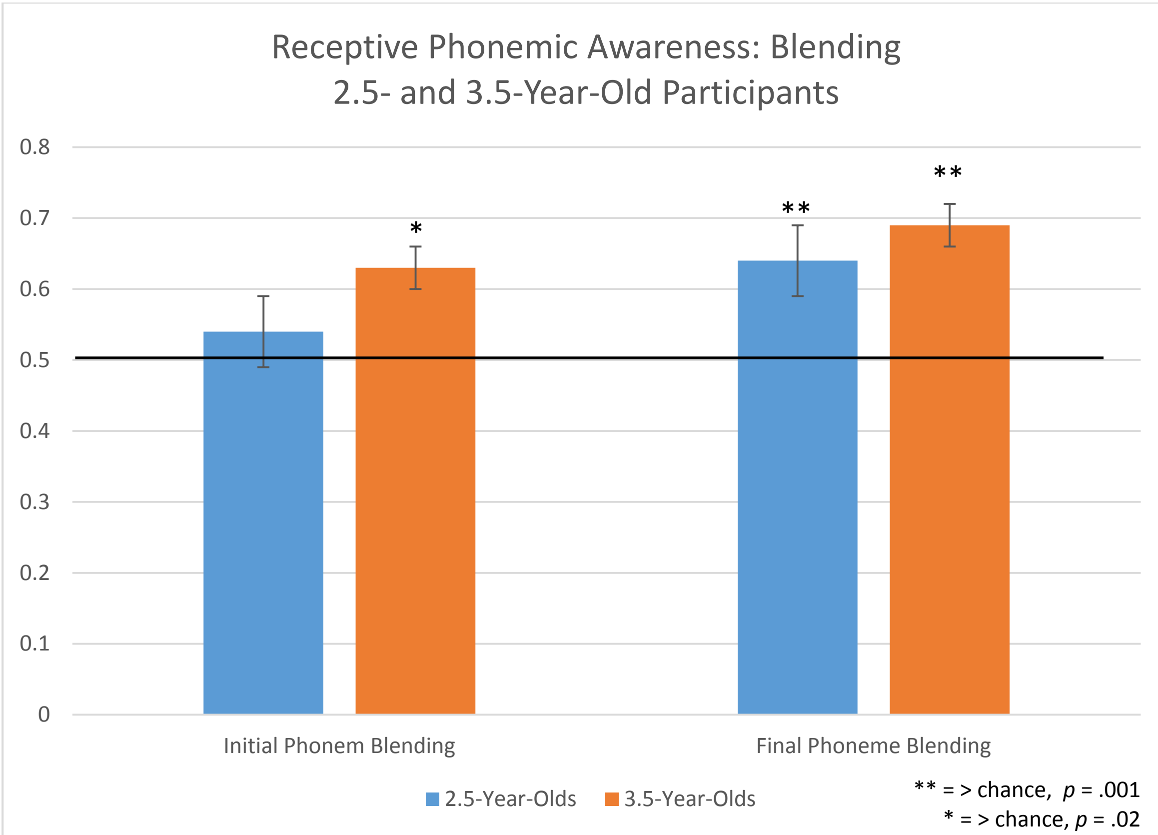

Figure 4

2.5-year-old and 3.5-year-old proportion of correct responses within initial- and final-phoneme blending conditions(Chance = .50)

Comparisons to Chance:

To assess children's overall performance on the receptive phoneme blending measure, we conducted comparisons to chance. First, we conducted an overall comparison to chance collapsing across initial and final phoneme blending trial types at each age. Children selected the correct response at above chance rates at both 2.5- (M = .59, SD =.14; $t(24) = 3.17$, p =.004; d = .91), and 3.5- years of age (M = .66, SD = .22; $t(24) = 3.72$, p = .001; d = 1.03).

When we break performance down by trial type, 2.5-years-olds, performed at above chance rates on the *final* phoneme condition (M = 0.64, SD = .19; $t(24) = 3.65$, $p <$ .001; d = 1.04), but not the *initial* phoneme condition, M = .54, SD = .21, $t(24) = .94$, $p >$ .05). At 3.5-years-old, children performed at above chance rates on both initial- (M = .63, SD = .26) and final- (M = .69, SD = .26) phoneme conditions of the blending task ($t_{initial}(24) = 2.49$, $p = .02$; d = .71; $t_{final}(24) = 3.61$, $p < .001$; d = 1.03).

Condition Comparisons by Age:

We conducted a 2 (initial- v. final-phoneme) X 2 (2.5- v. 3.5-year-olds) repeated measures ANCOVA, using trial type (initial- v. final-phoneme blending trials) as a within-subjects factor, age group as a between-subjects variable, and vocabulary scores from the PPVT-4 as a covariate. The model yielded no significant effects of either age or phoneme contrast placement, and no significant interactions. Additionally, there was no effect of the PPVT on performance ($F(1,47) = .10$, $p > .05$).

2. 6 Discussion

Our goals in this study were to elucidate the early emergence of phonemic awareness, and to address the extent to which performance-based factors (i.e., using production-based measures) may result in underestimates of children's early phonemic awareness abilities. We found, using receptive measures, evidence of phonemic awareness as young as 2.5 years of age. Although 2.5-year-olds exhibited comprehension of phonemic awareness in blending tasks, this ability was fragile and reliable only on phoneme-final trials, and their responses did not differ from chance on the segmenting task. In contrast, we found strong evidence of blending ability in 3.5-year-olds for both initial and final phoneme trials and evidence of segmenting ability as well. However 3.5-year-olds' segmenting performance was only reliably above chance in initial phoneme discrimination trials. These findings indicate that contrary to prevailing wisdom, there is emerging phonemic awareness prior to the age of 4, and that this emerging ability follows a predicted developmental progression of success when using more developmentally appropriate receptive phonemic awareness measures.

As we hypothesized, despite 3.5-year-old children's accurate performance on the receptive phonemic awareness segmenting measures, this age group exhibited performance above floor, but well below the expected Kindergarten benchmark the standardized productive DIBELS Phoneme Segmentation Fluency task. That receptive measures capture emerging ability that is not detected in productive measures implicates task demands as the basis for prior studies' failure to find phonemic awareness at these ages. Further validation of these receptive measures comes from the fact that the receptive phonemic awareness measure findings mirror the developmental progression of traditional productive phonemic awareness measures, with accurate production-based *blending* abilities appearing earlier in ontogeny than production-based *segmenting* abilities (Yopp & Yopp, 2000). Collectively, our findings indicate that 2.5- and 3.5-year-old children have stored phonemic representations that, although not exhibited in production-based tasks, can be indexed through more developmentally appropriate receptive measures.

Our work addresses important gaps in the literature regarding phonemic awareness development in young children, the skill most predictive of future reading achievement. This examination was motivated in part by the striking finding that 7-month-old native phonetic discrimination predicts 5-year-old phonological awareness

(Cardillo, 2010). From this finding, we developed a hypothesis that phonemic awareness is a progressive, incremental skill that develops throughout ontogeny, as opposed to emerging at a specific point in development, or with the introduction of formal reading instruction. Further, we suggested that current theories of phonological awareness development, including phonemic awareness, are based on an impoverished view of the developmental trajectory, limited by the measures used to assess such skills. Measures of phonological awareness have traditionally been production-based, requiring explicit oral production of word form, and/or other performative skills such as counting or tapping. Wackerle-Hollman and colleagues (2015) support the argument that production-based measures may underestimate phonological awareness. They found that when children were given both productive and receptive phonological awareness tasks, performance on receptive tasks was overall higher than performance on production tasks, and children appeared to comprehend receptive task expectations with more clarity.

Our theoretical bases for proposing incremental development of phonemic awareness from a receptive form of knowledge to a productive form of knowledge is anchored to Annette Karmiloff-Smith’s Representational Redescription (RR) Model, which postulated that early implicit knowledge, with use, becomes increasingly more explicit and available to verbal report. Cardillo's (2010) findings are consistent with a gradual transition from implicit to more explicit phonemic awareness that ultimately results in access to verbal report. However our findings flesh out the developmental trajectory predicted by the RR model, demonstrating that a measurable intermediate level of explicit but verbally inaccessible phonological awareness emerges during the toddler and preschool years.

Findings from this study support a potential paradigm shift in our thinking surrounding the overall development of phonological awareness, and phonemic awareness in particular. Whereas current theories of phonological awareness development argue for the development of incrementally smaller units of sound discrimination with age (i.e. from word awareness, to syllable and/or rhyme awareness, and finally to the level of the individual phoneme), our work reveals that phonological awareness development may indeed follow an alternative developmental trajectory. Specifically, we present evidence for the emergence of fine-grained (minimal-pair) phonemic awareness and discrimination as early as 2.5-years-old. Thus, even the smallest units of phonological discrimination are available early on, and developmental progress reflects increasingly more explicit and fluid awareness manifestations across a broader range of tasks and contexts rather than a shift in units of analysis over time.

We also examined the influence of general intelligence on children's performance on tasks by using PPVT-4 scores as a co-variate when examining performance within trial type (initial- v. final-phoneme discrimination) across age (2.5- v. 3.5-year-olds). We found no effects for trial-type or age, and no interactions. Additionally, we found no evidence that this developmental trajectory varied as a function of general intelligence as indexed by the PPVT, suggesting that other factors more specific to phonemic awareness are driving developmental change. Future efforts should extend this work to 4.5- and 5.5- year-old children to examine a more complete understanding of the relationship between receptive and productive phonemic awareness measures as children enter formal reading instruction. To better understand how phonological awareness unfolds prior to formal instruction, the contributions of factors such as memory span, the child's home language and literacy environment, and socioeconomic status should be examined. Finally, this work requires that we shift our thinking surrounding phonological awareness and pre-reading development, and more importantly provides a platform for potentially identifying children who are at-risk for reading failure earlier in ontogeny than is feasible using current assessment tools. Overall, this work underscores the importance for both theory and practice of utilizing developmentally appropriate measures that side-step performance factors that may have led to an underestimate of early and emerging phonological awareness development.

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CHAPTER 3

Cognitive and Environmental Predictors of Receptive Phonemic Awareness Development in 2.5- to 4.5-year-old Children: Implications for Theory and Practice

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3.1 Abstract

Prevailing models of phonological awareness posit that phonological awareness begins at the whole-word level and that development is characterized by incremental sensitivity to smaller units of sound discrimination with age (i.e. from word awareness, to syllable and/or rhyme awareness, and finally to the level of the individual phoneme). Accordingly, phonemic awareness development has traditionally been conceptualized as a sub-skill, and the smallest unit, of phonological awareness that emerges during the school-aged years in tandem with explicit, formal reading instruction. However, we know from developmental speech perception studies that infants acquire implicit knowledge of many aspects of phonological awareness including the phonological inventory, phonological contrasts, and phonotactic constraints of their native language before their first birthdays. As such, children's early emerging sensitivity to phonemic content of words may link directly to children's subsequent ability to analyze words into component sounds (Kuhl et al., 2005; Werker & Tees, 2002). Indeed, promising results have emerged from Cardillo (2010) who reported the striking finding that 7-month-old performance on a measure of native phonemic discrimination predicted 5-year-old phonological awareness. This suggests that phonological awareness, and particularly phonemic awareness, is likely developing earlier than traditional reading models would predict but that this awareness is masked by the more explicit nature of the tasks developed to index phonemic awareness as a pre-reading skill. We conducted a preliminary study to investigate the developmental precursors to phonemic awareness in 2.5- and 3.5-year-old children, using experimenter-developed *receptive* measures of phonemic awareness and comparing them to more standardized production measures (Kenner, Friehling, and

Namy, in preparation). The data revealed a developmental progression of receptive phonemic awareness abilities starting at 2.5 years. The current study further validates the measures employed, and fleshes out the developmental trajectory identified in our preliminary study, adding 4.5-year-old participants who have begun to exhibit phonological awareness on performance-based measures. This study also examines the cognitive, environmental, and sociocultural factors that predict phonemic awareness development in the early childhood years. Results are discussed in terms of implications for theory, as well as intervention and reform efforts at child, family, program, and community levels.

3.2 Background

The National Institutes of Health (NIH) has deemed illiteracy a national health crisis based on reading proficiency rates among American children. This crisis has led the education and developmental science communities toward more direct examination of the mechanisms underlying skilled reading and how the cognitive and linguistic precursors for reading develop throughout ontogeny. As noted by Lundburg, Larsman and Strid (2012), it has been generally accepted that gaining a complete understanding of the developmental trajectory of precursory reading skills can provide valuable translational insights into the prevention and intervention of reading difficulty Among the myriad pre-reading components, phonemic awareness, a sub-skill of phonological awareness, has repeatedly been found as the most critical foundational skill for proficient reading (See e.g. Anthony & Lonigan, 2004, Brady & Shankwiler, 1991, and Ehri, et. al. 2001).

Despite the importance of this precursory reading skill, our knowledge of its etiology has primarily been limited to studies that examine phonemic awareness development during the late preschool and early school-age years. The dearth of evidence from early in development can be attributed in part to theoretical assumptions that this is a late developing ability and in part to a lack of developmentally appropriate measures for indexing emerging phonemic awareness in the toddler and early preschool years. Current measures of phonological and phonemic awareness are *production* or performance measures, requiring oral responses, tapping, or counting, which cannot easily be administered with children under five-years-old (Liberman, Shankwiler, Fischer, & Carter, 1974; Lonigan et al., 1998; Wakerlee-Hollman et. al., 2015). As a result, few studies have attempted to examine phonemic awareness development in children under 4- or 5-years-old (e.g. Lonigan et al., 1998).

Prevailing models of phonological awareness (see Kenner, Friehling, and Namy, in preparation, for a review) posit that phonological awareness begins at the whole-word level and that development is characterized by incremental sensitivity to smaller units of sound discrimination with age (i.e. from word awareness, to syllable and/or rhyme awareness, and finally to the level of the individual phoneme). Accordingly, phonemic awareness development has traditionally been conceptualized as a sub-skill, and the smallest unit, of phonological awareness that emerges during the school-aged years in tandem with explicit, formal reading instruction.

Although current theories rest on the assumption that explicit phonological awareness appears to develop much later in ontogeny, we know from developmental speech perception studies that infants acquire implicit knowledge of many aspects of phonological awareness including the phonological inventory, phonological contrasts, and phonotactic constraints in their native language before their first birthdays. As such, children's early emerging sensitivity to the phonemic content of words may link directly to children's subsequent ability to analyze words into component sounds (Kuhl et al., 2005; Werker & Tees, 2002). Indeed, suggestive results have emerged from Cardillo (2010) who reported the striking finding that 7-month-old performance on a measure of native phoneme discrimination predicted 5-year-old phonological awareness. This suggests that phonological awareness, and particularly phonemic awareness, is likely developing earlier than traditional reading models would predict but that this awareness is masked by the more explicit nature of the tasks developed to index phonemic awareness as a pre-reading skill. Paradigms that have been employed to assess phonemic knowledge in infancy utilize, by necessity, implicit measures.

Guided by this logic, we conducted a preliminary study to investigate the developmental precursors to phonemic awareness in 2.5- and 3.5-year-old children, using experimenter-developed *receptive* measures of phonemic awareness and comparing them to more standardized production measures (Kenner, Friehling, and Namy, in preparation). Our goals were to elucidate the early emergence and developmental trajectory of phonemic awareness, and to address the extent to which performance-based factors (i.e., using production-based measures) may result in underestimates of children's early phonemic awareness. We developed and administered receptive versions of phonemic awareness assessments targeting both segmenting and blending constructs with both initial- and final-phoneme contrasts.

Findings from this study revealed emerging phonemic awareness well before early elementary school. The data revealed a developmental progression of receptive phonemic awareness abilities starting at 2.5 years. On the receptive phonemic awareness *blending* task, 2.5-year-old children performed at above chance rates on the final-phoneme discrimination trials but not the initial-phoneme discrimination trials, and 3.5-year-old children performed at above chance rates on *both* initial-and final-phoneme discrimination conditions of the receptive blending task. The receptive phonemic awareness *segmenting* task also revealed developmental progression prior to school age. The 2.5-year-olds revealed no evidence of phoneme discrimination in the segmenting task for either the initial- or final-phoneme condition. However, by 3.5-years-old children demonstrated an emerging understanding of this skill in the initial-phoneme but not the final-phoneme discrimination condition. Although 3.5-year-olds exhibited clear evidence of emerging phonemic awareness on these receptive measures, they performed at floor on the Dynamic Indicators of Basic Early Literacy Skills (DIBELS), the standardized productive phoneme segmentation measure. This evidence clearly indicates that there are precursory, receptive versions of phonemic awareness developing earlier in ontogeny that cannot be assessed using traditional production-based measures.

Given the robustness of the developmental trajectory observed in the receptive measures we developed, a principle goal for this study is to investigate potential factors that could be influencing phonemic awareness abilities during these early years and that may account for individual differences in performance on the receptive measures of phonemic awareness. Our evidence revealed that phonemic awareness appears first as a language *ability* as opposed to a taught academic *skill*, and is therefore likely a continuation of the phonological and phonotactic abilities observed in the infant speech perception literature. Accordingly, we turned to an examination of the home language and literacy environment for clues to parental, environmental, and socio-economic factors that may influence phonemic awareness development early in ontogeny. Additionally, we wanted to examine individual differences in children's cognitive abilities to explore relations between child- and environmental-level factors. If we understand the factors that influence development of this ability, the scientific community will be more astutely positioned to inform intervention practices at child, family, and community levels.

Individual Differences in Cognitive Functioning

As is to be expected with many developmental phenomenon, phonemic awareness has traditionally been known to co-vary with other areas of children's overall cognitive functioning, particularly working memory, even when controlling for IQ. For example, Muter and Snowling's (1998) longitudinal study found that when controlling for IQ, working memory and phonemic awareness at 4-, 5-, and 6-years-old accounted for approximately 90% of the variance in children's reading performance at 9-years-old. Given findings such as these, it is imperative that any examination of the factors contributing to phonemic awareness development include measures of cognitive functioning, particularly working memory.

Home Language & Literacy Environment

The need identified by Whitehurst and Lonigan (1998) to examine multiple aspects of the HLE as opposed to a single measure such as shared reading ,is still relevant today. Whitehurst and Lonigan argued that the tendency for studies to examine only one measure of the home language and literacy environment and one measure of emergent literacy may contribute to the lack of robust empirical support for a connection between the home language and literacy environment on the one hand and early language and literacy development on the other.

Although this need was identified nearly 20 years ago, few studies have examined multiple aspects of the home language and literacy environment. Recognizing the multi-faceted and complex nature of the home language and literacy environment, Burgess, Hecht, and Lonigan (2002) proposed several different conceptualizations of the Home Literacy Environment (HLE) as an alternative to previous simplistic views (i.e. social status measures or shared reading experiences) in their longitudinal study examining relations between the home literacy environment and early language and literacy development in 4- and 5-year-old preschool children. The primary conceptualizations in their HLE model included: The Limiting Environment (i.e., social status and parent education, parent values surrounding literacy such as number of books in the home, or parent literacy knowledge as indexed by the Title Recognition Test (see Lindsay, 2010 or Evans, Shaw, & Bell, 2000), and The Literacy Interface. The Literacy Interface conceptualization further divided into the Passive Home Literacy Environment (i.e., parental activities that expose children to literacy models such as seeing a parent read for pleasure) and the Active Home Literacy Environment (i.e., parental behaviors that directly engage children in language or literacy activities). Burgess and colleagues found that only the Active home language environment was related to phonological sensitivity, accounting for approximately 9% unique variance.

More recently, Sénéchal and LeFevre,(2002,2014) have more discretely defined the Active Home Language Environment to include Informal Literacy Activities (e.g., shared book reading) and Formal Literacy Activities (e.g., teaching graphemes and grapheme sounds). In their longitudinal study examining the relations between the home language/literacy environment and reading and vocabulary development, they found that the frequency of parental informal literacy activities when children were in Kindergarten was predictive of 1st grade vocabulary and oral language development, accounting for 2% unique variance, whereas formal literacy activities were predictive of 1st grade early literacy (i.e. word reading, invented spelling) accounting for 34% unique variance. However, it is worth noting that neither informal nor formal parental teaching behaviors were predictive of 1st grade phonemic awareness, despite the relations to early word reading. Given the predictive relationship between phonemic awareness and early word reading, one would expect that the Sénéchal and LeFevre, (2014) study would also have found some evidence of a relation between parental teaching behaviors and phonemic awareness. However, this finding further supports our argument that traditional production-based measures of phonemic awareness, though predictive of early reading, are often confounded by performance factors such as task comprehension or the child's ability to indicate their knowledge through a verbal response (Kenner, Friehling, & Namy, in preparation).

In addition to examining parental behaviors, others have examined what may be considered the, physical language and literacy environment or the language and literacy culture. For example, Raz and Bryant (1990) found that the number of books a child owned and frequency of visits to library each added significant variance to the prediction of phonological awareness (as measured by rhyme detection) when controlling for age and IQ. However, this study did not extend its findings to the level of the individual phoneme.

When examining environmental factors influencing phonemic awareness development, socioeconomic status is, of course, a critical consideration. Although SES does not necessarily play a causal role in children's language and literacy outcomes, it is a marker variable and other factors that directly influence phonological awareness development have been found to covary with SES. For example, Raz and Bryant (1990 found that frequency of shared book reading and parental leisure reading habits predicted certain aspects of phonological awareness sensitivity (i.e. rhyme awareness), but both variables covaried with SES.

3.3 Goals of Current Study

Results from our preliminary study underscore the importance for both theory and practice of further elucidating the factors that may contribute to phonemic awareness development prior to the school-age years.

The first goal of the current study is to provide validation of the measures employed, and developmental trajectory identified, in our preliminary study (Kenner, Friehling, & Namy, in preparation) of receptive measures of phonemic awareness. We found evidence for the emergence of phonemic awareness in 2.5- and 3.5-year-old children that is not yet verbally accessible during these ages, but nonetheless evident when using developmentally appropriate receptive performance measures. Accordingly, the current study extends our preliminary receptive phonemic awareness paradigms to include a small sample of 4.5-year-old children. Exploring receptive phonemic awareness development in 4.5-year-old children will allow us to establish that these measures track developmental progress from early emerging phonemic awareness to full mastery of both segmenting and blending abilities. We expect that the 4.5-year-old age group will demonstrate successful performance on both initial- and final- phoneme segmenting trials for both blending and segmenting conditions. These final stages of phonemic representation may be the bridge between the transition from phonemic awareness language abilities to more applied use of these abilities for reading-readiness related skills. We will address this goal through the following aim:

1) **To investigate the developmental progression of phonemic awareness, both receptively and productively, in 2.5-, 3.5-, and 4.5-year-old children**. Prior literature has posited that phonemic awareness abilities (segmenting and blending) do not emerge until the late preschool years. However we argue that this assumption is an artifact of the production-based nature of tasks used to measure this skill. Our preliminary research indicates receptive evidence of phonemic awareness in the absence of productive evidence. However the receptive evidence indicated only *emerging* knowledge at 2.5 and 3.5 years of age. To fully validate the measures and the developmental trajectory, we propose to compare 2.5 and 3.5-year-olds to 4.5-year-olds. We predict that by 4.5 years, children will show clear and compelling evidence of mastery of both blending and segmenting in the receptive tasks, but only emerging evidence in the standardized productive measure.

The second goal of the current study is to examine the contributing factors to phonemic awareness development prior to the introduction of formal reading instruction in the school age years. We examined the contribution of the child's cognitive capacities (in particular, working memory), as well as the child's home language and literacy environment and socioeconomic status. We extended the work of previous efforts by Burgess et al., (2002) and Sénéchal and LeFevre (2002, 2014) to more accurately identify the specific aspects of the home language and literacy environment that are related to phonemic awareness development in the preschool years as developed. We employed measures of the Limiting Literacy Environment (e.g., parent education level, number of books in the home, frequency of library visits, and parent knowledge of children's book titles), the Passive Home Literacy Environment (e.g., the frequency with which children observe their parent reading a book for pleasure or reading the newspaper), and the Active Home Literacy Environment), including *formal* (e.g., teaching letters and letter sounds), and *informal* (e.g., shared reading or telling fictional stories) parental teaching behaviors. We anticipated that exploring how these measures predict *receptive* indices of phonemic awareness would result in more sensitive indices of the relationship between environment and child phonemic sensitivity. Our goals are addressed through the following aims:

1) To examine the contribution of individual differences in overall cognitive functioning to children's receptive phonemic awareness development from 2.5- to 4.5-years of age. Prior literature has demonstrated that performance on productive measures of phonemic awareness often co-varies with children's cognitive abilities, particularly verbal working memory, even when controlling for IQ. If our receptive phonemic awareness tasks are indexing a pre-cursory, emergent form of traditional productive phonemic awareness tasks, we predict that performance on our receptive phonemic awareness measures will co-vary with individual differences in working memory, even when controlling for IQ.

2) To examine the contribution of the home language and literacy environment and socioeconomic status on 2.5-, 3.5-, and 4.5-year-old children's phonemic awareness development. The relationships between environmental and socioeconomic factors on the one hand and children's language and literacy development on the other are well established. To the extent that phonemic awareness is developing across the toddler and preschool years, I hypothesized that various active parental behavior indices of the home language and literacy environment (both informal and formal), as well as elements of the Limiting Literacy Environment, would be related to performance on the experimental *receptive* measures of phonemic awareness under investigation in the first experiment. As has been found in prior literature (Raz & Bryant, 1990), we anticipated that measures of the Limiting Literacy Environment, and consequently emerging phonemic awareness would vary with socioeconomic status.

3.4 Method

Participants

Twenty-five 2.5- and25 3.5-year-old children from a prior study (Kenner, Friehling, & Namy, in preparation), and a small sample of eight 4.5-year-old children from diverse socio-economic, racial, and ethnic backgrounds, both male and female, are included in the current cross-sectional study for a total of 58 child participants. There were a total of 33 female and 25 male participants. Per parent report, approximately 12% of our sample identified their children as Hispanic. The racial makeup of our child sample is as follows: American Indian – 1.7% (1 participant), Asian – 3.4% (2 participants), Black – 15.5% (9 participants), White – 65.5% (38 participants), Asian and White – 12.1% (7 participants), Black and White – 1.7% (1 participant). Participants were recruited from a database maintained by the Psychology Department containing families with children ranging in age from birth through adolescence who had volunteered to be contacted regarding research participation. Additionally, a parent or guardian of each child was asked to complete two parent-report measures as proxies for the child's home language and literacy environment.

Child Behavioral Measures

We employed one standardized production-based measure of phonemic awareness and two receptive phonemic awareness measures that were developed for this study to assess both segmenting and blending constructs. All three measures (one productive and two receptive) were administered to 3.5 and 4.5 year olds, however only the receptive measures were employed with 2.5 year olds. Pilot testing indicated that 2.5 year olds had difficulty completing the production-based measure, and exhibited distress due apparently to incomprehension of instructions during these tasks. The standardized production measure and experimental receptive measures are described below.

Stimuli and Materials

Auditory Stimuli:

Auditory stimuli consisted of single syllable, minimally paired words spoken one individual phoneme at a time. The items were drawn from the MacArthur-Bates Communicative Development Inventory to ensure familiarity with the words. Word pairs included some with word- initial- (e.g. '/c/ /a/ /t/' and '/b/ /a/ /t/') and some with word-final- (e.g. '/b/ /o/ /t/ and /b/ /o/ /l/') phoneme discriminations. The recorded speaker was a middle-aged Caucasian American female with a neutral, Midwest accent. The speaker produced each sound clearly, taking care to not place emphasis on any one phoneme. A complete list of the minimal pairs employed in this study appears in Appendix A.

Picture Cards:

Picture cards were developed to correspond to each auditory stimulus. The experimenters pilot tested a separate group of 2.5-year-old children's ability to recognize the images depicted by eliciting labels for each picture. Only picture stimuli that received 100% labeling accuracy during piloting were used.

Procedure

Productive Measure: DIBELS Phoneme Segmentation Fluency

Phoneme *segmentation* is one of the most common measures of phonemic awareness represented in the literature, and is routinely utilized in practice to assess pre-reading skills. Accordingly, we administered the Phoneme Segmentation task of the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) as a standardized test of *productive* phoneme segmentation competencies. The test assesses children’s ability to segment three- and four-phoneme words into their individual phonemic components. The experimenter presented the child with a word and asked the child to verbally produce the component sounds of the word. For example, if the experimenter said the word “cat” the child was expected to respond with the phonemes “/k/ /æ/ /t/”. The experimenter began with one training trial in which the child was asked to listen to a sample word such as “Sam”. The experimenter says: “I’m going to say a word. After I say it, you tell me the sounds in the word. So if I say ‘Sam’ you say ‘/s/ /a/ /m/’. Let’s try one. Tell me the sounds in ‘mop’". The child is expected to produce the sounds ‘/m/ /o/ /p/’. If the participant answers correctly, the experimenter says: “Very good. The sounds in ‘mop’ are /m/ /o/ /p/.” If the participant answers incorrectly, the experimenter says: “The sounds in ‘mop’ are /m/ /o/ /p/. Your turn, tell me the sounds in ‘mop’.” Following the training trial, the experimenter says: “Good. We’re going to do some more.” The experimenter then presents a series of words for 1 minute. Participants are allowed 3 seconds to respond to each presented word. If they do not respond within 3 seconds they receive 0 points for that particular word. Participants receive 1 point for each phoneme correctly pronounced within 1 minute. A segmentation fluency score is determined by calculating the proportion of correct phonemic responses produced in 1 minute to the total phonemes present in the task set. The total number of correctly produced phonemes is tallied to create a standard score. DIBELS is norm referenced on kindergarten children, and according to the administration handbook, children are expected to produce at least 33 correct phonemes in 1 minute by winter of their kindergarten year. Children who produce fewer than 28 correct phonemes by winter of the kindergarten year are identified as requiring intensive intervening instruction.

Receptive Phonemic Awareness Measures:

Receptive measures of both phoneme segmentation and phoneme blending were designed to measure children’s abilities to parse words into individual phonemes, and to blend individual phonemes to form whole words, respectively. Neither measure required that children produce an oral response, and both initial and final phoneme discrimination stimuli were developed for the task. Figure 1 is a pictorial representation of both the receptive phoneme segmenting and blending task presentations. Procedures for each task are explicated below.

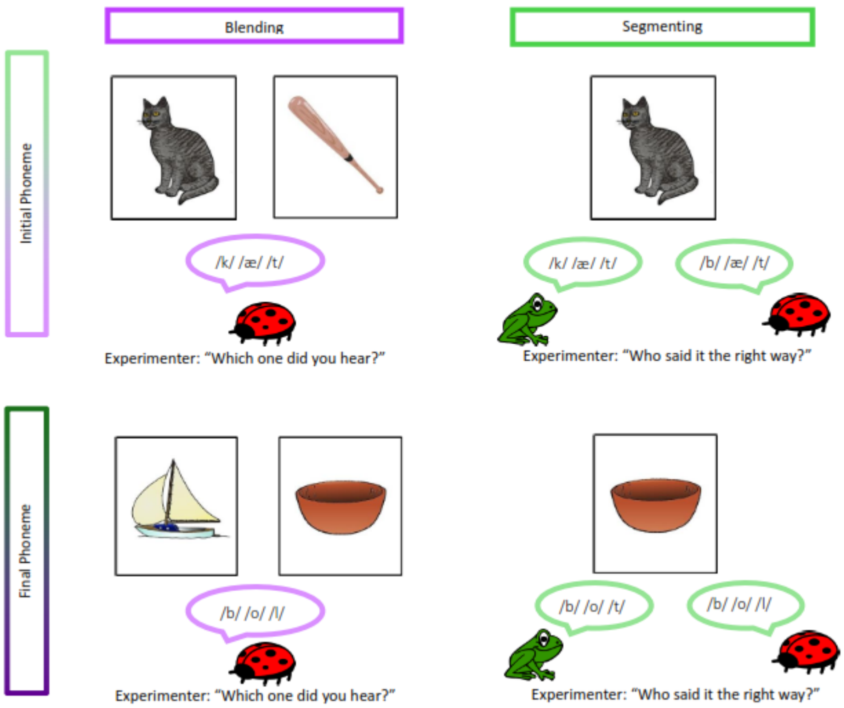

Figure 1:
Receptive, Initial and Final Phoneme Blending and Segmenting Discrimination Tasks

Receptive Measure: Segmentation

The receptive Segmentation task was designed to measure children's ability to parse words into individual phonemes without having to orally produce a response. Children were presented with a picture of a familiar object (e.g., a cat) and were told that two stuffed animal puppets, Lulu the Ladybug and Francine the Frog, were trying to break the name for that object into pieces. The experimenter asked the child to help by picking the puppet who breaks the word into pieces the right way. For example, when presented with the picture of a cat, Lulu might "say" /k/ /æ/ /t/ and Francine /b/ /æ/ /t/. Pre-recorded sound sequences were played over a computer speaker and paired with each puppet one at a time. Children were asked to point to, or touch, the stuffed animal that said the sounds the “right way.” Participants received two training trials during which feedback was provided

Training trials began with an introduction to the two puppets, Lulu and Francine. Children were allowed to play with the puppets for approximately 1 minute to lessen any effects of being distracted by them as novel objects in the sessions. After 1 minute, the experimenter explained the task stating: “We’re going to play a game with some pictures. You’re going to see a picture of a word. Then Lulu and Francine are going to try to break the word into pieces. You’re going to help me decide who breaks the word up the right way. Let’s practice one.” The experimenter then presents a training picture card: ‘pot’, and says: “This is a ‘pot’. Lulu calls the pot: (the experimenter plays the sounds associated with Lulu – e.g. ‘/p/ /o/ /t/’)…and Francine calls the pot: (the experimenter plays the sounds associated with Francine – e.g. ‘/g/ /u/ /m/’). Who said it the right way?” During training trials, the experimenters used words that were in stark contrast to ensure understanding of the task. If a child made an error, the experimenter corrected the child saying: “Let’s listen again. This is a ‘pot’. Lulu calls the pot ‘/p/ /o/ /t/’ and Francine calls the pot ‘/g/ /u/ /m/’. I think Lulu’s sounds more like ‘pot’”. After receiving 2 training trials, and feedback if needed, test trials began.

Test trials were completed without feedback and consisted of minimal pairs including 4 trials that required word-initial phoneme discrimination, and 4 trials that required word-final phoneme discrimination. Order of presentation of word-initial and word-final phoneme stimuli was randomized.. The verbiage was the same for test trials as training trials, minus any feedback for errors. The experimenter responded to both correct and incorrect responses by saying “Thank you.”, and then continued to the next trial.

Receptive Measure: Blending

The receptive Blending task was designed to measure children’s ability to blend individual phonemes to form whole words without having to orally produce a response. Participants were told that Lulu the Ladybug was going to say some broken words, and that the experimenter needed help figuring out what was she was saying. For example, the child may have heard “/k/ / æ / /t/” and then was simultaneously presented with a picture of a cat and a picture of a bat. The experimenter asked the child to touch the picture for the word that the puppet produced. If children are able to blend together each phoneme to form a complete word, they should choose the picture of the cat and not the bat.

As in the segmenting task, children received two training trials and feedback during the training for incorrect responses. Training trials began with an introduction to the puppet, Lulu the Ladybug. The child was then presented with two picture cards whose names have contrasting sound structures, e.g. ‘pot’ and ‘door’. The experimenter said: “This is a ‘pot’ and this is a ‘door’. The experimenter then played the target sound sequence: ‘/p/ /o/ /t/’, and said: “Which one did you hear?” If the child picked the picture of the door, instead of the pot, the experimenter provided feedback saying: “Let’s listen again. Lulu said ‘/p/ /o/ /t/’. That sounds like ‘pot’." After receiving 2 training trials, and feedback if needed, test trials began.

Testing trials were administered without feedback and included minimal pairs, 4 trials that required word-initial phoneme discrimination and 4 trials that required word-final phoneme discrimination. . The verbiage was the same for test trials as training trials, minus any feedback for errors. The experimenter responded to both correct and incorrect responses by saying “Thank you.”, and then continued to the next trial.

Child Cognitive Measures:

We administered two cognitive measures as proxies for children’s overall cognitive functioning. Receptive vocabulary was measured using the norm-referenced PPVT-4. Working memory was measured using an experimenter developed task involving Memory cards. The measures are described in detail as follows:

Proxy for General Intelligence: Receptive Vocabulary – PPVT - 4

The Peabody Picture Vocabulary Test, 4th Edition (PPVT-4) was utilized as a proxy for general intelligence to be used as a co-variate in the analyses. The PPVT-4 is a receptive vocabulary measure that is normed on children ages 2.5- years through adults, is known to be highly correlated with general intelligence measures, and is therefore consistently used in developmental and early reading literatures as a proxy for IQ. Administration of the PPVT-4 is as follows: Children are shown a page with four pictures presented in quadrants and asked to point to the picture depicting a target vocabulary word (see Appendix B). For example, the experimenter says: “I’m going to show you some pictures and ask you to point to one. Let’s try one. Show me ‘baby’. The participant is expected to point to the picture of the baby. The participant completes two practice trials and then continues until reaching a ceiling by missing 8 or more words within a set of words.

Working Memory – Memory Game

A measure of working memory was employed in which children were told the names of several objects the experimenter wanted the child to find. The experimenter then showed the child pictures of multiple objects, using Memory® cards, and asked the child to identify the pictures corresponding to the words they heard by pointing to the appropriate pictures. To administer the task, the experimenter says to the child: "You are going to listen to me say some words. Then I'm going to show you some pictures. You will point to the picture of the words that you heard." For example, the experimenter said: "cat, banana" then presented cards with pictures of a cat, bird, banana, and monkey. The child was expected to then point to the 'cat' and 'banana' pictures.

The memory task progressed in difficulty with 3 levels of difficulty and 3 trials at each level. The first level included two target words and 4 pictures presented in a 2 X 2 arrangement, the second level included 3 target words and 6 pictures presented in a 2 X 3 arrangement, and the third level included 4 target words and 8 pictures presented in a 2 X 4 arrangement. Trials within each level were scored by percentage correct. Participants were required to perform with 100% accuracy on 2/3 trials within a level to progress the next level within the task.

Parent Report Measures - Home Language & Literacy Environment and Socioeconomic Status:

Home Language and Literacy Environment Questionnaire

The Home Literacy Environment Questionnaire is an investigator-created questionnaire that assesses a variety of environmental, demographic, and socio-economic factors in the child's home that could impact a child's early language and literacy environment, and could therefore have an impact on performance on behavioral tasks in the experiment. The questionnaire was designed to index: 1) the Limiting Literacy Environment (e.g., parent education level, number of books in the home, frequency of library visits, and parent knowledge of children's book titles), 2) the Passive Home Language and Literacy Environment (e.g., the frequency with which children observe their parent reading a book for pleasure or reading the newspaper), and 3) the Active Home Literacy Environment, including formal (e.g., teaching letters and letter sounds) and informal (e.g., shared reading or telling oral fictional stories) indices.

The questionnaire was also designed to measure additional, external environmental factors that could be confounding with the home language and literacy environment, such as the number of hours children are exposed to a second language, and the number of hours children spend in childcare outside of the home, (or being cared for by someone other than their primary caregiver or guardian). We labeled this concept the External Language and Literacy Environment. Demographic data was collected to obtain a proxy for socioeconomic status. Although socioeconomic is traditionally indexed by examining mothers' or primary caregivers' education level, we also utilized the mother's education level as a proxy for socioeconomic status. Given the homogeneity of parent education levels in our Child Study Center Database, we also used the primary caregiver's parents' (i.e. the child's grandparents') education level as an exploratory proxy for SES. (See Appendix C).

Revised Title Recognition Test (TRT)

The Children's Title Recognition Test (TRT) has been routinely employed in the early literacy literature (e.g. see Lindsay, 2010 or Evans, Shaw, & Bell, 2000) and has served as a proxy for the home literacy environment, which can have an impact on emergent reading skills. The TRT is a list of approximately 50 children's book titles. Some are actual titles and others are foils. Traditionally, this task asks parents to merely indicate whether the title is an actual title or a foil. In addition to indicating whether or not the titles are foils, the task has been adapted to include opportunities for parents to indicate whether they have actually read the book with their child, as well as whether they think they have heard of the title before. Titles were updated to reflect recent best-selling titles over the past 5 years (see Appendix D). At the end of the task, parents were also given an opportunity to share the titles of other books that they consistently read with their children that may not have been represented in the title list. Each parent's score on the TRT is typically calculated as the total number of correct hits minus the total number of incorrect selections or false alarms. We adhered to the traditional scoring method, but also added an extra point for each additional children's book title that parents indicated in the open response portion of this task.

Task order:

Child Behavioral and Cognitive Tasks Order:

Child tasks were presented based on the order of presentation that proved most feasible given children's attention spans during pilot testing with an eye towards prioritizing completion of the receptive segmenting and blending tasks. As a result, order of presentation of the receptive tasks was counterbalanced but these tasks were always completed prior to the productive segmenting task, which was followed by the working memory task. The PPVT was administered at the end of the session. As noted previously, 2.5 year olds did not complete the production task.

Parent Report Measures:

The parent report measures of the child's home language and literacy environment including the questionnaire and the Title Recognition Test were completed by each parent in conjunction with consent forms prior to the commencement of the child's experimental session.

3.5 Results

Productive Measure: DIBELS Phoneme Segmentation Fluency Results:

As noted in the method section, this task was only administered to 3.5-year-old and 4.5-year-old participants, because pilot testing indicated that 2.5-year-olds had difficulty completing this production-based measure, and exhibited distress due apparently to incomprehension of instructions. The DIBELS Phoneme Segmentation Fluency task is normed on children 5.0 years and older. Therefore, we compared performance on this task to both floor (i.e., 0 correct trials) *and* the kindergarten benchmark of 33 correct trials or phonemes per minute. In our first study we reported that 3.5-year-old participants performed significantly above floor on this subset of the DIBELS (M = 4.92, SD = 7.56) but significantly below the Kindergarten benchmark of 33 correct phonemes per minute. Keeping the small sample size in mind, the current study found that 4.5-year-old participants performed significantly above floor as well (M

= 21.38, *SD* = 26.09; *t*(7) = 2.32, *p* = .05; d = 1.16), but unlike the 3.5-year-old sample, also exhibited performance not significantly different from the kindergarten benchmark standard of 33 correct trials per minute (*range* = 0 - 66; *t*(7) = -1.2, *p* = .25).

Receptive Measure: Segmenting Results

Figure 2 represents the mean proportional responding rates on the Receptive Phonemic Awareness Segmenting task for 2.5- , 3.5-, and 4.5-year-old children, shown separately for initial-phoneme and final-phoneme discrimination trials. As reported in Kenner et al. (in preparation), 2.5 year olds showed no evidence of phonemic awareness on this task, and 3.5 year olds responded at above chance rates only on initial phoneme trials. Here we also assessed the accuracy of 4.5 year old children's performance on the receptive segmenting task by conducting comparisons to chance (.5 given the two alternative forced-choice paradigm). The current study revealed that 4.5-year-old participants also responded overall at rates that exceeded chance on segmenting trials (*M* = .79, *SD* = .19; *t*(7) = 4.68, *p* < .01; d = 2.16). By 4.5-years-old, children performed significantly above chance on *both* initial- (*M* = .75, *SD* = .29) and final- (*M* = .82, *SD* = .19) phoneme segmentation trials ($t_{initial}(7)=2.83$, *p = .03;*d = 1.22*;* $t_{final}(7) = 5.23$, *p* = .001; d = 2.38). This fleshes out the systematic developmental trajectory observed in our previous study and validates the receptive segmenting measure by demonstrating that children can succeed on both initial- and final-phoneme trials in this paradigm by 4.5 years of age.

To confirm this apparent developmental trajectory, we explored how performance varied as a function of phoneme contrast placement (initial v. final phoneme discrimination) by age (2.5-year-olds v. 3.5-year-olds v. 4.5-year-olds).

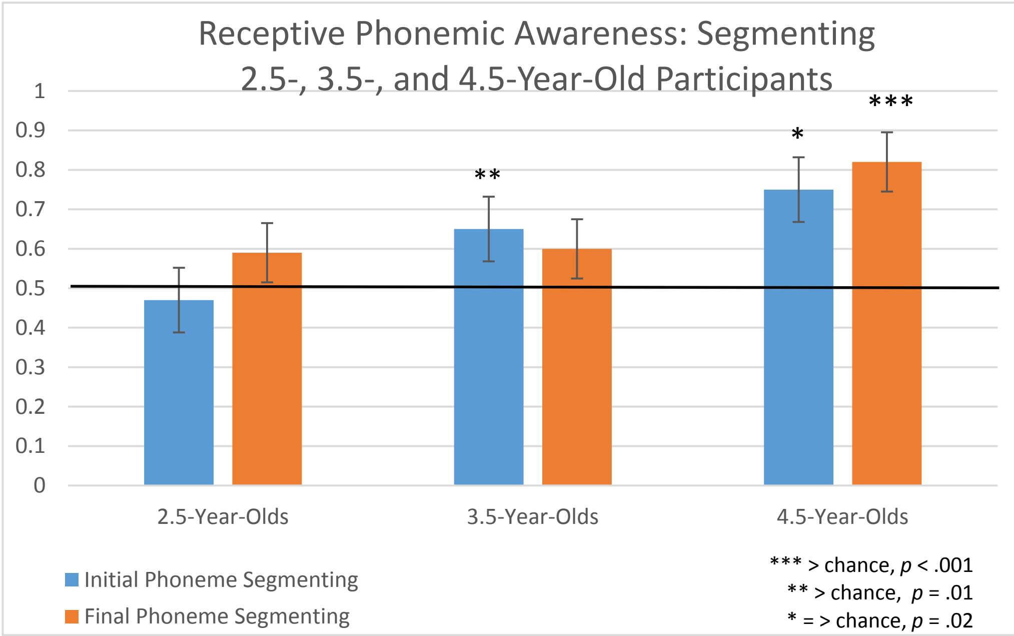

Figure 2
2.5-, 3.5- and 4.5-year-old proportion of correct responses within initial- and final-phoneme segmenting conditions (chance = .50).

We conducted a 2 (initial- v. final-phoneme) X 3 (2.5- v. 3.5- v. 4.5-year-olds) Repeated Measures ANCOVA, using vocabulary scores from the PPVT-4 as a covariate. The model yielded a significant main effect of age ($F(2, 54) = 4.14$, $p < .05$; $\eta^2 = .13$), indicating improvement across the three ages, but no effect of phoneme contrast placement, and no interaction. The effect of PPVT-4scores on performance did not reach significance ($F(1,54) = 3.0$, $p = .09$).

Receptive Measure: Blending Results

Figure 3 depicts the mean proportion of correct responses on the Receptive Phonemic Awareness Blending task for 2.5-, 3.5-, and 4.5-year-old children, shown separately for initial-phoneme and final-phoneme discrimination trials. As reported in Kenner et al. (in preparation), 2.5-year-olds responded overall at rates that exceeded chance, although this overall finding was driven by above-chance performance on only *final*-phoneme blending trials. We reported that 3.5-year-olds also responded at overall rates that exceeded chance, however they performed at above chance rates on *both* initial- and final-phoneme trials. Here we also assessed the accuracy of 4.5-year-old children's performance on the receptive blending task by conducting comparisons to chance (.5 given the two alternative forced-choice paradigm). Using this small sample ($n = 8$) the current study revealed that 4.5-year-old participants also responded overall at rates that exceeded chance on blending trials ($M = .80$, $SD = .20$; $t(7) = 4.65$, $p < .01$; d = 2.12). Like 3.5 year olds, 4.5-years-olds performed at above chance rates on both initial- ($M = .75$, SD = .29; ($t_{initial}(7) = 2.83$, $p < .05$; d = 1.22), and final- ($M = .86$, $SD = .28$; $t_{final}(7) = 3.97$, $p < .01$; d = 1.82) phoneme blending.

To confirm this apparent developmental trajectory, we explored how performance varied as a function of phoneme contrast placement (initial v. final phoneme discrimination) by age (2.5-year-olds v. 3.5-year-olds v. 4.5-year-olds). We conducted a 2 (initial- v. final-phoneme) X 3 (2.5- v. 3.5- v. 4.5-year-olds) Repeated Measures ANCOVA, using vocabulary scores from the PPVT-4 as a covariate. The model yielded a significant main effect of age ($F(2, 54) = 3.90$ p < .05; $\eta^2 = .13$), but no effect of phoneme contrast placement, and no interaction. There was no effect for the PPVT-4 ($F(1,54) = ..87$, $p = .36$).

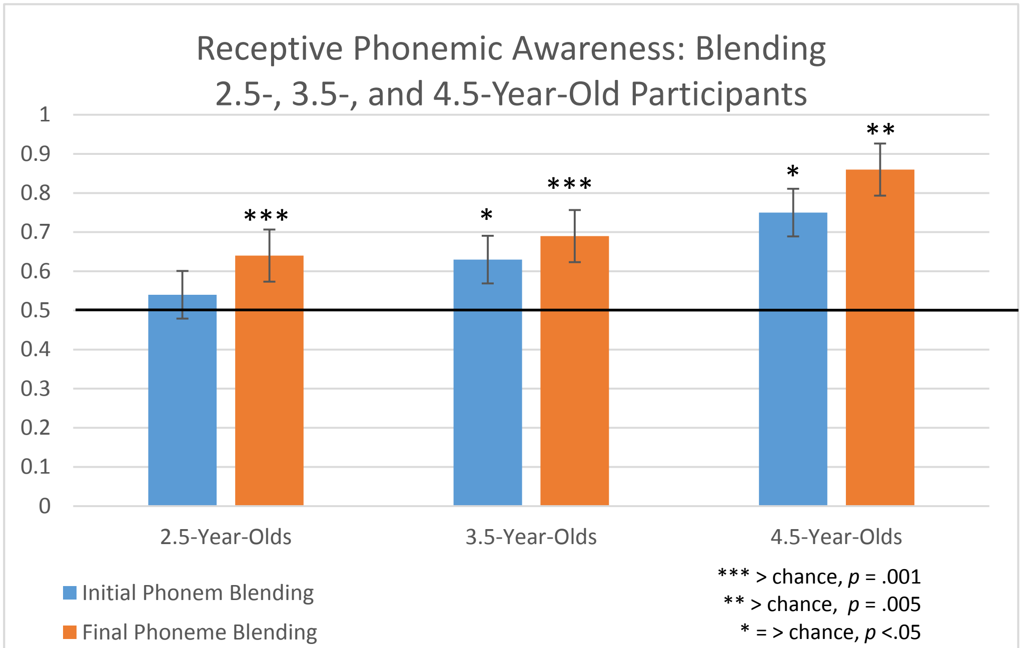

Figure 3
2.5-, 3.5-, and 4.5-year-old proportion of correct responses within initial- and final-phoneme blending conditions

Child Cognitive and Behavioral Variables

Descriptive Statistics:

Descriptive statistics for the child cognitive and behavioral variables, the PPVT and the Working Memory measure, are displayed in Table 1. The sample consisted of 58 children ranging in age from 2.41- to 4.67-years-old. We were only able to obtain working memory measures from seventeen of the 25 2.5-year-old participants, leaving 50 participants for whole sample analyses involving working memory. Raw scores for the working memory task were calculated out of 27 total possible points. Participants demonstrated average to high-average IQ as indexed by the standardized PPVT scores, reflecting the relative homogeneity of the SES of our sample. We were only able to obtain PPVT scores from 17of the 25 2.5-year-old participants. The population standard mean of 100 was utilized to fill in the eight missing data points, as a more conservative estimate than the elevated observed sample mean of 114 for 2.5-year-olds who actually completed the measure.

TABLE 1.
Descriptive Statistics for Child Cognitive Variables by Age

	Measures	Standardized/ Z-Scores		Raw Scores		Range	
Sample Sizes	**PPVT**	*M*	*SD*	*M*	*SD*	*Min*	*Max*
n = 25	2.5-year-olds	108.52	10.75	-	-	94	128
n = 25	3.5-year-olds	114.56	10.6	-	-	95	137
n = 8	4.5-year-olds	120.25	10.93	-	-	103	138
Sample Sizes	**Working Memory**						
n = 17	2.5-year-olds	0.0003	1.0	8.59	6.28	0	23
n = 25	3.5-year-olds	0.14	0.92	15.28	7.1	0	25
n = 8	4.5-year-olds	-0.0008	1.0	18.63	6.37	10	24

Pearson Correlations: Child Cognitive and Behavioral Measures

Pearson Correlation between Cognitive Measures and DIBELS Performance

Table 2 presents the correlation matrix for child cognitive variables and the standardized behavioral measures of phonemic awareness, DIBELS Phoneme Segmentation Fluency, for 3.5- and 4.5-year-old participants. There is a significant correlation between the PPVT-4 and working memory, and a significant correlation between the PPVT-4 and performance on the DIBELS. This replicates previous findings regarding the relationship between PPVT and the DIBELS but extends the ages at which this correlation holds downward relative to previous research. However, the correlation between working memory and DIBELS performance was not significant.

Regression analyses were performed to further examine the unique contributions of each measure given that PPVT and WM were highly correlated. We ran a multiple regression analysis with both PPVT-4 and Working Memory combined as predictor variables. Neither of these variables were significant independent predictors of DIBELS performance ($\beta_{PPVT} = .29$, $t(30) = 1.43$, $p > .05$; $b_{memory} = .40$, $t(30) = .80$, p > .05). Together they did approach significance as variables that contribute to variance in the DIBLES accounting for approximately 17% variance in performance ($R^2 = .17$, F(2,29) = 2.90, p = .07).

TABLE 2
Pearson Correlations for Child Cognitive and DIBELS Phoneme Segmentation Fluency in 3.5- and 4.5-year-olds

	WM	PPVT	DIBELS
Working Memory (WM)	1	.586**	.331
PPVT-4 (PPVT)		1	.385*
DIBELS (DIBELS)Segmentation Fluency			1

** p < 0.001

* $p < 0.05$

Correlations between Cognitive Measures and Receptive Phonemic Awareness Measures

Table 3 presents the inter-correlation matrix for child cognitive variables and the experimental receptive behavioral measures of phonemic awareness for all participants. As in the previous analysis including only the 3.5 and 4.5 year olds who completed the DIBELS, PPVT scores were significantly correlated with working memory ($r = .51$, $p < .01$) for the entire sample. Using simple correlations, PPVT scores were also reliably correlated with performance on the receptive segmenting task, but not the receptive blending task. Working memory is significantly correlated with performance on both the receptive segmenting and the receptive blending tasks. These correlations were bolstered by multiple regression analyses.

First, we regressed proportion correct on the segmenting task on PPVT and memory. We found that these predictors together accounted for approximately 20% variance in segmenting performance ($R^2 = .18$, $F(2,47) = 5.26$, $p < .01$). Memory was the only variable in the model that was a significant, unique predictor of performance on the segmenting task ($b = .13$, $t(48) = 2.31$, $p < .05$). Controlling for the PPVT, we found that working memory significantly accounted for approximately 10% unique variance in segmenting performance over and above our proxy for general intelligence ($R^2_{change} = .09$, $F(2, 47) = 5.26$, $p < .01$).

Next, we regressed proportion correct on the blending task on PPVT and memory. We found that these predictors together significantly accounted for 13% of the variance in blending performance ($R^2 = .13$, $F(2,47) = 3.39$, $p < .05$). Neither of these variables were significant independent predictors of performance on blending trials in the model ($\beta_{PPVT} = .12$, $t(48) = .72$, $p = .48$; $b_{memory} = .01$, $t(48) = 1.75$, p = .09). We suspect that this was due to a decrease in power from missing memory measure data when adding the working memory variable, listwise, into the model. When controlling for PPVT scores, working memory did account for 6% unique variance over and above the PPVT ($R^2_{change} = .06$, $F(2, 47) = 3.39$, $p < .05$).

Table 3
Pearson Correlations for Child Cognitive and Experimental Receptive Behavioral Measures

Measures	PPVT	WM	Segmenting	Blending
PPVT	-	.506**	.337**	0.252
Memory (WM)		-	.424**	.335*
Segmenting			-	.599**
Blending				-

** $p < 0.01$
* $p < .05$

Home Language and Literacy Environment Questionnaire Results

Descriptive statistics for each of the Home Language and Literacy Environment variables organized by environmental conceptualization derived from past literature are presented in Table 4. We were missing parts of questionnaire data for one parent, and a second parent opted not to complete the questionnaire. Additionally, we had to exclude the Title Recognition Test results for one parent due to experimenter error in omitting one page of the test.

Table 4.
Descriptive Statistics for Limiting Literacy Environment Variables

	Indices		Raw Scores			Range	
Sample Size	**Limiting HLE**	**Scale**	*Mean*	*Median*	*SD*	*Min*	*Max*
n = 51	Parent Ed	Ordinal (1-6)	4.88	6.0	1.23	2.0	6.0
n = 51	Grandmother Ed	Ordinal (1-6)	3.73	4.0	1.44	1.0	6.0
n = 52	Grandfather Ed	Ordinal (1-6)	4.04	4.0	1.51	1.0	6.0
n = 51	# Books in Home	Ordinal (0-4)	3.24	4.0	1.24	0.0	4.0
n = 52	Library Freq.	Ordinal (0-5)	1.19	1.0	1.16	0.0	4.0
n = 52	Title Recog. Test	Interval	24.31	23.0	12.09	3.0	70.0
	Passive HLE						
n = 51	SeesParentReadPleasureFreq.	Ordinal (0-5)	3.61	4.00	1.54	0.0	5.0
n = 52	SeesParentReadNewsPaperFreq.	Ordinal (0-5)	2.63	3.00	1.68	0.0	5.0
n = 51	SeesParentWithElectronicsFreq.	Ordinal (0-4)	3.22	4.00	1.14	0.0	4.0
	Active, Informal HLE						
n = 52	Telling fictional Stories	Ordinal No/Yes (0-1)	0.29	0.00	0.46	0.00	1.00
n = 52	Talking about the Day	Ordinal No/Yes (0-1)	0.94	1.00	0.24	0.00	1.00
n = 52	Pretend Talking	Ordinal No/Yes (0-1)	0.52	1.00	0.50	0.00	1.00
n = 52	Reading Picture Books	Ordinal No/Yes (0-1)	0.78	1.00	0.43	0.00	1.00
n = 52	Singing Songs	Ordinal No/Yes (0-1)	0.85	1.00	0.36	0.00	1.00
n = 52	Talk about Objects in Environ.	Ordinal No/Yes (0-1)	0.92	1.00	0.27	0.00	1.00
	Active Formal HLE						
n = 52	Teach to Read Words	Ordinal (0-1)	0.54	1.00	0.50	0.00	1.00
n = 52	Teach Letter Sounds	Ordinal (0-1)	0.69	1.00	0.47	0.00	1.00
n = 52	Teach Letter Names	Ordinal (0-1)	0.92	1.00	0.27	0.00	1.00
n = 52	Teach to Print Letters	Ordinal (0-1)	0.44	0.00	0.50	0.00	1.00
n = 52	Total Reading Activities	Interval	3.44	3.00	1.61	0.00	6.00

Limiting Literacy Environment

Our Limiting Literacy Environment variables include: primary parent/guardian's education level, primary parent/guardian's parents' (i.e., the child's grandparents') education levels, number of books in the home, frequency of library visits, and scores on the revised version of the Children's Title Recognition Test. Analysis of intercorrelations among the indices revealed only a correlation between Title Recognition Test (TRT) scores and number of books in the home ($r = .39$, $p = .01$). We employed Spearman correlation to examine relations between measures of phonemic awareness and the variables in the Limiting Literacy Environment indices and Pearson correlation analyses for the TRT. None of the Limiting Literacy Environment Indices nor the TRT were correlated with performance on the DIBELS Phoneme Segmentation Fluency task. There were also no significant correlations between any of our Limiting Literacy Environment indices and either the segmenting or blending versions of the receptive phonemic awareness measures.

Passive Literacy Environment Variables

The Passive Literacy Environment items in the questionnaire include: the frequency with which children see their primary parent/guardian reading for pleasure, the frequency with which children seen their primary parent/guardian reading a newspaper or magazine, and the frequency with which children see their primary parent/guardian engaging with an electronic device such as a cell phone or tablet. Each Passive Literacy Environment variable was measured on an ordinal scale. The first two variables range from 'Almost Never' (score = 0) to 'Daily' (score = 5). The last variable ranges from 'No More than Weekly' (score = 0) to 'Many Times per Day' (score = 4). Spearman correlation analyses revealed no significant correlations between any indices of the Passive Literacy Environment and performance on the DIBELS or receptive phonemic awareness measures.

Active Home Literacy Environment – Informal Language and Literacy Practices Variables

Active, informal, literacy practice indices include questions pertaining to whether parents regularly engage in any of the following six language play-based activities: Talking about objects in the environment (e.g. a bird outside or a truck on the road), singing songs, reading picture books, "pretend talking" with dolls, puppets, or other toys, telling fictional stories orally, and talking about their child's day. Each of these variables was scored dichotomously with 'yes' indicating consistent parental engagement in the particular behavior, and 'no' indicating that the parent does not frequently engage in the particular behavior or practice. We ran independent t-tests comparing mean DIBELS performance of 3.5- and 4.5-year-old participants whose parents indicated that they did v. did not participate in each these activities. There were no significant mean differences in performance on the DIBELS for participants who did vs. did not engage in any of the active informal indices.

When including all age groups in the analyses for the receptive measures, we found a reliable difference in segmenting performance for participants whose parents indicated they do (M = .73, SD = .20) v. do not (M = .59, SD = .20) engage in telling fictional stories orally to their children, $t(50) = 2.19$, $p < .05$; d = .62). Similar results were found for the mean difference in blending performance between those participants whose parents do (*M* = .79, *SD* = .18) v. do not (*M* = .60, *SD* = .19) tell oral fictional stories to their children ($t(50) = 3.41$, p < .01; d = .96).

These results were bolstered by a linear regression analysis which found that the 'telling fictional stories orally' index significantly predicted performance on both segmenting ($b = .13$, $t(50) = 2.19$, $p < .05$) and blending ($b = .19$, $t(50) = 3.41$, $p < .01$) trials, accounting for approximately 10% of the variance in segmenting performance ($R^2 = .09$, $F(1,50) = 4.79$, $p = .03$), and approximately 20% of the variance in blending performance ($R^2 = .19$, $F(1,50) = 11.62$, $p < .01$).

Active Home Literacy Environment – Formal Literacy Practices Variables

Parents were asked to indicate whether they engage directly in teaching any of the following literacy skills to their children: Letter names, letter sounds, printing letters, reading words, reading sings or logos in the environment. Any additional specific reading related teaching activities could be indicated through an "other" open response option. Open responses were included in a composite "total reading related teaching activities" variable that tallied the total number of open responses plus the total number of reading-related activities indicated as 'yes' in this specific questionnaire item.

We conducted and independent samples t-test to compare mean DIBELS performance for 3.5- and 4.5-year-old participants whose parents indicated they do v. do not engage in each of the active formal literacy activities. Assuming unequal variance, we found that there was a significant difference in DIBELS performance for those participants whose parents indicated that they do (*M* = 12.67, *SD* = 18.31) v. do not (*M* = 2.09, *SD* = 4.30) teach their child to read words ($t(24) = 2.51$, $p < .05$; d = 1.02). When entering these data into a linear regression model, this index is not a significant predictor of performance on the DIBELS.

Next we conducted independent samples t-tests to compare mean performance on receptive segmenting tasks between those participants whose parents indicated that they do v. do not engage in each of the formal literacy practices of the Active Home Language and Literacy Environment listed above. These analyses included participants in all three age groups. We found significant mean differences in both segmenting ($t(50) = 2.45$, $p = .02$; d = .69) and blending trials, (assuming unequal variance), ($t(48) = 2.22$, $p < .05$; d = .64) between participants whose parents do ($M_{segmenting} = .69$, $SD = .21$; $M_{Blending} = .71$, SD = .23) v. do not ($M_{segmenting} = .56$, $SD = .18$; $M_{Blending} = .59$, $SD = .15$) teach their children to read words.

The ‘teach child to read words’ index was a significant predictor of receptive phoneme segmenting trials ($b = .14$, $t(50) = 2.45$), accounting for 11% of the variance in performance on this trial type (($R^2 = .11$, $F(1,50) = 6.0$, $p = .02$). This index also significantly predicted success on blending trials ($b = .12$, $t(50) = 2.15$), accounting for 9% of the variance in blending performance ($R^2 = .09$, $F(1,50) = 4.62$, $p < .05$).

We also found significant mean differences in both segmenting ($t(50) = 3.06$, $p < .01$; d = .87) and blending performance, (assuming unequal variance), ($t(48) = 2.15$, $p < .05$; d = .62) between participants whose parents do ($M_{segmenting} = .68$, $SD = .20$; $M_{Blending} = .69$, $SD = .23$) v. do not ($M_{segmenting} = .51$, $SD = .17$; $M_{Blending} = .59$, $SD = .12$) teach letter sounds to their children. This index was a significant predictor of segmenting ($b = .18$, $t(50) = 3.06$, p < .01) trials only, accounting for 16% of the variance in segmenting performance ($R^2 = .16$, $F(1,50) = 9.34$, $p < .01$).

Pearson correlations revealed that the total composite for reading related, parent directed teaching activities was correlated with segmenting trials (r = .46, p = .001), accounting for approximately 20% of the variance in performance (R^2 = .21, F(1,50 = 13.10, p < .01). The composite score did not reliably predict performance on blending trials.

External Language and Literacy Environment Variables

We indexed children's external language and literacy environments by asking questions that measured the amount of time spent in childcare, including care outside of the home, or by someone other than the primary care provider. We also indexed the total amount of time spent immersed in a second language other than their primary language, if applicable. The first variable was ordinal, progressing from 'no care outside of the home' (score = 0) to 'full-time care outside of the home, 4- to 5- days/week for full days' (score = 6). The second variable was scaled based on the actual number of hours spent immersed in another language outside of the home. There were no significant correlations between any indices and performance on any of the phonemic awareness tasks.

3.6 Discussion

The current study was motivated by our initial finding that 2.5- and 3.5-year-old children exhibit knowledge of receptive versions of phonemic awareness (Kenner, Friehling, & Namy, in preparation), and that this knowledge follows a developmental trajectory from tentative success on blending measures at 2.5-years-old to success on the blending task and emerging success on the segmentation task by 3.5-years-old. Guided by these findings, the current study had two primary aims: 1) to further validate the receptive phonemic awareness measures employed, and developmental trajectory observed in our primary study by extending the paradigm to include a small sample of 4.5-year-old children, and 2) to examine the cognitive and environmental factors that contribute to receptive phonemic awareness development during these years in ontogeny.

We began the study with an examination of receptive phonemic awareness development in 4.5-year-old children and compared their performance to the 2.5- and 3.5-year-old children from our primary study. At 4.5-years-old, children performed at above chance rates on all receptive measures of phonemic awareness, confirming the predicted developmental progression. This finding validated our experimental, receptive phonemic awareness measures, demonstrating systematic growth in mastery across the three ages.

That younger children succeeded only on the receptive measures whereas 4.5-year-old children exhibited successful performance on both the receptive measures and the production-based phonemic awareness task demonstrates that there are multiple phonemic representational capacities developing simultaneously over time. In contrast to an account of children’s phonological awareness development as transitioning from success on larger phonological units (e.g. syllables or rhymes) to smaller units (e.g. phonemes), our findings indicate that this developmental transition is likely not based on phonological unit size, but rather the transition from receptive understandings, to explicit access to verbal report.

These findings have important implications for theory. First, our findings support the need for a paradigm shift in our current thinking surrounding theories of phonological awareness development. Our findings indicate that phonological awareness development likely progresses in a more complex fashion than has been conceptualized by current theories. Specifically, rather than phonological awareness progressing from larger to smaller linguistic units (Anthony, et al., 2003), or through phases (Goswami, 1990), our findings provide evidence that phonemic awareness is evident earlier in development than has previously been conceptualized when indexed with developmentally appropriate, receptive measures that are sensitive to emerging abilities and are not dependent upon performance-based factors.

The current study also challenges the notion that phonemic awareness is an explicit, pre-literacy skill that develops in tandem with the onset of formal reading instruction in the early school-age years. Our work provides evidence that phonemic awareness is more likely a *language ability* rather than a *pre-reading skill*, and that although this ability is ultimately leveraged for the sake of more explicit, reading related tasks (i.e. decoding), it is ultimately a language-based function that develops from infancy and through the early childhood preschool years.

Having validated the receptive phonemic awareness measures, we examined the potential factors that could be contributing to the observed developmental trajectory in these abilities. Guided by the literature on production-based phonological awareness, we decided to examine cognitive, environmental, and sociocultural factors that may predict early phonemic awareness.

Based on prior literature (e.g., Muter & Snowling, 1998), we examined the contribution of working memory to performance on both our experimental, receptive phonemic awareness tasks and the standardized production-based phoneme segmenting measure, DIBELS Phoneme Segmentation Fluency. We found evidence for the unique contribution of working memory, over and above general intelligence on performance in the receptive segmenting scores in our sample, but no significant influence of working memory on blending performance. We suggest that the blending relation may be strengthened by an increase in sample size, but nonetheless speaks to differences in the cognitive demands of segmenting v. blending in receptive measures, with segmenting being a more cognitively demanding task.

It is also worth noting that although working memory did not predict performance on overall blending task performance, an exploratory analysis revealed that there was a significant correlation between working memory and *initial*-phoneme blending trials. This was an interesting result considering our finding that receptive phonemic awareness development appears to follow a trajectory of success on *final*-phoneme blending discriminations at 2.5-years-old, followed by *initial*-phoneme segmenting at 3.5-years-old. We propose that initial-phoneme blending may be a more cognitively taxing task. As a result, at 2.5-years-old, a recency effect may be bolstering performance on final-phoneme discrimination blending trials. Conversely, the receptive segmenting task appears to provoke a primacy effect, such that successful performance on this task emerges later than blending but appears earlier for initial-phoneme discriminations. This relation should be examined further in a larger sample size to increase power in the analyses.

We found no evidence of working memory contributing to performance on the DIBELS Phoneme Segmentation Fluency task, although it should be noted that this finding is not surprising considering the fact that this is a production-based measure that is normed on children 5-years-old and older, and our 3.5-year-old sample performed significantly below the Kindergarten benchmark of 33 correct trials per minute. As such, performance on this task is likely not an accurate reflection of children's emerging phonemic awareness development, as is supported by the findings of receptive phonemic awareness measures, and therefore any relations between working memory and performance on this measure should be interpreted with caution. However, the finding that working memory predicts receptive but not productive phonemic awareness performance at this age underscores how readily early precursors and contributors to pre-reading can be examined with developmentally appropriate measures.

Our analysis of relations between Home Language and Literacy Environment factors and phonemic awareness yielded different patterns for production-based and receptive measures. Aspects of the home language and literacy environment were grouped into four subtypes based on findings from previous literature. The Limiting Literacy Environment was indexed by parental socioeconomic status (e.g., parent education and grandparent education) and attitudes toward literacy (e.g. the number of books in the home and frequency of visits to the library). The Passive Language and Literacy Environment was indexed by literacy-related behaviors that a child observes in the home such as watching a parent read a book for pleasure or read the newspaper. The Active Informal Language and Literacy Environment was indexed by parent-led informal language play-based activities and interactions. Finally, the Active Formal Language and Literacy Environment was indexed by specific parent-led literacy based instructional activities such as teaching children to read words or decode letter sounds. We also added an additional environmental conceptualization to our model: The External Language and Literacy Environment, indexed by the amount of time spent in childcare outside of the home, or inside the home by a care provider other than the child's primary parent or guardian and the amount of time spent immersed in a second language.

We found numerous interesting relations between our environmental indices and performance on our receptive phonemic awareness measures, and found that children whose parents engaged in certain language and literacy-based activities performed significantly better on the experimental measures than those whose parents did not engage in the specific activities. The Limiting Literacy Environment, Passive Language and Literacy Environment, and External Language and Literacy Environments were the conceptualizations of the Home Language and Literacy Environment that were not significantly predictive of performance on any of the phonemic awareness tasks. We hypothesize that there were no significant relations, specifically between socioeconomic status indices of this environmental conceptualization and performance on tasks, due to the lack of variability in education levels of parents and grandparents in our sample. However, we did find significant correlations between the number of books in the home and parents' scores on the Title Recognition Test, suggesting that parents were likely generally honest when answering the question on the Home Language and Literacy Environment Questionnaire.

An examination of the Active, Informal Language and Literacy Environment found that the 'Telling Fictional Stories Orally' index was significantly predictive of performance on the experimental receptive phonemic awareness measures, both segmenting and blending trials, accounting for approximately 10% of the variance in segmenting trials and 20% of the variance in performance for blending trials..

Although it is unclear why telling stories specifically might relate to development of phonemic awareness, we propose that this measure may be a strong indicator of overall parental interaction style and may represent consistency of language input in the child’s home. This finding has theoretical implications, as it further supports our argument that phonemic awareness likely develops across ontogeny as a language ability, as opposed to developing at the onset of formal reading instruction as a pre-reading skill.

Two indices of the Active Formal Language and Literacy Environment were also related to receptive phonemic awareness abilities. Both blending and segmenting abilities were significantly predicted by parents' self-reported incidence of teaching letter sounds to their children, as well as parents’ self-reported incidence of teaching their children to read words. We also created a ‘Reading Teaching Activities Total Composite’ index totaling all of the direct instruction literacy-related behaviors indicated by parents and found that this composite significantly predicted receptive segmenting.

Prior literature (Sénéchal & LeFevre, 2014) found that active, formal language and literacy environment practices in Kindergarten were significant predictors of early literacy (i.e., word reading and invented spelling) in 1st grade. However, ours is the first study to report a relation between any parental teaching behaviors and phonemic awareness specifically. Our findings address an important gap in the literature regarding specific home language and literacy environment factors that are directly related to measures of both phoneme segmenting and blending.

That the ‘teaching letter sounds’ index of our active formal environmental conceptualization was predictive of segmenting, but not blending performance, provides some additional validation to our receptive measures and has important implications for practice. First, this index is one of the pre-reading teaching practices that is used in practice to teach phonemic awareness as a skill, with an emphasis on phoneme segmenting. Phoneme segmenting, specifically, is the most significant phonological awareness predictor of early reading achievement in the literature (e.g. Muter et al, 1997). Therefore, it is promising that we are finding parallel results in terms of the explicit, direct practices that support both *receptive* and *productive* segmenting phonemic awareness.

In addition to theoretical implications, the current study has implications for best practices and early intervention at child, family, program, and community levels. We found evidence of cognitive factors at the child level being related to phonemic awareness development. These findings could have implications for practice, as teachers and interventionists can potentially leverage working memory functions when explicitly teaching or remediating phonemic awareness and reading decoding skills. Current best practices suggest that phoneme blending and segmenting tasks be introduced with initial-phoneme identification, isolation, and/or discrimination. However, our evidence indicates that when introducing tasks that require phoneme blending, it may be best to introduced tasks that require word-final phoneme discrimination first. Conversely, when approaching tasks that rely upon phoneme segmentation (i.e., word attack strategies), our evidence suggests that it may be best to introduce word-initial phonemes.

There may also be utility in targeting the enhancement of working memory itself. Recent research indicates that working memory, which was once thought to be a static cognitive function (e.g. Miller, 1956), is plastic, and can therefore be exercised and trained through extended adaptive programs and interventions that target the frontal and parietal cortex areas of the brain, as well as the basal ganglia, and can increase productivity of the executive functions (see Klingberg, 2010 for a review). The current study provides evidence to warrant further examination of the importance of working memory in the development of phonemic awareness, and the eventual development of skilled, fluent reading. It also provides support for the development of early intervention programs that target both explicit skill knowledge and use, and exercise of the cognitive functions, particularly working memory.

The findings from our home language and literacy environment have implications for practice as well. Our results indicate that phonemic awareness development is being supported not only by cognitive development, but also language input in the home. The relation between the Active Informal indices of our home language and literacy environment provide support for the importance of language usage in the home and elsewhere. Children whose parents reported more consistent engagement in language-based activities performed better on phonemic awareness tasks than those whose engagement was less intentional. Accordingly, it is important that both parents and early childhood educators be aware of their potential role in shaping children’s phonemic awareness development through basic, everyday language-based activities.

Similarly, our found relations between the Active Formal language and literacy environment and phonemic awareness development have implications for practice as well. If phoneme segmentation is the phonological awareness skill most predictive of early reading achievement in the literature, it may be important that we begin indexing this ability early in development, and intervene when necessary. Our results indicate that the same teaching behavior that is used to teach explicit phonemic awareness in school age children (i.e. letter sounds) is a significant predictor of phonemic awareness development in younger children. Although we do not advocate for “skill and drill” practices with toddler and pre-school age children, these findings could inform the development of developmentally appropriate assessment and intervention practices to support children who are at-risk for reading failure at a point in ontogeny that is earlier than currently feasible. These results could inform early intervention practices for children at ages much younger than currently feasible, and could inform wide-scale early childhood education reform efforts at child, family, program, and community levels.

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CHAPTER 4: Grand Discussion

4.1 Motivation

This dissertation was motivated by the goal of elucidating the early development of phonemic awareness, one of the pre- reading skills most predictive of early reading achievement in the literature. This was achieved by 1) addressing the extent to which performance-based factors (i.e., using production-based measures) may result in underestimates of children's early phonemic awareness skills, and 2) investigating the cognitive, environmental, and sociocultural factors that may contribute to the development of such skills. I addressed these goals with several primary aims nested within two separate manuscripts. Manuscript 1 was written with the aims of **1) investigating the developmental progression of phonemic awareness, both receptively and productively, in 2.5- and 3.5-year old children, and 2) determining whether *receptive* phonemic awareness abilities are consistent across blending (i.e., /k/ /æ/ /t/ → cat) and segmenting (i.e., cat → /k/ /æ/ /t/) tasks**. The second manuscript served as a follow-up, validation study to further examine the developmental trajectories observed in manuscript 1 by including a small sample of 4.5-year-old participants in the paradigm, and examined the cognitive, environmental, and sociocultural factors that may contribute to the development of phonemic awareness. Accordingly, the aims of manuscript 2 were 1) **To investigate the developmental progression of phonemic awareness, both receptively and productively, in 2.5-, 3.5-, and 4.5-year-old children**, **2) To examine the contribution of individual differences in overall cognitive functioning to 2.5-, 3.5-, and 4.5-year-old children's receptive phonemic awareness development, and 3) To examine the contribution of**

the home language and literacy environment and socioeconomic status to 2.5-, 3.5-, and 4.5-year-old children's phonemic awareness development.

4.2 Manuscript 1 Summary of Findings

The findings from Manuscript 1 revealed that when using developmentally appropriate, receptive measures, children indeed demonstrated evidence of emerging phonemic awareness as young as 2.5 years of age. Specifically, although 2.5-year-olds exhibited comprehension of phonemic awareness in *blending* tasks, this ability was fragile and reliable only on phoneme-final trials, and their responses did not differ from chance on the *segmenting* task. In contrast, I found strong evidence of blending ability in 3.5-year-olds for both initial and final phoneme trials, and evidence of segmenting ability as well. However 3.5-year-olds' segmenting performance was only reliably above chance in initial phoneme discrimination trials. These findings indicated that, contrary to prevailing wisdom, there is emerging phonemic awareness prior to the age of 4, and that this emerging ability follows a predicted developmental progression of success when developmentally appropriate, receptive phonemic awareness measures are employed.

In addition to examining receptive phonemic awareness development, Manuscript 1 examined 3.5-year-olds' performance on a production-based phonemic awareness measure. As I hypothesized, despite 3.5-year-old children's accurate performance on the *receptive* phonemic awareness segmenting measures, this age group exhibited floor effects on the standardized productive DIBELS Phoneme Segmentation Fluency task. My argument that receptive measures capture emerging ability that is not detected in productive measures implicates task demands as the basis for prior studies' failure to find evidence of phonemic awareness at these ages. Further validation of these receptive measures comes from the fact that the receptive phonemic awareness measure findings mirror the developmental progression of traditional productive phonemic awareness measures, with accurate production-based *blending* abilities appearing earlier in ontogeny than production-based *segmenting* abilities (Yopp & Yopp, 2000). Importantly, the PPVT-4, our proxy for general intelligence had no significant effects on children's performance on any of the phonemic awareness measures, indicating that specialized cognitive functions beyond general intelligence were likely driving performance on these tasks. Collectively, the findings from Manuscript 1 indicated that 2.5- and 3.5-year-old children have stored phonemic representations that, although not exhibited in production-based tasks, can be indexed through more developmentally appropriate receptive measures.

More broadly, Manuscript 1 addressed important gaps in the literature regarding phonemic awareness development in young children, the skill most predictive of future reading achievement. Traditional theories of phonemic awareness development argue that phonemic awareness is a skill that develops later in ontogeny than many other aspects of pre-reading (such as RAN of letters and objects) and is the final precursor necessary to begin skilled reading. The overarching belief to date is that phonological awareness begins at the word level, and development is characterized by incremental sensitivity to smaller units of sound discrimination with age, moving from word awareness, to syllable and/or rhyme awareness, and finally to the level of the individual phoneme (e.g., Anthony, Lonigan, Driscoll, Phillips, & Burgess, 2003). An alternative model posited by Goswami (1990)argues that children pass through phases (i.e., Phase 1 – rhyme and alliteration awareness during the preschool years, followed by Phase 2 - phoneme level knowledge and phonemic awareness during the early school-aged years, and ultimately Phase 3 – fluent skilled reading). Accordingly, phonemic awareness --involving discrimination at the level of the smallest meaningful unit-- has traditionally been conceptualized as a sub-skill of phonological awareness that emerges during the school-aged years in tandem with explicit, formal reading instruction.

Based on decades of findings in the infant speech perception literature pointing to the precision with which infants attune perceptually to phonemic speech content (e.g. Kuhl et al., 2005; Werker & Tees, 2002) and the striking finding that 7-month-old native phonetic discrimination predicts 5-year-old phonological awareness (Cardillo, 2010), I hypothesized that contrary to these conventional theories and beliefs, phonemic awareness development begins in infancy and transitions through gradually more explicit and verbally accessible forms. Further, I suggested that current theories of phonological awareness development, including phonemic awareness, are based on an impoverished view of the developmental trajectory, limited by the measures used to assess such skills. Measures of phonological awareness have traditionally been production-based, requiring explicit oral production of word form, and/or other performative skills such as counting or tapping. Wackerle-Hollman and colleagues (2015) support the argument that production-based measures may underestimate phonological awareness. They found that when children were given both productive and receptive phonological awareness tasks, performance on receptive tasks was overall higher than performance on production tasks, and children appeared to comprehend receptive task expectations with more clarity.

My theoretical basis for proposing incremental development of phonemic awareness from a receptive form of knowledge to a productive form of knowledge was anchored to Annette Karmiloff-Smith’s (1992) Representational Redescription (RR) Model, which postulated that early implicit knowledge, with use, becomes increasingly more explicit and available to verbal report. Cardillo's (2010) findings are consistent with a gradual transition from implicit to more explicit phonemic awareness that ultimately results in access to verbal report. However my findings flesh out the developmental trajectory of the intermediary early childhood years predicted by the RR model, demonstrating that a measurable intermediate level of explicit but verbally inaccessible phonological awareness emerges during the toddler and preschool years.

4.3 Manuscript 2 Summary of Findings

Manuscript 2 began with a continued examination of the developmental trajectories of receptive phonemic awareness identified in Manuscript 1, by extending my work to 4.5-year-old participants. Utilizing a small sample (to be bolstered with additional participants prior to manuscript submission) of 4.5-year-old participants, I further validated the receptive measures employed and developmental trajectories observed in my first study, showing that –as predicted-- by 4.5-years-old, children performed at above chance rates on all receptive measures of phonemic awareness, with a significant effect of age on segmenting trials across these three age groups.

Additionally, although 3.5-year-old children still exhibited poor performance on the production-based phonemic awareness task, there was evidence of growth from 3.5- to 4.5-years-old, indicating that production-based phonemic awareness also may following an age-sensitive trajectory prior to the ages at which this task is typically employed.

Next, based on the predictive relations found in prior literature between verbal working memory and productive phonemic awareness tasks when controlling for IQ (e.g. Muter & Snowling, 1998), I examined the potential individual cognitive differences that could have impacted performance on all receptive and productive phonemic awareness tasks employed in my studies. Accordingly, I developed a receptive, verbal working memory measure to examine the extent to which working memory was impacting performance on phonemic awareness development in all ages. Although PPVT-4 scores and working memory measures in our sample were highly correlated, when running a regression analysis and controlling for IQ, we found evidence for the unique contribution of working memory, over and above, general intelligence to performance on the receptive segmenting task.

It should be noted that we found no evidence of working memory contributing to performance on the DIBELS Phoneme Segmentation Fluency task. However, this finding was not surprising considering the fact that this is a production-based measure that is normed on children 5-years-old and older so there were floor effects masking any potential relations to working memory.

Finally, the second manuscript examined the contributions of the home language and literacy environment and sociocultural factors on phonemic awareness development. Guided by the charge from prior literature to extend our knowledge of the specific aspects of the home language and literacy environment that are predictive of language and literacy development (Whitehurst & Lonigan, 1998), I divided the

Home Language and Literacy Environment into sub-contexts. Using a combined model of Burgess, Burgess, Hecht, and Lonigan's (2002), and Sénéchal, M., & LeFevre's, (2002, 2014) conceptualizations of the Home Literacy Environment, I developed a Home Language and Literacy Environment questionnaire that indexed specific environmental exposures and experiences, as well as parental behaviors in multiple contexts. The Limiting Literacy Environment was indexed by parental socioeconomic status (e.g., parent education and grandparent education) and attitudes toward literacy (e.g., the number of books in the home and frequency of visits to the library). The Passive Language and Literacy Environment was indexed by literacy-related behaviors that a child observes in the home such as watching a parent read a book for pleasure or read the newspaper. The Active Informal Language and Literacy Environment was indexed by parent-led informal language play-based activities and interactions. Finally, the Active Formal Language and Literacy Environment was indexed by specific parent-led literacy based instructional activities such as teaching children to read words or decode letter sounds. I also added an environmental conceptualization to the model: The External Language and Literacy Environment, indexed by the amount of time spent in childcare outside of the home, or inside the home by a care provider other than the child's primary parent or guardian. Although these measures are all parental self-report, I did find significant correlations between the number of books parents reported in the home and parents' scores on the Title Recognition Test, providing at least some indication that parents were likely generally honest when answering the question on the Home Language and Literacy Environment Questionnaire. I found several significant and interesting relations between our environmental indices and performance on my receptive phonemic awareness measures.

No elements of the Limiting Literacy Environment, the Passive Language and Literacy Environment, or the External Language and Literacy Environment were significantly predictive of performance on phonemic awareness tasks. I suspect that there were no significant relations, specifically for those aspects of environment that tend to co-vary with socioeconomic status (SES) due to the relative lack of variability in education levels of parents and grandparents (our proxies for SES) in my sample which was more educated in general than the general population.

An examination of the Active, Informal Language and Literacy Environment found that the 'Telling Fictional Stories Orally' index was significantly predictive of performance on the experimental receptive phonemic awareness measures for both segmenting and blending trials, accounting for approximately 10% of the variance in segmenting trials and 20% of the variance in blending trials. These findings support our argument that phonemic awareness develops across early ontogeny as a language ability and suggest that incidental learning during informal interactions with parents contribute to heightened phonemic awareness.

Several indices of the Active Formal Language and Literacy Environment were also related to receptive phonemic awareness abilities. The 'Teach Child to Read Words' index significantly predicted both receptive segmenting and blending composites, whereas the 'Teach Letter Sounds' indices only predicted segmenting composite scores.

I also created a 'Reading Teaching Activities Total Composite' index combining all of the direct instruction literacy-related behaviors indicated by parents. I found that this composite significantly predicted receptive segmenting performance. There were no significant predictive relations found between any of our Active Formal Language and Literacy Environment indices and performance on the DIBELS. These findings are noteworthy, as we have elucidated factors that contribute to phonemic awareness development only as indexed by *receptive* phonemic awareness. Relying upon only production-based measures of phonemic awareness has obscured the emerging phonemic representations that are present earlier in ontogeny than has traditionally been conceptualized and the environmental factors that may support them.

4. 4 Implications for Theory and Practice

The collective findings from this dissertation have extensive implications for both theory and practice. First, my findings support the need for a paradigm shift in our current thinking surrounding theories of phonological awareness development. My findings indicate that phonological awareness development likely progresses in a more complex fashion than has been conceptualized by current theories. Specifically, rather than phonological awareness progressing from larger to smaller linguistic units as argued by Anthony, et al. (2003), or through phases as has been posited by Goswami (1990), my findings provide evidence that phonemic awareness is evident earlier in development than has previously been conceptualized. My findings suggest that the smallest units of phonological awareness are present in children's representations continuously across development, and that developmental change is a process of explicitization as opposed to phonological unit size. It is also possible that the developmental trajectories observed in my work are due to both the explicitization process of phonemic awareness development, and a heightened robustness of children's linguistic representations across development. It may be that as children's phonemic category representations tighten or become less sparse, this access to a greater variety of linguistic forms facilitates the mechanistic process of explicitization. In other words, these two processes may be influencing phonemic awareness development in a non-mutually exclusive fashion.

Importantly, these new insights regarding the developmental trajectory of phonemic awareness were only possible because of the development of new, sufficiently sensitive, developmentally appropriate measures that could index earlier knowledge. Receptive measures that are sensitive to emerging abilities and are not dependent upon performance-based factors reveal critically important new information that directly impacts our understanding of the development of phonemic awareness.

Consequently, my work challenges the theoretical assumption that phonemic awareness is an explicit, pre-literacy skill that develops in tandem with the onset of formal reading instruction in the early school-age years. My findings provide evidence that phonemic awareness more likely develops as a *language ability* as opposed to a *pre-reading skill*, and that although this ability is ultimately leveraged for the sake of more explicit, reading related tasks (e.g. reading decoding), it is ultimately a language-based function that develops from infancy and through the early childhood preschool years, given the ideal environmental (and other inputs), including what has recently been referred to in the literature as adequate "language nutrition" (Zauche et al., 2016).

That the ‘teaching letter sounds’ index of our active formal environmental conceptualization was predictive of segmenting, but not blending performance, provides some additional validation to our receptive measures and has important implications for practice. First, this index is one of the pre-reading teaching practices that is used in practice to teach phonemic awareness as a skill, with an emphasis on phoneme segmenting. Phoneme segmenting, specifically, is the most significant phonological awareness predictor of early reading achievement in the literature (e.g. Muter et al, 1997). Therefore, it is promising that I found parallel results in terms of the explicit, direct practices that support both *receptive* and *productive* segmenting phonemic awareness. As such, although I do not advocate for “skill and drill” practices with toddler and pre-school age children, these findings could inform the development of developmentally appropriate assessment and intervention practices to support children who are at-risk for reading failure at a point in ontogeny that is earlier than currently feasible.

Cognitive factors at the child level were significantly related to phonemic awareness development. Specifically, despite the shared variance found between PPVT scores, (our proxy for general intelligence), and working memory, working memory alone contributed significantly to performance on the receptive segmenting tasks, accounting for approximately 10% of the variance in composite receptive segmenting scores, over and above general intelligence. This was an interesting result considering our finding that receptive phonemic awareness development appears to follow a trajectory of success on *final*-phoneme blending discriminations at 2.5-years-old, followed by *initial*-phoneme segmenting at 3.5-years-old. I propose that at 2.5-years-old, a recency effect may be bolstering performance on final-phoneme discrimination blending trials. Conversely, the receptive segmenting task appears to provoke a primacy effect, such that successful performance on this task emerges first with initial-phoneme discriminations.

The findings from these studies provide additional insights about how the early language and literacy environment impacts the development of phonemic awareness. My work replicates prior findings that the home language and literacy environment and parental behaviors likely play a detectable role in the development of early language and pre-reading abilities. However, unlike prior literature that found relations between active formal parental teaching behaviors and early reading abilities, but no relation between such behaviors and phonological awareness measures, I found that the frequency of active, formal parental literacy-related teaching behaviors (e.g. teaching letter sounds or teaching children to read words) was related directly to my receptive measure of phonemic awareness. Further, my work is the first to establish a role for active, *informal* parental teaching behaviors (e.g., telling fictional stories) and phonemic awareness. The use of receptive measures revealed a direct relation between more informal, language usage and play-based activities, and segmenting performance. These findings provide additional support for a shift in our conceptualization of the phonemic awareness as a language *ability* as opposed to a pre-reading *skill*. Phonemic awareness is likely nurtured and cultivated by parents and families across the toddler and preschool years, often quite implicitly on the part of parents without formal tutoring strategies, and this supportive environment is leveraged and utilized to support children's growing explicit understanding and eventual success on performance-based language and literacy-based tasks. It is important to note that this could be a bi-directional relationship such that children who are more cognitively astute, more readily elicit precise communicative feedback from their parents or caregivers during precisely the right moments in development. This mutual exchange may be more motivating to parents, yielding cyclical, serve and return communicative interactions between parent and child that in turn benefit the child's language development.

My findings relating to environmental effects as well as the findings regarding the role of working memory in phonemic awareness performance have implications for best practices and early intervention at child, family, program, and community levels. My findings regarding working memory have implications for practice, as teachers and interventionists can potentially leverage working memory functions when explicitly teaching or remediating phonemic awareness and reading decoding skills. Current best practices suggest that phoneme blending *and* segmenting tasks be introduced with initial-phoneme identification, isolation, and/or discrimination. However, my evidence indicates that it is perhaps best, when introducing tasks that require phoneme blending, to focus initially on discrimination of word-*final* phonemes. Conversely, when approaching tasks that rely upon phoneme segmentation (i.e., word attack strategies), it is likely best to conform to traditional practices of introducing word-initial phonemes.

Furthermore, there has been recent emerging evidence in the literature to indicate that working memory, which has classically been conceptualized as a static cognitive function (e.g. Miller, 1956), is plastic, and can therefore be exercised and trained through extended adaptive programs and interventions that target the frontal and parietal cortex areas of the brain, as well as the basal ganglia, and can increase productivity of the executive functions. (See Klingberg, 2010 for a review). In light of my findings, it may be that early intervention programs should target not only explicit skill knowledge and use, but also the exercise and strengthening of cognitive functions, particularly working memory.

4.5 Future Directions

Collectively, my dissertation findings call for a shift in our conceptualization of phonemic awareness as a pre-reading skill that develops in the early school years with the onset of early reading instruction. My work indicates that contrary to current theories of phonological awareness development, phonemic representations undergo a process of gradual explicitization across ontogeny, as opposed to a process of movement from larger- to smaller phonemic representations, and that development of these abilities can be reasonably predicted by both cognitive and environmental factors. As my work is the first to robustly index phonemic awareness in children under school age, future efforts should examine additional measures of phoneme category structure, including medial phoneme discriminations. Additionally, receptive phonemic awareness development should be examined in a longitudinal design, with more socioeconomically and cognitively diverse samples. This work could allow the scientific community to gain more sensitive insights into: 1) the cognitive and environmental factors contributing to individual differences in performance within each child, 2) how development of this ability might vary within diverse populations, and 3) whether receptive phonemic awareness abilities are related to early reading achievement. Such a comprehensive examination could provide the foundation for groundbreaking, wide-scale intervention and reform efforts at child, family, program, and community levels.

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Appendix A
Word Lists: Receptive Phoneme Blending and Segmenting Measures

Blending Task Stimuli

Training Auditory Stimuli	**Training Picture Pair Stimuli**
/g/ / ʌ / /m/	gum, watch
/p/ /ɒ/ /t/	pot, door

Test Trial Stimuli Lists

Initial Phoneme Lists		Final Phoneme Lists	
Target Auditory Stimulus	Picture Pair Stimuli	Target Auditory Stimulus	Picture Pair Stimuli
/s/ɒ/k/	sock, lock	/k/aʊ/tʃ/	couch, cows
/w/ɪə//l/	seal, wheel	/k/eɪ/k/	cake, cage
/k/æ/n/	can, fan	/d/ɒ/l/	dog, doll
/f/ɪ/ʃ/	dish, fish	/b/ɪə/tʃ/	beach, beak
/k/æ/t/	cat, bat	/k/əʊ/m/	comb, coat
/h/əʊ/z/	hose, nose	/m/eɪ/l/	man, mail
/w/ʌ/n	one, sun	/b/əʊ/l/	bowl, boat
/g/uː/s/	Goose, juice	/b/ʌ/s/	bus, bug

<u>Segmenting Task Stimuli</u>

Training Auditory Stimuli	**Training Picture Stimuli**
/w/ /ɒ/ /tʃ/ ; /g/ / ʌ / /m/	gum *or* watch
/p/ /ɒ/ /t/ ; /d/ɔː/	pot *or* door

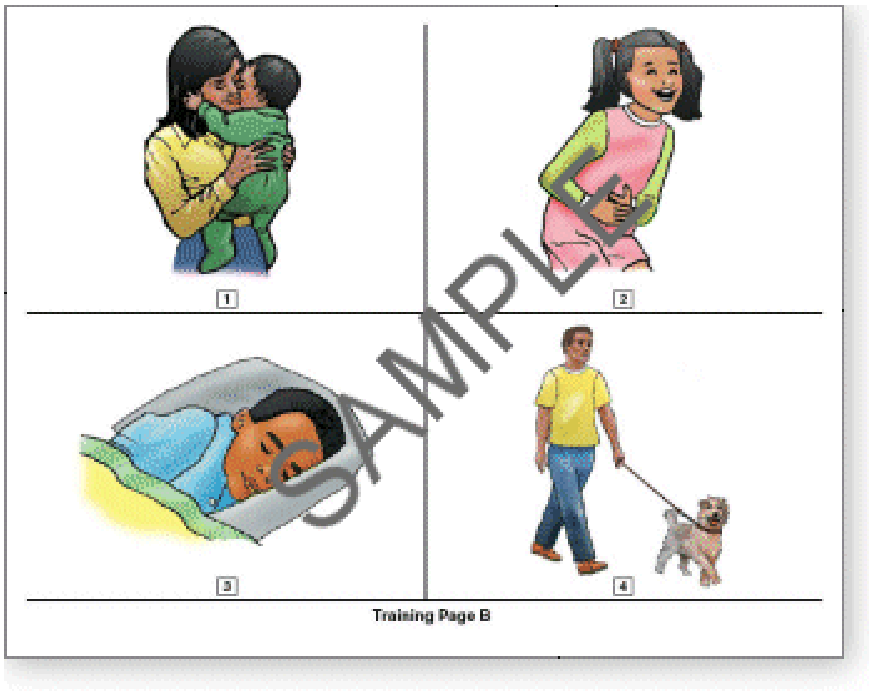
Test Trial Stimuli – List

Initial Phoneme Trials		Final Phoneme Trials	
Target Auditory Stimuli	Picture Stimulus	Target Auditory Stimuli	Picture Stimulus
/h/əʊ/z/; /n/əʊ/z/	hose or nose	/k/əʊ/m/; /k/əʊ/t/	comb or coat
/w/ʌ//n/; /s/ʌ/n/	one or sun	/b/ʌ/g/; /b/ʌ/s/	bus or bug
/k/æ/t/; /b//æ//t/	cat or bat	/b/əʊ/t/; b/əʊ/l	boat or bowl
/g/uː/s/; /ʤ/uː/s/	goose or juice	/m/eɪ/l/; /m/eə/n/	mail or man
/k/æ/n/; /f/æ/n/	can or fan	/d/ɒ/g/; /d/ɒ/l/	dog or doll
/f/ɪ/ʃ/; /d/ɪ/ʃ/	fish or dish	/k/aʊ/tʃ/; /k/aʊ/z/	couch or cows
/l/ɒ/k/; /s/ɒ/k/	lock or sock	/b/ɪə/tʃ/; /b/ɪə/k/	beach or beak
/w/ɪə/l/; /s/ɪə/l/	wheel or seal	/k/eɪ/k/; /k/eɪ/ʤ/	cake or cage

Appendix B

Peabody Picture Vocabulary Test-4th Edition

(PPVT-4) Sample Page



Appendix C

Home Language and Literacy Environment Parent Questionnaire

Directions: Please answer the following questions:

1. What is your relationship to the child participating in this study?
    a. Mother
    b. Father
    c. Legal Guardian
    d. Other: ____

2. What is the primary language spoken by the adults in your home?

    ____

3. Is there second language spoken by any adults in your home? If so, please list the language. If not, write N/A.

    ____.

4. If a second language is spoken in your home, please tell us how often the language is spoken.
    a. Daily
    b. Several days per week
    c. One day per week
    d. Less often than once per week
    e. Not applicable

5. If a second language is spoken in your home, please tell us who uses the second language. (Circle all that apply).
    a. Myself
    b. My spouse/partner
    c. My child's grandparent
    d. Our family's nanny or babysitter
    e. Other: ________________________

6. Is your child exposed to a second language outside of the home such as in a preschool setting or Mommy's morning out program? ____yes _____no .

If so, which language? ________________________. If so, how many hours per week? _____________.

7. How much of your child's **independent** free play with toys would you estimate is spent engaging in "pretend play" (such as putting a doll to bed, driving a car around, or making stuffed animals dance or sing)?
    a. None
    b. Very Little
    c. Some
    d. Most

8. How much of **your free playtime** with your child is spent engaging in "pretend play" (such as you demonstrating putting a doll to bed, driving a car around, or making stuffed animals dance or sing)?
    a. None
    b. Very Little
    c. Some
    d. Most

9. What other kinds of activities do you engage in during free-play with your child?

    ____
    ____

10. About how many children's books do you have in your home?
    a. 0-15
    b. 16-30
    c. 31-45
    d. 46-60
    e. More than 60

11. How often does your child see you reading a book for pleasure?
    a. Almost never
    b. Monthly
    c. Twice a month
    d. Weekly
    e. Every other day
    f. Daily

12. How often does your child see you spending time on the computer, iPad, iPhone, or other hand-held electronic device?
    a. No more than weekly
    b. Every other day
    c. Once Daily
    d. 2-3 times per day
    e. Many times per day

13. How often does your child see you reading a newspaper or magazine?
    a. Almost never
    b. Monthly
    c. Twice a month
    d. Weekly
    e. Every other day
    f. Daily

14. How often do you and your child visit a library?
    a. Almost never
    b. Monthly
    c. Twice per month
    d. Weekly
    e. Every other day
    f. Daily

15. How often do you and your child download or checkout books electronically from your Kindle Fire, iPad, or other electronic media devise?
    a. Almost never
    b. Monthly
    c. Twice per month
    d. Weekly
    e. Every other day
    f. Daily

16. Which of the following language-related activities do you engage in with your child on a **daily basis**?
    a. Talk about objects in the environment (e.g. a bird outside or a truck on the road)
    b. Singing songs
    c. Reading picture books

d. “Pretend talk” with dolls, puppets, or other toys
e. Telling fictional stories orally
f. Talk about your child’s day

17. Does someone in your home directly teach your child pre-reading skills?
____yes ____no
If yes, which of the following skills is your child learning? (Circle all that apply).
a. Letter names
b. Letter sounds
c. Printing letters
d. Reading words
e. Reading Signs or logos in the environment (e.g. Whole Foods, Stop signs, etc…)
f. Other: ______________________________

18. What is your highest level of education?
a. Some high school
b. Earned a high school diploma
c. Some college
d. Earned a college degree
e. Some graduate school
f. Earned a graduate degree (Masters, Doctorate, Law, Medicine, etc…)

19. How many hours per week do you work outside of the home?
a. I don’t work outside the home (Please go to question 22).
b. 1-15 hours
c. 16-30 hours
d. 31-40 hours
e. More than 40 hours

20. Please list the industry in which you are employed (e.g. manufacturing, education, eCommerce, Government Services, etc..)
____

21. Please list your specific job title.

____

22. Which of the following best describes the household you grew up in as a child.
    a. I grew up in a two-parent household
    b. I grew up in a one-parent household (Please state mother or father): ____________
    c. I grew up in a household with a grandparent or other relative
    d. Other: ____

Please answer the following questions to the best of your ability regardless of your childhood household make-up.

23. What is/was your **mother's** highest level of education?
    a. Some high school
    b. Earned a high school diploma
    c. Some college
    d. Earned a college degree
    e. Some graduate school
    f. Earned a graduate degree (Masters, Doctorate, Law, Medicine, etc…)

24. How many hours per week did **your mother** work outside of the home when you were a child?
    a. My mother didn't work outside the home (Please go to question 27).
    b. 1-15 hours
    c. 16-30 hours
    d. 31-40 hours
    e. More than 40 hours

25. Please list the industry in which **your mother** was/is employed (e.g. manufacturing, education, eCommerce, Government Services, etc..)

    ____

26. Please list your **mother's** specific job title.

____

27. What is/was your **father's** highest level of education?
    a. Some high school
    b. Earned a high school diploma
    c. Some college
    d. Earned a college degree
    e. Some graduate school
    f. Earned a graduate degree (Masters, Doctorate, Law, Medicine, etc…)

28. How many hours per week did **your father** work outside of the home when you were a child?
    a. My father didn't work outside the home (Please go to question 31).
    b. 1-15 hours
    c. 16-30 hours
    d. 31-40 hours
    e. More than 40 hours

29. Please list the industry in which **your father** was/is employed (e.g. manufacturing, education, eCommerce, Government Services, etc..)

    ____

30. Please list your **father's** specific job title.

    ____

31. Do you have a spouse or partner?
    a. Yes
    b. No (Go to question 36).

32. What is your **spouse/partner's** highest level of education?
    a. Some high school
    b. Earned a high school diploma
    c. Some college
    d. Earned a college degree
    e. Some graduate school
    f. Earned a graduate degree (Masters, Doctorate, Law, Medicine, etc…)

33. How many hours per week does **your spouse/partner** work outside of the home?
    a. My spouse/partner doesn't work outside the home (Please go to question 36).
    b. 1-15 hours
    c. 16-30 hours
    d. 31-40 hours
    e. More than 40 hours

34. Please list the industry in which **your spouse/partner** is employed (e.g. manufacturing, education, eCommerce, Government Services, etc..)
    ____

35. Please list your **spouse/partner's** specific job title.

    ____

36. Which of the following best describes the amount of care that your child receives outside of the home or from someone other than you?
    a. My child does not receive any care outside of the home.
    b. My child is at home with a part-time nanny.
    c. My child is at home with a full-time nanny.
    d. My child spends ½ days, three days per week or less at a Mommy's Morning Out or similar program.
    e. My child spends ½ days, four-five days per week at a preschool or early learning center.
    f. My child spends a full day at a preschool or early learning center three or less days per week.
    g. My child spends a full day at a preschool or early learning center four-five days per week.
    h. Other:
    ____

37. Your child who is participating in this study is:
    a. Your only child
    b. The older of two children
    c. The oldest of three or more children
    d. The younger of two children
    e. The second of three or more children
    f. The youngest of three or more children
    g. Other: ________________________________

Appendix D

Revised Title Recognition Test

(*Actual titles are indicated in bold font)

Revised Title Recognition Test

The following is a list of children's books. Some are real titles and some are foils. Please place a checkmark next to the titles that you think are real titles. For each title that you choose, please indicate whether you have heard of it or actually read it with your child. Please only choose titles that you have relative confidence are real titles.

	Actual title?	Heard of it?	Read it with child?
Mr. Brown Can Moo, Can You?			
Epposumondas			
Blue Jeans for Ben			
Freedom Train			
Abuela Means Grandmother: A Celebration of Latin-American Culture			
The Innkeeper and the Cricket			
Swimmy			
Why Mosquitoes Buzz in People's Ears			
The Snowy Day			
Wilfrid Gorden McDonald Partridge			
Don't Go Away			
A Light in the Attic			
The Polar Express			
Silver Stanley			
The Sun Rose on Kalamazoo			
Brown Bear, Brown Bear, What do you See?			
Pickle Sandwiches with Ice Cream on Top			
It's Kwanzaa Time!			
Mufaro's Beautiful Daughters			
Whoever You Are			
Barnyard Bath			
Just Me and My Dad			
Babushka's Magic Buttons			
Possum Magic			
The Rollaway Cart			
The Velveteen Rabbit			

	Actual title?	Heard of it	Read it with child
Moo Baa La La La			
Love You Forever			
The Spider and the Banana Tree: An African Folktale			
If you Give a Mouse a Cookie			
Guess How Much I Love You			
Go Away, Big Green Monster!			
The Missing Letter			
Tales from the Tails of Baxter Street			
Stellaluna			
Henny Penny			
Lon Po Po			
I Love Saturdays Y Domingos			
Stone Soup			
Flowers for Francis			
Nana Upstairs, Nana Downstairs			
How to Eat Fried Worms			
The Mitten: A Ukrainian Folktale			
Tell Me a Story Mama			
Sadie goes to Hollywood			
Five Chinese Brothers			
If you Give a Dog a Donut			
Llama, Llama, Red Pajama			
Just Me and My Pops			
Frog and Toad are Friends			
The Three Wise Travelers: A Chinese Folktale			
Froggy's Baby Sister			
Friends are Friends			
My Mommy Hung the Moon			
Granny and the Strawberry Thieves			
The Very Hungry Caterpillar			
Where the Wild Things Are			
The Artist Who Painted a Blue Horse			
Goodnight Moon			
Don't Go Away			
Tiki Tiki Tembo			
Pebble Stew			
The Very Busy Spider			
Number the Stars			
Hannah of the Hills			
Inch by Inch			
The Patchwork Quilt			
From Seed to Plant			

The Caramel Touch			
Sarah and the Runaway Bunny			
Ten Little Fingers and Ten Little Toes			
Zin! Zin! Zin A Violin			
Pigs and Pancakes			
Two Cool Cows			

Please take the time to list any other titles that you frequently read with your child that were not listed here:

____

____

____

____

____

Thank You!